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| PREPARED BY: TM | CHECKED BY | |

| REF | CALCULATIONS | OUTPUT |
|---|---|---|
| | Calculations for assessment of ground movement using Ciria C580. | |

CALCULATION SHEET

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| | Existing / Proposed site conditions | |

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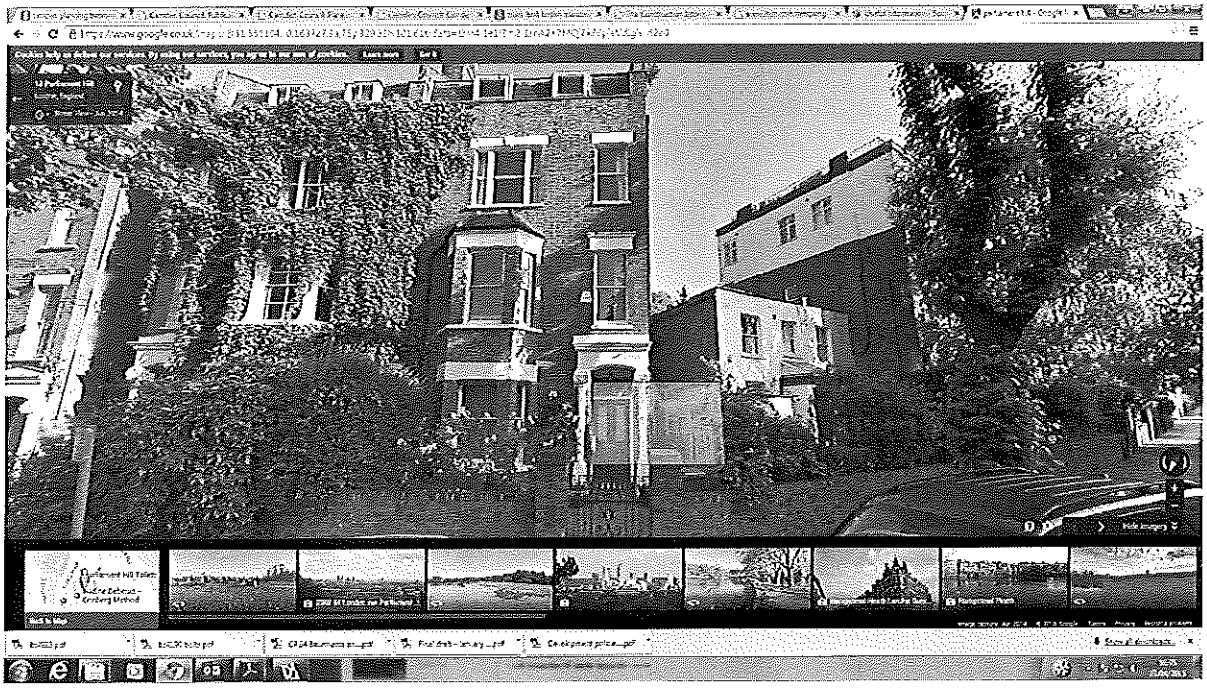

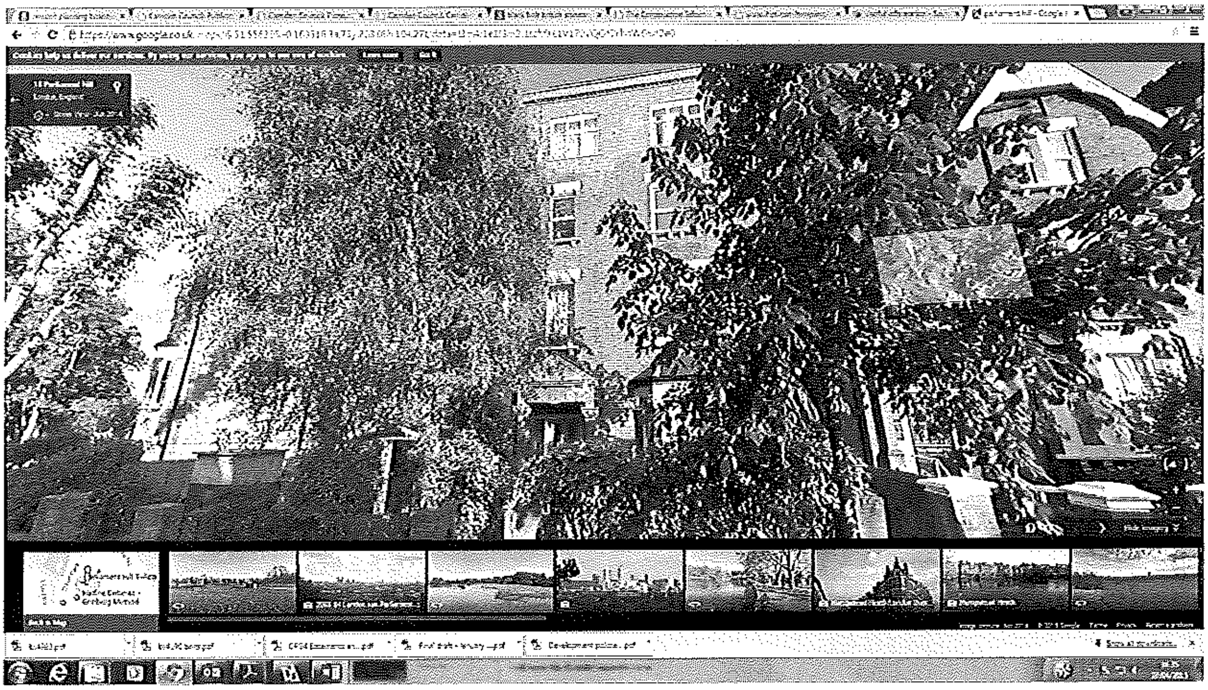

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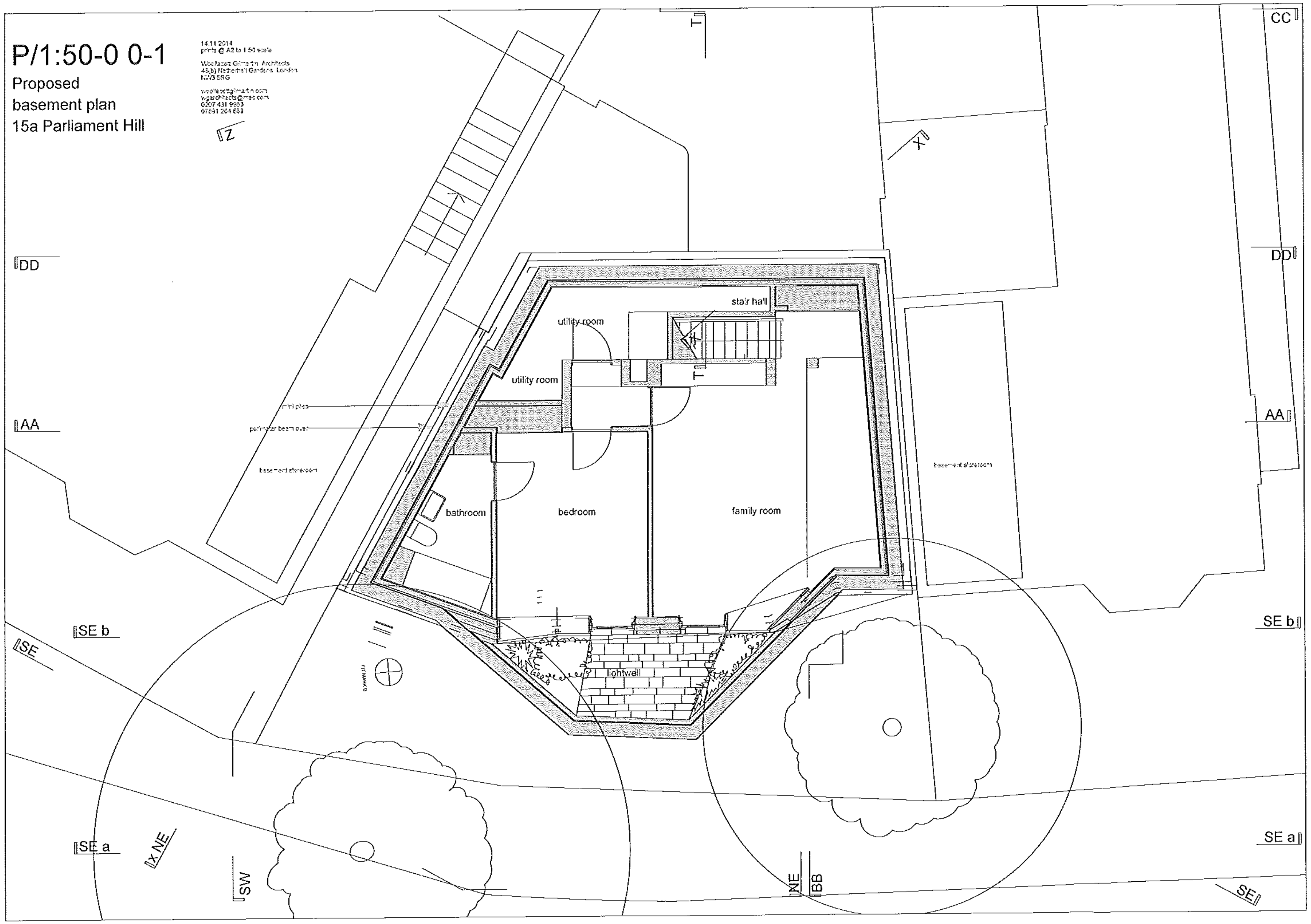


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| | Extracts Ciria C580. | |

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**Table 2.3** *Support stiffness categories (Carder, 1995)*

| Support stiffness | Description/examples |
|---|---|
| High | *Top-down construction*, temporary props installed before permanent props at *high* level |
| Moderate | Temporary props of high stiffness installed before permanent props at *low* level |
| Low | *Cantilever walls*, temporary props of *low* stiffness or temporary props installed at low level |

Table 2.4 summarises the magnitude and extent of the monitored ground surface movements due to excavation in front of bored pile, diaphragm and sheet pile walls wholly embedded in stiff clay under conditions of good workmanship. The case history data, upon which Table 2.4 is based, relate to excavations that range in depth from 8 m to 31 m, have a factor of safety against base heave in excess of 3 and where walls are wholly embedded in stiff clay.

**Table 2.4** *Ground surface movements due to excavation in front of bored pile, diaphragm wall and sheet pile walls wholly embedded in stiff clays*

| Movement type | High support stiffness (high propped wall, top-down construction) | | Low support stiffness (cantilever or low-stiffness temporary props or temporary props installed at low level) | |
|---|---|---|---|---|
| | **Surface movement at wall** (per cent of max excavation depth) | **Distance behind wall to negligible movement** (multiple of max excavation depth) | **Surface movement at wall** (per cent of max excavation depth) | **Distance behind wall to negligible movement** (multiple of max excavation depth) |
| Horizontal | 0.15 | 4 | 0.4 | 4 |
| Vertical | 0.1 | 3.5 | 0.35 | 4 |

**Notes**

1. Maximum surface movement occurs close to the wall and is expressed as a percentage of maximum excavation depth in front of the wall.
2. Extent of movement is calculated non-dimensionally by dividing by maximum excavation depth.
3. Movements exclude those arising from wall installation effects.
4. Movements correspond to good workmanship and to walls wholly embedded in stiff clays retaining stiff clays or competent soils.
5. Movements will be greater where soft soils are encountered at formation level; see Appendix 2.

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Extract Ciria C580.

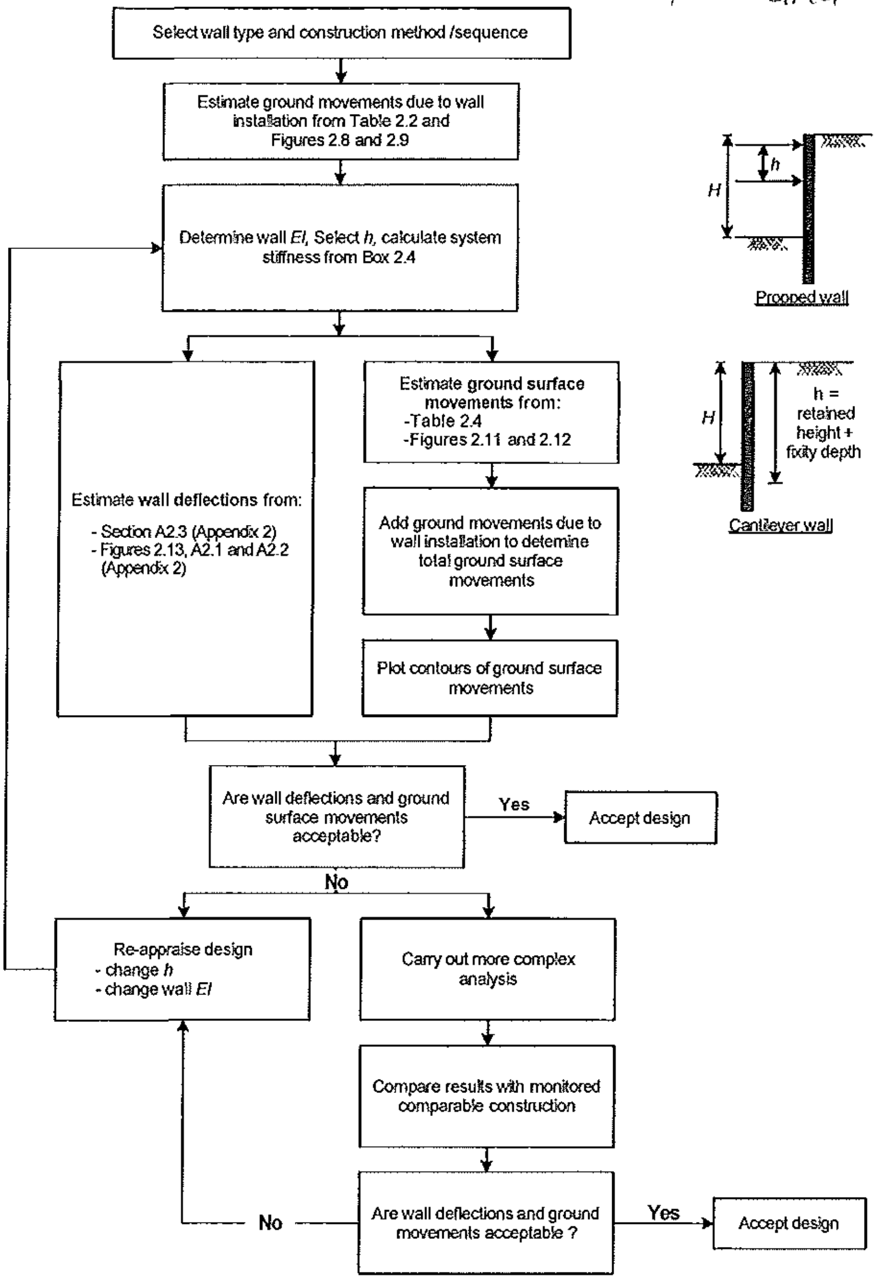


**Figure 2.14** *Procedure for prediction of wall deflections and ground surface movements*

**Estimates of wall deflections and associated ground surface movements should follow the procedure shown in Figure 2.14. Case-history-based empirical methods of prediction are to be preferred to use of complex analyses, unless such analyses are first "calibrated" against reliable measurements of well-monitored comparable excavations and wall systems.** Table 2.4, in conjunction with Figure 2.11, can be used to estimate *ground surface movements associated with walls wholly embedded in stiff clay.* Figure 2.12 can be used for walls wholly embedded in sands. Preliminary estimates of *wall deflection* can be obtained from Figure 2.13 and from Section A2.3 in Appendix 2. This will depend upon the system stiffness, $p_s$, and the factor of safety against base heave. System stiffness is defined in Box 2.4. The reader is referred to CIRIA publication C517 (1999), Appendix 4, for a good definition and explanation of base stability.

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## 2.5.4 Principles of building damage assessment

*See also*

**Figure 2.14**
Procedure for prediction of wall deflections and ground surface movements

**A three-stage approach should be adopted for assessing potential damage to buildings near excavations supported by embedded retaining walls; see Figure 2.17.**

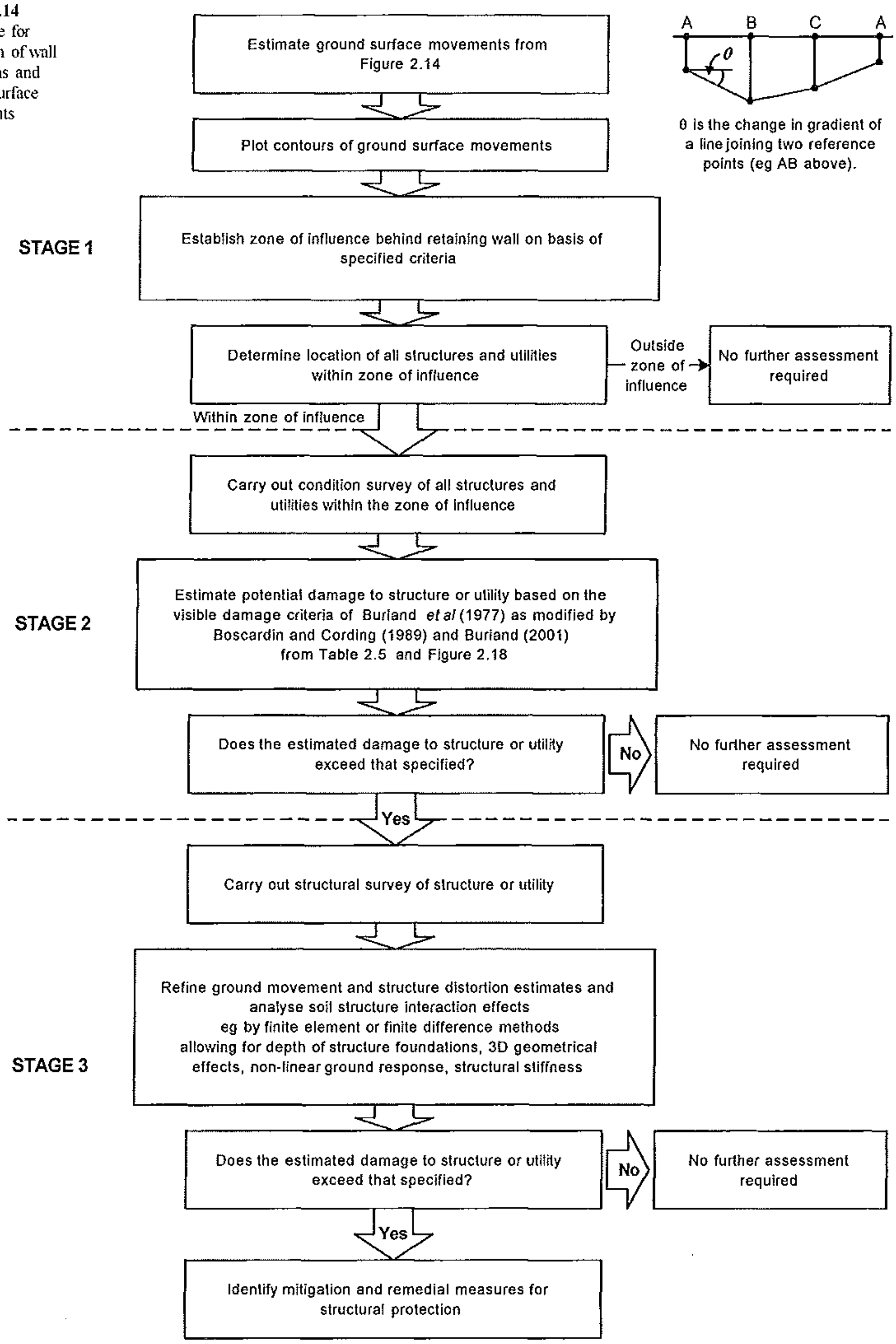


**Figure 2.17** *Procedure for building damage assessment*

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**Stage 1**

Ground movements behind the retaining wall should be estimated as described in Section 2.5.2 assuming greenfield conditions, ie ignoring the presence of the building or utility and the ground above foundation level. Contours of ground surface movements should be drawn and a zone of influence established based on specified settlement and distortion criteria. All structures and utilities within the zone of influence should be identified.

**Stage 2**

A condition survey should be carried out on all structures and utilities within the zone of influence before starting work on site. The structure or utility should be assumed to follow the ground (ie it has negligible stiffness), so the distortions and consequently the strains in the structure or utility can be calculated. The method of damage assessment should adopt the limiting tensile strain approach as described by Burland *et al* (1977), Boscardin and Cording (1989) and Burland (2001); see Table 2.5 and Figure 2.18.

**Table 2.5** *Classification of visible damage to walls (after Burland* et al, *1977, Boscardin and Cording, 1989; and Burland, 2001)*

| Category of damage | Description of typical damage (ease of repair is underlined) | Approximate crack width (mm) | Limiting tensile strain $\varepsilon_{lim}$ (per cent) |
|---|---|---|---|
| 0 Negligible | Hairline cracks of less than about 0.1 mm are classed as negligible. | < 0.1 | 0.0–0.05 |
| 1 Very slight | <u>Fine cracks that can easily be treated during normal decoration.</u> Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection. | < 1 | 0.05–0.075 |
| 2 Slight | <u>Cracks easily filled. Redecoration probably required.</u> Several slight fractures showing inside of building. Cracks are visible externally and <u>some repointing may be required externally</u> to ensure weathertightness. Doors and windows may stick slightly. | < 5 | 0.075–0.15 |
| 3 Moderate | <u>The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.</u> Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired. | 5–15 or a number of cracks > 3 | 0.15–0.3 |
| 4 Severe | <u>Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.</u> Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted. | 15–25 but also depends on number of cracks | > 0.3 |
| 5 Very severe | <u>This requires a major repair involving partial or complete rebuilding.</u> Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability. | usually > 25 but depends on number of cracks. | |

**Notes**

1. In assessing the degree of damage, account must be taken of its location in the building or structure.
2. Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

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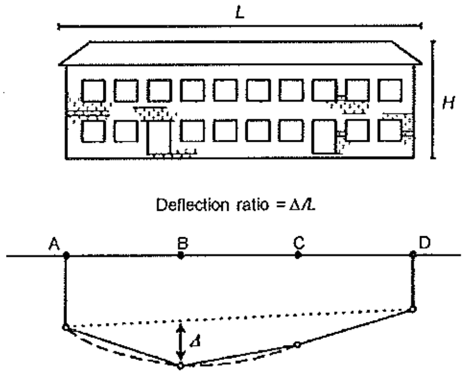
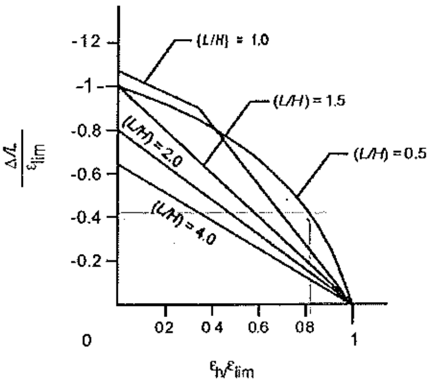
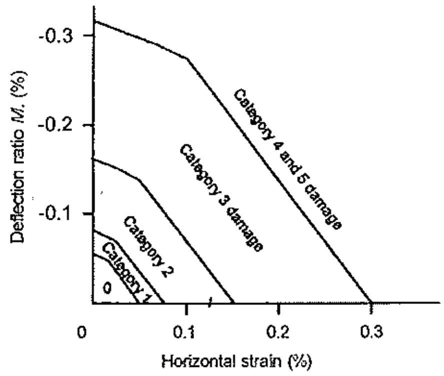



(a) Definition of deflection ratio.




(b) Influence of horizontal strain on $\Delta/L / \varepsilon_{lim}$ (after Burland. 2001)




(c) Relationship between damage category and deflection ratio and horizontal tensile strain for hogging for (L/H) = 1.0 (after Burland, 2001)

By adopting values of $\varepsilon_{lim}$ associated with the various damage categories given in Table 2.5, Figure (b) can be developed into an interaction diagram showing the relationship between Δ/L and $\varepsilon_h$ for a particular value of L/H Figure (c) shows such a diagram for (L/H) = 1.0.

**Figure 2.18** *Relationship between damage category, deflection ratio and horizontal tensile strain (after Burland, 2001)*

Reinforced concrete-framed structures are more flexible in shear than are masonry structures and are consequently less susceptible to damage. Nevertheless, for the purposes of a stage 2 assessment of potential damage, all structures should be treated as masonry structures.

**Box 2.5** *Procedure for stage 2 damage category assessment*

The following steps should be undertaken in making a stage 2 assessment of the damage to a structure:

(i) establish *L* and *H* for the structure (see Figure 2.18(a) for definitions of *L* and *H*)

(ii) determine *(L/H)*

(iii) determine relationship between (Δ/L) and $\varepsilon_h$ for the required *(L/H)* from Figure 2.18(b) for $\varepsilon_{lim}$ values from Table 2.5

(iv) estimate vertical and horizontal ground surface movements in the vicinity of the structure from Figure 2.14

(v) determine (Δ/L) and $\varepsilon_h$ (= $\delta h/L$) where $\delta_h$ is the horizontal movement

(vi) estimate damage category from the relationship between *(Δ/L)* and $\varepsilon_h$ established from step (iii) above.

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Ciria C580 - Section 2.5.4.

Stage 1 - Table 2.4

Basement depth : d = 3.59

High support stiffness

Surface movement of wall - Table 2.4

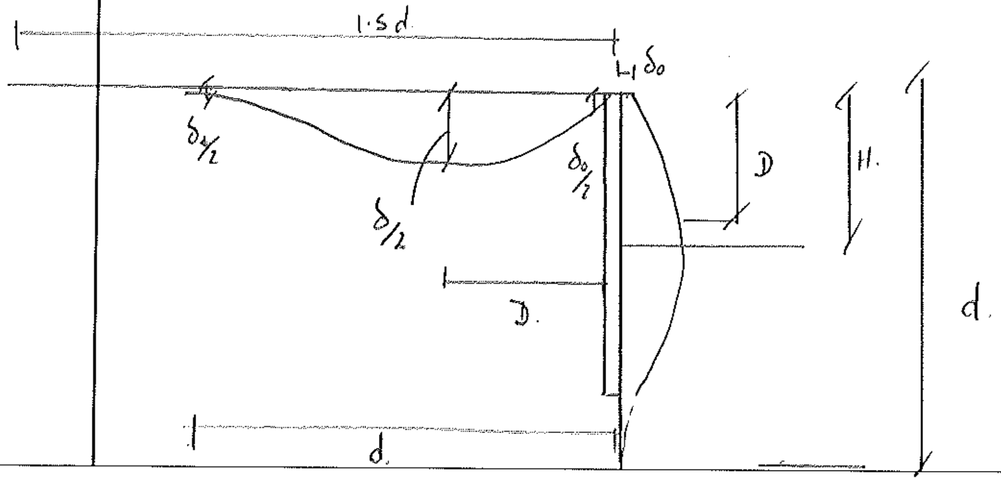
H = $0.15/100 \times d$ = 5.4mm.

V $0.1/100 \times d$ = 3.59mm

Zone Influence :

H $4 \times 3.59$ = 14.36 m

V $3.5 \times 3.59$ = 12.56 m.

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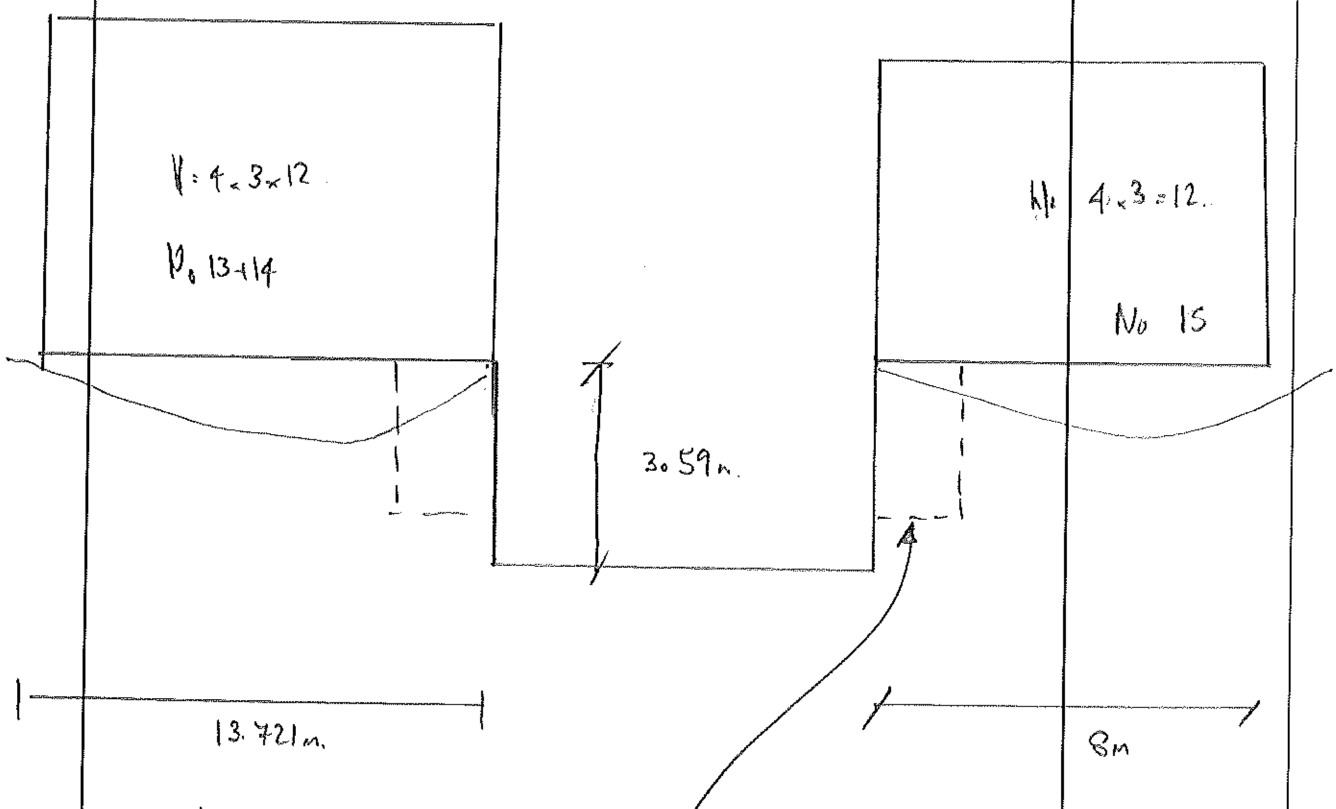
$\delta_0 = 5.4mm \qquad \delta_0/2 = 2.7m$

$\delta_{\text{limit 10m}} = 10mm \qquad \delta/2 = 5mm$

$\delta_t$ say $5m \qquad \delta_t = 2.5mm.$

Take $d = 3 \times 3.59 = 10.77m.$




$L/H = 1.14 \qquad L/H \; 0.66.$

Conservatively ignore basements and assume adjoining buildings are immediately adjacent to basement

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| Ref | Calculations | Output |
|---|---|---|
| | Box 2.5. | |
| | Take $\Delta = \delta_2 = 5mm$. | |
| No 13/14 | Deflection ratio $= \Delta/L = 5/13.7\times10^3$, | $3.6\times10^{-4}$. |
| No 15 | $\Delta/L = 5/8\times10^3$, | $6.25\times10^{-4}$. |
| | $\varepsilon_{lim}$ for cat 2 damage $= 0.075 - 0.15$ | table 2.5. |
| | No. 13/14 $\quad \dfrac{\Delta/L}{\varepsilon_{lim}} = \dfrac{3.6\times10^{-4}}{0.15/100} = 0.24$. | |
| | $\Rightarrow \varepsilon_h/\varepsilon_{lim} = 0.82$ | |
| | $\varepsilon_h = 0.82\times 0.15/100 = 0.123\%$ | |
| | $= 1.23\times10^{-3}$ | |
| | $\varepsilon_h = \delta_h/L \Rightarrow \delta_h = 16.85 mm$. | |
| | Actual $\delta$ limited to 10mm $\therefore$ okay | |

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| REF | CALCULATIONS | OUTPUT |
|---|---|---|
| No. 15 | $\Rightarrow \dfrac{\Delta/L}{\varepsilon_{lim}} \Rightarrow \dfrac{6.25\times10^{-4}}{0.15/100} = 0.41$ | |
| | $\Rightarrow \dfrac{\varepsilon_h}{\varepsilon_{lim}} = 0.9$ | |
| | $\varepsilon_h = 0.85\times\dfrac{0.15}{100} = 1.27\times10^{-3}\%$ | |
| | $\varepsilon_h = \dfrac{\delta_L}{L} \Rightarrow \delta_h = 1.27\times10^{-3}\times8 =$ | 10.2mm accept. |

Conclusion

Using an upper bound limiting tensile strain of 0.15 (Burland category 2, slight) wall deflection will need to be limited to 10mm.

The above calculations using conservative assumptions demonstrates predicted damage will be 'slight' where the wall $\delta$ is limited to 10mm.