



CROSSRAIL INFORMATION PAPER

D12 – GROUND SETTLEMENT

This paper explains the arrangements for assessing, monitoring and mitigating the effects of ground settlement arising from Crossrail construction.

It will be of particular relevance to those in proximity to the Crossrail running tunnels.

This is not intended to replace or alter the text of the paper itself or any commitments contained in it, and it is important that you read the paper in order to have a full understanding of the subject. If you have any queries about this paper or about how settlement might affect you, please contact either your regular Petition Negotiator at CLRL or the Crossrail helpdesk, who will be able to direct your query to the relevant person at CLRL. The helpdesk can be reached at:

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APPROVED

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D12 – GROUND SETTLEMENT

1. Introduction

1.1 A number of major tunnelling 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 are constructed and how to minimize settlement affecting buildings above.

1.2 The construction of Crossrail tunnels, station boxes and shafts will lead to settlement of the ground at the surface. The amount of settlement will depend on a number of factors including the depth and volume of the works below ground, soil conditions and the presence and nature of building foundations. The amount of settlement will vary across the area affected and for some buildings the magnitude of settlement varies across the building, this is known as differential settlement. If there is no differential settlement and all of a building settles the same amount then the building is very unlikely to be damaged, whereas differential settlement has the potential to damage buildings and other infrastructure, including utilities. If damage were to occur, it could range from small internal cracks in plaster to effects on the structural integrity of the building, although in most cases there is no discernible effect on the structure itself. The Promoter has already begun an assessment of potential settlement along the route of the railway that will assess the risk of damage to all buildings within the zone affected by settlement. Depending on the level of risk either no action will be required, buildings will be monitored during construction, or special protective measures will be implemented to protect the buildings.

1.3 This paper covers the following issues:

- a) Method of assessing settlement
- b) Monitoring
- c) Protective works
- d) Defects surveys
- e) Repairs
- f) Listed buildings
- g) Settlement Deed

2. Settlement Assessments

2.1 Buildings which may be affected by structural excavations¹ carried out by the nominated undertaker are assessed using a three phase process similar to that developed on other projects including the Jubilee line extension and the Channel

¹ See Appendix A for the excavations to which this applies.

Tunnel Rail Link and this assessment consists of one, two or three phases as described below.

2.2 PHASE 1

- 2.2.1 The Phase 1 assessment is based on “green-field” site conditions. This means that the effect of building foundations on the pattern of settlement is ignored.
- 2.2.2 For bored tunnels the settlement predictions for “green-field” site conditions are produced based on empirical methods such as those described by O’Reilly and New (1982) and Attewell and Woodman (1982) using parameters for ground loss determined from case histories and taking into account the method of tunnelling and ground conditions.
- 2.2.3 For excavations comprising shafts, boxes and retained cuttings, a conservative² methodology for predicting settlements has been developed specifically for use on Crossrail, based on relevant case studies of similar excavations in stiff clay.
- 2.2.4 Where the predicted settlement from bored tunnels and from the excavations referred to above is less than 10mm and the predicted ground slope is less than 1/500 (equivalent to damage risk category 1 as defined by Rankin, 1988) buildings are not subject to further assessment. Those for which predicted settlement is 10mm or more, or for which predicted ground slope is 1/500 or more, are subject to a Phase 2 assessment.

2.3 PHASE 2

- 2.3.1 In Phase 2 the settlement calculated for “green-field” conditions is imposed on buildings, i.e. it is assumed that buildings behave completely flexibly and their own stiffness has no influence on the settlement behaviour. In addition the deformation due to horizontal ground movement is taken into account. This is a conservative assumption as, in reality, a building’s structure and foundations will modify the settlement effects and limit the development of horizontal strain, reducing the potential for damage.
- 2.3.2 A generic area-wide assessment of settlement, which has been developed specifically for use on Crossrail, identifies zones in which buildings might be at risk of sustaining damage at levels which require individual investigation (that is, in which they may be in risk category 3 or above) based on correlation with the calculated maximum tensile strain values (see Harris and Franzius (2005)). For the buildings within these zones, an individual assessment is required in Phase 3 of the assessment process (see paragraph 2.3.6).

² 'conservative' in this paper means assessed ground movement and settlement effects are larger and more extensive; the real effects are likely to be much less.

- 2.3.3 The potential for damage in this area-wide assessment is defined using the procedure described by Burland (1995) and Mair et al (1996). Each building is categorised into one of six risk categories by reference to maximum tensile strain as described in column 2 of Table 1. This classification is conservative as it assumes a simple brick masonry construction, whereas other forms of construction, such as framed buildings, are more robust.
- 2.3.4 This generic assessment is only sufficiently informative for buildings with relatively shallow foundations. Buildings with a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis, automatically qualify for a Phase 3 assessment after the Phase 2 process.
- 2.3.5 Subject to paragraph 2.3.4 above and 2.3.7 below, buildings assessed to be in risk category 0, 1 or 2 after the Phase 2 assessment are not subject to further assessment.
- 2.3.6 All buildings which are placed in risk category 3 or above in the Phase 2 assessment are subject to a Phase 3 assessment.
- 2.3.7 Any building which has been subject to a Phase 2 assessment but which does not qualify for further assessment under paragraph 2.3.6 above is nonetheless subject to a Phase 3 assessment if:
- (a) it is on shallow foundations and is within a distance from a retained cutting, shaft or box equal to the excavated depth of superficial deposits or 50% of the total excavation depth (whichever is the greater). In this context, superficial deposits are taken to be soils such as Made Ground, Alluvium or Terrace Gravels,
 - (b) it has a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis,
 - (c) it is a listed building, or
 - (d) the nominated undertaker considers that for some other reason the determination of whether protective works for the building are required, or the form that such protective works should take, requires further assessment in Phase 3 to be undertaken.

2.4 PHASE 3

- 2.4.1 In Phase 3 of the assessment procedure, each building is considered individually in contrast to the first 2 phases where the area of interest is analysed generically.
- 2.4.2 The Phase 3 assessment consists of several sub-steps (referred to as "Iterations"), each refining the building and tunnel model to a higher degree. In this phase both the strain developing within the building and the applicability of the standard risk categories (which are based on masonry structures) is reappraised. In the first Iteration the same model is used as in the Phase 2 assessment. This model is then successively

refined in the following iterations. If necessary, the tunnel-excavation-soil-building interaction problem is modelled numerically. The approach is to use simplified assumptions in the first instance and refine the analysis to see if a more accurate approach results in the risk of damage reducing to an acceptable level.

2.4.3 A structural survey will be undertaken to determine the structural form and condition of the building where reasonably necessary for the assessment. In every case where a building is subject to a phase 3 assessment, a desktop structural appraisal by a qualified structural engineer will be carried out for the purpose of confirming the likely structural behaviour and determining whether such a structural survey is so necessary.

2.4.4 As a result of the Phase 3 assessment, the risk category of the building is assessed or reassessed, the requirement for any protective works is established and the design and implementation of any protective works and associated specialised monitoring are determined. These matters are stated in the settlement assessment report for the building.

2.5 OTHER MATTERS

2.5.1 Settlement assessments for listed buildings have already been completed as far as the first iteration of Phase 3 as set out in paragraph 2.4.2 above (and paragraph 7.2 below). Non listed building assessments have been completed to the end of Phase 2. Where buildings have qualified for further assessment, this will take place as part of the on-going detailed design process when the precise construction programme and methodology have been determined.

2.5.2 Building owners may request a copy of the assessment report which Crossrail will supply and discuss with the owners if the building has progressed to at least Phase 2 of the assessment process.

3. Monitoring

3.1 Requirements for monitoring will be confirmed by the settlement report. Generally, however, all buildings in risk category 3 or above will be monitored during tunnel construction. Monitoring for category 2 and below will be covered by the general background surface monitoring undertaken to confirm ground movements are within predictions. If unexpected movements occur they will be fully investigated and, if necessary, modifications made to the tunnelling method and/ or protective works taken to safeguard the building. In addition to this, general settlement monitoring will be carried out over the whole area affected by settlement.

3.2 Where practicable, it is proposed to carry out a full 1 year of area background monitoring to establish seasonal trends, with building specific monitoring commencing at least 1 month prior to commencement of the works. Monitoring will continue until all potentially damaging settlement due to the Crossrail works

has ceased. This is defined as when the rate of settlement is less than or equal to 2mm/annum.

3.3 Generally, construction phase monitoring will consist of precise surveying of studs or targets installed on the outside of the building or inside subsurface structures. Occasionally, dependent on structure size and extent of settlement, precise levelling will take place inside structures. Other forms of monitoring may also be employed, which will be determined on a case by case basis.

4. Protective Measures

4.1 It is intended that the primary form of mitigation will be to use good tunnelling practice, including continuous working, erecting linings immediately after excavation and providing tight control of the tunnelling process to reduce the magnitude of settlement. Where these are considered insufficient to mitigate the risk of damage to buildings as forecast in the Phase 3 assessment, intrusive mitigation measures will be considered. These include direct works on the building, as well as ground treatment around and beneath the building. These three categories are described in more detail below:

- *At-source measures.* These include all actions taken from within the tunnel, shaft or box excavation during its construction to reduce the magnitude of ground movements generated at source.
- *Ground treatment measures.* These comprise methods of reducing or modifying the ground movements generated by tunnelling/box excavation 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 settlement; and control of ground water to avoid changes which could potentially cause ground movement.
- *Structural measures.* These methods reduce the impact of ground movements by increasing the capacity of a building or structure 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 structure and its existing foundations to compensate for the settlement.

4.2 These mitigation measures are tried and tested. They have proven effective in mitigating potential settlement effects on other major projects involving a similar scale and complexity of tunnelling and excavation (see Mair (2001)).

5. Survey

5.1 Defect surveys will be undertaken on all properties assessed to experience 10mm or more of settlement in the assessment carried out under section 2 above with respect to the nominated undertaker's structural excavations. These will

capture the condition of the properties immediately prior to tunnel construction commencing in an area. They are a written and photographic record of existing cracking and the state of the finishes and structures. They will be carried out by a chartered building surveyor commissioned by the nominated undertaker at the nominated undertaker's cost but in joint names with the building owner and any other persons as the nominated undertaker may determine. Owners are free to commission their own survey but this will be at their own cost since the Crossrail survey is an objective survey/record of pre existing defects and is not intended to draw any conclusions as to the cause.

5.2 An electronic copy of the report will be available to the owner on request.

5.3 If, following the construction of the Crossrail tunnels in the vicinity of the building, the owner responsible for repairing a building reasonably believes damage has occurred then he should notify the nominated undertaker in writing before the end of the period of two years from the date of opening for public traffic of the railway comprised in the authorised works in the vicinity of the building, or if later, the end of the period of three months from the day on which any monitoring specific to the building ceased. A second survey will then be undertaken by the nominated undertaker's surveyor to record changes from the first survey. The owner may request his own surveyor to attend when the second survey is undertaken and to comment on the draft survey report produced by the nominated undertaker. Reasonable professional fees (agreed in advance) incurred by the owner in making a successful claim will be reimbursed by the nominated undertaker.

5.4 A comparison of the 2 surveys may form the basis of any claim. The nominated undertaker may appoint a loss adjuster to assess the extent to which the damage has been caused by Crossrail and agree the remedial works to be undertaken at the expense of the nominated undertaker.

6. Repairs

6.1 The Promoter will require the nominated undertaker to reimburse property owners for the reasonable cost they incur in remedying material physical damage arising from ground settlement caused by the authorised works, provided:

- the damage is caused by the nominated undertaker's works;
- the owner gives not less than 28 days notice in writing to the nominated undertaker of the proposal to carry out the repair work;
- the owner takes reasonable steps to obtain 3 competitive quotes for the repairs beforehand where required by the nominated undertaker; and
- any claim is made before the end of the period of two years from the date of opening for public traffic of the railway comprised in the authorised works in the vicinity of the building, or if later, the end of the period of three months from the day on which any monitoring specific to the building ceased (see paragraph 3.2 above)

6.2 The nominated undertaker may, on receiving the advanced notice of the proposal to carry out the repair work, elect to undertake the repair work itself.

6.3 If there are any pre-existing defects which have worsened as a result of Crossrail then the recoverable loss will be limited to the additional cost of repair over and above that which would have been required to deal with existing defects.

6.4 If it can be demonstrated that the undertaking to assess the compensation claim based on the reasonable cost of repairs does not compensate the claimant fully for the reduction in value of his interest in the property then this does not prejudice a further claim for compensation in accordance with the Crossrail Bill and the national compensation code within the normal limitation period applying to such claims.

7. Listed Buildings

7.1 All listed buildings are subject to the provisions of this paper as set out in Sections 1 to 6 above. In particular, as stated in paragraph 2.3.7, all listed buildings (with settlement of 10mm or more) automatically qualify for a detailed assessment at Phase 3.

7.2 In the first iteration of the Phase 3 assessment, the heritage value of a listed building is considered by reviewing the sensitivity of the building structure and of any particular features against the risk category assigned in Phase 2. The heritage assessment examines the following:

(a) the sensitivity of the building / structure to ground movements and its ability to tolerate movement without significant distress. The potential for interaction with adjacent buildings / structures is also considered. A score within the range of 0-2 will be allocated to the building/structure in accordance with the criteria set out in Table 2.

(b) the sensitivity to movement of particular features within the building / structure and how they might respond to ground movements. A score within the range of 0-2 will be allocated to the building in accordance with the criteria set out in Table 2.

7.3 In addition, a score corresponding to the Phase 2 settlement assessment risk category within the range of 0-5 is allocated to the building.

7.4 The scores for each of the three categories (7.2 (a), 7.2 (b) and 7.3) are added together to inform the decision making process. In general, listed buildings which score a total of 3 or higher are subject to further assessment as part of the Phase 3 iterative process. Buildings which score a total of 2 or less are predicted to suffer a degree of damage which will be easily repairable using standard conservation based techniques and hence no protective measures for the building's particular features are required. However, ultimately the professional judgement of engineering and historic building specialists will be used to determine whether additional analysis is required. Upon conclusion of the Phase 3 iterations, a final composite score will be arrived at, comprising the risk category of the building (ignoring the fact that it is a listed building) assessed in accordance with the normal principles of Phase 3 assessment, to which will be added final scores for each of the two additional sensitivities referred to in

paragraph 7.2(a) and (b) in accordance with Table 2, and this final composite score will constitute the risk category of the listed building for the purposes of paragraph 2.4.4 above.

- 7.5 The relevant local authority will be consulted on the results of the listed building assessment reports for listed buildings subject to Phase 3 assessment and the proposals for protective measures, if any are required. English Heritage will also be consulted in relation to listed buildings subject to Phase 3 assessment where they would normally be notified or consulted on planning applications or listed building consent applications (as set out in DETR and DCMS Circular 1/01).
- 7.6 When considering the need and type of protective measures, due regard will be given to the sensitivity of the particular features of the building which are of architectural or historic interest and the sensitivity of the structure of the building to ground movement. Where the assessment highlights potential damage to the features of the building which it will be difficult or impossible to repair and/or if that damage will have a significant effect on its heritage value, the assessment may recommend appropriate measures to safeguard those features either in-situ or by temporary removal and storage off-site if those with relevant interest(s) in the building consent.
- 7.7 The form of monitoring of listed buildings will be determined based on the results of the assessment process.
- 7.8 If repair works are necessary, the arrangements for their carrying out or for reimbursement referred to in section 6 above will apply. Reimbursable costs will include the costs of any necessary expert advice from a person suitably qualified to advise on heritage issues. The carrying out of the relevant works will however require the consent of those with relevant interest(s) in the building.

8. Settlement Deed

- 8.1 The Promoter has developed a Deed which the owner of a building may request. This is a formal legal undertaking concerning settlement, giving effect to the matters set out in this paper. The qualifying criteria for the deed are attached as Appendix A and the Deed itself, the terms of which are subject to change whilst the Bill is in Parliament, as Appendix B. Subject to paragraph 9.1 below, and to paragraph 3.1 of the qualifying criteria, the Secretary of State will require the nominated undertaker concerned to enter into a deed in substantially the form of the final version of those terms, in accordance with the procedures set out in the qualifying criteria, with eligible owners complying with those procedures. It is not necessary to enter into the deed in order to benefit from the process set out in this paper.

9. New Buildings

- 9.1 The requirements set out in this paper (including the requirement for the nominated undertaker to enter into a settlement deed) do not apply to a new building, for the construction of which planning permission was granted after 1 March 2008. They also do not apply to any new buildings which are not

substantially completed by the date referred to in paragraph 1.2 of the qualifying criteria for the settlement deed in Appendix A. References to a building in the qualifying criteria are to be construed accordingly.

10. References

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Burland, J.B., Broms, B.B., & de Mello, V.F.B. (1977). Behaviour of foundations and structures. Pages 495-546 of: *Proc. 9th Int. Conf. Soil Mech. and Found. Eng.*, vol. 2.

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O'Reilly, M.P. and New, B.M. (1982). Settlements above tunnels in the United Kingdom – their magnitude and prediction. *Tunnelling '82*. Ed Jones, M.J. pp 173-181. London, IMM.

Rankin, W.J. (1988). Ground movements resulting from urban tunnelling: predictions and effects. Pages 79-92 of: *Engineering geology of underground movements*. The Geological Society, London.

TABLE 1

Building Damage Classification ¹				
1	2	3	4	5
Risk Category	Max Tensile Strain %	Description of Degree of Damage	Description of Typical Damage and Likely Form of Repair for Typical Masonry buildings	Approx ² Crack Width (mm)
0	0.05 or less	Negligible	Hairline cracks.	
1	More than 0.05 and not exceeding 0.075	Very Slight	Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	0.1 to 1
2	More than 0.075 and not exceeding 0.15	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible; some repointing may be required for weather-tightness. Doors and windows may stick slightly.	1 to 5
3	More than 0.15 and not exceeding 0.3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Repointing and possibly 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
4	More than 0.3	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks
5		Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	Usually greater than 25 but depends on number of cracks

Notes

1. The table is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 2) used in phase 2 settlement analysis.

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

TABLE 2

Scoring for the Sensitivity Assessment of Listed Buildings

Score	Criteria	
	Sensitivity of the structure to ground movements and interaction with adjacent buildings	Sensitivity to movement of particular features within the building
0	Masonry building with lime mortar not surrounded by other buildings. Uniform facades with no particular large openings.	No particular sensitive features
1	Buildings of delicate structural form or buildings sandwiched between modern framed buildings which are much stiffer, perhaps with one or more significant openings.	Brittle finishes, e.g. faience or tight-jointed stonework, which are susceptible to small movements and difficult to repair.
2	Buildings which, by their structural form, will tend to concentrate all their movements in one location.	Finishes which if damaged will have a significant effect on the heritage of the building, e.g. cracks through frescos.

Appendix A

Qualifying Criteria For Deed Concerning Settlement

Qualifying Criteria For Deed Concerning Settlement

1. Criteria for eligibility

- 1.1 The person must have a legal estate in all or part of a building (which where relevant is treated as including any bridge, tunnel or major service media in which the person has a legal estate or interest and which is connected to the building) within 30 metres on plan of the tunnels, retained cuttings³, shafts⁴ and boxes⁵ forming part of the works authorised to be carried out under the Bill by the nominated undertaker concerned, as finally designed by the nominated undertaker. The legal estate he holds must be sufficient for him to comprise an “owner” within the meaning of the Acquisition of Land Act 1981.
- 1.2 The person must give notice to the nominated undertaker concerned at least ten months before construction of the part of the tunnel, retained cutting, shaft or box concerned is intended to be begun by the nominated undertaker. After delivery of the deed to him executed by the nominated undertaker, he must within 21 days return his own part of the deed or a duplicate (as the nominated undertaker requires) to the nominated undertaker duly executed by him. This is to give sufficient time after completion of the deed for the nominated undertaker to prepare a settlement report and for its discussion where required under the deed.
- 1.3 To ease administration, any person whose building falls within the limits of deviation for a part of a railway work which is shown on the deposited plans and sections as intended to be in tunnel, retained cutting, shaft or box, or which is within 30 metres of those limits, is to be able to give notice to the nominated undertaker in advance of final design of the works concerned by the nominated undertaker (or in the period before his appointment, to the Secretary of State). The procedures for doing this will be drawn up in due course. The nominated undertaker would then be under a duty to deliver the deed if, on final design within the relevant limits of deviation, it is found that the building is within 30 metres of a tunnel, retained cutting, shaft, or box.
- 1.4 In the deed, the expression “the Building” in clause 1(1) will be defined to be the whole building to which any assessment to be carried out under clause 2 of the deed relates, and “the Protected Property” as the particular part of the Building in which the person holds a legal estate or has repairing obligations.

³ In these criteria “retained cutting” means a retained cutting of a depth of 3 metres or more.

⁴ In these criteria “shaft” means an excavated shaft of a depth of 3 metres or more

⁵ In these criteria “box” means an excavated structural box of a depth of 3 metres or more

2. Multiple owners of a building

- 2.1 If any particular building has more than one person who is an “owner” (within the meaning of the Acquisition of Land Act 1981), each of them is to be entitled to a deed. However, the deed makes provision (amongst other matters) in clause 2(14) for the appointment of a single engineer for the building, and in clause 9(12) for a single consolidated dispute resolution proceeding in cases where clause 2(8) to (15) apply.

3. Other matters

- 3.1 Where there is more than one person responsible for repair of the building concerned the nominated undertaker is to be able to insert provision in clause 6 of the draft deed limiting the application of that clause in relation to any particular owner to the damage for which the owner has a repairing responsibility.
- 3.2 The notice mentioned in paragraph 1.2 above must give sufficient information to enable the nominated undertaker to prepare the relevant deed, and in particular must identify the building concerned, the nature of the interest in it of the person giving the notice and of his repairing obligations, and whether there are other owners within the meaning of the Acquisition of Land Act 1981 of the building or occupiers.

Department for Transport
22 March 2007

Appendix B

Settlement Deed

Note: references to sections, Schedules and paragraphs of the Crossrail Act of a particular number are taken from the Crossrail Bill as it passed from the House of Commons to the House of Lords in December 2007, and may require to be renumbered to take account of any subsequent amendments of the Bill as enacted

Draft 18.02.2008

DEED

between

[THE NOMINATED UNDERTAKER]

and

[]

Deed concerning the mitigation of the effects of settlement
arising from the construction of Crossrail

the meaning of the Companies Act 1985;

“the Secretary of State” means the Secretary of State for Transport¹ or any successor Secretary of State or Minister holding the Transport portfolio and includes so far as relevant any person or body exercising powers or functions by virtue of an order under section [60] of the Act.

(2) The Undertaker may appoint any of its contractors or sub-contractors for any of the authorised works as agent in relation to the exercise of any of its functions under this Deed (but without prejudice to any liability of the Undertaker in the event of a failure to comply with the terms of this Deed).

(3) References in this Deed to a person or persons include references to bodies corporate.

SETTLEMENT AND PROTECTIVE WORKS

2. (1) In this clause and clause 3 and the Appendix to this Deed:

“the Assessment” means the Assessment described in paragraph (2) below;

“box” means an excavated structural box of a depth of 3 metres or more;

“listed building” means a listed building within the meaning of the Planning (Listed Buildings and Conservation Areas) Act 1990;

“the Notice” means the Notice described in paragraph (8) below;

“the Owner’s Engineer” means the Engineer appointed in accordance with paragraph (14) below;

“protective works” means works for the supporting or strengthening of the Building or its foundations undertaken to minimise damage to the Building arising as a result of the relevant construction;

“the relevant construction” in relation to the Building, means any part of:
(a) the bored tunnels, or

¹ If the title of the minister responsible for transport issues has changed by the time the deed in question is entered into, insert the then current title of the minister or Secretary of State concerned and for “or any successor” substitute “and any predecessor or successor”.

(b) the excavations comprising shafts, boxes and retained cuttings,

comprised in the authorised works and which is within 30 metres on plan of the Building;

“the Report” means the Report for the Building described in paragraph (3) below;

“retained cutting” means a retained cutting of a depth of 3 metres or more;

“sent” means (in relation to the sending to the Owner of the Report under this clause 2 and of the notice mentioned in paragraph (14)(b) below) posted by ordinary first-class post addressed to the address referred to in clause 10(1) below, and “send” shall be construed accordingly;

“settlement” means movement of the ground in response to the excavation of the bored tunnels, shafts, boxes and retained cuttings comprising the relevant construction;

“shaft” means an excavated shaft of a depth of 3 metres or more.

Preparation of Assessment and Report

(2) Before it commences the relevant construction, the Undertaker shall carry out an Assessment (to be undertaken by a suitably qualified person with appropriate experience) to predict any settlement to the Building that may result from that construction and any damage to the Building which may be caused by such settlement.

(3) The Assessment shall be carried out in accordance with the procedures in the Appendix to this Deed; and following the Assessment the Undertaker shall prepare a Report in respect of the Building which shall contain such of the following as may be applicable:-

- (i) an assessment of predicted settlement to the Building caused by the relevant construction;
- (ii) if the Building has been subject to a Phase 2 or Phase 3 assessment as described in the Appendix to this Deed, the assessed maximum tensile strain and an assessment of the predicted damage to the Building;
- (iii) the results of any structural inspection of the Building;

- (iv) any proposed monitoring specific to the Building;
- (v) an assessment of the need for protective works, if any;
- (vi) details of any such protective works, including designs, method of working and programme of such protective works; and
- (vii) if the Building is a listed building, particulars of any such additional safeguarding measures as are referred to in paragraph 22 of the Appendix.

(4) The Report shall be sent to the Owner before commencement of the relevant construction, following which the Undertaker will (subject always to paragraphs (6) to (15) below in a case where those paragraphs apply) be entitled to proceed with that construction without prejudice to any claim for compensation which the Owner may have.

(5) Without prejudice to paragraphs 5(7), 6(7) and 9 of Schedule 2 to the Act the Undertaker may, as often as it may reasonably require and upon giving not less than 14 days' notice in writing to the Owner, enter the Protected Property at any reasonable time for the purposes of carrying out the Assessment.

Cases in risk category 2 or below

(6) Subject to paragraph (7) below, if following the carrying out of the Assessment (as described in the Appendix to this Deed) the assessment of the predicted damage to the Building concerned contained in the Report assesses that the Building falls into Risk Category 2 or below, the Undertaker, if so requested by the Owner by notice given in writing to the Undertaker not later than 20 working days after the day on which the Report is sent to the Owner, shall seek to consult with the Owner regarding the Report following which the Undertaker shall be entitled to proceed with the relevant construction without prejudice to any claim for compensation which the Owner may have.

Cases in risk category 3 or above

(7) Paragraphs (8) to (15) below apply if following the carrying out of the Assessment the assessment of the predicted damage to the Building concerned contained in the Report assesses that the Building falls into Risk Category 3 or above or if the Report recommends that protective works should be carried out wholly or partly from within the Building.

(8) The Owner's Engineer may, not later than 25 working days after the day on which the Report was sent to the Owner, give written Notice to the Undertaker stating whether or not the Report is agreed.

(9) If the Owner's Engineer does not agree the Report the Notice shall contain detailed reasons for the Owner's objections.

(10) In the event that the Notice contains reasonable objections the Undertaker and the Owner's Engineer shall seek to agree such amendments to the Report as are reasonably necessary to address those objections.

(11) In the event that no Notice is served within the period specified in paragraph (8) above the Report shall be deemed to have been agreed.

(12) In the event that the Undertaker and the Owner's Engineer fail to agree the Report within 25 working days of the giving of the Notice or in the opinion of the Undertaker the objections contained in the Notice are unreasonable, the dispute shall be referred in accordance with Clause 9 (Disputes) of this Deed.

(13) Upon the Report being agreed or deemed to be agreed or upon determination of the dispute (as the case may be) the Undertaker shall be entitled to proceed with the relevant construction and any protective works specified in the Report in accordance with the Report as so agreed or determined; but if the Notice contains objections to the Report and the Report has not been agreed or finally determined within the period of 90 working days after the day on which the Report was sent to the Owner then provided that the Undertaker has used its reasonable endeavours to agree the Report and facilitate the determination of the adjudicator the Undertaker shall be entitled to proceed with the relevant construction and any protective works specified in the Report in accordance with its terms without prejudice to any claim for compensation which the Owner may have.

(14) The Owner's Engineer shall be appointed by the Owner save that:

(a) in the event of the Undertaker entering into a Deed with any other person or persons (whether on, before or after the date of this Deed) in relation to the whole or part of the Building containing provisions similar to this clause 2 –

(i) the Owner's Engineer shall be appointed jointly by the Owner and the other person or persons (or, failing agreement between them, by the President of the Institution of Civil Engineers on the written application of either or, as the case may be, any of them), and

(ii) as regards any disputes concerning the Report and the appropriate protective works for the Building (if any), for the purpose of obtaining a consistent outcome with respect to the Building capable of implementation by the Undertaker clause 9(12) has effect;

(b) where the Undertaker enters (or is to enter) into such a Deed as is mentioned in sub-paragraph (a) above with any other person or persons, to enable the joint appointment referred to in sub-paragraph (a)(i) above to be made the Undertaker shall either send a notice in writing to the Owner specifying the other person or persons before the beginning of the period of 35 working days ending with the day on which the Report is sent to the Owner under paragraph (4) above, or

shall send that notice at some later time before the Report is sent (in which case the Report shall be deemed to have been sent for the purposes of paragraphs (4) to (13) above on the day 35 working days after the day on which that notice is sent).

(15) The Undertaker shall repay to the Owner all reasonable costs, charges and expenses properly incurred by the Owner, including VAT thereon insofar as the same is not recoverable by the Owner (whether as a deduction against output tax or as a VAT credit or otherwise), in connection with:-

- (a) the services of the Owner's Engineer under paragraphs (8) to (10) above; and
- (b) the services of architects, surveyors, engineers and other technical advisers to whom the Owner's Engineer finds it reasonably necessary to refer in connection with paragraph (10) above.

General

(16) Subject to paragraph (17) and (18) below, if the Undertaker carries out the relevant construction it shall also carry out the relevant protective works (including the method of working and programme therefor); and for this purpose "the relevant protective works" means the protective works described as necessary in the Report (whether as consulted on under paragraph (6) above or as agreed or deemed to have been agreed under paragraphs (10) and (11) above or as determined as mentioned in clause 9 or in the form that the Undertaker prepared and sought to agree in accordance with paragraph (13) above, as the case may be) which the Undertaker is able to carry out in accordance with that method and programme under paragraph 5 of Schedule 2 to the Act.

(17) The duty to carry out protective works under paragraph (16) above has effect subject to the obtaining of any necessary consents, agreements or other approvals (which the Undertaker shall use reasonable endeavours to obtain) required for the purpose, whether required under any provision having effect under statute, or under any undertaking or agreement given or entered into by the Secretary of State or the Undertaker which governs the exercise of the powers given by the Act, or otherwise; and the obligation to use reasonable endeavours to obtain such consents, agreements or other approvals includes an obligation –

- (a) where the Report in the form sent to the Owner identifies protective works as necessary, to serve notice under paragraph 5(2) of Schedule 2 to the Act not later than one week after the day on which the Report is so sent to the Owner (or if earlier not later than 8 weeks before, under the Undertaker's construction timetable, it is to carry out the protective works so identified), on all persons who have not entered into a Deed in relation to the whole or part of the Building containing provisions similar to this clause 2 and who after reasonable inquiry by the Undertaker are (as at that time) found eligible to receive such notice in relation to the Building and the protective works so identified; and

- (b) after the sending of the Report to the Owner, to do what else is reasonable under paragraph 5 of Schedule 2 to the Act to enable the protective works referred to in paragraph (16) above to be carried out at a time consistent with the Undertaker's construction timetable including, if a person gives notice of dispute under paragraph 5(3) of that Schedule in relation to the Building (whether in consequence of a notice by the Undertaker given pursuant to sub-paragraph (a) above or subsequently)–
 - (i) to pursue the arbitration with all due despatch; and
 - (ii) to do all that is reasonable to argue the case in the arbitration in favour of the protective works concerned in consultation with the Owner.

(18) For the avoidance of doubt –

- (a) for the purposes of paragraph (16) above the circumstances in which the Undertaker shall be treated as not being able to carry out any protective works under paragraph 5 of Schedule 2 to the Act include a case where the decision of an arbitrator under paragraph 5(3) or (4) of Schedule 2 to the Act precludes those works being carried out, or makes the carrying out of those works impractical; and
- (b) if the Undertaker has done the things required by paragraph (17)(a) and (b) above but, on an arbitration under paragraph 5(3) or (4) of Schedule 2 to the Act relating to the Building, a decision of the arbitrator has not been obtained by the time that would be required in order to maintain the Undertaker's construction timetable for the relevant construction (or for the protective works referred to in paragraph (16) above), the Undertaker may carry out the relevant construction in accordance with its construction timetable without carrying out such of the protective works referred to in paragraph (16) above as it could not or cannot lawfully or practicably carry out in accordance with that timetable because the decision has not been obtained.

(19) Protective works carried out in accordance with paragraph (16) above shall be treated as carried out under the powers conferred by paragraph 5 of Schedule 2 to the Act, save that the Owner agrees that:

- (a) sub-paragraph (3) of that paragraph 5 shall not apply to the Owner, and
- (b) the reference to 8 weeks in sub-paragraph (2) of that paragraph 5 shall be treated in relation to the Owner as a reference to 14 days.

MONITORING OF PROTECTED PROPERTY

3. (1) If the Report prepared under clause 2(3) above recommends that monitoring specific to the Building should be carried out, subject to paragraph (6) below the Undertaker shall, if it proceeds with the construction of the authorised works, undertake monitoring of the Building.

(2) Except so far as further or different times or methods of monitoring are recommended in that Report, monitoring shall consist of precise surveying of studs and targets on the outside of the Building, and shall take place prior to the commencement of the carrying out of the relevant construction and during the period that any settlement of the Building arising from it is occurring until the monitoring indicates that building settlement arising in consequence of the relevant construction has reduced to a rate of 2mm per annum or less.

(3) As soon as practicable after the monitoring results have been obtained the Undertaker shall make them available for inspection by the Owner and those results shall remain available until the end of the period of three months from the date when the monitoring ceases; and the Undertaker shall send to the Owner a copy of such of those results as the Owner may before the end of that period request.

(4) Such monitoring will be recommenced at the written request of the Owner if:

- (a) the Owner can show reasonable grounds for concluding that building settlement arising in consequence of the relevant construction of a rate greater than 2mm per annum has started again after the monitoring period specified in paragraph (2) above or a monitoring period under this paragraph has elapsed, and
- (b) that request is made within two years from the date of opening for public traffic of the railway comprised in the authorised works in the vicinity of the Building;

and any such recommenced monitoring shall continue until the monitoring indicates that building settlement arising in consequence of the relevant construction has reduced to a rate of 2mm per annum or less.

(5) The Owner hereby agrees that prior to and during the construction of the authorised works the Undertaker may as often as it may reasonably require, upon giving not less than 7 days' notice in writing to the Owner, enter the Protected Property to monitor the effect of the authorised works (including entering to place and maintain studs and targets for the purposes of monitoring referred to above): Provided always that such inspection, entering, placing and maintaining shall be conducted with a duly authorised representative of the Owner and at reasonable hours and that before placing such studs and targets on any of the Protected Property the Undertaker shall consult with the Owner on their positioning.

(6) The obligations of the Undertaker to carry out monitoring under this clause 3 are subject to the obtaining of any other necessary consents, which the Undertaker shall use its reasonable endeavours to obtain.

COSTS

4. (1) The Undertaker shall repay to the Owner all reasonable costs charges and expenses properly incurred by the Owner, including VAT thereon insofar as the same

is not recoverable by the Owner (whether as a deduction against output tax or as a VAT credit or otherwise), in connection with:-

- (a) the services of the Surveyor under clause 5(2) (Schedules of Defects) of this Deed;
- (b) the services of the Surveyor in connection with the successful proving of a claim under clause 6(1) (Compensation for Damage) of this Deed; and
- (c) the services of architects, surveyors, engineers and other technical advisers to whom the Surveyor finds it reasonably necessary to refer in connection with the successful proving of a claim under sub-paragraph (b) above.

(2) Before any services in respect of which repayment may be claimed under paragraph (1)(b) and (c) above are undertaken, the Owner or the Surveyor shall give the Undertaker not less than 28 days' notice in writing of the services proposed to be undertaken, the basis on which any costs charges or expenses are to be calculated, and an estimate of the total amount of those costs charges and expenses.

(3) Any amount payable under paragraph (1) above shall be paid by the Undertaker within 30 days of that amount being agreed between the Undertaker and the Owner or being determined in accordance with clause 9 (Disputes) of this Deed.

SCHEDULES OF DEFECTS

5 (1) In a case where the settlement assessed for the Building under the Report prepared under clause 2(3) above is 10mm or more, before it commences construction of so much of the authorised works as will or may affect the Building, the Undertaker shall at its own expense appoint in the joint names of the Undertaker and the Owner (and such other persons as the Undertaker may determine so that the Undertaker shall not be obliged to prepare more than one such schedule for the Protected Property) a reputable firm of chartered building surveyors or chartered engineers to prepare a schedule of defects existing in the Protected Property (including, so far as relevant and it can be established from the visual inspection normally conducted in relation to the preparation of such schedules, a description of the apparent magnitude of any defect) and that firm shall submit a copy of the schedule of defects to the Undertaker and the Owner.

(2) In a case where paragraph (1) above applies, after the Undertaker has constructed the authorised works in the vicinity of the Building and at the written request of the Owner a schedule shall be prepared by and at the expense of the Undertaker in consultation with the Surveyor similar to (and with similar inspection techniques as) the one prepared in accordance with that paragraph but setting out what changes of defects appear to have occurred to the Protected Property since the preparation of the schedule under that paragraph, provided such request is made before the end of the period of 2 years from the date of opening for public traffic of the railway comprised in the authorised works in the vicinity of the Building or if later (and building-specific monitoring of the Building is carried out under clause 3 above)

the end of the period of three months from the day on which that monitoring ceased, and provided further that the Undertaker will not be obliged to prepare more than one such schedule for the Protected Property.

COMPENSATION FOR DAMAGE

6 (1) In addition to any claim which the Owner may make under the provisions of any enactments incorporated with or applied by the Act with respect to compensation for lands taken or injuriously affected, the Owner may (subject to paragraphs (2), (3) and (6) below) make a separate claim upon the Undertaker for compensation for the reasonable and proper cost properly incurred by the Owner in remedying any material physical damage caused to the Protected Property by ground settlement arising from the construction of the authorised works, provided that the claim is made before the end of the period of two years from the date of opening for public traffic of the railway comprised in the authorised works in the vicinity of the Building, or if later (and building-specific monitoring of the Building is carried out under clause 3 above) the end of the period of three months from the day on which that monitoring ceased.

(2) For the avoidance of doubt, if the Building or the Protected Property suffers from a pre-existing defect or defects which are worsened by the construction of the authorised works, the compensation payable under paragraph (1) above is limited to the additional costs of repair of the Protected Property which go beyond those that would be incurred upon remedying the pre-existing defect or defects (assuming the authorised works had not been constructed).

(3) Before carrying out any work in respect of which a claim may be made under paragraph (1) above, the Owner shall give not less than 28 days' notice in writing to the Undertaker, specifying the material physical damage concerned and the proposed remedial work; and if within the period of 28 days after the giving of such notice –

(a) the Undertaker elects by notice in writing to the Owner to remedy all or part of that damage, then no claim may be made under that paragraph in respect of the damage or part, but the Undertaker shall be under a duty to remedy the damage or part to the reasonable satisfaction of the Owner as soon as reasonably practicable thereafter in accordance with a specification agreed with the Owner or in default of such agreement, determined under clause 9 below, and/or

(b) the Undertaker by notice in writing to the Owner requires the Owner to obtain competitive quotes for all or any of the remedial work, then before entering into a contract for or arranging for the carrying out of the work concerned the Owner shall (i) take reasonable steps to obtain not less than 3 competitive prices for the work and (ii) obtain the consent of the Undertaker to the quote to be accepted, such consent not to be unreasonably withheld.

(4) If it appears to the Owner or the Undertaker that any damage in respect of which notice is given by the Owner under paragraph (3) above is likely to be of a recurring nature by reason of the programme for or the nature of the authorised works, either of them may, in the relevant notice, require a timetable for the carrying out of

the remedial work relating to the damage (including a timetable and specification of any interim repairs reasonably necessary in consequence of the damage) to be agreed or, in default of agreement, determined under clause 9 below; and for this purpose “the relevant notice” means –

- (a) where the requirement is made by the Owner, the notice given by him under paragraph (3) above;
- (b) where the requirement is made by the Undertaker, and the Undertaker gives a notice of election under paragraph (3)(a) above, the notice of election;
- (c) where the requirement is made by the Undertaker, and the Undertaker gives notice requiring competitive quotes under paragraph (3)(b) above, the notice requiring competitive quotes;
- (d) where the requirement is made by the Undertaker and the Undertaker gives no such notice of election or notice requiring competitive quotes, a separate notice in writing stating the requirement, which is given within the period of 28 days after the giving of the notice by the Owner under paragraph (3) above.

(5) The Owner hereby agrees that the Undertaker may as often as it may reasonably require and upon giving not less than 14 days’ notice in writing to the Owner, enter the Protected Property at any reasonable time to carry out works in compliance with any duty under paragraph (3) or (4) above, but in doing so the Undertaker agrees that it will have due regard to any activities carried out by those with an interest in the Building.

(6) For the avoidance of doubt, the Owner shall not be entitled to (and hereby accepts the fulfilment of the obligations of the Undertaker under this clause in satisfaction of any right to) compensation under any enactment as regards any damage or claim in respect of which the Owner is entitled to payment under paragraph (1) above or which the Undertaker is under a duty to remedy under paragraph (3) or (4) above.

(7) So far as concerns compensation payable by the Secretary of State under any enactment, the Owner acknowledges that the Undertaker holds the benefit of paragraph (6) above for, and may assign it to, the Secretary of State.

(8) In paragraphs (6) and (7) above, reference to “any enactment” includes reference to the Act.

AS TO THE UNDERTAKER’S LIABILITY IN CERTAIN CASES

7. The fact that any work or thing has been executed or done in accordance with a Report prepared or agreed under clause 2 above or in accordance with any decision of an adjudicator shall not relieve the Undertaker from any liability for damage caused to the Protected Property or affect any claim by the Owner in respect of such damage.

POWERS OF THE UNDERTAKER

8. For the avoidance of doubt nothing in this Deed shall be taken to detract from any powers of the Undertaker, other than powers conferred on the Undertaker under the Act.

DISPUTES

9. (1) Any dispute or difference arising between the parties hereto as to their respective rights duties and obligations under this Deed or as to any matters arising out of or in connection with the subject matter of this Deed shall be determined by adjudication in accordance with the provisions of this clause.

(2) Either party may give notice in writing to the other referring the dispute to adjudication under this clause, and that notice shall briefly state the matter which is in dispute between them.

(3) Unless the dispute in question is one that falls to be consolidated under paragraph (12) below with other disputes relating to the Building and an adjudicator has already been appointed for any of the disputes (under a provision in another Deed similar to this clause 9) which fall to be so consolidated (in which case that adjudicator shall act on the consolidated proceedings), the party giving notice under paragraph (2) shall upon giving that notice forthwith request the appointing body to nominate an independent person to act as adjudicator, who shall be a person professionally qualified for not less than 10 years and who is also a specialist in relation to the subject matter of the dispute, and the request shall ask the appointing body to nominate the adjudicator within 7 days of the notice being given with a view to the matter being referred to the adjudicator within that period.

(4) Except in the case of a dispute or difference with regard to the meaning or construction of this Deed, the appointing body for the purposes of paragraph (3) shall be the President, Vice-President or other duly authorised officer of the Institution of Civil Engineers, and in the case of a dispute or difference with regard to the meaning or construction of this Deed, the appointing body shall be the President, Vice-President or other duly authorised officer of the Law Society.

(5) The terms of reference of the adjudicator shall be as follows –

- (a) the adjudicator is to reach a decision within 28 days of the dispute being referred to him or within such longer period (if any) as may be agreed by the parties after the dispute has been referred to him;
- (b) the adjudicator may extend that period of 28 days by up to 14 days without the agreement of the parties to the dispute if the party referring the dispute consents;
- (c) the adjudicator must act impartially;

(d) the adjudicator may take the initiative in ascertaining the facts and the law.

(6) In reaching his decision, the adjudicator shall act as an expert and not an arbitrator and he shall accordingly take into account his expert knowledge and judgement.

(7) The parties hereto agree that the decision of the adjudicator shall be final and binding except in a case of manifest error.

(8) In a case of manifest error the decision shall (so far as consistent with the terms of this deed) be binding until the matter is finally determined by legal proceedings or by agreement between the parties.

(9) The adjudicator shall not be liable for anything done or omitted in the discharge or purported discharge of his functions as adjudicator unless the act or omission is in bad faith, and any employee or agent of the adjudicator shall be similarly protected from liability.

(10) The incidence of the adjudicator's reasonable costs and fees in the adjudication shall lie (as between the parties to the dispute) at the award of the adjudicator.

(11) This clause 9 shall apply to disputes falling both within and outside section 108 of the Housing Grants, Construction and Regeneration Act 1996, and (in the case of a dispute falling within that section) if there is any inconsistency between the provisions of this Deed and the requirements of subsections (1) to (4) of that section the inconsistency shall be resolved in favour of those subsections and those subsections shall to the extent of such inconsistency be deemed to be incorporated in this Deed and have effect accordingly (so that amongst other matters the Scheme for Construction Contracts is not intended to apply).

(12) In the event of the Undertaker entering into a Deed with any person or persons other than the Owner (whether on, before or after the date of this Deed) in relation to the whole or part of the Building containing provisions similar to clause 2 above, then—

(a) all disputes of the kind mentioned in clause 2(12) relating to the Building shall be consolidated into a single proceeding with a single adjudicator for all of them and this clause 9 shall have effect accordingly; and

(b) the finding of the adjudicator shall have effect with respect to the Building for the purposes of clause 2 with respect to the Owner even if the Owner did not become or did not remain a party to the adjudication.

SERVICE OF NOTICES

10. (1) Any notice in writing that is to be given by the Undertaker to the Owner shall be deemed effectively given if left at, or despatched by a postal service in which receipt is recorded addressed to, [*specify address within United Kingdom*] or such

other address within the United Kingdom as the Owner notifies to the Undertaker in writing, and in the case of the documents referred to in the definition of “sent” in clause 2(1) above, the documents shall be deemed effectively given if posted by ordinary first class post to that address (whether or not received).

(2) Any notice in writing that is to be given by the Owner to the Undertaker shall be deemed effectively given if left at, or sent by a postal service in which receipt is recorded addressed to, the address as set out in this Deed or at such other address within the United Kingdom as is notified in writing by the Undertaker to the Owner.

IN WITNESS of which the parties have executed this document as a Deed on the day and year first before written

THE COMMON SEAL OF [] was hereunto affixed in the presence of:

DIRECTOR

DIRECTOR/COMPANY SECRETARY

[Signed as a deed² by the said []

in the presence of:

Witness Name _____

Address _____

Occupation _____]

² Or other appropriate execution provision(s) for a deed having regard to the status and legal personality of the Owner

APPENDIX

REFERRED TO IN CLAUSE 2

(SETTLEMENT AND PROTECTIVE WORKS)

INTRODUCTION

1. The assessment consists of one, two or three Phases as described below and (subject always to the provisions of this Appendix) is carried out in accordance with the general approach set out in the document “Assessment of Ground Movement and Potential Building Damage: 3 Phase Methodology” (Crossrail project reference 1D1010-G0G00-0100) Revision [] *Note final revision number to be inserted.*

PHASE 1

2. The Phase 1 assessment is based on “green-field” site conditions. This means that the effect of building foundations on the pattern of settlement is ignored.
3. For bored tunnels the settlement predictions for “green-field” site conditions are produced based on empirical methods such as those described by O’Reilly and New (1982) and Attewell and Woodman (1982) using parameters for ground loss determined from case histories and taking into account the method of tunnelling and ground conditions.
4. For excavations comprising shafts, boxes and retained cuttings, a conservative methodology for predicting settlements has been developed specifically for use on the Crossrail Project, based on relevant case studies of similar excavations in stiff clay.
5. Where the predicted settlement from bored tunnels and from the excavations referred to above is less than 10mm and the predicted ground slope is less than 1/500 (equivalent to damage risk category 1 as defined by Rankin, 1988) buildings are not subject to further assessment. Those for which predicted settlement is 10mm or more or for which predicted ground slope is 1/500 or more are subject to a Phase 2 assessment.

PHASE 2

6. In Phase 2, the settlement calculated for “green-field” conditions is imposed on buildings, i.e. it is assumed that buildings behave completely flexibly and their own stiffness has no influence on the settlement behaviour. In addition the deformation due to horizontal ground movement is taken into account.
7. The Phase 2 assessment comprises a generic area-wide assessment of settlement, developed specifically for use on the Crossrail Project, which identifies zones in

which buildings might be at risk of sustaining damage at levels which require individual investigation (that is, in which they may be in risk category 3 or above) based on correlation with the calculated maximum tensile strain values (see Harris and Franzius (2005)). For the buildings within these zones, an individual assessment is required in Phase 3 of the assessment process (see paragraph 11 below).

8. The potential damage in this area-wide assessment is defined using the procedure described by Burland (1995) and Mair et al (1996). Each building is categorised into one of six risk categories by reference to maximum tensile strain as described in column 2 of Table 1 below.
9. This generic assessment is only sufficiently informative for buildings with relatively shallow foundations. Buildings with a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis, automatically qualify for a Phase 3 assessment after the Phase 2 process (see paragraph 12(b) below).
10. Subject to paragraph 12 below, buildings assessed to be in risk category 0, 1 or 2 after the Phase 2 assessment are not subject to further assessment.
11. All buildings which are placed in risk category 3 or above in the Phase 2 assessment are subject to a Phase 3 assessment.
12. Any building which has been subject to Phase 2 assessment but which has not qualified for further assessment under paragraph 11 above is nonetheless subject to a Phase 3 assessment if
 - (a) it is on shallow foundations and is within a distance from a retained cutting, shaft or box equal to the excavated depth of superficial deposits or 50% of the total excavation depth (whichever is the greater). In this context, superficial deposits are taken to be soils such as Made Ground, Alluvium or Terrace Gravels,
 - (b) it has a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis,
 - (c) it is a listed building, or
 - (d) the Undertaker considers that for some other reason the determination of whether protective works for the building are required, or the form that such protective works should take, requires further assessment in Phase 3 to be undertaken.

PHASE 3

13. Paragraphs 14 to 17 below apply to all buildings subject to Phase 3 assessment. In addition, paragraphs 18 to 23 below apply to listed buildings which are subject to

Phase 3 assessment (all listed buildings which are assessed to experience settlement of 10mm or more automatically qualify for an assessment at Phase 3).

Provisions applying to all buildings which are subject to Phase 3 assessment

14. In Phase 3 of the assessment procedure, each building is considered individually in contrast to the first 2 Phases where the area of interest is analysed generically.
15. The Phase 3 assessment consists of several sub-steps (referred to as “Iterations”), each refining the building and tunnel model to a higher degree. In this Phase both the strain developing within the building and the applicability of the standard risk categories (which are based on masonry structures) is reappraised. In the first Iteration the same model is used as in the Phase 2 assessment. This model is then successively refined in the following Iterations. If necessary, the tunnel-excavation-soil-building interaction problem is modelled numerically. The approach is to use simplified assumptions in the first instance and refine the analysis to see if a more accurate approach results in the risk of damage reducing to an acceptable level.
16. A structural survey will be undertaken to determine the structural form and condition of the building where reasonably necessary for the assessment. In every case where a building is subject to Phase 3 assessment, a desktop structural appraisal by a qualified structural engineer will be carried out for the purpose of confirming the likely structural behaviour and determining whether such a structural survey is so necessary.
17. As a result of the Phase 3 assessment, the risk category of the building is assessed or reassessed, the requirement for any protective works is established and the design and implementation of any protective works and associated specialised monitoring are determined.

Provisions also applying to listed buildings which are subject to Phase 3 assessment

18. In the first Iteration of the Phase 3 assessment, the heritage value of a listed building is considered by reviewing the sensitivity of the building structure and of any particular features against the risk category assigned in Phase 2. The heritage assessment examines the following:
 - (a) the sensitivity of the building / structure to ground movements and its ability to tolerate movement without significant distress. The potential for interaction with adjacent buildings / structures is also considered. A score within the range of 0-2 will be allocated to the building/structure in accordance with the criteria set out in Table 2.
 - (b) the sensitivity to movement of particular features within the building / structure and how they might respond to ground movements. A score within the range of 0-2 will be allocated to the building in accordance with the criteria set out in Table 2.

19. In addition, a score corresponding to the Phase 2 settlement assessment risk category within the range of 0-5 is allocated to the building.
20. The scores for each of the three categories (18(a), 18(b) and 19) are added together to inform the decision making process. In general, listed buildings which score a total of 3 or higher are subject to further assessment as part of the Phase 3 iterative process. Buildings which score a total of 2 or less are predicted to suffer a degree of damage which will be easily repairable using standard conservation based techniques and hence no protective measures for the building's particular features are required. However, ultimately the professional judgement of engineering and historic building specialists will be used to determine whether additional analysis is required. Upon conclusion of the Phase 3 Iterations, a final composite score will be arrived at, comprising the risk category of the building (ignoring the fact that it is a listed building) assessed in accordance with the normal principles of Phase 3 assessment, to which will be added final scores for each of the two additional sensitivities referred to in paragraph 18(a) and (b) in accordance with Table 2, and this final composite score will constitute the risk category of the listed building for the purposes of paragraph 17 above and clause 2(6) to (15) of this Agreement.
21. The relevant local authority will be consulted on the results of the listed building assessment reports and the proposals for protective measures for the building's particular features, if any are required. English Heritage will also be consulted in relation to buildings where they would normally be notified or consulted on planning applications or listed building consent applications (as set out in DETR and DCMS Circular 1/01).
22. When considering the need and type of protective measures, due regard will be given to the sensitivity of the particular features of the building which are of architectural or historic interest and the sensitivity of the structure of the building to ground movement. Where the assessment highlights potential damage to the features of the building which it will be difficult or impossible to repair and/or if that damage will have a significant effect on its heritage value, the assessment may recommend appropriate measures to safeguard those features either in-situ or by temporary removal and storage off-site if those with relevant interest(s) in the building consent. If the Owner so requires, and provided that all relevant consents and other approvals are obtained from the local authority and/or English Heritage and/or any other relevant authority (whether by way of listed building consent, or under any undertaking or agreement requiring similar approvals given or entered into by the Secretary of State or the Undertaker, or otherwise) and from those with relevant interests in the building or its fabric, the Undertaker is to use all reasonable endeavours to implement any such safeguarding measures recommended in the Report. The Owner is to assist in obtaining such consents and approvals.
23. The form of monitoring of listed buildings will be determined based on the results of the assessment process.

REFERENCES

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“Assessment of Ground Movement and Potential Building Damage: 3 Phase Methodology” (Crossrail project reference 1D1010-G0G00-0100) Revision []

TABLE 1

			Building Damage Classification¹	
1	2	3	4	5
Risk Category	Max Tensile Strain %	Description of Degree of Damage	Description of Typical Damage and Likely Form of Repair for Typical Masonry buildings	Approx² Crack Width (mm)
0	0.05 or less	Negligible	Hairline cracks.	
1	More than 0.05 and not exceeding 0.075	Very Slight	Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	0.1 to 1
2	More than 0.075 and not exceeding 0.15	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible; some repointing may be required for weather-tightness. Doors and windows may stick slightly.	1 to 5
3	More than 0.15 and not exceeding 0.3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Repointing and possibly 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
4	More than 0.3	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks
5		Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	Usually greater than 25 but depends on number of cracks

Notes

1. Table 1 is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 2) used in Phase 2 settlement analysis.
2. Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

TABLE 2

Scoring for Sensitivity Assessment of Listed Buildings

Score	Criteria	
	Sensitivity of the structure to ground movements and interaction with adjacent buildings	Sensitivity to movement of particular features within the building
0	Masonry building with lime mortar not surrounded by other buildings. Uniform facades with no particular large openings.	No particular sensitive features
1	Buildings of delicate structural form or buildings sandwiched between modern framed buildings which are much stiffer, perhaps with one or more significant openings.	Brittle finishes, e.g. faience or tight-jointed stonework, which are susceptible to small movements and difficult to repair.
2	Buildings which, by their structural form, will tend to concentrate all their movements in one location.	Finishes which if damaged will have a significant effect on the heritage of the building, e.g. cracks through frescos.