MALCOLM HOLLAND

PRACTICAL GUIDE TO

DIAGNOSING STRUCTURAL MOVEMENT IN BUILDINGS

WILEY-BLACKWELL

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A John Wiley & Sons, Ltd., Publication

This edition first published 2012 © 2012 by John Wiley & Sons, Ltd

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered Office
John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

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Library of Congress Cataloging-in-Publication Data

Holland, Malcolm.
Practical guide to diagnosing structural movement in buildings / Malcolm Holland.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-470-65910-6 (pbk. : alk. paper)
1. Buildings–Defects. 2. Earth movements and building. 3. Structural analysis (Engineering) 4. Building failures. 5. Buildings–Repair and reconstruction. I. Title.
TH441.H635 2012
690′.21–dc23

2011051077

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image courtesy of Shutterstock
Cover design by Edge Creative www.edgecreativestudio.com

Set in 10/12pt Minion by SPi Publisher Services, Pondicherry, India

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Introduction

It is often the layman's first reaction when cracking is observed in a building, that it must be the foundations and that it is serious. This is not true.

In the vast majority of cases it is not subsidence or settlement of the foundations and in most cases cracks do not indicate a serious defect.

So when analysing cracks, it is essential to always keep an open mind. A good rule of thumb for the beginner is to try to find what has caused the crack other than foundation movement. Only when all other possibilities have been ruled out, consider then whether it is foundation movement. In my experience (teaching university students and graduate surveyors) it is very difficult to instil this discipline. There is a great temptation to jump to a conclusion or to shortcut the process of analysis.

Many people, including surveyors, are nervous about diagnosing cracks. This is understandable, as the consequences of getting it wrong can be potentially onerous. It is a subject that is difficult to teach in the lecture theatre and there may be little or no time for field experience within an academic syllabus at university. Most text books on the subject are aimed more towards Engineers or Building surveyors, who specialize in this area. Necessarily such books are very technical in nature. This book is not aimed at the experienced engineer or surveyor. It is primarily intended for the relatively inexperienced surveyor, engineer, undergraduate or even competent layman. It is intended as a practical guide or as on site manual. The intention is to remain as un-technical as possible. It avoids references to regulations, digests and other technical sources. These can be found elsewhere in other books on the subject. The book is concerned with identification and diagnosis not the detailed specification of remedial work.

The intention is to know, with a reasonable level of confidence, when movement is potentially serious or not. To know when it is necessary to call in the more experienced or qualified professional to deal with it.

The purpose of this book is to show that by understanding one simple first principle and by following a simple methodology, the vast majority of cracks, probably as many as nine out of ten cracks, can be diagnosed in just a few minutes.

By looking at the cracks in a little more detail and by understanding the factors that distort crack patterns, this diagnosis rate can be raised even further.

Couple this with a reasonably good knowledge of building construction and the key features of the most common causes of cracking; and almost all cracks can be diagnosed relatively quickly and with a high degree of confidence. There will however always be some cracks that cannot be diagnosed from a single inspection. Inevitably, when movement first starts to develop, the evidence can be insufficient to reach a conclusion. In some cases movement will have to be monitored for a period of time. In other cases the only way to obtain enough evidence to make a diagnosis, might involve opening up the structure of a building or carrying out excavations to expose the foundations. Material or sub soil samples may need to be taken for testing. A building may need to be monitored for a period of time to make a diagnosis or to confirm a preliminary opinion. The number of cases where such action is necessary is likely to be small providing that the basic principles are understood and applied in an objective manner.

This may seem too easy and too good to be true but why should it not be true? Cracks are caused by a simple physical process and the physics always acts in the same way. It is a 'law' of physics; there is no hidden agenda, no politics; just a simple physical process. Tension in a material or structure will act to try to pull it apart.

When the tension is sufficiently large in relation to the strength of the material it will pull it apart and cause a crack. It is a simple physical process in the same way that adding heat to a liquid causes a physical process of temperature rise and when enough heat is added in relation to the boiling point of the liquid it will cause it to boil. It will always give the same result.

This book provides a methodology by which cracks and movement in buildings can be diagnosed.

The book is in four parts. The first part describes the first principles. The second part of the book contains 'swatches' which describe the key features of the most common forms of movement in buildings and the crack patterns associated with them. This part covers movement and cracks NOT caused by ground or foundation movement. The third part of the book contains similar ‘swatches’ giving the key features relating to movement caused by ground or foundation problems. Part four describes the techniques used to repair damage cause by movement and to arrest further movement.

By applying the FIRST PRINCIPLE and then referring to the ‘swatches’ there should be a high probability that the correct diagnosis can be reached.

The methodology contained within this book will not only help to derive the correct diagnosis but it will also demonstrate a process to show and record how the diagnosis was reached. When giving advice to a third party, the ability to demonstrate a proper methodology, a chain of thought and logical process is critically important should it ever become a negligence claim. When advising a third party it is also imperative to make clear that any diagnosis is an opinion, not a guarantee. In theory an opinion can turn out to be wrong without negligence automatically occurring provided that a correct methodology has been followed and that other reasonably competent persons would have arrived at the same opinion. In the light of previous case law some might argue this to be an over optimistic view for a professional working in this field to take; but objectively that should be the case.

So it is absolutely critical that one understands the FIRST PRINCIPLES before moving on to the second part of this book. It is straight forward and relatively simple but if on first reading you do not completely grasp it, read it again. Do not be tempted to short cut the process by simply looking at the examples or photographs in the book and finding one that looks similar.

And finally, good luck.

List of Figures

Acknowledgements

I would like to acknowledge my mother in law, Mrs Jill Porter, and my ex-boss, Martin Brown FRICS, for their help with editing and proof reading.

I would also like to acknowledge all those people who have freely passed on their knowledge and experience to me throughout my career. I hope that I can pass on their baton.

Part 1

First Principles

1.1

First Principles

Most traditional building materials are relatively weak in tension, when compared to their compressive strength. If a building is distorted, by whatever force, some parts of it will be stretched. Cracking is likely to occur at right angles to the force that caused the stretching. By imagining arrows at right angles to a crack, it is possible to determine the direction of movement. The direction of the movement is usually directly related to its cause. There are, however, always some cracks that cannot be diagnosed quickly by a simple visual inspection.

The over riding first principle that one must understand when diagnosing cracking is that the materials we are dealing with, bricks and concrete, are weak in tension.

STEP ONE

Brickwork and most materials crack when pulled apart in tension. Tension is caused by elongation (Figure 1.1.1).

Practical Guide to Diagnosing Structural Movement in Buildings, First Edition.
Malcolm Holland.
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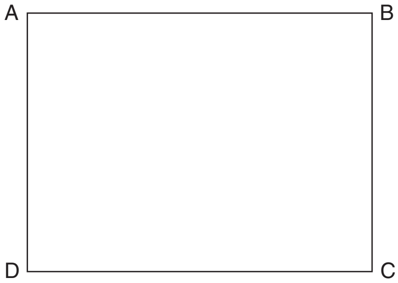

Figure 1.1.1 Diagonals of equal length.

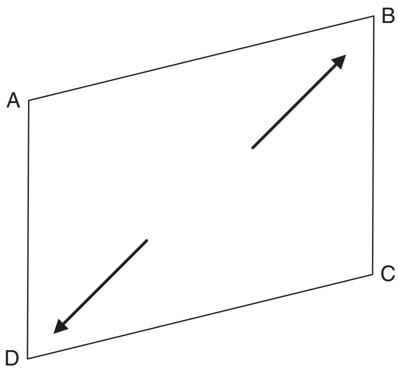

Figure 1.1.2 Diagonal B–D stretched.

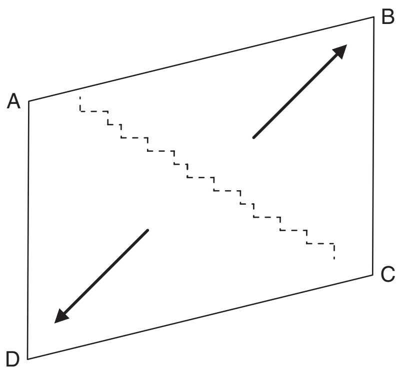

Figure 1.1.3 Crack at right angles to tension.

Imagine a square or rectangle of material – A, B, C, D.
Think of this as the front elevation of a building or a panel of part of a building.

Within normal tolerances buildings are built square and plumb. In a square or rectangle the diagonals are the same length. Please measure them. A–C is the same length as B–D (Figure 1.1.2). Please write the measurements down.

If the left hand side settles, the diagonal A–C is shortened. It is put into compression (Figure 1.1.3). The diagonal B–D is lengthened. It is put into tension. Please measure B–D and write the measurements down. You will see that it is longer than it was. It is this stretching that is important as it creates tension.

The tension force pulls the panel apart, in tension. If it was brickwork it would pull it thus. The crack would be perpendicular to the elongation. THE CRACK IS AT A RIGHT ANGLE TO THE TENSION.

This is always the first point to look at when observing cracks. The movement is at right angles to the crack. The building has either moved up to the right hand side or down to the left hand side. There are very few reasons for upward movement and this possibility can quickly be assessed and usually dismissed. Buildings are heavy and gravity pulls them down. It is the downward arrow that is usually significant.

Example 1

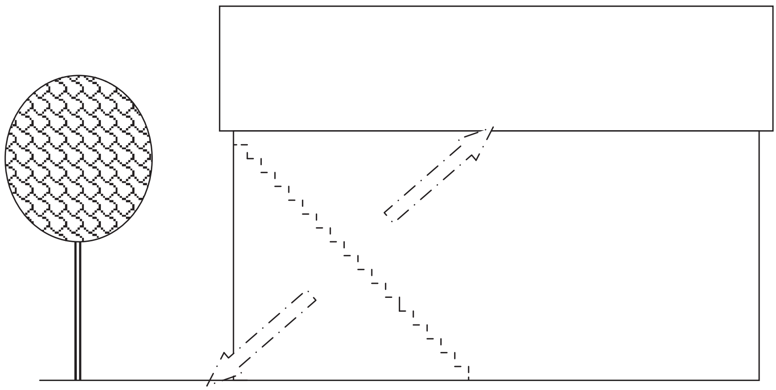

Figure 1.1.4 Imaginary arrows at right angles to tension.

If one imagines arrows at right angles to the crack, as shown dashed in the diagram in Figure 1.1.4, then one can see that the movement is either down to the left hand corner or up to the right hand side. The arrows point to where the movement is and this is usually pointing at the defect. In this case one would look down to the left and there is the tree. Alternatively, the movement could be up to the right hand side. This is very unlikely and in this case there is nothing that could possibly cause movement up to the right. The solution is therefore reasonably obvious. In the absence of other evidence the movement is likely to be caused by the tree.

There are some instances where upward movement can occur in buildings; the most common being clay heave or corrosion of steel fixings and wall ties. Although upward movement is far less likely than downward movement the possibility of upward movement should be assessed before dismissing the possibility.

Example 2

It is quite common to see diagonal cracking above an opening in a brick wall, similar to that shown in the diagram in Figure 1.1.5. The cracking forms a triangle running diagonally through the brick courses at around 45° from the support points at either side.

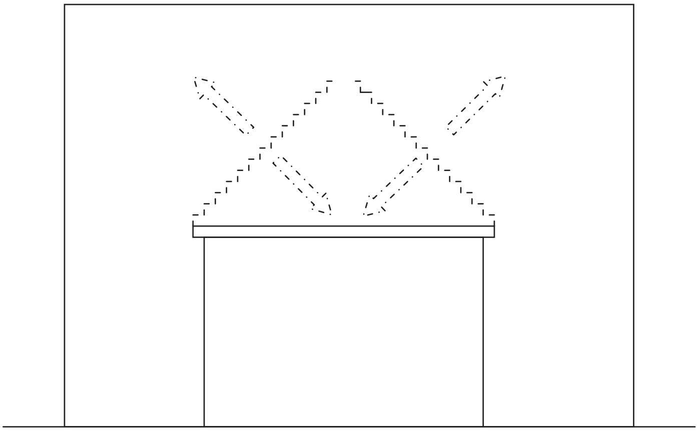

Figure 1.1.5 Imaginary arrows of tension intersecting on a supporting beam.

Once again, imagine arrows at right angles to the cracks as shown in the diagram. In this case two of the imaginary arrows at right angles to the cracks intersect on the lintel – good evidence. In fact if two arrows intersect at the same point it is almost certainly the position of the defect. The two arrows pointing up contradict each other, one up to the left and one up to the right. The solution is again obvious. The movement is deflection of the lintel (beam) supporting the masonry above the opening.

Example 3

Look at a very similar situation in Figure 1.1.6.

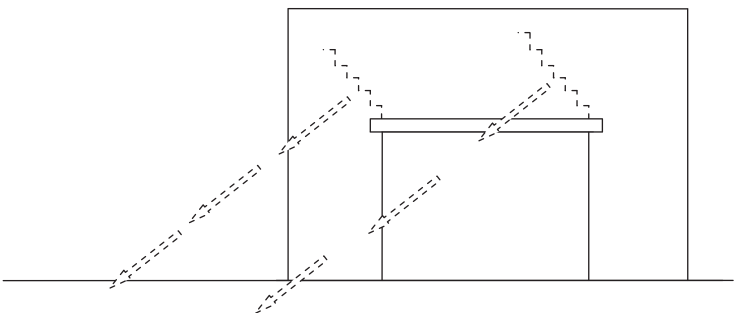

Figure 1.1.6 Imaginary arrows of tension point to left hand pier.