

Guidance Document

G0058 Civil Engineering - Technical Advice Notes

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G0058 - Civil Engineering - Technical Advice Notes

1 Purpose

- 1.1 The purpose of this guidance document is to publish all advisory Civil Engineering Technical Advice Notes (CETAN's) in one document.
- 1.2 CETANs provide information and advice which may be helpful in managing the London Underground's Civil Engineering assets.
- 1.3 Section 3 of this manual has been structured to mirror that of LU's Category 1 standards.

2 Scope

- 2.1 The scope of CETANs covers all aspects of Civil Engineering.
- 2.2 London Underground manages infrastructure which has been constructed over many years, incorporating assets, materials and methodologies, some no longer used, and subject to system specific effects. CETANs are written to provide information and advice on these assets, materials, methodologies and effects in a way which may be helpful in managing the assets into the future. As individual new CETAN's are produced these will be added to this guidance document.
- 2.3 CETANs have been written for various reasons covering topics which are not readily applicable to the guidance documents which directly support the civil engineering standards. Hence this document is separate but forms part of the suite of Civil Engineering Guidance documents (refer to Section 5).
- 2.4 It should be noted that some CETANs were written some time ago and some references to currency of standards may no longer be correct. These have been left unaltered to show derivation of source.



3 Civil Engineering Technical Advice Notes (CETAN)

3.1 Common Requirements

3.1.1 Settlement due to deep excavations

3.1.1.1 Summary

- 1 This Advice Note sets out appropriate empirically based models for the prediction of movement around deep excavations. It is principally intended to address the movements around shafts but also has potential application to other structures such as boxes, particularly where movements must be assessed close to the corners of such structures.
- 2 Settlement due to shaft construction can be predicted using simple empirically derived models. In the case of shafts constructed from embedded retaining walls a model can be used which is based on observations of movement during the construction of a number of retaining walls. CIRIA publication C580, "Embedded retaining walls - guidance for economic design" provides a commentary on the prediction of ground movements due to wall installation and also provides a significant amount of useful case history data. The predictions for circular shafts can be made using the model proposed by New and Bowers (1994) based on observations of movement made during the sinking of a circular shaft at Heathrow.
- 3 This Advice Note addresses the movements due to the installation of embedded retaining walls, movements due to excavation and propping behind embedded walls, movements around circular shafts and also the likely settlement behaviour adjacent to "short" retaining walls such as those which comprise deep diaphragm wall shafts. The term "short wall" is used to describe walls that have a length that is less than or of a similar order to their depth.
- 4 The latter group may cause some particular concerns related to apparent over prediction of movement. This problem arises in part because of the limited availability of field data from similar structures. A methodology has been proposed which will reduce over prediction of settlement adjacent to these "short" walls by correcting the model to take account of the true shape of the walls. The model output has been validated by comparison with other predictive models and available field observations and has been shown to remain conservative.

3.1.1.2 Introduction

- 1 The construction and excavation of deep structures such as shafts and retaining walls is likely to give rise to some ground movement. This movement will be dependent on a number of factors including the ground conditions, the construction method and the form of the final structure.
- 2 Settlement due to the construction of deep excavations can be predicted using two simple empirically derived models.
- 3 Predictions for circular shafts can be made using the model proposed by New and Bowers (1994) based on observations of movement made during the sinking of a circular shaft at Heathrow.
- 4 Shafts designed as embedded in-situ retaining walls, including diaphragm walls, may be constructed top-down with multiple levels of propping. Settlement predictions for these structures can be made using an empirical model based on past observations. This model is based on data from the construction of a number of relatively long retaining walls. A number of published sources provide appropriate information (for example Clough and O'Rourke 1990).



- 5 In the remainder of this advice note the term “long wall” is used to describe retaining walls having a length substantially greater than their depth. The term “short wall” is used to describe walls that have a length that is less than or of a similar order to their depth. In practical terms the latter group are shafts or the ends of deep boxes.
- 6 This Advice Note is divided into sections reflecting the key issues that should be considered.

3.1.1.3 Movement due to wall installation

- 1 The process of installing an embedded retaining wall may involve pile driving or excavation to place bored piles or diaphragm walls. These processes may give rise to some ground movement through a combination of direct ground displacement, compaction and local stress relief effects. The best available guidance on the movements likely to be caused by such works is from case history data.
- 2 A study of the observed movements arising from the installation process alone for embedded retaining walls in the London area has been previously reported (Thompson 1991). This study demonstrated that in all cases the maximum ground surface settlement that occurred was less than 10mm. There was also a general trend of reduction of the magnitude of the movement with increasing distance from the wall. In the case of diaphragm walls the largest reported settlement was 7mm. Beyond about 10m from the walls reported settlements were limited to 1 or 2mm. The associated ground strains (and therefore the potential strain in any existing facility) would have been negligible.
- 3 The findings of Thompson's study are summarised in Figure 1 (see section 3.1.1.10).

3.1.1.4 Movement due to excavation and support installation

- 1 Excavation behind an embedded retaining wall may give rise to some deflection of the wall which will in turn lead to ground movement behind the wall. Clearly the wall stiffness will have a critical influence on this movement. A number of workers have reported settlement case history data related to the excavation and subsequent support of retaining structures. Key summaries have been given by Peck (1969), Clough and O'Rourke (1990) and for the London area Burland et al (1977). These papers provide empirically based guidance on the prediction of movements due to excavation of retaining walls (typically long walls with a length of at least 2.5 times the depth). In the general case of “Stiff to Very Hard Clays” Clough and O'Rourke indicate that a suitable upper bound model is a linear variation of surface settlement from a maximum of 0.3% of the excavation depth at the wall to zero at a distance away from the wall equal to three times the height of the wall.
- 2 Additional useful case histories from top down deep excavations in the London area have included those presented by Burland and Hancock (1977), St John (1975 & 1992), Loxham et al (1989) and Fernie et al (1991). Figure 2 (see section 3.1.1.10) summarises this data and illustrates an empirically derived relationship that provides a good fit to the data. This relationship provides a good basis for prediction of vertical surface settlements along a line perpendicular to a long wall and remote from the ends of the wall (and remote from the corners in the case of a box).
- 3 This expression to predict the settlement due to excavation of a long wall by top down construction in London is as follows:
$$S_v/H = 0.0015 \exp[1-(1+2x/3H)^2]/2$$
- 4 Where H is the excavation depth, x is the distance away from the wall and S_v is the settlement at x. It should be noted that confidence in this model will be reduced in the area immediately adjacent to the wall where local construction process effects and wall friction may dominate any movement.

- 5 Figure 3 (see section 3.1.1.10) illustrates a corresponding set of horizontal movement data.

3.1.1.5 Movement due to short walls

- 1 The approach used in the previous two sections is appropriate for predictions of movements in a plane perpendicular to a long wall and remote from the ends of the walls, or the corners, of a box. A practical problem arises with the application to short walls. The resulting predictions are found to be very substantially greater than either experience or the known behaviour of circular shafts of similar size would suggest. However, there is little published data available to confirm this. The data set that comes closest to demonstrating the actual ground movement at the corner of an excavation is that from the construction of the Palace of Westminster car park (Burland and Hancock 1977). This case history included monitoring around the corner of a box excavation and clearly demonstrated that settlement in front of the walls tends to reduce towards the corners of the box (Figure 4 - see section 3.1.1.10).
- 2 Within the CIRIA publication C580, "Embedded retaining walls - guidance for economic design", some commentary is provided on corner effects. A number of authors have considered the fact that the corners of an excavation tend to restrict movement. A study by Ou et al (1996) presents some interesting results. A two dimensional (2D) finite element (FE) analysis was conducted for the main section of the wall and a three dimensional FE analysis of the corner section. Ground conditions were principally firm clays. On the long sides of the excavation the predicted movements from the 2D analysis gave good agreement with field measurements. At the corners the measured deflections were 40-50% of the movements predicted by the 2D analysis.
- 3 On reflection it is apparent that the unexpectedly large predictions are a function of the fundamental differences between short walls and long walls; the latter represent the base data from which the empirical wall model has been derived. There are two principal differences between the two types of structure.
- 4 Firstly, a short wall may be substantially deeper than it is wide. In contrast the walls on which the model was based are longer than they are deep. The ground movement occurring at a point very close to the wall will be dominated by the performance of the closest part of the wall and will therefore tend to be insensitive to the lateral extent of the wall. However, settlement at a point further away from the wall will be significantly influenced by a much longer section of the wall. Thus the ground movement at points further away from the wall is more dependent on the length of the wall. Where shafts are effectively composed of very short walls they would therefore be expected to give rise to less movement at points remote from the wall than would be indicated by the long wall data used to develop the model.
- 5 Secondly, the stiffness of the two groups of structures is likely to differ. Embedded retaining walls are substantially propped by the walls on the adjacent faces, and walls constructed top down will have extensive additional propping at frequent vertical intervals during excavation. In addition the toes of the walls will be embedded into stiff soils. This means the effective stiffness of the shaft structure is likely to be much greater than the effective stiffness of the longer walls. As movement during the excavation phase must be principally associated with the deflection of the wall under earth pressure this additional stiffness will directly reduce the magnitude of the movement.
- 6 Thus in summary it is inferred that the model is over-conservative for modelling the movements around shafts constructed of short walls for two main reasons:

The model is based on an upper bound envelope including data from a range of walls, none of which has the effective propping of a shaft.

The walls on which the model is based have a ratio of length to depth (L/H) of typically > 2.5, compared to a value of less than 1.0 for shafts constructed of short walls.

- 7 This argument indicates that the empirical model is appropriate to predict ground movement in the central section of long walls but that it will over predict near the ends of a wall or at the corners of boxes and shafts. It is also apparent that the problem can therefore be partly managed by the application of a correction factor that takes account of the geometric problem to the result from the long wall model. A suitable methodology for this correction is proposed below.
- 8 Consider a long wall and its influence (in terms of ground movements) on a remote point. The wall may be considered to be composed of a large number of vertical elements. Each element contributes a part of the total ground movements such that the sum of the contributions from all the strips is the total movement.
- 9 The movement at the remote point will not include an equal contribution from all of the elements. The contribution of each strip will depend on the distance (x) between the point and the element. Because the model is based on the assumption that all movement is due to deflection into the plane of the wall the contribution of each strip will also vary depending on what offset there is between the point and the element. It is convenient to express this as an angle (β).
- 10 The contribution due to an element may therefore be expressed as a function of x and β . Thus the settlement at the remote point due to the elementary strip of wall (S_x) is approximated by:

$$S_x = f(x) \cdot \sin(\beta)$$

where f is a function describing the variation of settlement with distance away from the wall.

- 11 Integration of this function over the length of the wall would give the total settlement at the remote point due to the whole of the wall. In the case of a long wall this will approximate to the empirical model based on long wall data. In the case of a shorter wall the resulting total movement will be somewhat less.
- 12 This result may also be obtained by approximation. This has been done for a range of values. The results have been derived as a set of factors by which a prediction derived from the long wall models described above may be reduced to correct for the geometry of short walls. The tabulated results are presented in Table 1 (see section 3.1.1.11) and Figure 5 (see section 3.1.1.10). This may be used as a look up table to derive approximate solutions for shafts with geometry covered by the ranges in the table. Guidance on the application of this approach is provided in section 3.1.1.12.
- 13 A check may be made on the result obtained by this method by comparing the output of the model with that given by the New & Bowers (1994) model for circular shafts. The two would be expected to give similar results as they must tend towards the same limiting case. In fact the combined segmental and shotcrete construction of the shaft on which the circular shaft model was based was substantially more flexible than an embedded retaining wall structure and so it may be expected that the latter would give less movement. Figure 6 (see section 3.1.1.10) provides a direct comparison of the results for the two models. This demonstrates that the proposed approach gives results of a similar order to the results of the New and Bowers model. This in turn confirms that the basis of the model is reasonable.
- 14 The method proposed here does not exploit the likely higher stiffness of the shaft structures and therefore is expected to remain very conservative. The stiffness factor is likely to account for a further reduction in the ground movement but is difficult to quantify without extensive analysis supported by site observations of actual movements.



3.1.1.6 Movement due to circular shafts

- 1 The difficulties that have been experienced in modelling settlement at shafts with in-situ embedded walls do not extend to circular shafts. The approach previously used (New and Bowers 1994) remains the most appropriate tool for simple analysis of movement due to this excavation. However, the application of this model is limited because it does not take account of shaft diameter. It should also be noted that the shaft from which the model was developed was sunk for about 17m as a caisson and thereafter underpinned using sprayed concrete. The output from this model is a value of total settlement due to the complete construction and excavation process.

- 2 The expression used to predict settlement due to the circular shaft is as follows:

$$S/H = \alpha \{1-(d/H)\}^2$$

Where S is the settlement at a distance d from the shaft wall, H is the depth of the excavation and α is a dimensionless coefficient. The best fit for α was found to be a value of 0.0006, which is equivalent to a settlement at the shaft wall of 0.06% of the excavated depth of the shaft. A normalised plot of this model is presented in Figure 7 (see section 3.1.1.10).

3.1.1.7 Applicability of models

- 1 Some general constraints apply to the application of all the models discussed in this Advice Note.
- 2 Firstly, caution should be applied to any predictions of movement in a local zone very close to the excavations. In practical terms this local zone may be defined as being within a distance from the excavation equal to the depth of the superficial deposits. Experience has shown that movement in this zone may be less readily predicted because it is dominated by construction processes close by and factors such as ground water conditions. Control of these factors is primarily a matter of good construction management. The use of ground treatment may provide greater control in practice. Additionally settlement very close to an embedded wall may be locally reduced by friction between the soil and the wall. Past observations have indicated that the soil adjacent to the wall may tend to “hang” on the wall leading to these locally reduced movements.
- 3 The case histories on which these models are based are predominantly in London Clay. Where other materials are encountered an assessment of their stiffness should be made. Providing the material tends to be stiffer than the London Clay the data based on observations of the London Clay will provide a suitably conservative indication of their likely performance.
- 4 The models presented in this Advice Note are all derived from data obtained at or near the ground surface. In some situations it may be necessary to assess likely movements at some depth below the surface. The settlement experienced at any point will only be due to excavation below that level. Therefore the projection of movements predicted at a surface point to a location at depth directly below the surface point will be unduly conservative. Because of this it is recommended that in predicting movement at a point significantly below the surface only that part of the structure and excavation below the level of the point of interest is considered. Thus if the point of interest is ten metres below the surface and the excavation is to a depth of 30m from the surface then the settlement at the point of interest should be predicted on a basis of an assumed 20m deep excavation.



3.1.2 Guidance on sizing of tunnelled passageways and openings in Deep Tube Tunnels

3.1.2.1 Summary

1. This Advice Note sets out guidance for good practice in layout planning of passageways and openings in Deep Tube Tunnels. Tunnel layouts conforming to this guidance are likely to be relatively straightforward to construct.
2. The size of the civil engineering structures is generally dictated by spaceproofing and passenger flow considerations defined in accordance with S1371 Station Planning. Therefore the civil designers and others must work together to produce an optimum design.
3. The guidance given in this note is not a substitute for design analysis but is illustrative of typical geometric arrangements in stations.

3.1.2.2 Introduction

- 1 The upgrading of existing underground stations and design of new tunnelled station infrastructure can require the addition of new passageways that junction with both existing and new tunnels and shafts. The design of the connections between these tunnels and shafts is often a significant factor in planning the station layout.
- 2 Where a project is complex and congested it may not be possible to comply with all of this guidance. Architects and designers should consult with the tunnel structural designer to develop an optimum solution.
- 3 The sketches presented in this guidance show certain simplifications (circular tunnels, perpendicular junctions etc.) for ease of discussion. This does not rule out the possibility of other geometries. This guidance should not rule out consideration of alternative solutions for particular junctions where these may offer saving in materials or a reduction in the required excavation.

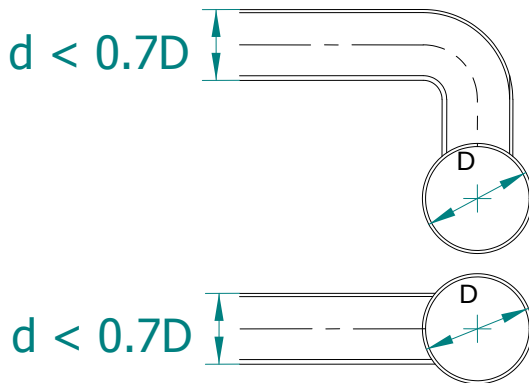
4 Definitions

- a) Parent tunnel – At a junction the larger tunnel in which the tunnel eye is formed
- b) Child tunnel – At a junction the smaller tunnel connecting to the Parent tunnel
- c) R – Radius of Parent tunnel
- d) r – Radius of Child tunnel
- e) D – Diameter of Parent or larger tunnel
- f) d – Diameter of Child or smaller tunnel

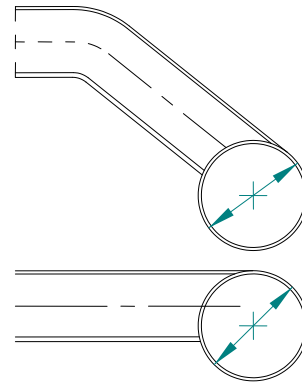
3.1.2.3 Tunnel “T” junctions

- 1 The following guidance applies to both new-to-new and new-to-existing T-junction connections between tunnels.
- 2 The junction should be arranged so that the connection is as close to perpendicular as possible.
- 3 The Child tunnel excavated diameter (d) should be $\leq 70\%$ of Parent tunnel diameter (D). In cases where the Parent tunnel is an existing tunnel it may be necessary to locally enlarge the Parent to enable the connection.

- 4 The axis of the Child tunnel should be close to the axis of the Parent tunnel (as illustrated below).



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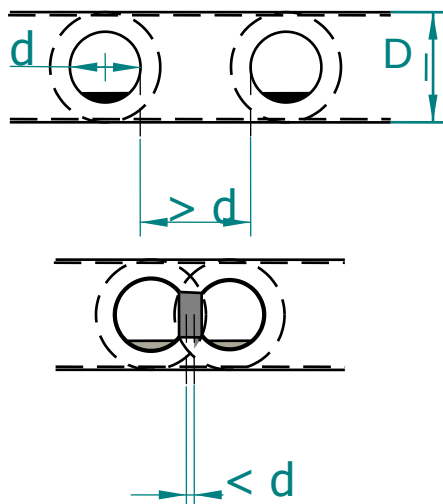
UNDESIRABLE

- 5 In the horizontal plane the Child tunnel excavated crown and invert should be $\geq 1\text{m}$ inside the Parent tunnel crown and invert.
- 6 Allowance should be made for an increased thickness of Parent tunnel primary lining around junction openings. Typically this will be at least a doubling of thickness within $0.5d$ of the edge of the opening.
- 7 A reinforced concrete collar may be required in the permanent lining of the Parent tunnel around openings. This may also give rise to a requirement for greater thickness in the lining in this area. Typically this will affect the Parent lining at $\leq d$ from the edge of the opening.

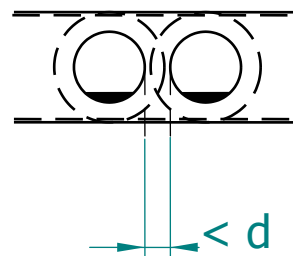
3.1.2.4 Multiple junctions on the same side

- 1 Where multiple openings are required into the same side of a tunnel the spacing between the openings affects constructability. Therefore, where possible, the spacing between Child tunnels should be $\geq d$.
- 2 Where two child tunnels must join the Parent at a separation of less than d consideration should be given to formation of a "binocular" tunnel. This is where two Child tunnels are constructed close together and a ground-bearing structural wall replaces the soil between the two. This avoids dependence on a highly stressed and disturbed soil column between the two tunnels.
- 3 Desirable and undesirable multiple junction arrangements are illustrated below.

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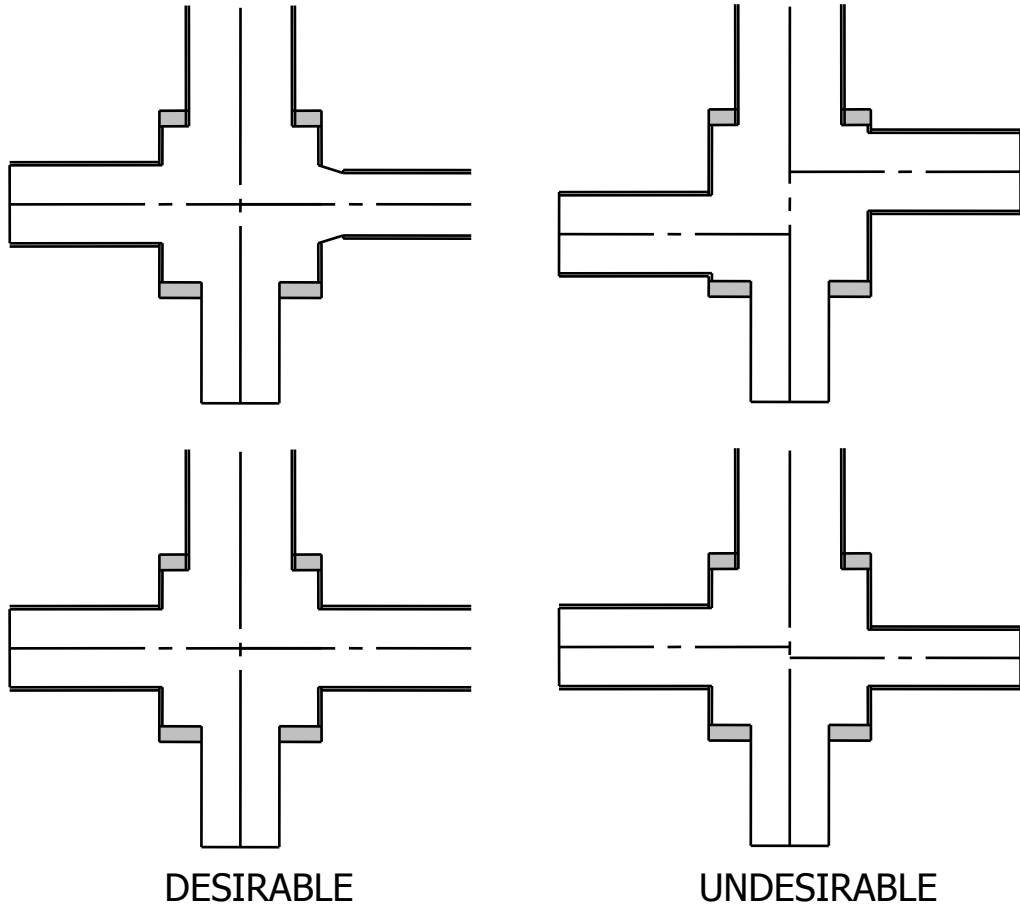
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3.1.2.5 Tunnel cruciform junctions

- 1 A requirement for cruciform junctions typically occurs where two passageways cross. These are particularly difficult structures to construct and should be avoided unless doing so necessitates a staggered junction. A staggered junction is a junction where connections on opposite sides of the parent are within one diameter (D) of each other.
- 2 Where cruciform tunnels are required these should be arranged as symmetrically as possible. In cases where two Child tunnels are arranged opposite one another these should be made coaxial where possible even if they have different diameters.
- 3 It is quite common for cruciform junctions to occur where two similarly sized passageway tunnels cross. This may necessitate local enlargement of one of the tunnels to form a Parent tunnel.
- 4 Each Child tunnel excavated diameter should be $\leq 70\%$ of the Parent tunnel diameter.
- 5 Each Child tunnel excavated crown and invert should be $\geq 1.5\text{m}$ inside the Parent tunnel crown and invert.
- 6 It should be noted that cruciform junctions may be a problematic area in terms of excavation induced ground movement. This risk should be considered at an early stage in design.
- 7 Allowance should be made for an increased thickness of Parent tunnel primary lining around junction openings. Typically this will be at least a doubling of thickness within $0.5d$ of the edge of the opening. Because a cruciform junction will require two such thickened areas it may be more practical to thicken the lining in the entire area of the junction.
- 8 A reinforced concrete collar may be required in the permanent lining of the Parent tunnel around openings. This may also give rise to a requirement for greater thickness in the lining in this area. Typically this will affect the Parent lining at $\leq d$ from the edge of the opening.

9 Desirable and undesirable cruciform junction arrangements are illustrated below.



3.1.2.6 Parallel tunnels

- 1 Where two tunnels have to be constructed parallel to one another the desirable tunnel clearance is at least one diameter (extrados to extrados).
- 2 Where a clearance of less than one diameter is necessary it should be assumed for planning purposes that the first tunnel constructed, if constructed of sprayed concrete, will require a double thickness lining.

3.1.2.7 Crossing tunnels

- 1 Where two tunnels have to cross the desirable tunnel clearance is at least one diameter (extrados to extrados).
- 2 Sequences that enable lower tunnels to be excavated and lined in advance of upper tunnels are preferred.
- 3 If it is necessary to construct the upper tunnel first and the upper tunnel is constructed of sprayed concrete allowance should be made for thickening the upper tunnel invert. Typically this will be a doubling of the thickness over a section extending at least one diameter beyond the area of the crossing.

3.1.2.8 Conclusions and recommendations

- 1 The approaches described in this Advice Note provide models for relatively simple predictive modelling of best estimates for settlement around the various forms of deep excavation used to construct shafts.
- 2 Application of the model proposed for short walls results in a reduction of the predicted settlements when compared with earlier analyses.
- 3 These models are either based on established published sources or have been validated by comparison with the most appropriate published data and with other predictive models.
- 4 It is concluded that the use of models derived from observations of construction related movements associated with long retaining walls tends to lead to over prediction of movement adjacent to shorter sections of walls. A revised model is proposed for these short walls which results in a reduction of the predicted settlement when compared with earlier analyses.
- 5 The summary of published data reported here provides a resource that demonstrates likely movement due to construction of similar long walls and circular shafts in London. The long wall data also provide an indication of the possible upper bound movements adjacent to shorter walls.
- 6 It is likely that the proposed method for predicting movement around deep shafts constructed using embedded retaining walls will still return a moderately conservative result (i.e. an over-prediction of settlement). Monitoring during construction should be used to confirm the magnitude of the movements. This monitoring may be primarily of surface settlements around the shafts. It is possible that data from the early part of the works will provide useful evidence for reducing the level of movement predicted around subsequent excavations.

3.1.2.9 References

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3.1.2.10 Figures

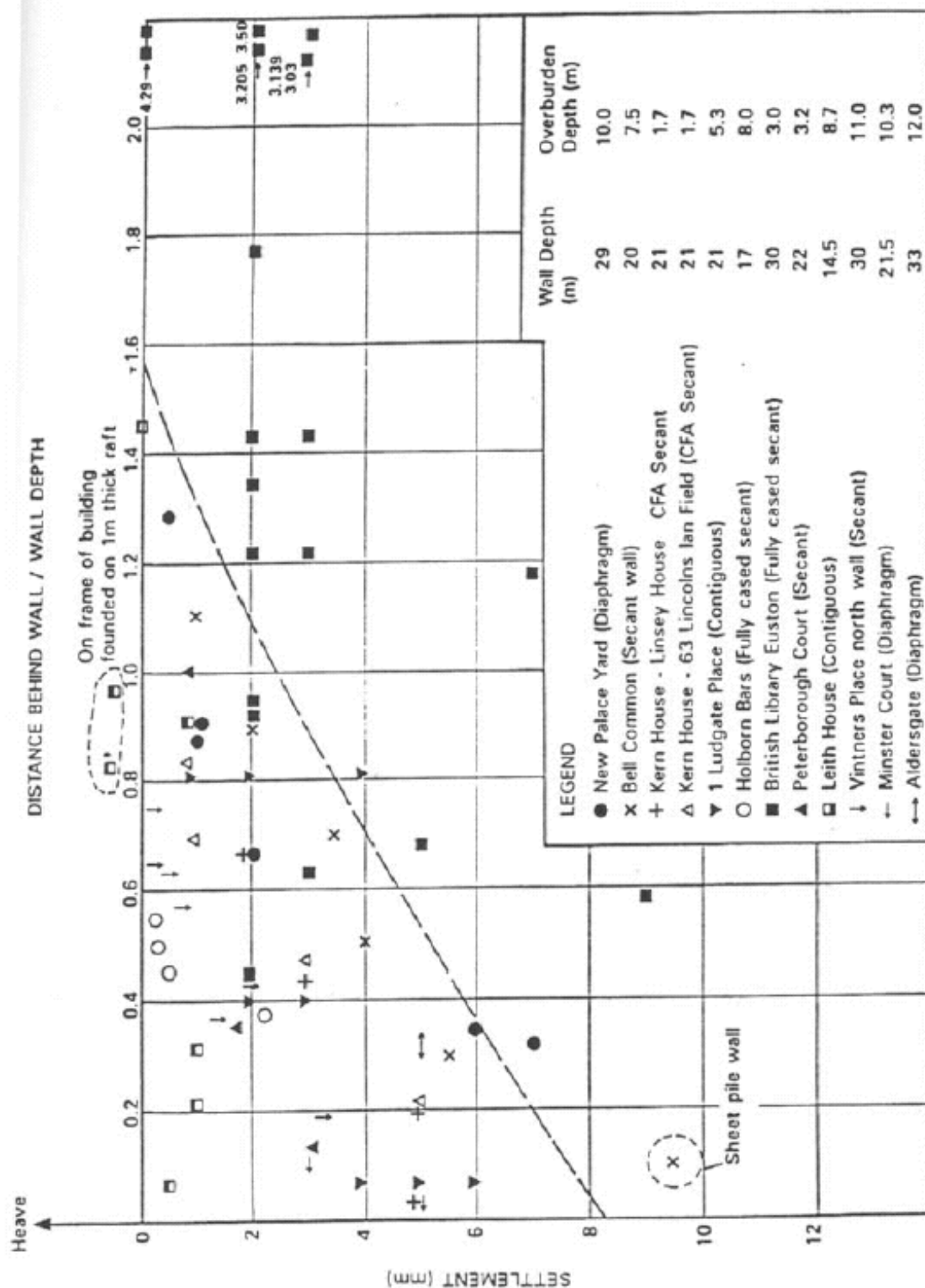


Figure 1 - Summary of measured ground surface settlements caused by retaining wall installation in the London area (after Thompson 1991)

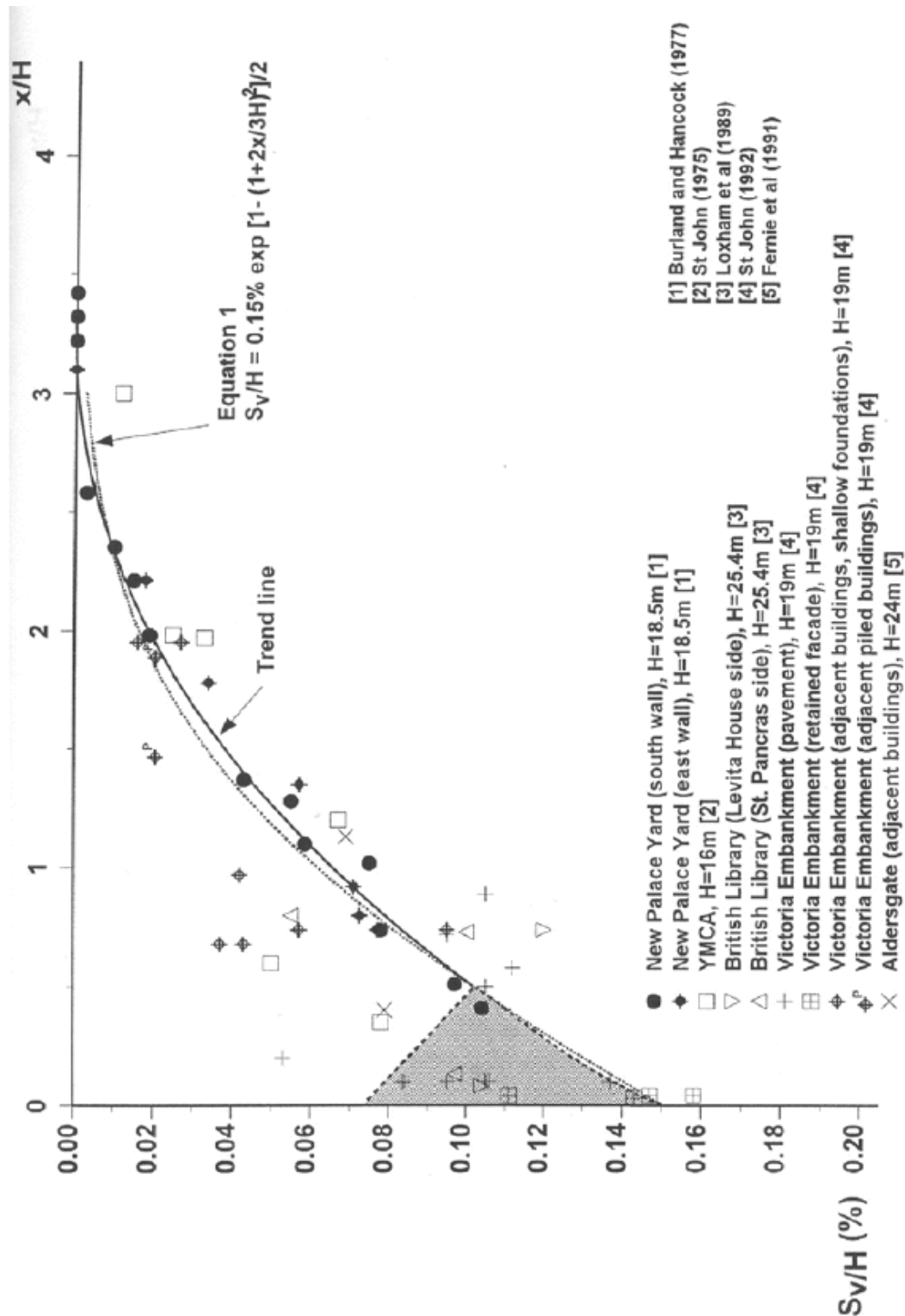


Figure 2 - Surface settlement adjacent to deep excavations (top down construction) in London Clay

S_v is surface settlement, H is the excavated depth and x is the distance away from the wall

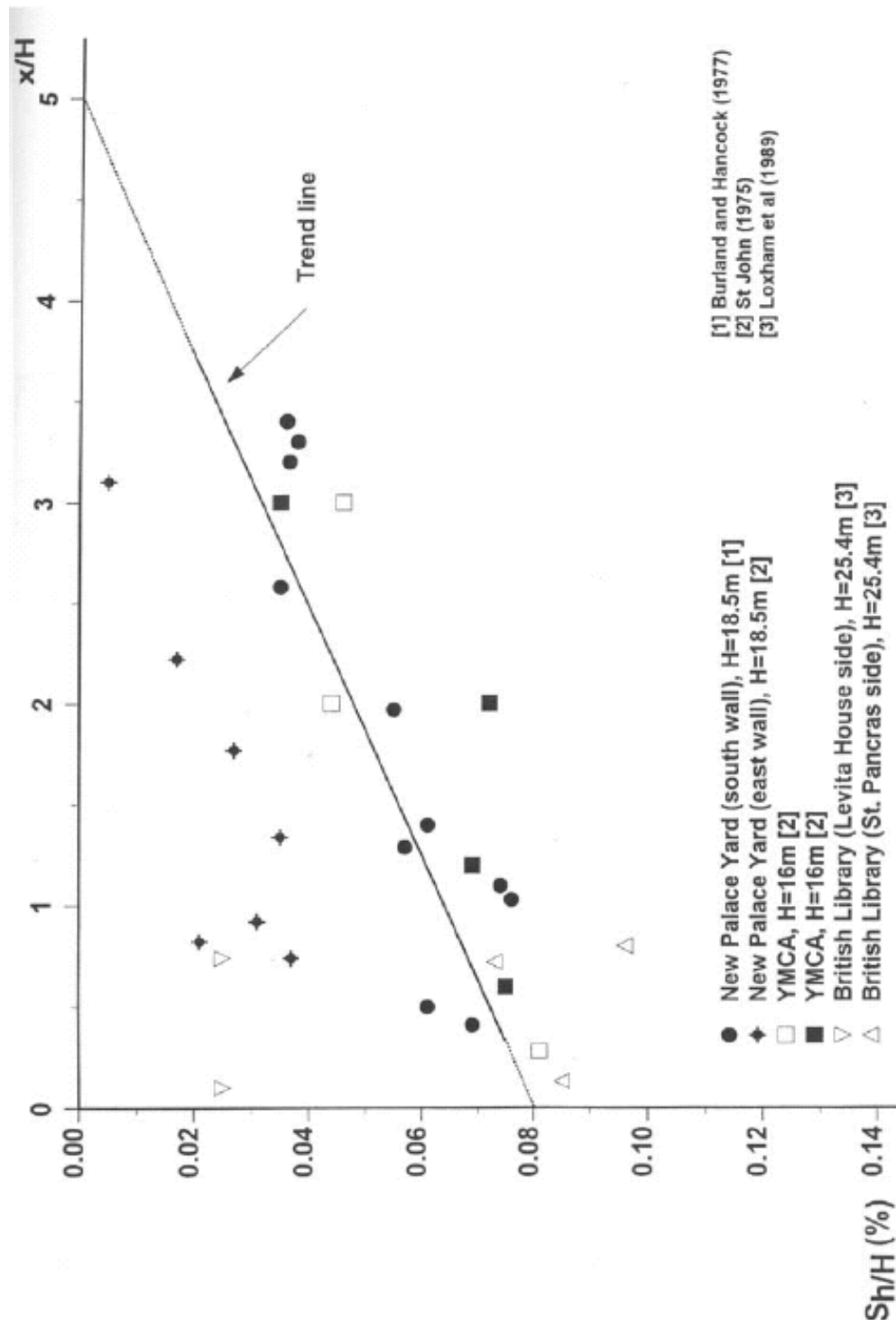


Figure 3 - Horizontal surface movements adjacent to deep excavations (top down construction) in London Clay

S_h is horizontal movement, H is the excavated depth and x is the distance away from the wall

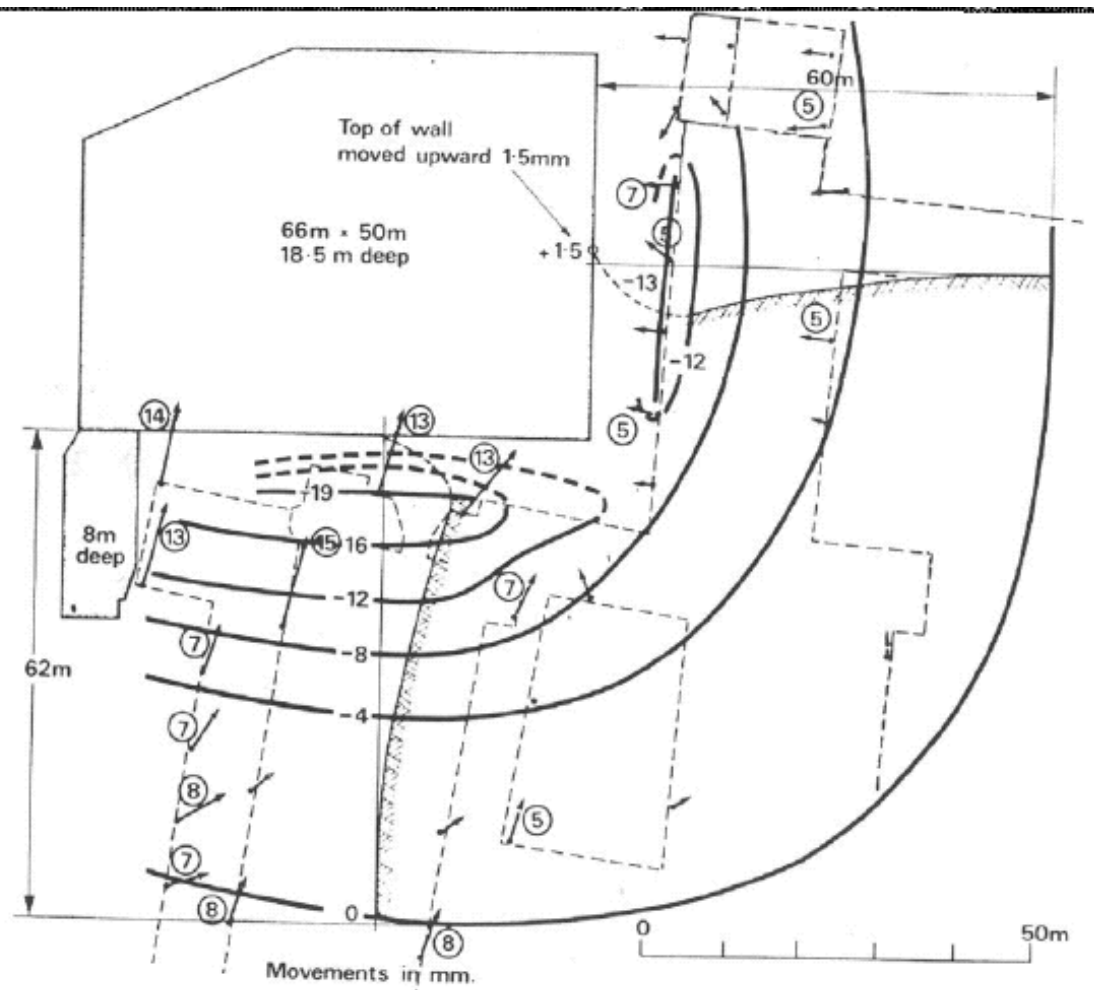


Figure 4 - Observed movements near the House of Commons underground car park (Burland and Hancock 1977). Contours indicate surface settlements

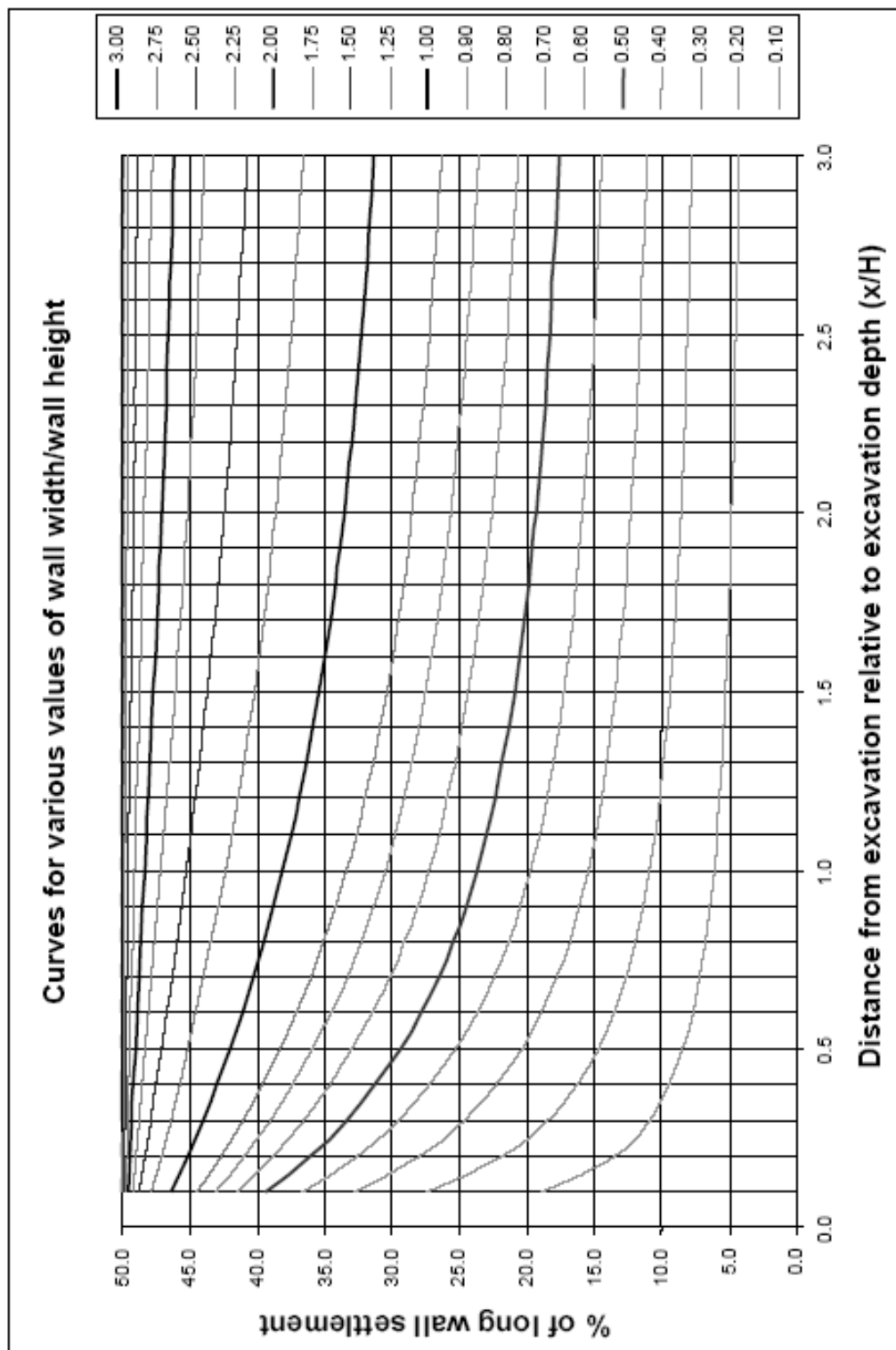


Figure 5 - Curves for various values of wall width / wall height

These curves may be used to determine the percentage of the settlement predicted using a long wall model that would be expected for a shorter wall of specified dimensions.

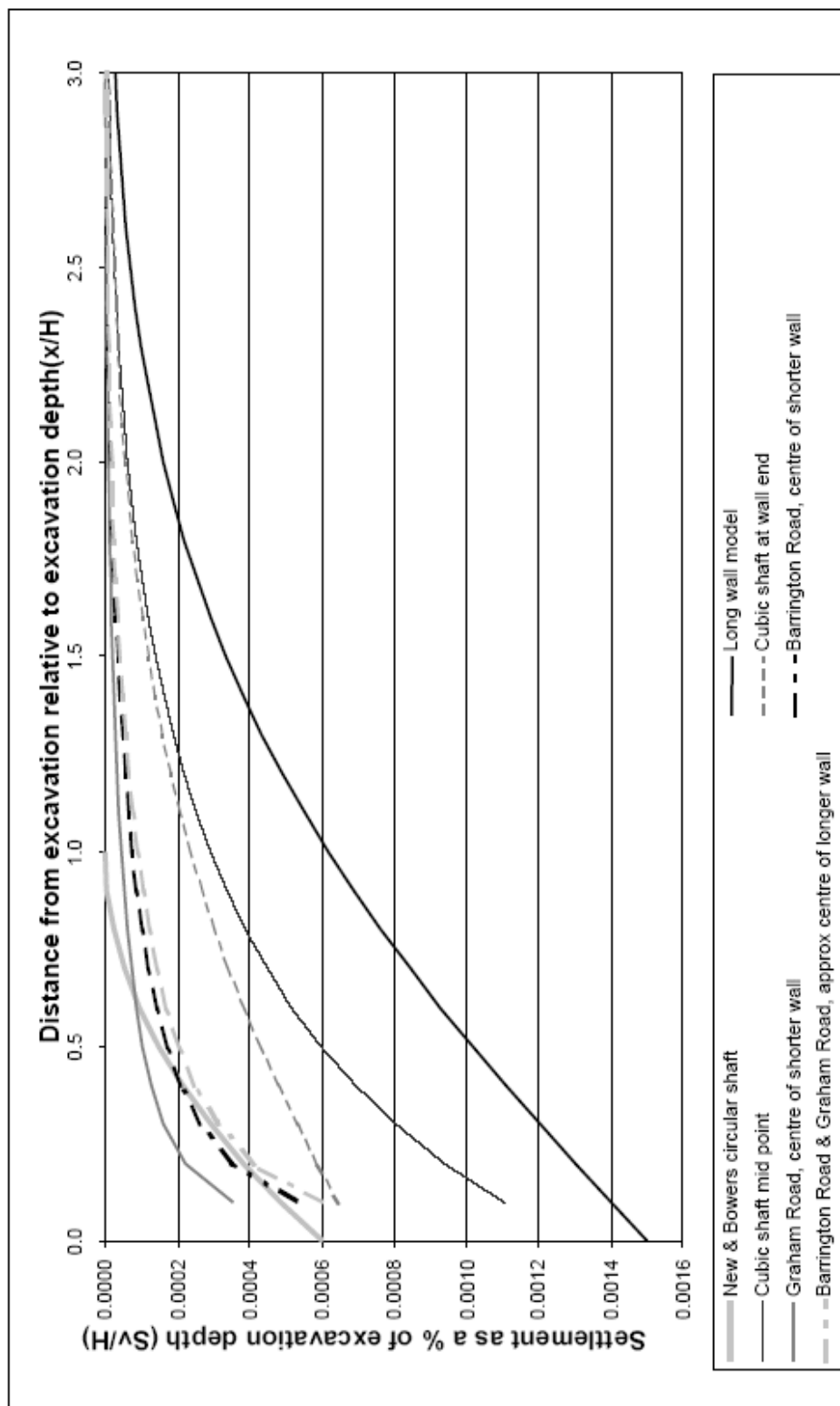


Figure 6 - Comparison of outputs from various shaft settlement prediction models

NB The "cubic" shaft is plotted in an illustration and corresponds to a shaft that is square in plan and has sides equal in length to its depth.

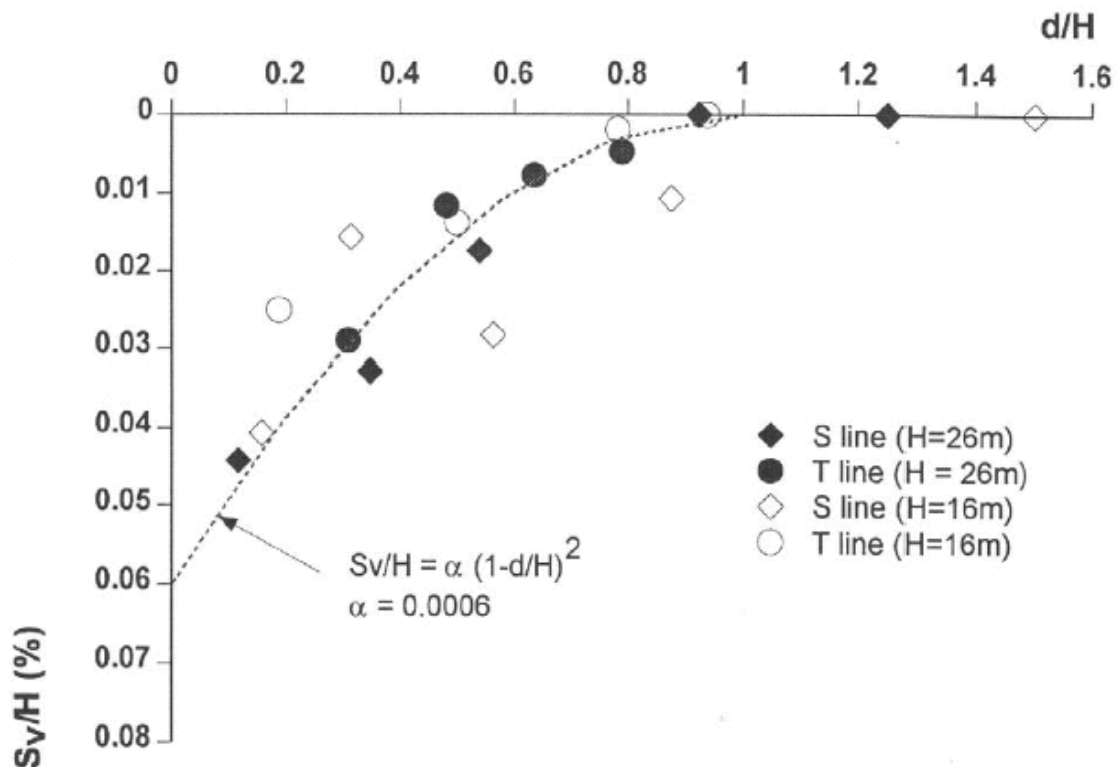


Figure 7 - Normalised settlement induced by sinking a circular shaft (after New and Bowers 1994)

S_v is surface settlement, H is the excavated depth and d is the radial distance away from the shaft extrados. "S line" and "T line" represent two arrays of surface monitoring points, both of which were perpendicular to the shaft wall. The "T line" was over the centreline of the tunnel. The "S line" was on the side of the shaft remote from the tunnel.



3.1.2.11 Tables

		Distance to point where movement is being predicted (x) / depth of excavation (H)																													
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
Width of excavation / depth of excavation (H)	0.00	4.6	2.9	2.3	1.9	1.7	1.6	1.4	1.4	1.3	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	0.05	12.7	8.5	6.7	5.7	5.1	4.7	4.3	4.1	3.9	3.7	3.6	3.4	3.3	3.2	3.2	3.1	3.0	3.0	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.6
	0.10	18.9	13.6	11.0	9.5	8.4	7.7	7.2	6.8	6.4	6.1	5.9	5.7	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.7	4.6	4.6	4.5	4.5	4.4	4.4	4.4	4.3
	0.15	23.7	18.1	14.9	13.0	11.7	10.7	10.0	9.4	8.9	8.5	8.2	8.0	7.7	7.5	7.3	7.2	7.1	6.9	6.8	6.7	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1
	0.20	27.4	21.9	18.5	16.3	14.7	13.6	12.7	12.0	11.4	10.9	10.5	10.2	9.9	9.6	9.4	9.2	9.0	8.9	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	8.0	7.9	7.8	7.8
	0.25	30.4	25.2	21.8	19.4	17.6	16.3	15.3	14.5	13.8	13.2	12.8	12.4	12.0	11.7	11.4	11.2	11.0	10.8	10.6	10.5	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.5
	0.30	32.9	28.0	24.7	22.2	20.3	18.9	17.8	16.9	16.1	15.5	14.9	14.5	14.1	13.7	13.4	13.2	12.9	12.7	12.5	12.3	12.1	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.1
	0.35	34.9	30.5	27.3	24.8	22.9	21.4	20.2	19.2	18.4	17.7	17.1	16.6	16.1	15.7	15.4	15.1	14.8	14.5	14.3	14.1	13.9	13.8	13.6	13.5	13.3	13.2	13.1	13.0	12.9	12.8
	0.40	36.6	32.6	29.6	27.1	25.2	23.7	22.4	21.4	20.5	19.8	19.1	18.6	18.1	17.7	17.3	16.9	16.6	16.4	16.1	15.9	15.7	15.5	15.3	15.2	15.0	14.9	14.8	14.6	14.5	14.4
	0.45	38.1	34.5	31.6	29.3	27.4	25.8	24.6	23.5	22.6	21.8	21.1	20.5	20.0	19.5	19.1	18.8	18.4	18.1	17.9	17.6	17.4	17.2	17.0	16.8	16.7	16.5	16.4	16.3	16.2	16.0
	0.50	39.4	36.1	33.4	31.2	29.4	27.9	26.6	25.5	24.5	23.7	23.0	22.4	21.8	21.4	20.9	20.5	20.2	19.9	19.6	19.3	19.1	18.9	18.7	18.5	18.3	18.2	18.0	17.9	17.7	17.6
	0.55	40.5	37.5	35.1	33.0	31.2	29.7	28.4	27.3	26.4	25.5	24.8	24.2	23.6	23.1	22.7	22.3	21.9	21.6	21.3	21.0	20.7	20.5	20.3	20.1	19.9	19.7	19.6	19.4	19.3	19.2
	0.60	41.5	38.8	36.5	34.6	32.9	31.4	30.2	29.1	28.1	27.3	26.6	25.9	25.3	24.8	24.3	23.9	23.5	23.2	22.9	22.6	22.3	22.1	21.9	21.7	21.5	21.3	21.1	21.0	20.8	20.7
	0.65	42.4	39.9	37.8	36.0	34.4	33.0	31.8	30.7	29.8	29.0	28.2	27.6	27.0	26.4	26.0	25.5	25.1	24.8	24.4	24.2	23.9	23.6	23.4	23.2	23.0	22.8	22.6	22.4	22.3	22.2
	0.70	43.2	40.9	39.0	37.3	35.8	34.5	33.3	32.3	31.3	30.5	29.8	29.1	28.5	28.0	27.5	27.1	26.7	26.3	26.0	25.7	25.4	25.1	24.9	24.6	24.4	24.2	24.1	23.9	23.7	23.6
	0.75	43.9	41.8	40.1	38.5	37.1	35.9	34.7	33.7	32.8	32.0	31.3	30.6	30.0	29.5	29.0	28.5	28.1	27.8	27.4	27.1	26.8	26.6	26.3	26.1	25.9	25.7	25.5	25.3	25.1	25.0
	0.80	44.5	42.6	41.0	39.6	38.3	37.1	36.0	35.1	34.2	33.4	32.7	32.0	31.4	30.9	30.4	30.0	29.5	29.2	28.8	28.5	28.2	27.9	27.7	27.5	27.2	27.0	26.8	26.7	26.5	26.3
	0.85	45.0	43.4	41.9	40.6	39.4	38.2	37.2	36.3	35.5	34.7	34.0	33.3	32.8	32.2	31.8	31.3	30.9	30.5	30.2	29.9	29.6	29.3	29.0	28.8	28.6	28.4	28.2	28.0	27.8	27.7
	0.90	45.5	44.0	42.7	41.5	40.3	39.3	38.3	37.4	36.6	35.9	35.2	34.6	34.0	33.5	33.0	32.6	32.2	31.8	31.5	31.1	30.9	30.6	30.3	30.1	29.9	29.6	29.5	29.3	29.1	28.9
	0.95	46.0	44.6	43.4	42.3	41.2	40.3	39.4	38.5	37.7	37.0	36.4	35.8	35.2	34.7	34.2	33.8	33.4	33.0	32.7	32.4	32.1	31.8	31.6	31.3	31.1	30.9	30.7	30.5	30.3	30.2
	1.00	46.4	45.1	44.0	43.0	42.0	41.1	40.3	39.5	38.8	38.1	37.5	36.9	36.4	35.9	35.4	35.0	34.6	34.2	33.9	33.6	33.3	33.0	32.7	32.5	32.3	32.1	31.9	31.7	31.5	31.3
1.05	1.05	46.7	45.6	44.6	43.7	42.8	41.9	41.2	40.4	39.7	39.1	38.5	37.9	37.4	36.9	36.5	36.1	35.7	35.3	35.0	34.7	34.4	34.1	33.9	33.6	33.4	33.2	33.0	32.8	32.7	32.5
	1.10	47.0	46.0	45.1	44.3	43.5	42.7	42.0	41.3	40.6	40.0	39.4	38.9	38.4	37.9	37.5	37.1	36.7	36.4	36.1	35.8	35.5	35.2	35.0	34.7	34.5	34.3	34.1	33.9	33.7	33.6
	1.15	47.3	46.4	45.6	44.8	44.1	43.4	42.7	42.0	41.4	40.9	40.3	39.8	39.3	38.9	38.5	38.1	37.7	37.4	37.1	36.8	36.5	36.2	36.0	35.8	35.5	35.3	35.1	35.0	34.8	34.6
	1.20	47.6	46.8	46.0	45.3	44.6	44.0	43.3	42.7	42.2	41.6	41.1	40.7	40.2	39.8	39.4	39.0	38.7	38.3	38.0	37.7	37.5	37.2	37.0	36.7	36.5	36.3	36.1	36.0	35.8	35.6
	1.25	47.8	47.1	46.4	45.8	45.1	44.5	44.0	43.4	42.9	42.4	41.9	41.4	41.0	40.6	40.2	39.9	39.5	39.2	38.9	38.6	38.4	38.1	37.9	37.7	37.5	37.3	37.1	36.9	36.8	36.6
	1.30	48.0	47.4	46.8	46.2	45.6	45.1	44.5	44.0	43.5	43.0	42.6	42.2	41.8	41.4	41.0	40.7	40.4	40.1	39.8	39.5	39.2	39.0	38.8	38.6	38.4	38.2	38.0	37.8	37.7	37.5
	1.35	48.2	47.6	47.1	46.5	46.0	45.5	45.0	44.6	44.1	43.7	43.2	42.8	42.5	42.1	41.8	41.4	41.1	40.8	40.6	40.3	40.1	39.8	39.6	39.4	39.2	39.0	38.9	38.7	38.5	38.4
	1.40	48.4	47.9	47.4	46.9	46.4	46.0	45.5	45.1	44.6	44.2	43.9	43.5	43.1	42.8	42.5	42.1	41.9	41.6	41.3	41.1	40.8	40.6	40.4	40.2	40.0	39.8	39.7	39.5	39.4	39.2
	1.45	48.6	48.1	47.6	47.2	46.8	46.3	45.9	45.5	45.1	44.8	44.4	44.1	43.7	43.4	43.1	42.8	42.5	42.3	42.0	41.8	41.6	41.4	41.1	41.0	40.8	40.6	40.4	40.3	40.1	40.0
	1.50	48.7	48.3	47.9	47.5	47.1	46.7	46.3	46.0	45.6	45.3	44.9	44.6	44.3	44.0	43.7	43.4	43.2	42.9	42.7	42.5	42.2	42.0	41.8	41.7	41.5	41.3	41.2	41.0	40.9	40.7
	1.55	48.8	48.4	48.1	47.7	47.4	47.0	46.7	46.4	46.0	45.7	45.4	45.1	44.8	44.5	44.3	44.0	43.8	43.5	43.3	43.1	42.9	42.7	42.5	42.3	42.2	42.0	41.9	41.7	41.6	41.4
	1.60	49.0	48.6	48.3	48.0	47.6	47.3	47.0	46.7	46.4	46.1	45.8	45.5	45.3	45.0	44.8	44.5	44.3	44.1	43.9	43.7	43.5	43.3	43.1	43.0	42.8	42.6	42.5	42.4	42.2	42.1
	1.65	49.1	48.8	48.5	48.2	47.9	47.6	47.3	47.0	46.8	46.5	46.2	46.0	45.7	45.5	45.2	45.0	44.8	44.6	44.4	44.2	44.0	43.9	43.7	43.5	43.4	43.2	43.1	43.0	42.9	42.7
1.70	49.2	48.9	48.6	48.4	48.1	47.8	47.6	47.3	47.1	46.8	46.6	46.4	46.1	45.9	45.7	45.5	45.3	45.1	44.9	44.7	44.6	44.4	44.2	44.1	43.9	43.8	43.7	43.6	43.4	43.3	
1.75	49.3	49.0	48.8	48.5	48.3	48.1	47.8	47.6	47.4	47.1	46.9	46.7	46.5	46.3	46.1	45.9	45.7	45.5	45.4	45.2	45.0	44.9	44.7	44.6	44.5	44.3	44.2	44.1	44.0	43.9	
1.80	49.3	49.1	48.9	48.7	48.5	48.3	48.1	47.8	47.6	47.4	47.2	47.0	46.8	46.7	46.5	46.3	46.1	46.0	45.8	45.6	45.5	45.4	45.2	45.1	45.0	44.8	44.7	44.6	44.5	44.4	
1.85	49.4	49.2	49.0	48.8	48.6	48.5	48.3	48.1	47.9	47.7	47.5	47.3	47.2	47.0	46.8	46.7	46.5	46.3	46.2	46.0	45.9	45.8	45.7	45.5	45.4	45.3	45.2	45.1	45.0	44.9	
1.90	49.5	49.3	49.1	49.0	48.8	48.6	48.4	48.3	48.1	47.9	47.8	47.6	47.4	47.																	



		Distance to point where movement is being predicted (x) / depth of excavation (H)																														
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	
Width of excavation / depth of excavation (H)	2.05	49.6	49.5	49.4	49.3	49.1	49.0	48.9	48.8	48.7	48.5	48.4	48.3	48.2	48.1	47.9	47.8	47.7	47.6	47.5	47.4	47.3	47.2	47.1	47.0	46.9	46.8	46.8	46.7	46.6	46.5	
	2.10	49.7	49.6	49.5	49.4	49.2	49.1	49.0	48.9	48.8	48.7	48.6	48.5	48.4	48.3	48.2	48.1	48.0	47.9	47.8	47.7	47.6	47.5	47.4	47.3	47.2	47.2	47.1	47.0	46.9	46.9	
	2.15	49.7	49.6	49.5	49.4	49.3	49.2	49.1	49.0	49.0	48.9	48.8	48.7	48.6	48.5	48.4	48.3	48.2	48.1	48.0	47.9	47.8	47.7	47.6	47.5	47.5	47.4	47.3	47.3	47.2	47.2	
	2.20	49.7	49.7	49.6	49.5	49.4	49.3	49.2	49.2	49.1	49.0	48.9	48.8	48.7	48.6	48.6	48.5	48.4	48.3	48.2	48.2	48.1	48.0	47.9	47.9	47.8	47.7	47.7	47.6	47.6	47.5	
	2.25	49.8	49.7	49.6	49.6	49.5	49.4	49.3	49.3	49.2	49.1	49.0	49.0	48.9	48.8	48.7	48.7	48.6	48.5	48.4	48.4	48.3	48.2	48.2	48.1	48.0	48.0	47.9	47.9	47.8	47.8	
	2.30	49.8	49.7	49.7	49.6	49.6	49.5	49.4	49.4	49.3	49.2	49.2	49.1	49.0	48.9	48.9	48.8	48.7	48.7	48.6	48.6	48.5	48.4	48.4	48.3	48.3	48.2	48.2	48.1	48.1	48.0	
	2.35	49.8	49.8	49.7	49.7	49.6	49.6	49.5	49.4	49.4	49.3	49.3	49.2	49.1	49.1	49.0	49.0	48.9	48.8	48.8	48.7	48.7	48.6	48.6	48.5	48.5	48.4	48.4	48.3	48.3	48.3	
	2.40	49.9	49.8	49.8	49.7	49.7	49.6	49.6	49.6	49.5	49.5	49.4	49.4	49.3	49.3	49.2	49.2	49.1	49.0	49.0	48.9	48.9	48.8	48.8	48.7	48.7	48.6	48.6	48.5	48.5	48.5	
	2.45	49.9	49.8	49.8	49.8	49.7	49.7	49.6	49.6	49.6	49.5	49.5	49.4	49.4	49.3	49.3	49.2	49.2	49.1	49.1	49.1	49.0	49.0	49.0	48.9	48.9	48.8	48.8	48.8	48.7	48.7	
	2.50	49.9	49.9	49.8	49.8	49.8	49.7	49.7	49.7	49.6	49.6	49.6	49.5	49.5	49.5	49.4	49.4	49.3	49.3	49.3	49.2	49.2	49.1	49.1	49.1	49.0	49.0	48.9	48.9	48.9	48.8	
	2.55	49.9	49.9	49.9	49.8	49.8	49.8	49.7	49.7	49.7	49.6	49.6	49.6	49.5	49.5	49.5	49.4	49.4	49.4	49.3	49.3	49.3	49.2	49.2	49.2	49.2	49.1	49.1	49.1	49.0	49.0	
	2.60	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.8	49.7	49.7	49.7	49.6	49.6	49.6	49.6	49.5	49.5	49.5	49.4	49.4	49.4	49.4	49.3	49.3	49.3	49.3	49.2	49.2	49.2	49.2
	2.65	49.9	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.8	49.7	49.7	49.7	49.7	49.6	49.6	49.6	49.6	49.6	49.5	49.5	49.5	49.5	49.5	49.5	49.4	49.4	49.4	49.3	49.3	49.3
	2.70	50.0	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.8	49.7	49.7	49.7	49.7	49.7	49.6	49.6	49.6	49.6	49.6	49.6	49.5	49.5	49.5	49.5	49.5	49.4	
	2.75	50.0	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.8	49.8	49.7	49.7	49.7	49.7	49.7	49.7	49.6	49.6	49.6	49.6	49.6	49.6	49.6	49.6	
2.80	50.0	50.0	50.0	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.7	49.7	49.7	49.7	49.7	49.7	49.7	49.7		
2.85	50.0	50.0	50.0	50.0	50.0	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8		
2.90	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9		
2.95	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9		
3.00	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0		

Table 1 (continued) - Correction factors required to derive movements due to short walls from modelled data for long walls.

Notes:

The use of this table is described further in Section 2.1.1.12.

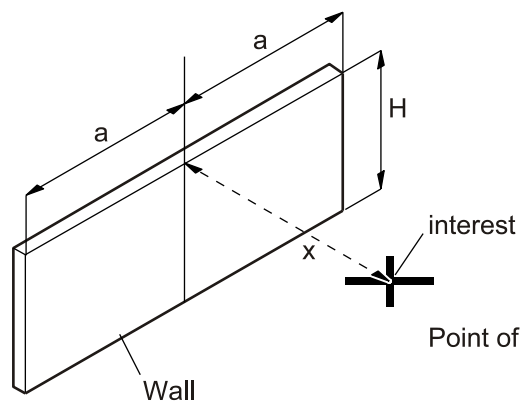
All values in the body of the table are percentages.

Figure 5 (within section 2.1.1.10) provides a graphical representation of part of the data in this table.

The data in this table is also based on the conservative assumption that a section of wall having a length equal to six times its depth will account for 100% of the movement.

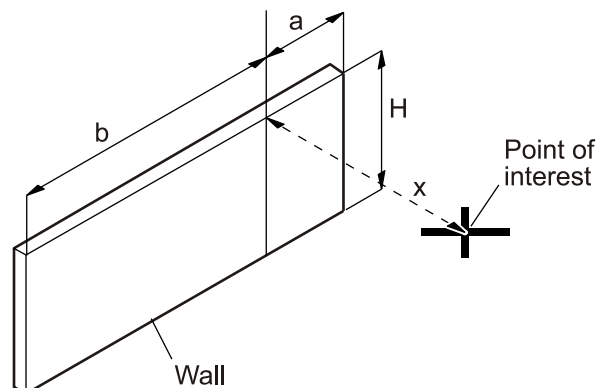
3.1.2.12 Simplified guide to application

- 1 Determine the width and depth of the excavation (H). Determine the value of the width divided by the depth (H).
- 2 Determine the plan distance from the excavation to the point where movement is to be predicted (x), measured in a plane perpendicular to the face of the excavation. Determine the value of this distance divided by the excavation depth (H).
- 3 Use Table 1 to look up the correction factor corresponding to the values determined in steps 1) and 2). The table provides a correction factor based on a half wall. The way in which the table must be read depends on the relative arrangement of the excavation (wall) and the point at which settlement is being predicted. There are four possible variants on this arrangement as follows:
 - a) Variant 1: The point of interest is immediately opposite the centre of the wall as illustrated below.



In this case the value of a (which corresponds to exactly half the length of the wall) is determined. Divide a by the depth of the excavation (H). Look up the resulting value in the left-hand column of Table 1. Divide x by the depth of the excavation (H). Look up the resulting value in the top row of Table 1. Find the point where the row and column that have been identified intersect. The value in this cell must be doubled (because a represents exactly half the wall). The result is the correction factor for this point.

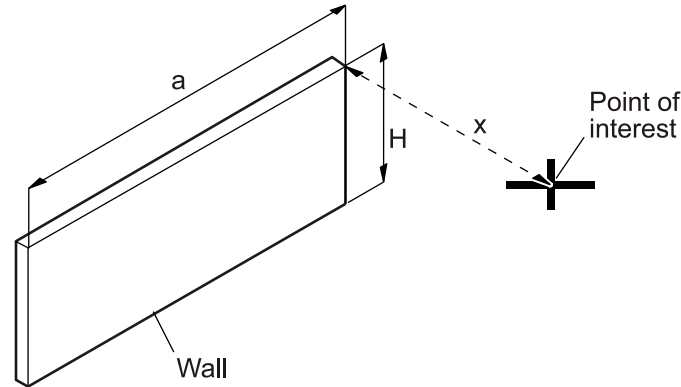
- b) Variant 2: The point of interest is opposite some other part of the wall as illustrated below.



In this case the value of a and b must both be determined. Divide a and b in turn by the depth of the excavation (H). Look up the resulting values in the left-hand column of Table 1. Divide x by the depth of the excavation (H). Look up the resulting value in

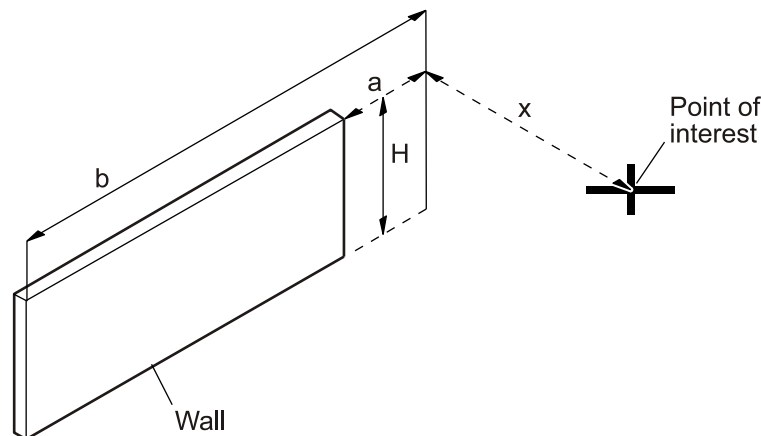
the top row of Table 1. Find the points where the two rows and the column that have been identified intersect. Sum the values from these two cells. The result is the correction factor for this point.

- c) Variant 3: The point of interest is opposite one end of the wall as illustrated below.



In this case the value of a must be determined. Divide a by the depth of the excavation (H). Look up the resulting value in the left-hand column of Table 1. Divide x by the depth of the excavation (H). Look up the resulting value in the top row of Table 1. Find the point where the row and the column that have been identified intersect. The value in this cell is the correction factor for this point.

- d) Variant 4: The point of interest is opposite some other part of the wall as illustrated below.



In this case the value of a and b must both be determined. Divide a and b in turn by the depth of the excavation (H). Look up the resulting values in the left-hand column of Table 1. Divide x by the depth of the excavation (H). Look up the resulting value in the top row of Table 1. Find the points where the two rows and the column that have been identified intersect. Subtract the value in the cell corresponding to a from the value in the cell corresponding to b . The result is the correction factor for this point.

- 4 Multiply the correction factor obtained in step 3 by the predicted movement for a long wall (derived according to the methods given in the main text of this Advice Note) to obtain the predicted movement for the short wall at the point under consideration.



3.1.3 Loading

3.1.3.1 LOADING GENERAL

- 1 This CETAN has been produced to consolidate the loading information from standards, manuals of good practice and other sources, as this is the usual manner in which engineers expect loading data to be presented. The loadings given in this CETAN are for the design of new works; design for maintenance works and for renewals. They are NOT assessment loads; these are given in the relevant parts of the LU standards.
Where the loadings are taken from an LU standard the terminology “shall and will” is used to reflect this. Advisory loadings are prefixed with “should”
- 2 LU loading standards are based as far as possible on National Standards where these exist. In the case of loadings in and on buildings, LU must comply with The Building Regulations. However the Building Regulations do not specify loadings as such, they refer to Approved Document A which in turn refers to BS 6399. BS6399 does not specify loadings for railway stations, generating stations, nor sub generating stations. Loadings in these buildings are always the responsibility of the relevant authority. It is for this reason that LU specifies loadings where they are not specified in BS6399, and where there is a choice of loadings as is the case with handrail loadings, LU specify which loading should be used. In addition the Building Regulations only apply to NEW BUILD they do not apply to existing structures, and therefore cannot apply to assessment loading. It is for this reason that LU define specific assessment loadings which may differ from BS6399, so assessors must always work to the LU assessment standards, not to loading standards

3.1.3.2 LOAD FACTORS (S1051, Clause 3.1.16.1, S1053 Clause 3.1.16.1)

The loads set out in LU standards are the characteristic loads. For both the ultimate and serviceability limit states the loads shall be factored (for beneficial or adverse effects) using the load factors contained or referred to in the LU standard relevant to the material being used, with the most severe effect on each element of the structure being considered.

3.1.3.3 DEAD LOADING (S1051, Clause 3.1.16.2)

- 1 Dead loads shall be calculated in accordance with BS 6399: Part 1, from the unit weights given in BS648, or from the actual known weights of materials used.
- 2 The loadings set down in the table below are for the structural floors of station buildings etc. They do not apply to proprietary raised floors, but it is recommended that the raised floors resist safely the same distributed load as the structural floor. Heavy permanently imposed loads should be carried by plinths (S1053 Table 1). They do not apply to proprietary accommodation or electrical equipment units supplied as a package typified by Portakabin units. Structural members should be designed for the distributed load and should be checked for the ability to carry the concentrated load applied separately in the most onerous position.

STATION & BUILDING IMPOSED FLOOR LOADING (S1053 Clause 3.1.16.3)

Type of floor or horizontal surface loading	Distributed load (kN/m ²)	Concentrated load (kN)
Ticket halls Concourses, including escalator floor trays but NOT floor plates The horizontal surfaces of platforms and all other passenger areas Station offices	5	20 on a 300 X 300 square
Lift pits	5	Refer to the clause on tower and lift pit loading below
Platform ramps	Nil	1 at 1m centres
Toilets	2	Nil
Staff rooms	2.5	1.8
Staircases	The greater of the loadings of the floors to which they lead.	



Nosing stone (stability). The LU standard precast nosing stones types PC10, PC20 and PC30 are deemed to be stable when they are within the cantilever limits set down in standard S1131. The loadings given in this table apply to non-standard nosing stones	5	1.3 at 600mm centres
Light equipment rooms, IMRs, CERs etc	5	20 on a 300 x 300 square
Store rooms Plant rooms with the exception of traction and distribution sub-stations	10	20 on a 300 x 300 square
Signal gantries Access gantries Service and access platforms in depots Vent shaft mesh screening	3	1.8
Traction and distribution sub-stations. Sewage ejector rooms: the weight of the tank plus its maximum content at overflow conditions shall be used for the area occupied by the tank.	To be determined from the actual weight of equipment to be used.	

Table 1 - Station Buildings Floor Loadings**3.1.3.4 PLANT LOADS (S1053 Clause 3.1.16.6)**

- 1 The floors and supporting structural members in sub-stations, switch rooms, plant rooms or other places containing switch gear or machinery shall be designed for the following loads:
 - a) The full Dead Load of an assembled piece of equipment at any reasonable position likely to be occupied during or after installation; and the dynamic effect due to the operation of equipment.
 - b) Items of equipment with dynamic load characteristics contained on the same sub-structure shall be assumed to exert their load simultaneously except that, when the number of items exceeds four, the dynamic factor shall be reduced by one item.
 - c) Due provision shall be made for the concentrated nature of such loading. Prior to final design the specific plant loads shall be obtained and the design adjusted accordingly. Until such loads are obtained, and their location finalised, in traction sub-stations the following static distributed loads may be assumed to satisfy the previous two clauses:
 - i. rectifier or transformer loads: 25 kN/m²;
 - ii. switch gear plant room: 25 kN/m².

3.1.3.5 SERVICES LOADS (S1053 Clauses 3.1.16.4 a) & b))

- 1 Structures shall be designed for a load from services of not less than the following:
 - a) supported areas up to 10m²: 2.0 kN/m²;
 - b) supported areas between 10 and 30m²: 1.5kN/m²;
 - c) supported areas greater than 30m²: 1.0 kN/m².
- 2 The supported area is the plan area of the structure supported by the structural element under consideration. The designer should consider whether these service loads are to be classified as dead or live.

3.1.3.6 RAILWAY TRAFFIC LOADING (S1051 Clause 3.1.16.3 a))

- 1 Live loads from railway traffic shall be calculated in accordance with BS5400: Part 2. Structures under tracks owned by LU shall be designed for RL loading, except where TOCs have rights to operate over the lines, when the structures shall be designed for RU loading. TOCs have rights to operate over the following lines:



- a) Metropolitan Line – Neasden to Amersham (including Chesham and Watford branches);
 - b) Jubilee Line – Neasden to Wembley Park
 - c) District Line – East Putney to Wimbledon
- 2 Partial load factors and load combinations shall be applied in accordance with BS5400 Part 2
- 3 The designer should always check that there has been no variation in the loadings for the particular railway line.

3.1.3.7 LONGITUDINAL TIMBERS (G0051 Clause 3.1.15.4)

- 1 Longitudinal timbers, where they span between cross girders should be designed for the appropriate RL or RU loading with the γ factors as laid down in standards. Where longitudinal timbers do not span between girders, the effects of RL or RU loading on the structure should be calculated, and sufficient fixings and restraints designed to resist these loads.

3.1.3.8 ACCIDENTAL LOADS – RAILWAY TRAFFIC (S1051 Clause 3.1.16.3 a) iii) & iv)

- 1 The supports or other elements of the following structures which risks either destruction or loss of capacity when struck by shall be designed to resist the accidental impact loads specified in Table 3.
- a) railway overbridges;
 - b) road overbridges;
 - c) footbridges;
 - d) any major structure spanning 2 or more railway tracks, but not cable bridges or ancillary structures.
- 2 The accidental loads shall be used with a load factor of one. Associated loads from the supported structure (dead, superimposed dead and imposed loading) shall be factored by the ultimate limit state in accordance with the LU standard relevant to the material being used.
- 3 The intensity of the loading specified should not be treated as being that required to enable the structure to completely resist the effects of a derailed train but as a minimum level of accidental loading to provide a reasonably “robust” structure, capable of surviving the incident without partial collapse or significant permanent damage or distortion.
- 4 Where columns are located on platforms, the platform structure shall be designed for the effects of a 500 kN load acting horizontally at the level of the platform nosing. This load shall be treated as an ultimate load acting over a length of 2.5m and the depth of the platform nosing. The platform structure shall be such that the 500kN load is not transferred into the column.
- 5 Wind loading need not be considered to act together with accidental loading.

3.1.3.9 WAYBEAMS – RAIL LOADING (S1051 Clause 3.1.17.1 b))

- 1 Waybeams under LU track where TOCs do not have the rights to operate shall be designed for RL loading. However the γ_{fl} factor shall be reduced to 1.25, and, if speeds over the waybeams are restricted to less than 25km/h, the dynamic factor shall be reduced to 1.0. If there is no speed restriction, the dynamic factor shall be 1.4
- 2 Waybeams under LU tracks where TOCs have the rights to operate shall be designed for RU loading. However, the γ_{fl} shall be reduced to 1.25. The dynamic factor shall still be applied as specified in BS 5400: Part 2, clause 8.2.3.1.

**3.1.3.10 HIGHWAY TRAFFIC – LOADING (S1051 Clause 3.1.16.3 b))**

- 1 Where structures are subjected to highway loading. The loads shall be determined from DfT Standard BD 37/88 or other relevant current Highways Agency Standards or memoranda. Parapets shall be designed to BS EN 1317 Road Restraint Systems type H4a, although it is recommended that type H4b which represents the highest loading is used.
- 2 The level of HB loading shall be agreed with the Highways Agency or the local authority, and LU, but should normally be not less than 30 units of HB loading. Structures subject to highway loading may require to be checked against DfT standard BD 2/89 Part 1, Category 111, unless the load is less than 10% of the total highway load.
- 3 Other areas which could be traversed or mounted by vehicular traffic should be designed for the appropriate loading.

3.1.3.11 ACCIDENTAL LOADS – HIGHWAY TRAFFIC (S1051 Clause 3.1.16.3 b) iii)

- 1 Any support or other element of a structure which risks either destruction or loss of carrying capacity when struck by a highway vehicle shall be designed in accordance with HA DMRB BD60/04.

IMPOSED FOOTBRIDGE, CABLE BRIDGE AND GANTRY LOADING (S1051)

Structure category	Imposed Loads			
	Imposed load	Imposed roof load	Wind load	Parapet load
Footbridges and stairs				
1) In stations and protected totally from elements	5kN/m ² or 20kN on a 300 x 300 square	Nil other than the services load	Nil	BS6399 Part 1 category C5 (XI)
2) In stations and subject to the elements	5kN/m ² or 20kN on a 300 x 300 square	BS 6399 Part 3	BS 6399 Part 2	BS6399 Part 1 category C5 (XI)
3) Remote from or not accessible from LU property	5kN/m ²	On the caging 0.6kN/m ² or 0.9kN Concentrated	BS 6399 Part 2	BS6399 Part 1 category C5 (XI)
Cable bridges				
1) In stations and subject to the elements	3kN/m ² or 1.8kN concentrated load	Nil	Nil	BS6399 Part 1 category C3 (VIII)
2) In stations and subject to the elements	3kN/m ² or 1.8kN concentrated load	Nil	BS 6399 Part 2	BS6399 Part 1 category C3 (VIII)
3) Remote from stations	3kN/m ² or 1.8kN concentrated load	Nil	BS 6399 Part 2	BS6399 Part 1 category C3 (VIII)
Gantries				
1) In stations and subject to the elements	3kN/m ² or 1.8kN concentrated load	NIL	NIL	BS6399 Part 1 category C3 (VIII)
2) In stations and subject to the elements	3kN/m ² or 1.8kN concentrated load	NIL	BS 6399 Part 2	BS6399 Part 1 category C3 (VIII)
3) Remote from stations	3kN/m ² or 1.8kN concentrated load	NIL	BS 6399 Part 2	BS6399 Part 1 category C3 (VIII)

Table 2 - Footbridge, Cable Bridge and gantry loading

- 2 Footbridge user comfort standards shall be in accordance with the requirements of appendix B of BD37/01.

**3.1.3.12 DESIGN LOADS – ADJACENT BUILDINGS (S1051, Clause 3.1.16.7)**

- 1 Where existing buildings are adjacent to proposed works they shall be individually assessed and the surcharge loading from each should be determined. Calculations should be produced to confirm the actual load conditions.
- 2 Where there are no existing buildings adjacent to the structure, a uniform surcharge of 10kN/m^2 applied at ground level shall be assumed to be applied alongside (but not over) underground structures. This surcharge should be deemed to cater for the effect of future buildings adjoining the LU structures.

3.1.3.13 DESIGN LOADS – RAIL DEPOTS AND MISCELLANEOUS

- 1 The designer should consider any unusual loads that may occur, such as cable drums and forklift trucks, which apply large point loads over a small area. Consideration should also be given to loads applied by other equipment that may be used in such environments.
- 2 In situations where train arrestors or buffer stops may be supported by a structure the designer should determine the loading requirements in consultation with LU regarding expected train speeds and vehicle weights.
- 3 The dynamic load factors given in BS5400:Part 2, for RL loading may be taken as unity in rail depots where train speeds are restricted to less than 25km/h.
- 4 Runway beams should be designed for loading as described in BS 2853.

3.1.3.14 LOADING DURING CONSTRUCTION (S1053, Clause 3.1.16.17)

- 1 Where structures forming part of the works are subject to loading from construction plant and materials, temporary buildings or structures, the structural elements shall be checked for the effects of such loads.
- 2 Where mobile construction plant is used, structures should be checked for the effects of such loading in accordance with the requirements of BS 5400:Part 2, subject to a minimum loading of:
 - a) HA loading (comprising HA UDL and KEL); or
 - b) 30 units of HB loading; or
 - c) any other higher loading which may be imposed during the construction due to the particular aspects of the design.

3.1.3.15 ROOF IMPOSED LOADING (S1053, Clause 3.1.16.13)

- 1 The imposed loads for roofs of buildings shall be in accordance with BS 6399: Part 3.
- 2 Full account should be taken of any loading from access platforms or mobile gantries that may be required for maintenance and cleaning, and any local effects they may impose on individual structural elements.

3.1.3.16 LIFT SUPPORT STRUCTURES (S1053, Clause 3.1.15.5)

- 1 Lift support structures shall be designed in accordance with BS EN 81 except the design shall recognise that the design rules given in BS EN 81 are not wholly adequate for LU heavy-duty station lifts and shall be validated for specific applications.

3.1.3.17 LIFT TOWER AND PIT LOADING (S1053, Clause 3.1.16.11)

- 1 Floor loadings shall be a uniformly distributed load of 5kN/m^2 together with all loads from the supporting lift framework tower or guide rails and the loads set down below.



- 2 When appropriate the Loadings and Load Factors shall be in accordance with BS EN 81. However it should be noted that the dynamic factors cited in BS EN 81 have been found to be inadequate. For example some progressive safety gears cause deceleration in excess of 1g, resulting in the need for a factor of 3 rather than 2 called for in BS EN 81.
- 3 When calculating the appropriate dynamic factors, the true maximum deceleration levels shall be considered.
- 4 To allow for the possibility of failure of temporary supports when maintaining the car or counterweight, the lift pit shall be designed for the load which might be caused by the car or counterweight falling from a height of 2m above the base of the lift pit.
- 5 The construction of the base of the lift pit shall also be designed to withstand a nominal load at any point (150mm x 150mm) from a 120kg item falling down the shaft during construction or maintenance.

3.1.3.18 WIND LOADING (S1051 Clause 3.1.16.5, S1053 Clause 3.1.16.14 and S1057 Attachment 7)

- 1 Wind loading for buildings shall be in accordance with BS 6399: Part 2. with a return period of 50 years. For other structures, the return period shall be 120 years.
- 2 References should be made to the BRE publication "Wind Loading Handbook" for additional information.
- 3 Wind loadings on bridges subject to dynamic loading shall be in accordance with BS 5400: Part 2. Wind loading on other bridges shall be in accordance with the requirements of BS 6399: Part 2.
- 4 Wind loadings on lattice towers and masts shall be in accordance with BS 8110: Pt 1.
- 5 Wind loading shall not be considered to act in combination with accidental impact loading.
- 6 Some assets may be susceptible to aerodynamic excitation, where this is considered to be credible; it should be evaluated in accordance with HA DMRB BD 49/01

3.1.3.19 LOADING DUE TO DYNAMIC PRESSURE AND SUCTION FROM RAILWAY TRAFFIC (S1051 Clause 3.1.16.4)

- 1 All structures adjacent to the track on the **surface and in sub-surface** locations subject to the effects of the slipstream of passing trains shall be designed to resist the air pressure calculated from ERRI D 189/RPI and UIC Leaflet No 779-IR, using a train shape coefficient K1 factor of 1.0, the train speed coefficient v_s shall be taken as the "line speed".
- 2 In **deep level tube station platform areas**, all structures, cladding, cladding support frames and fixings of the same shall be designed to resist both pressures and suctions of 0.2kN/m^2 using a γ_f or γ_{fl} as appropriate of 1.0.



3.1.3.20 HANDRAILS AND PEDESTRIAN BARRIERS (S1051, Clause 3.1.14.3, attachment 7.1 & S1053, Clause 3.1.16.7)

- 1 Handrails and barriers shall be designed to resist the loads specified in BS EN 1991-1-1, adopting the building use categories stated below:
 - a) Category C5 (x) for all locations to which the public normally have access or may have access (e.g. in an emergency), except where the definition given in (ii) below applies;
 - b) Category C5 (ix) for other locations to which the public normally have access, where a barrier is provided for the guidance or separation of passenger flows. These are the central handrails on staircases and in other situations where the passenger width is limited by the barrier to not more than 2m, and also barriers at the ends of platforms in surface stations;
 - c) Category C2, C3, C4 (vi) and (vii) additionally a uniformly distributed load of 1.0kN/m² shall be applied to any infill and a point load of 0.5 kN shall be applied to the infill. This loading shall be used for locations not normally accessible to the public.
- 2 Temporary hoardings in stations should be designed to resist Category C5 (x) loading.
- 3 There is no requirement to apply these loadings to the walls of rooms or buildings, which are deemed to have sufficient inherent strength to resist loads applied by passengers
- 4 Vehicle barriers for car parks shall be designed to resist the loads determined from BS EN 1991-1-1

3.1.3.21 CABLE POSTS (G0058)

- 1 Cable posts should be designed assuming that brackets will be fitted to all holes and that a single "top hat" extension will be installed on the post. The brackets should be assumed to be fitted with the maximum number of cables that can be placed on the brackets. The posts should be designed for wind loading and pressures and suctions from passing trains, and the maximum applied moment from cables should be assumed by applying the total load on one side of the post at the eccentricity specified for brackets in Manual of Good Practice G0057.

3.1.3.22 CAR PARK VEHICLE BARRIERS (S1057)

- 1 Vehicle barriers for car parks should be designed to resist the loads for vehicle barriers for car parks determined from BS 6399 – Part 1 1996

3.1.3.23 ADVERTISING HOARDINGS (G0057)

- 1 Advertising hoardings should be designed to resist wind loads in accordance with BS6399 Part 3, and pressures and suctions from passing trains as defined above. In addition the panels should be designed to resist a tension of 0.2kN/m at an angle of 60° to the face of the panels to represent the stripping of the posters.

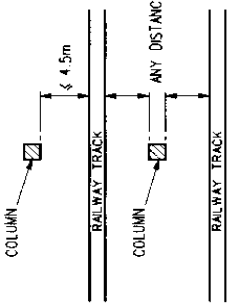
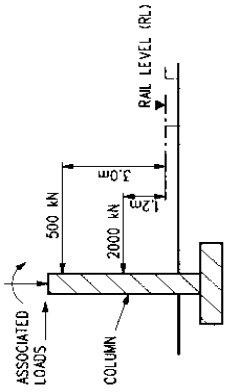
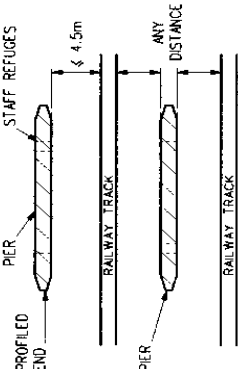
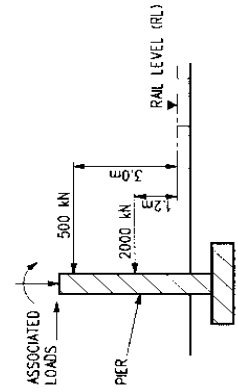
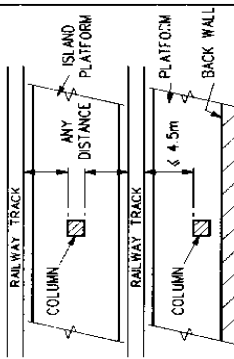
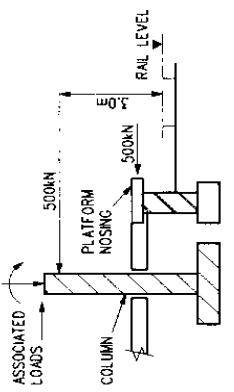
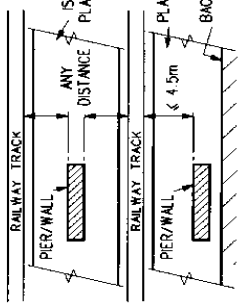
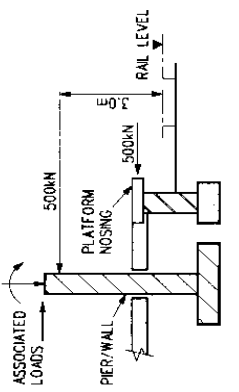
LOCATION	DESIGN ACCIDENTAL LOADS	NOTES
		A1 HORIZONTAL LOADS ARE ALTERNATIVES WHICHEVER GIVES THE WORSE CONDITION A2 HORIZONTAL LOADS ACT IN ANY DIRECTION A3 ASSOCIATED LOADS ARE DUE TO SUPPORTED STRUCTURE A4 SOLID PLINTH 900mm ABOVE RL ALSO REQUIRED
		B1 HORIZONTAL LOADS ARE ALTERNATIVES WHICHEVER GIVES THE WORSE CONDITION B2 HORIZONTAL LOADS ACT IN ANY DIRECTION B3 ASSOCIATED LOADS ARE DUE TO SUPPORTED STRUCTURE B4 PIER ENDS TO BE PROFILED, REFUGES PROVIDED
		C1 HORIZONTAL COLUMN LOAD ACTS IN ANY DIRECTION C2 HORIZONTAL PLATFORM LOAD ACTS NORMAL TO THE PLATFORM EDGE OVER A LENGTH OF 2.5m AND THE DEPTH OF THE PLATFORM NOSING C3 ASSOCIATED LOADS ARE DUE TO SUPPORTED STRUCTURE
		D1 HORIZONTAL COLUMN LOAD ACTS IN ANY DIRECTION D2 HORIZONTAL PLATFORM LOAD ACTS NORMAL TO THE PLATFORM EDGE OVER A LENGTH OF 2.5m AND THE DEPTH OF THE PLATFORM NOSING D3 ASSOCIATED LOADS ARE DUE TO SUPPORTED STRUCTURE

Table 3 - Accidental Loads on Railway Traffic



3.1.4 Computer Aided Drawing (CAD)

1 Summary

This Advice Note gives guidance for the production and management of CAD drawings for LU Civil Engineering assets.

All CAD files generated directly by LU or on behalf of LU by its suppliers must comply with LU CAT 1 Standard S1037 (Computer Aided Design (CAD) Data). This standard sets out the general requirements for the production and storage of CAD files and defines how CAD files and layers are to be numbered. S1037 requires that all CAD drawings be produced in Microstation (Bentley) V8i format.

Reference document R0583 (Production of Civil Engineering Drawings) has been produced to ensure that Civil Engineering drawings have a consistent presentation and are compliant with industry standards. R0583 defines drawing types, includes common abbreviations and makes references to relevant standards.

LU requires all CAD files to be stored in ProjectWise. There are currently independent ProjectWise databases in LU, Crossrail, JNP, London Overground, DLR and London Tramlink. It is intended to move all the CAD data into a single ProjectWise database. External consultants or contractors undertaking CAD work on behalf of LU should be issued with CAD Start-Up Packs which are available from the LU CAD Support Team. The CAD Start-Up Packs include drawing templates and Project drawing numbers. All external consultants and contractors must provide LU with a digital copy (in Microstation format) of all drawings produced.

LU CAD drawings must be located using the LU Survey Grid. This grid is more accurate than the Ordnance Survey Grid and minimises errors caused by the curvature of the earth when projected onto a 2D plane. The origin of the LU Survey Grid is offset from the origin of the Ordnance Survey Grid. It should be noted that vertical levels shown on Ordnance survey maps are to Newlyn datum. Vertical levels shown on LU drawings are 100m above Newlyn datum. This is to avoid negative values.

A number of cell files with standard details are available in the ProjectWise library.

2 CAD filing

SSL and BCV files are stored in the LU ProjectWise database. This database has a Metronet Project folder and a Trans4M Project folder. Engineers have access to one of these folders but not both. The choice of folder will depend of which folder the engineer has access to.

Drawing are filed under SSL, BCV or JNP, then under LCS code and finally by drawing number.

Before any drawings can be filled in ProjectWise, a project folder and project drawing number must be created by the LU CAD Support Team. The LU CAD Support Team will require the SAP number for the project as this will form part of the drawing number.

3 Drawing format and approvals

CAD drawings are produced in model files at a scale of 1 to 1. When the model file is completed, it is placed on to a template at the correct scale and saved as a drawing file. Any drawing changes must be done in the model file. All drawings must be marked "for comments", "for information", "for approval", "for tender", "for construction" or "as built". No drawing should be issued unless it has been "T" checked by the designated CAD technician and approved by the competency listed designer. Approvals must be recorded on ProjectWise.

It should be noted that "As built" drawings must be approved by the designer. By approving the drawings, the designer is confirming that they are in accordance with the approved design.

After a drawing has been approved in ProjectWise, it is frozen and no further changes may be made unless a new revision number is created.