

# Contents

Foreword	7
COST	9
<b>1 Background to the study</b>	<b>11</b>
1.1 Introduction	11
1.2 Collection of case studies	12
1.2.1 <i>Data collection sheets</i>	13
1.2.2 <i>Preliminary conclusions from the database study</i>	13
1.3 Scope of the handbook	14
<b>2 Defining and predicting ground movements and building damage</b>	<b>15</b>
2.1 Introduction	15
2.2 Definitions of ground and foundation movement	15
2.3 Classification of damage	15
2.3.1 <i>Introduction</i>	15
2.3.2 <i>Categories of damage</i>	16
2.3.3 <i>The division between damage categories 2 and 3</i>	18
2.4 Concept of limiting tensile strain and strains in elastic beams	18
2.4.1 <i>Onset of visible cracking</i>	18
2.4.2 <i>Limiting tensile strain – a serviceability parameter</i>	19
2.4.3 <i>Strains in simple rectangular beams</i>	19
2.4.4 <i>Sagging and hogging modes</i>	19
2.4.5 <i>The influence of horizontal strain</i>	20
2.4.6 <i>Use of simplified charts</i>	21
2.5 Incorporating building stiffness into settlement predictions	21
2.6 Evaluation of risk of damage to buildings owing to subsidence	22
2.6.1 <i>Level of risk</i>	22
2.6.2 <i>Preliminary assessment</i>	23
2.6.3 <i>Second stage assessment</i>	23
2.6.4 <i>Detailed evaluation</i>	23
2.7 Conclusions	24

### 3 Damage arising from the construction of new foundations

25

3.1	Introduction	25
3.2	The nature of damage caused by new foundations	25
3.2.1	<i>Movements caused by the construction of new foundations</i>	26
3.2.2	<i>Vibration-induced movements</i>	26
3.3	Typical examples of damage caused by new foundations	27
3.3.1	<i>Reduction of stability of existing foundations</i>	28
3.3.2	<i>Immediate and long-term settlement of existing foundations</i>	28
3.3.3	<i>Construction of new foundations above an existing structure</i>	29
3.3.4	<i>Construction of new foundations below an existing structure</i>	29
3.3.5	<i>Deformation of utilities and services</i>	30
3.3.6	<i>Loading and deformation of subsurface structure (e.g. tunnels)</i>	30
3.3.7	<i>Instability of existing foundations on sloping ground</i>	31
3.3.8	<i>Lateral loading and deflection of existing retaining structures</i>	31
3.3.9	<i>Displacements and deformations of existing structures from pile driving</i>	32
3.3.10	<i>Vibration of existing foundations owing to pile driving</i>	33
3.4	Recommendations for avoiding damage from new foundations	33

### 4 Damage resulting from deep excavations

35

4.1	Introduction	35
4.2	Principal sources of damage	35
4.3	Failure of retaining structures	36
4.3.1	<i>Failure of the retaining wall itself</i>	36
4.3.2	<i>Collapse of struts or pull-out/breakage of anchors</i>	37
4.3.3	<i>Instability due to inadequate embedment</i>	38
4.3.4	<i>Base heave of the excavation</i>	38
4.4	Excessive movements associated with excavation	40
4.4.1	<i>Ground movements due to deep excavations</i>	40
4.4.2	<i>Movements due to construction of the wall itself</i>	40
4.4.3	<i>Excessive lateral displacements</i>	41
4.4.4	<i>Piping and erosion resulting from dewatering operations</i>	43
4.4.5	<i>Modification of the local groundwater level</i>	43
4.5	Lessons to be learnt from deep excavation case studies	45
4.5.1	<i>Origin of the damage</i>	45
4.5.2	<i>General lessons</i>	45

<b>5 Tunnelling-induced ground movements and damage</b>	<b>46</b>
5.1 Introduction	46
5.2 Ground movement due to tunnelling	46
5.2.1 <i>Settlements due to tunnelling</i>	48
5.2.2 <i>Horizontal displacements due to tunnelling</i>	48
5.2.3 <i>Assessment of surface displacements caused by tunnelling</i>	48
5.3 Tunnelling-induced damage to existing structures	49
5.3.1 <i>Potential damage to existing structures at the serviceability state</i>	49
5.3.2 <i>Potential damage to existing structures from tunnel instability</i>	51
5.3.3 <i>Environmental impact from tunnel construction</i>	53
5.4 Causes of excessive ground movement and damage	53
5.4.1 <i>Inadequate initial investigation</i>	54
5.4.2 <i>Poor design and analysis</i>	54
5.4.3 <i>Poor control of construction works</i>	54
5.5 Protective measures	55
5.5.1 <i>In-tunnel measures</i>	55
5.5.2 <i>Ground treatment measures</i>	55
5.5.3 <i>Structural measures</i>	56
5.6 Summary and lessons learnt	56
<b>6 Damage resulting from slope instability</b>	<b>58</b>
6.1 Introduction	58
6.2 Classification of slope failures	58
6.3 Causes of landslides	58
6.3.1 <i>Changes in geometry</i>	59
6.3.2 <i>Changes in pore pressure regime</i>	60
6.3.3 <i>Erosion</i>	60
6.4 Categories of slope instability	61
6.4.1 <i>Overall failure</i>	61
6.4.2 <i>Small progressive surface movements</i>	61
6.4.3 <i>Indicators of previous or imminent landslides</i>	61
6.5 Depreciation of property	62
6.6 Preventative measures to avoid slope movements	62
6.6.1 <i>Adjusting geometry</i>	62

6.6.2	<i>Groundwater control</i>	63
6.6.3	<i>Slope protection</i>	63
6.7	Conclusions and lessons learnt from case studies involving slope instability	64
<b>7 Overall conclusions and recommendations relating to damage</b>		<b>65</b>
7.1	Introduction	65
7.2	Damage due to foundation construction	65
7.3	Excavations adjacent to existing buildings	66
7.3.1	<i>Failures</i>	66
7.3.2	<i>Excessive movements</i>	66
7.3.3	<i>Dewatering</i>	66
7.3.4	<i>Lateral ground reinforcement</i>	67
7.4	Excavation of tunnels and subsurface construction work	67
7.5	Construction on slopes and activation of landslide movements	68
7.6	Influence of construction activity on ground water flow	69
7.7	Assessing the risk of damage	69
7.8	Preventative and repair measures	70
7.9	General lessons	70
<b>8 References</b>		<b>72</b>
<b>COST C7 Working Group C: members' details</b>		<b>74</b>