Northern line extension

Factsheet B: Tunnelling and ground movement

1. Introduction

Some owners and occupiers of properties along the proposed route of the Northern line extension (NLE) have concerns about the potential impact of tunnelling works on the structure of their properties.

A number of major tunnelling and civil engineering projects have been undertaken in London in recent years, including the London Water Ring Main, Heathrow Express, Jubilee line extension, extensions to the Docklands Light Railway, the Channel Tunnel Rail Link and the Heathrow Express and Piccadilly line extensions to Heathrow Terminal 5. As a result, there is extensive experience of how the ground behaves when tunnels, shafts and station boxes are constructed and how to minimise the effects of ground movement on structures and utilities above.

Initial studies of the route suggest that the predicted settlement caused by the tunnelling will, at most, cause only slight damage to properties along the route. This means that if this predicted damage does occur it will be limited to damage that can be easily repaired such as cracks that could be filled or doors and windows that may stick slightly.

2. Ground movement risk

Subsurface excavations may cause ground movements. These movements commonly result in settlement. This ground movement has the potential to damage buildings and other infrastructure including utilities. Where such damage occurs it is commonly apparent as minor cracks to building finishes, although more significant structural defects are possible. In practice the vast majority of recent tunnelling and deep excavation work in London has resulted in little or no discernible effect at the surface. This has been achieved through the use of a range of measures, described later, which limit ground movement at source and mitigate its effect on existing infrastructure.

3. Assessment process

In order to control the risk of damage, assessments will be undertaken for existing infrastructure including buildings within the zone potentially affected by ground movements. This is a routine part of the tunnel and infrastructure design process and involves using well established methods to assess the need for any mitigation works.

The assessments will be carried out in accordance with section 3.6 of London Underground's Category 1 standard S1050 which follows industry best practice and will use a staged process similar to that applied on other recent projects. The guiding principles of this process are:

- To assess the risk of buildings experiencing ground movements that will result in the risk of slight damage being exceeded;
- To investigate alternative designs to reduce ground movements and the risk of the slight damage category being exceeded;
- To undertake an assessment of the potential consequences where there is a significant likelihood that the risk of slight damage will be exceeded and identify specifically what the risks are;
- To design protective measures where necessary to mitigate against the risk of slight damage being exceeded;
- To demonstrate that the environmental effects of excavation induced ground movements have been considered and taken account of in the design;
- To assess the risk of damage to utilities and to design

mitigation measures in agreement with the utility owner;

- To assess the effects of excavation to existing above ground and below ground infrastructure and to design suitable mitigation measures;
- To indicate where property may require demolition or structural modification; and
- To prepare contingency plans to deal with residual risks.

This process is carried out in a series of stages summarised below.

- Stage 1: Scoping

Calculations are undertaken to identify the extent of the area where movement may occur due to the works. The results are usually presented as plan drawings showing contours of worst case ground movement overlaid on the existing infrastructure. This assessment represents the worst case because the effect of buildings on the pattern of ground movement is ignored and moderately conservative parameters are chosen which tend to overestimate ground movements.

- Stage 2: Initial assessment.

Buildings and other infrastructure within the area identified as subject to significant settlement in Stage 1 will be analysed using simple engineering models to determine the degree of damage risk. This assessment is based on consideration of the strains likely to be induced within the structure.

- Stage 3: Detailed assessment

Detailed analysis of buildings or other infrastructure identified as being at risk of moderate damage or worse in Stage 2.

4. Mitigation measures

In areas where significant[1] damage risk (moderate or above) is predicted, appropriate measures will be taken to limit the effects.

Depending on the findings of the assessment process the following types of mitigation may be undertaken during construction to protect buildings from the effects of ground movement.

- **Minimisation of ground movement at source**

A range of measures can be used during tunnelling and excavation works to reduce the magnitude of ground movements generated. The detail of the measures will depend on the type of

construction involved.

These include all actions taken from within the tunnel, shaft or box construction to reduce the ground movements generated at source.

- **Ground treatment measures**

These comprise methods of reducing or modifying the ground movements generated by tunnelling, excavation required for new station boxes, by improving or changing the engineering response of the ground.

Categories of ground treatment include: compensation grouting, which involves injecting grout into the ground above the tunnel to compensate for the ground loss at the tunnel face, permeation or jet grouting which involves the creation of stiffer ground to reduce movement and control of ground water to avoid changes which could potentially cause ground movement.

- **Structural measures**

It is not expected that structural mitigation measures will be necessary for any residential property as a result of the NLE. Structural measures reduce the impact of ground movements by increasing the capacity of a building to resist, modify or accommodate those movements. Typical measures would include underpinning or jacking. Underpinning involves the introduction of a new strengthened foundation system to a building or structure potentially affected by settlement. Jacking is a technique whereby a system is introduced between the building and its existing foundations to compensate for any movements.

5. Provisions in relation to Listed Buildings

Specific consideration will be given to buildings which are listed as being of special architectural or historic interest ("listed buildings") in order to protect the building and any sensitive features or features of heritage value.

The specific mitigation measures to be used for each building will be determined during the detailed design and construction phases.

6. Pre-construction defect surveys

Defect surveys will be undertaken on any property predicted to experience 1mm or more of settlement before tunnelling works are started, as per London Underground Standards. This is a written and photographic record of the existing cracking and deterioration of finishes and structures and will be carried out by an appropriately qualified engineer or surveyor working jointly for the promoter of the works and the owner of the building. Owners of properties where defect surveys are required will be contacted in advance to arrange access but the survey will not be undertaken until shortly before the start of construction activities that could affect the building.

7. Monitoring

The need for monitoring will be determined on a case-by-case basis

as part of the assessment process. Where required, monitoring will start prior to the start of the works and continue until significant movement attributable to the works has ceased.

8. Consultation and commitments

For most major projects legal powers are required to construct the works, and in the case of the NLE these are provided through a Transport and Works Act Order application (TWAO). This process required formal consultation and the production of an environmental statement (ES). In order to inform the ES it would be normal practice to carry out at least Stages 1 and 2 described in this document.
However these stages are often repeated or re-examined once a contractor has been appointed and the exact method of construction established. The ES includes the results of this assessment.

The actual TWAO includes the powers to undertake protective works to properties. If it is proposed that a property will be subject to these protective works the landowner will receive a notice informing them of that proposal.

9. Settlement deed

TfL is prepared, at a landowner's request, to enter into TfL's standard form of settlement deed with any landowner who is concerned about settlement at their property and who has a property within the limits of deviation of the NLE scheme.
This will provide a personal legal undertaking from TfL concerning settlement and a formal legal agreement between owners of a potentially affected property and TfL.

The settlement deed contains standard undertakings offered by LU to all owners of qualifying buildings and its terms are not subject to individual negotiation. Each party is responsible for its own costs of entering into a deed. A copy of the deed is available in the Environmental Statement Addendum Volume 11 Appendix 1A at tfl.gov.uk/nle.

Property owners do not have to enter into the deed unless they choose to. It is not necessary to enter into the deed to benefit from TfL's policy (as set out in this factsheet and detailed in London Underground's (LU) Category 1 standard S1050) to receive compensation in the event of damage to a property as a result

of tunnelling or construction work carried out by TfL.

10. Further information

Full details about the NLE TWAO application, and the documents to support our application are available at tfl.gov.uk/nle

If you would like more information about the proposals please email nle@tfl.gov.uk

To receive this document in large print, audio or another language please call 0800 298 3009.

Table 1

Building damage classification				
Damage category	Description of degree of damage†	Description of typical and likely forms of repair for typical masonry buildings	Approx. crack width* (mm)	Max. tensile strain%
0	Negligible	Hairline cracks		<0.05
1	Very slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior visible upon close inspection	0.1 to 1.0	0.05 to 0.075
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible; some repainting may be required for weather-tightness. Doors and windows may stick slightly	1 to 5	0.075 to 0.15
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Tuck pointing and possible replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired	5 to 15 or a number of cracks greater than 3	0.15 to 0.3
4	Severe	Extensive repair involving removal and replacement of walls especially over door and windows required. Window and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably. Some loss of bearings in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	>0.3
5	Very severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and required shoring. Windows broken by distortion. Danger of instability.	Usually > 25 but depends on No. of cracks	

†In assessing the degree of damage, account must be take of its location in the building or structure

*Crack width is only one aspect of damage and should not be used on its own as a direct measure of it

Burland, J.P. and Wroth, C.P., Settlement of Buildings and Associated Damage, Proceedings of a Conference on the Settlement of Structures, Cambridge, 1974, pp 611 – 54 and 764 – 810;