THE SIGNIFIGANCE OF CRACKS IN LOW-RISE BUILDINGS.

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“Is that crack serious?” asks the owner of a domestic house a day before they are due to exchange contracts on the sale!

Figure 1:

This is one of the simplest questions to ask, but for the professional adviser one of the most difficult to answer – at least within the timescale demanded by some property owners.

Most buildings crack at some time during their service life. The appearance of cracks is a symptom of distress within the fabric of the building. Often the cracking is of little consequence and once it is established as static, simple repair by filling or re-pointing is all that is required. However a crack maybe the first sign of a serious defect which may affect the serviceability or the stability of the building.

The appearance of cracks can also affect the value of the building, its insurability, the saleability and can be the subject of litigation. Therefore correctly assessing the significance of cracks is essential. However it is a far from a simple task and is often a subjective exercise. The implications of an incorrect assessment can lead to expensive and unnecessary remedial work. In some instances the remedial work may exacerbate the problem resulting in yet further and more extensive cracking.

So how does the professional adviser decide if the cracks are significant?

Professor Malcolm Hollis once stated:

“Surveying buildings is an art, verifying the cause of failure is a science”. (Hollis 2000).

It is therefore important to develop a methodology or systematic approach so that any action taken is appropriate to the cause. The following methodology should not be followed rigidly because each case will differ on its merits but it provides a systematic method of gathering information and then assessing the significance of cracks.

The first stage of the methodology is the initial inspection:

THE INITIAL INSPECTION.

During the initial inspection do not give opinions under pressure from the client. If you speak at all confine your comments to asking questions as part of the data gathering exercise. Do not just stand and stare at the cracks – they are unable to speak and will not give you any clue as to their cause. Instead stand back, look at the whole building from a distance. Walk round the building. Look at the condition of adjoining buildings and other features such as trees. Always work from the general to the particular.

Structural alterations to the building should be identified or any alterations that may have affect the structural integrity of the building. Note the age of the building and if it has been extended or if any part of the building has been demolished. Always be suspicious of how a building is constructed. Recent decorations may conceal existing cracks.

Figure 2.

There is clear evidence this crack has been filled before, probably with cement mortar. The wall appears to be random stone wall laid originally in lime mortar. The repairs to part of the wall with cement mortar can alter the manner in which the wall behaves.

The pattern of the cracks should be studied. Cracks in masonry generally manifest perpendicular to the line of force, (Bonshor & Bonshor, 1996) although this can be distorted by the relative stiffness of the building elements. Cracks will tend to follow lines of weakness, for example cracks in a wall panel will usually occur between door and window openings which are the areas of weakness

Figure 3:
The foundation is subsiding due to action of the tree roots. The line of force is diagonal and the cracks are appearing perpendicular to the line of force. The cracks follow the line of weakness, in this case the window openings.

The construction materials should be noted. The age of the cracks should be determined if possible. The building owner or occupier may be able to provide some information. The edges of old cracks are often weathered and the crack filled with debris and cobwebs. Some cracks are of uniform width, others taper. The direction of the taper should be noted. Cracks caused by shear forces tend to leave lumps of debris attached to one side of the crack. Occasionally cracks will occur due to compression.

Figure 4:
Crack caused by shear.

Figure 5:
Crack caused by compression.

At this preliminary stage it may be possible to develop a hypothesis to identify a link between the symptom and cause of cracking. There will usually be insufficient information to fully diagnose the cause of cracking at this stage of the investigation, so develop a conceptual model. This will help you to decide how the building is behaving and assist you in developing the systematic strategy for moving the investigation forward. The strategy is an iterative process that is reviewed and amended throughout the investigation.

Figure: 6
A conceptual model.
In this example the cracks are wider at the top the elevation than the bottom, suggesting that maybe the foundations to the two gable ends are experience settlement or subsidence, or perhaps the centre of the building is lifting due to heave. This observation is not conclusive but it can help with deciding on the next stage of the investigation.

THE CRACK SURVEY

The next stage is for you to undertake a present condition survey of the cracks. The crack widths are measured. The characteristics of each crack are plotted onto a drawing or sketch of the building. The characteristics to be recorded are width, direction, taper, frequency and location. If it is possible it will be useful to differentiate between cracks caused by tension, compression and shear stress. A crack on the opposite side of the wall can be shown as a broken line. Standing back from the building and plotting the cracks can help with identifying the overall pattern of movement.

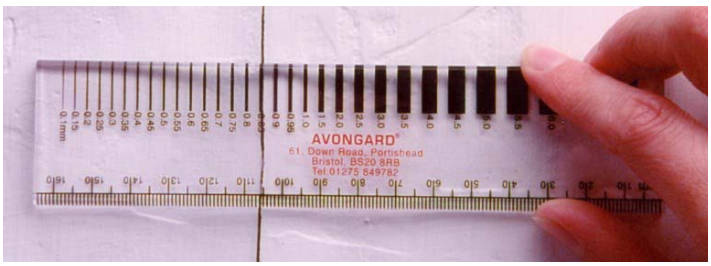

Figure 7.
It is quicker and easier to use a proprietary crack width gauge to measure the crack widths.

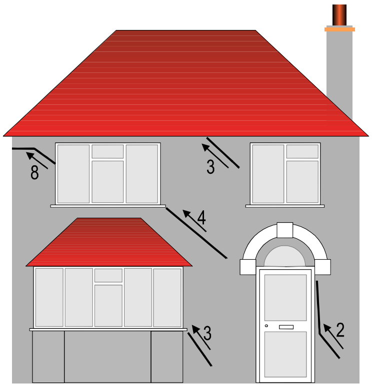

Figure 8.
Plot the cracks onto a drawing and note the crack widths in mm. The arrows indicate increase in widths of cracks.

CRACK MONITORING

Crack monitoring should be started as soon as possible. The longer the crack monitoring period, the more data will be available for diagnosing the cause. The monitoring should continue throughout the data gathering, the investigation and the remedial work. It should continue beyond the completion of the remedial work in order to validate the performance of the remedial measures.

Monitoring is important because a local authority was sued for the cost of foundation underpinning, but was held not liable because the structural engineer who recommended the underpinning had not monitored the cracks to establish if the movement was progressive. (Bluett and Another v. Woodspring District Council 1982).

CRACK MONITORING METHODS

The next step is to decide the type of crack monitoring equipment to use.
Proprietary gauges, using the generic name “Tell-Tales” are an inexpensive, easy to install method of crack monitoring. Always make sure you use a “tried and tested” type manufactured to ISO 9002. You are placing great reliance on the readings and you may be liable if you recommend unnecessary remedial work on the results of unreliable products. They are accurate to a resolution of 1.0mm and by interpolation to 0.5mm. They can record horizontal opening and closing of the crack as well as vertical shear movements. They are ideal for plotting the trends and direction of movement and verifying the adequacy of remedial work.

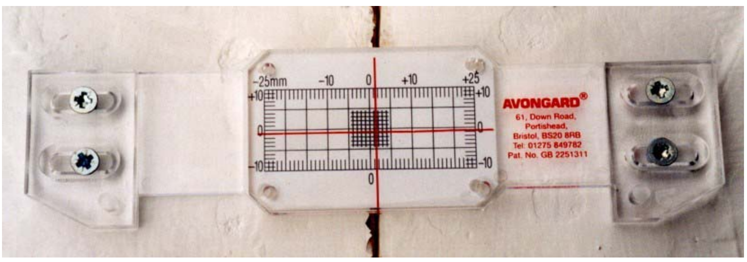

Figure 9.

Use the type of gauge which has the facility to “upgrade” the resolution of the readings to 0.1mm with precision calipers. This will give you the option to speed up the monitoring period if you are trying to identify trends of movement across the crack.

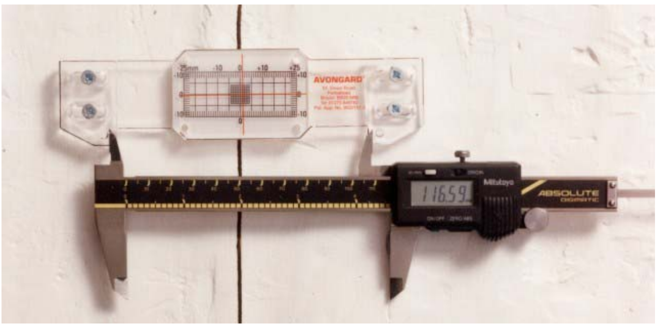

Figure:10
Upgrading the resolution with precision calipers.

Cracks commonly occur in corners at the junction of walls. Use the type of gauge that is hinged. Most corners are not built precisely to 90 degrees and this type will fit snugly into a corner of any angle, even a bay window corner of 45 degrees. If the gauges are used in pairs and “handed” movement in three dimensions can be monitored.

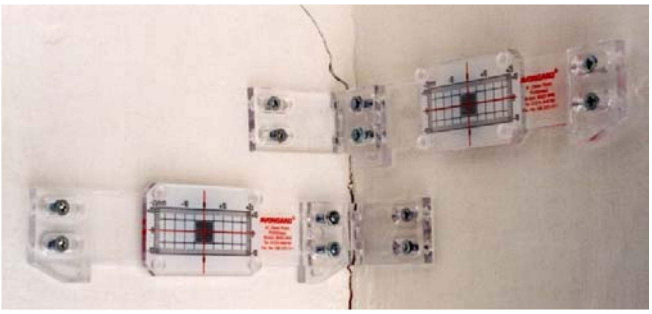

Figure 11.
.Monitoring cracks in corners

Precision calipers are used for more accurate monitoring. A vernier, dial or digital caliper can achieve an accuracy of 0.1mm if used by an experienced operator. The distance between two datum points fixed either side of the crack is measured with the jaws of the caliper. Three datum points can be used for the monitoring of vertical movements across the crack. The datum points are 6mm stainless steel discs with a hole drilled in the centre into which the jaws of the caliper are placed.

Figure 12.

The following factors need to be considered when selecting the appropriate crack monitoring system:

- The sensitivity of the location needs to be considered.

Will Tell-Tales draw unwelcome attention to the cracks in the building? In which case will unobtrusive stainless steel discs be more appropriate? Will the presence of Tell-Tales provide comfort and re-assurance to the building owner that no movement of the crack is occurring?

- Who is going to take the readings?

Is the building owner going to record the movements with the results sent to the professional for analysis during the monitoring period? In that case Tell-Tales are much easier to read.

- What is the required resolution?

Is 1.0mm sufficiently accurate or is a finer resolution required?

GATHERING DATA

Throughout the crack monitoring period further information should be gathered. This may include the following:

- The history of the site:
  Examining aerial photographs.
  Reviewing old maps, archive material and local authority records.

- The geology of the site:
  Studying geological maps and memoirs.

- Further inspection of the site:
  Noting signboards, examining open trenches, vegetation, adjacent buildings and features on adjoining land. Lifting drainage manhole covers to inspect if drains are leaking.

If the cracking appears to be the result of foundation subsidence or settlement, trial pits should be excavated to expose the foundation and supporting soils for inspection and taking of soil samples for testing. The possible sinking of boreholes and plumb and level surveys (BRE, 1995).

If chemical reaction appears to be the cause, samples of material for laboratory testing should be taken.

COMMON CAUSES OF CRACKING.

The majority of low-rise buildings in the UK are constructed using brick, concrete block or stone with mortar joints. These materials possess significant compressive strength but their ability to accommodate tension is limited. As a consequence if tension stress develops cracking frequently occurs. There are numerous possible causes of cracking. There may be a single cause or a combination of several causes, or one primary cause with several contributory factors. It is beyond the scope of this paper to list more than just a few.

Some common causes of cracking are listed below:

- Foundation subsidence:

  Foundation subsidence is the downward (or upward or lateral) movement of the foundation and takes place independent of the load from the building foundation.

  Typical causes of subsidence in the UK are:
  - The expansion and shrinkage of clay soils with changes in moisture content.
  - The collapse of former mineworkings.
  - Leaking drains which causes “washout” or softening of the soils supporting the foundation.
  - Landslip of sloping ground.
  - Made or filled ground.
  - Peat.
- Foundation settlement:

  Foundation settlement is the downward movement of the foundation caused by the imposed load from the building. This takes place on loose, soft and highly compressible soils where the load imposed from the foundation overstress the soils supporting the foundation.

  Although subsidence or settlement can cause cracking and distortion to the fabric of the building, it is differential settlement that causes the more serious damage.

- Incompatibility of building materials:

  The use different materials in a building can result in cracks occurring. For example, supporting brittle concrete block walls on timber beams or lintels. The timber is flexible and will shrink with reduction of moisture content as well as experiencing long-term load creep deflection. This can result in cracking of the concrete block wall.

- Chemical reaction of materials:

  Many materials used in the construction of a building are susceptible to chemical reactions. For example the cracking that occurs in the horizontal bed joint in brick walls due to sulphate from the bricks reacting with the mortar.

- Thermal movements.

  Tensile and compressive stresses develop within the building elements due to temperature changes. The magnitude of the stress depends on the coefficient of thermal expansion of the material. Cracks can occur if the building element is restrained and lacks sufficient joints to accommodate the movement.

- Changes in moisture content:

  There is a significant change in the moisture content of many building materials after construction especially during the first few months. Clay bricks initially expand and concrete blocks experience shrinkage following curing. If the materials are used together monolithically, stresses can develop with resulting cracks.

- Structural instability:

  The structural failure of the building can cause cracks as well as exerting stresses on individual elements causing further cracking.

There are many published documents describing in more detail the various causes of cracking in low-rise buildings (IStructE, 2000), (Bonshor & Bonshor, 1996), (BRE, 1991).

The objective of the initial inspection, the crack survey and monitoring and gathering data is to enable you to collect sufficient evidence to support an objective opinion on the significance of the cracking.

DECIDING IF THE CRACKING IS SIGNIFICANT.

The client has asked the question – "is that crack serious?"

In the midst of the collecting evidence it is an easy matter to lose sight of the original concern of the client.

The results of the initial inspection, the crack survey, crack monitoring and gathering data should answer the following questions:

Is the movement across the crack static?

This can point to the following possible causes:

- The initial "bedding in" of foundations of a new building.
- Initial shrinkage of construction materials.
- Load induced deflection of beams and slabs as a result of imposed dead load.

Is the movement across the crack cyclic?

This can point to the following possible causes:

- Thermal movement.
- Seasonal clay shrinkage and swelling affecting shallow foundations.
- The formation of ice lenses in certain soils causing the effects of expansion and shrinkage on shallow foundations.

Is the movement across the crack progressive?

This can point to the following possible causes:

- Roof spread of a pitched roof.
- Foundation subsidence and / or settlement due to:
- Leaking drains
- Filled ground
- Peat and compressible soils.
- Clay shrinkage and swelling caused by trees.
- Hillside creep and instability.
- Chemical reaction:
- Sulphate attack.
- Carbonation.
- Alkali silica reaction.
- Wall tie corrosion.

The cracks can be classified into three categories:

Is the crack only aesthetic?

Some cracks only affect the aesthetic appearance of the building and do not affect the functioning or the building nor do the cracks cause structural instability.

Figure 13.
This crack is aesthetic damage only.

Is the crack affecting the serviceability?

If the cracking affects the functioning of the building or individual elements the damage is described as serviceability damage. For example the building is not longer watertight, the functioning of the drains and the services are impeded, the glazing in the windows break or the doors do not open or close.

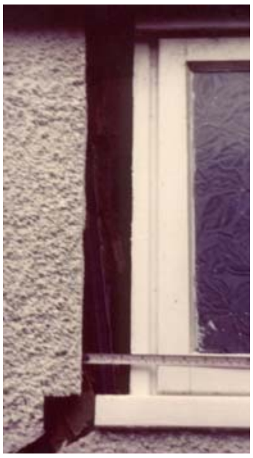

Figure 14.
The crack width adjacent to the window frame is about 60mm. Clearly the building no longer watertight and the thermal insulation is being compromised. In time the construction materials will degrade.

Is the cracking affecting the stability?

It is rare for a building or structure to suffer sufficient damage for it to affect the overall stability, but if movement is allowed to continue unchecked, individual elements may become unstable for example the reduced bearing of a beam due to differential movement at its support.

Figure 15.
The panel of wall on the left of the crack is leaning outwards. There is only minimal lateral restraint at the gable and first floor. This section of wall could be categorised as unstable.

In order to focus your mind on assessing the significance of the cracks the following decision matrix is a methodology that may be applied, (Johnson, 2001).

	Static	**Cyclic**	**Progressive**
Aesthetic			
Serviceability			
Stability			

All that is required is to tick the appropriate box in the matrix for the combination of factors that are appropriate to the cracking.

For example, if the cracking is found to be only aesthetic and static, the remedial work is usually simple and inexpensive and there is no need for further monitoring. However remedial work becomes potentially more complex and expensive if the cracking is found as a result of the monitoring to aesthetic and progressive, because the movement may progress from only aesthetic damage to affecting serviceability and ultimately the stability of the building.

This methodology will not eliminate the need through analysis and investigation to identify the cause or causes of cracking and specify appropriate remedial work. However if it is applied it will result in a more rational and consistent approach to the assessment of cracking in buildings. Its application will result in recommendations that reflect the severity of the cracking, the need for urgent remedial work or whether further monitoring is required.

INTERATIVE WORKSHOP

This article is an extract from the material used in a full or half day interactive workshop organised by Avongard on the subject of *Crack Diagnosis in Low-Rise Buildings.*

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