Simple measuring and monitoring of movement in low-rise buildings

Part 1: cracks

Cracks appear in masonry buildings for a variety of reasons: these are discussed in Digests 251 and 361. Determining the cause of cracking is usually easier if cracks and movement are monitored. This can establish if there is any deterioration and if there is any seasonal or other pattern.

This Digest discusses simple but reliable methods of measuring and recording movement and cracking in low-rise buildings. It gives full details of the recommended methods, comments on others and warns against some inferior techniques. The subjects dealt with are:

in Part 1:
● measurement and monitoring of cracks

in Part 2:
● determination of settlement or heave that has already taken place
● measurement of the out-of-plumb of walls.

CRACK MEASUREMENT
Measurement of the size and extent of cracks for a ‘present condition’ survey involves techniques different from those needed for the monitoring of continuing movements over a period of time.

When assessing the present condition of a building, the approximate width and position of cracks are important clues to the cause of movement but precise measurement is not required. The situation is different when repeated observations are required over a period of time to study the way damage is progressing. Here, changes in dimension must be recorded, generally to ±0.1 mm — see Fig 1. In this way, small continuing movements and seasonal fluctuations can be reliably recorded and the trends and rates of larger movements can be determined relatively quickly.
‘PRESENT CONDITION’ SURVEYS OF EXISTING CRACKS

For a ‘present condition’ survey, the positions and sizes of cracks need to be recorded in a way sufficient only to determine the scale and extent of the damage. The survey outlined below will satisfy these requirements. The inclusion of cracks in the survey does not imply that they all need eventual significant repair. Many will be very small, falling into category 0, 1, or possibly 2 in the classification of damage (Table 1 of Digest 251) and would be dealt with in the course of normal decoration.

The criterion for the purposes of a crack survey is ‘evidence of strain’ that will help to create an overall picture of the behaviour of the building and from this to expose causes of damage.

Required accuracy of measurement

The width of cracks should be measured to the nearest millimetre. For cracks under 1 mm, the designations ½ mm or, for those even smaller, ‘hairline’ may be used as appropriate.

It is much quicker to make reliable measurements like this, rather than attempt general sub-millimetre resolution of crack width. Not only is sub-millimetre resolution unnecessary, it can often be impossible due to the ragged-edged nature of many cracks. On the other hand, the width of cracks should not be guessed: visual ideas of, say, 7 mm can vary considerably between observers.

Recommended method of measurement

The width of cracks should be measured by reading a graduated ruler held in contact with the wall at right angles across the crack (Fig 2). If possible, choose part of the crack where it has approximately straight edges or make sensible allowance for indentations and roughness of edge. The aim is to determine approximately the average width of that part of the crack.

The depth of step in a crack due to out-of-plane shear should be measured to the nearest millimetre with a ruler held normal to the wall. A second ruler can be held as a straight-edge along the top of the step, the two rulers pinched between thumb and finger and withdrawn to read the dimension (Fig 3). Steps less than 2 mm can be ignored.

Recommended type of ruler

The type of ruler can make a lot of difference to the ease and speed at which readings can be taken.

Required accuracy of measurement

A matt, chrome-faced steel 150 mm ruler (+1), graduated in full millimetres on both edges of one side, is suitable. A normal stainless steel ruler is too reflective. The ruler must be graduated right to one end so that cracks at internal return wall corners can be measured. Rulers graduated in half millimetres are unsuitable because they are much harder to interpret.

Other types of ruler

Transparent plastics rulers graduated in black are not generally suitable. At low light levels, or when working on dark surfaces, the graduations can become almost unreadable. If a transparent ruler must be used, contrast can be improved by sticking a white self-adhesive label on the back or by using white or yellow correction fluid. Most do not have graduations right to the end and so cannot be used at internal corners.

A special transparent plastics ruler (+2) has marked blocks of various widths to offer up to cracks for comparison. The current version has a block of 0.5 mm and blocks of full millimetres from 1 mm to 12 mm. It is suitable for a ‘present condition’ survey. The back of the ruler may be whitened as discussed above. Although the blocks cannot be used for measuring at internal-return wall corners, the ruler incorporates a linear scale of millimetres, which measures from one end of the ruler, for this purpose and to measure very large cracks.

Recording and preservation of data

Freehand pencil sketches are generally satisfactory for recording crack surveys. It may be convenient to record directly on to copies of the original constructional drawings. However, these are not always easily available, can be bulky, and often do not show all aspects required to be marked.

Information may be transferred from the sketches to drawings if necessary for presentational or other purposes. This may lead to transcription errors and can be very time-consuming, especially if a large number of properties are being surveyed. It is generally

Fig 2 Measuring crack width to nearest millimetre using recommended type of rule

Fig 3 Measuring a crack step to nearest millimetre using a rule and straight-edge
more satisfactory to tidy up the field sketches before preserving them as the basic reference material.

Sketch a plan of each floor of the building showing major dimensions and North. All rooms or compartments should be identified.

Sketch all walls, floors and ceilings where cracks are observed, identifying each sketch in relation to the building floor plan in terms of room identity, aspect, and interior or exterior view.

Make written positive comment concerning those parts of the building where sketches are not made because there is no cracking or where inspection has not been made.

Make sure that every sketch sheet is marked with the identity of the building, the observer’s name and the date of observation.

It might be more convenient to use a tape recorder when working in awkward places, for example on ladders or in roof spaces. Notes should be concise and should be transcribed at the earliest opportunity.

**Extent of measurement**

Sketch all cracks revealed by a close inspection. This will often reveal more cracks than the obvious ones that led to the survey. Binoculars are useful for scanning exteriors above first floor level. The survey should concentrate on cracks in the structure itself. Craze-cracking often found in defective rendering is usually of no concern when building movement is being studied.

Measure and record the width of, and significant steps in, accessible cracks on the sketch adjacent to the position of crack measurement — see Figs 2, 3 and 4.

Where crack width varies considerably along its length, record the width at more than one position. Tapered cracks should be marked at, or near, each end.

If part of a crack is inaccessible (higher up a wall, for example), and there is an obvious difference in width, indicate by drawing beside the sketch of the crack a long wedge mimicking the crack taper.

Cracks marked on the sketch are assumed to be tensile in the plane of the wall unless otherwise indicated.

Indicate shear cracks by a pair of opposite-pointing half-head arrows suitably placed on the sketch. Shear will show as relative displacement along the crack of a recognisable feature on either side of the crack.

Indicate compressive cracks by a pair of arrows facing each other across the crack. Compression will show as spalling, flaking or crushing of the masonry surface, at the edges of the crack.

The depth of a step at a crack, which indicates out-of-plane shear, should be marked in millimetres with an arrow flight on the depressed side of the crack.

It is often convenient to sketch external walls in their exterior aspect and to include cracks showing on the interior as dotted lines. A similar technique can be used with interior walls between rooms or compartments.

Figure 5 shows a floor plan and an elevation sketch.
Other signs of movement

Notes should be made of any other signs of movement, for example, movement of ridge tiles, eaves boards, gutters and down pipes.

Another example is evidence of slip, generally showing as over or under-sailing of masonry at the main damp-proof course or at parapet level. Indicate the direction or type of slip, and note the extent measured in full millimetres.

The distortion of door and opening window frames usually takes the form of wracking: the rectangular frame is distorted into a parallelogram. This will show as a tapered widening of one of the gaps around the frame and a narrowing of the others which can result in jamming. Indicate the widening gap by sketching a wedge mimicking the gap taper and show the width of gap at both ends to the nearest millimetre. Show the position of jamming by an arrow head annotated ‘J’. Glass in fixed and opening windows may have cracked; note where this has happened.

A ball will roll on a sloping floor. Its direction should be marked by an arrow annotated ‘down’ — see Measuring out-of-level floors in Part 2 of this Digest.

MONITORING MOVEMENT AT EXISTING CRACKS

To determine if movement is still taking place, and at what rate, changes in crack width should be monitored over a period of time. This period will almost always extend for several months at least; it is often necessary to continue monitoring for a year or more to fully understand the nature of continuing movement.

Choice of cracks to be monitored

It is not usually necessary to monitor all the cracks noted on a ‘present condition’ survey, only a selection. The largest ones should be included as they are most likely to have the greatest rates of movement and will indicate continuing movement in the structure in a shorter period of time.

A selection should be made from the other cracks, chosen to satisfy two criteria.

- The whole of the cracked area of the building is represented monitoring. A ‘wave’ of settlement, heave or other ground movement may be progressing along the building.

- Cracks should be chosen to reveal modes of distortion in the building. For example, monitoring a long vertical crack near its top and bottom may indicate rotation, possibly due to hogging. Similarly, angled cracks at positions of stress concentration at the corners of doors and windows can be good indicators of shear or wracking.

There will always be an element of subjectivity in the selection; consultation with a colleague may be useful.

Required accuracy of measurement

Observation should determine changes in crack width to an accuracy of 0.1 mm, even when different observers are used.

Comments on methods of observation

The use of glass tell-tales stuck across a crack to determine if future movement takes place is deprecated. They often fail owing to anchorage slip and are subject to vandalism. Even when they do crack it often shows little more than that the glass has cracked — see Fig 6.

Plastics tell-tales (*3) measure movement in cracks. They consist of two plates screwed to the wall, one on each side of the crack. The plates overlap and cursors on one, which is transparent, can be read against millimetre scales on the other. They measure to the 1 mm accuracy claimed by the manufacturer, but this is an order less accurate than recommended. They are subject to vandalism and are fairly obtrusive — see Fig 7.

Where vandalism can be ruled out, and they are aesthetically acceptable, plastics tell-tales are useful for coarse monitoring, particularly when the occupier can take observations. They provide a simple, easily readable indication of movement and can be particularly useful as ‘alarm raisers’; occupiers can alert the authorities if movements rapidly accelerate or exceed a given limit in cases of landslip, or where excavations or demolition works are taking place nearby.

Plastics tell-tales can also enable occupiers to keep a watching brief in settlement or heave problems associated with shrinkable clay, but they should only be used in addition to the ‘screws and calliper’ method described later. They are available in several different versions to measure cracks at wall corners and at floor level, as well as cracks in a plane wall. They can measure shear movement as well as simple opening and closing of cracks.

A demountable mechanical strain gauge (*4) incorporates an invar bar and a dial gauge which will measure, to a resolution of 0.002 mm, changes in the distance between two drilled location discs (*5) that are stuck some centimetres apart spanning a crack. Because it is designed for fine resolution of strain, shrinkage or swelling in building materials, it will reveal an alarming multitude of minute movements across any crack in a building due to insignificant thermal, shrinkage and moisture effects which are not normally of any concern in the scope of this Digest. It can deal only with maximum movements of 1.6 mm reduction or 2.4 mm increase in the measured dimension. These small maxima are likely to be exceeded in many cases where structural cracking is...
being studied. It would be necessary to set replacement discs before the measurable movement was reached to preserve continuity of observations. It is relatively expensive, although once obtained it can be used with any number of pairs of discs: these cost only a few pence each. Its use could be considered where only very small movements are expected and where very fine resolution of crack movement is required.

Monitoring exterior cracks in plane walls
Measurements should be taken with a calliper gauge between small screws set in the wall. The screws are hardly visible to the casual observer and tend not to attract vandals. The calliper gauge should preferably be of the digital display type (*6) but must be of a type that has no projection behind the rear slide. A digital calliper is much easier to read than the normal vernier or dial gauge types and its use leads to fewer observational errors. There is a ‘two screws’ and a ‘three screws’ method.

The ‘two screws’ method measures the change in distance between two screws set about 90 mm apart, one on each side of the crack. It measures changes in crack width but can give erroneous readings if there is a large shear movement. This method will usually be sufficient to determine if movement is continuing, and will often give a good indication of its rate.

Drill a 30 mm deep hole using a 4.5 mm (No. 8) masonry drill (*9). Clear the debris by inserting and withdrawing the drill several times while it is still rotating, or by blowing. Insert a 20 mm long wall plug (*10) to the base of the hole.

Nearly fill the remaining void with epoxy resin glue by stirring a laden matchstick in the hole. Smear the glue round the inside of the hole mixing in any remaining drilling dust so that good adhesion will be obtained. Use the ‘permanent bonding’ type of glue (*11) as the ‘rapid version’ is not so waterproof and sets too early if a batch has been mixed for several holes.

Fig 7 Unsuitable use of a commercial plastics tell-tale in a vandal-prone situation. See text for suitable use in other conditions

Installation of screws
The screws (*8) used should be traditional, brass roundhead No. 6 size 3 1/4 in long; the following procedure will ensure long-term stability in all climates. The system cannot be expected to withstand fire because the glue starts to soften above 60 °C; it will be satisfactory in fire-contaminated buildings if they are reasonably dried out.

Wait until the glue has hardened before taking initial calliper readings: about 16 hours at normal temperatures but considerably longer in very cold weather.
If readings must be taken before the glue has hardened, ensure that the calliper does not exert any force on the screws while taking the reading. The wall plug will provide considerable rigidity but by no means as much as is provided by the hardened glue.

Longer screws will be needed if the wall is rendered so that they can be anchored in the wall proper with their heads sufficiently proud of the render. If no. 6 screws longer than 1\(\frac{1}{4}\) ins are difficult to obtain, no. 8 can be used with the same size drill and wall plug. A no. 6 or no. 8 screw may be glued directly into a 25 mm deep hole using a 4.0 mm (No. 6) masonry drill (*12) without using a wall plug. This method will produce a satisfactory final installation, but the screws are subject to vandalism or inadvertent disturbance before the glue sets, and it is not possible to take initial readings until then.

**Measuring with the digital calliper**

The calliper is used in its ‘outside measurement’ mode to record the overall distance between the barrels of a pair of screws, just below the heads.

Check before each reading that the LCD reads zero with the jaws closed. The calliper can be read while it is in position or the hold control can be used to ‘freeze’ the display while the calliper is removed.

Figure 1 shows how the chamfers of the jaws are held in contact with the under-side of the screw heads. This automatically positions the calliper to measure the true ‘in-line’ distance. Repeat measurements by either the same or a different observer will agree within ±0.02 mm and the desired accuracy of ±0.1 mm for monitoring purposes is easily and reliably obtained.

In the ‘three screws’ method, the lengths of the two sides of the triangle at right angles to each other are measured as above. The longest side of the triangle is not measured.

**Monitoring ‘internal return’ corner cracks**

The ‘three screws’ method cannot be used for cracks at ‘internal return’ corners. However, such a crack is often fully contained in one of the walls forming the corner and an adaptation of the ‘two screws’ method can be used. One screw is set in the wall about 50 mm from the corner on which contains the crack. Measurement is made using the calliper in its ‘step measurement’ mode between the screw barrel and a small object pressed on to a blob of epoxy resin suitably positioned on the other wall — Fig 11. Any metal item that will make point contact with the calliper is suitable, for example the sawn-off head of a round-head screw or a small dome-headed nut.

This method tends to be less accurate than measuring between two screw heads but repeatability should normally be within ±0.1 mm.

**Monitoring steps in cracks in plane walls**

Systems that monitor to an accuracy of 0.1 mm are tedious to install and lie outside the scope of this Digest. If the crack is less than about 5 mm wide and the wall is carefully marked, an attempt can be made using a digital calliper in its ‘depth measurement’ mode — Fig 12. Accuracy depends on the wall surface texture but can be as good as ±0.3 mm. Otherwise, a plastics tell-tale (*3) of the displacement type will easily give 1.0 mm resolution, but the problem of vandalism must be considered.

**Monitoring interior cracks in plane walls**

If the wall has a smooth finish and screws would be considered unsightly, a magnifier with a glass graticule (*13) can be used to measure between marks made on the wall. The magnifier is available with a torch-handle illuminator.

Two methods can be used:

- the ‘two dots’ method (similar to the ‘two screws’ method);
- the ‘crossed lines’ method (similar to the ‘three screws’ method).

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Fig 10 A screw set with wall plug and resin adhesive for the ‘screws and calliper’ methods of crack monitoring

Fig 11 Using the digital calliper in its ‘step’ mode to monitor a crack at an internal return wall corner

Fig 12 The ‘step’ in narrow cracks on fairly smooth-textured surfaces can be monitored using the ‘depth’ mode of the digital calliper
The marks are made with a propelling pencil using 0.5 mm ‘H’ leads. On gloss surfaces a very fine, waterproof ink felt pen (*14) should be used. It may be convenient to draw a very small crack-identity number near the wall markings so that it is in view when using the magnifier.

‘Two dots’ method
Carefully make two very small dots on the wall, one on each side of the crack and about 3 mm or 4 mm from the edge — see Fig 13(a). Draw a small circle round each point to identify the dots among any other marks on the wall.

Place the magnifier with its graticule in contact with the wall and read the distance from one dot to the other on one of the scales to a resolution of ±0.1 mm. Avoid using the crossing point of the two scales for identifying a dot position. Instead, use one of the other full millimetre graduations at one dot and read the scale difference to the other dot as shown in Fig 13(b).

The measurements are taken between the outer extremities of the dots, which will be seen under the magnifier to be by no means circular. Do not attempt to locate the centre of the dots in the course of measurement as this will be less accurate.

‘Crossed lines’ method
Draw two thin straight lines, about 30 mm long, at right angles to each other to form a cross straddling the crack as shown in Fig 14(a). As both lines traverse the crack, each will develop an offset when the crack opens — Fig 14(b). These movements are measured using the magnifier and both scales of the graticule. One scale is positioned as an overlay-and-projection of one of the pencil lines on the ‘cross’ side of the crack (see Fig 14(c)). The other scale is used to read the offset in this line due to crack movement; take care to read the scale at the centre of the width of the pencil line. The whole operation is repeated to measure the offset in the other line.

Recording and presentation of data for recommended methods of crack monitoring
All measurements should be recorded in tables, and the results plotted graphically. Figures 15 and 16 show examples of the various methods of measurement. With the exception of the ‘crossed lines’, all methods require calculation of a ‘movement to date’ column which is used for the preparation of graphs. In the ‘crossed lines’ method, the offset readings themselves give the values of the vector movements to date. All tables should include an orientation sketch of the layout used.

Figure 15 shows that for the simple methods of crack monitoring, the ‘two screws’ and ‘two dots’ methods, the graph is of movement with time, plotted at suitable scales of 1 mm on the graph paper for each 0.1 mm of movement and 3 mm for 1 month. Note that the crack width at the start of monitoring is noted on the graph and used to provide a secondary numeration, in brackets, of the movement axis. Where the crack width was less than 1 mm, the bracketed figures are omitted.
In Fig 16, the ‘three screws’ method, the graphical presentation is different. The ‘movements to date’ for each of the two measurements made on a particular date are used to produce a point on the graph. The example in Fig 16(a) represents the screw configuration shown in Fig 8(a). For other configurations using vertical and horizontal measurements, e.g., Fig 8(c), one or both of the positive directions of the graph axes may need to be reversed, thus producing a plot in different quadrants of the graph.

The rule is simple. Treat the common measurement screw as the origin of the graph and mark the positive directions of the axes as the other screws lie. Mark the upward vertical axis ‘UP’ as shown in Fig 16(a). This will produce a correctly orientated graph such that the vector movement of the part of the wall containing the two screws, relative to the other part of the wall, can be read off the graph, scaling with a ruler from the graph origin to the dated point.

Where the triangle of screws has been rotated 45°, Fig 8(b) and (d), the two movements are plotted with the axes marked +A and +B to correspond to the configuration on the wall. Figure 16(b) represents the configuration shown in Fig 8(b). To resolve the direction of the vector of movement in these cases, it is necessary to draw two more axes rotated 45° from the original ones and to mark them H (for the horizontal one) and V (UP) in relation to the configuration on the wall. The vector of movement can then be read off the graph, using a ruler, in relation to the two new axes.

The ‘crossed lines’ method is dealt with in a way broadly similar to the ‘three screws’ method. The intersection of the pencil lines (Fig 14(a)) equates to the screw at the right angle, and the positive direction of movement for the graph axes is from the cross towards the crack. The offset of the vertical line measures directly, and should be recorded as, the movement to date of the horizontal vector (and vice versa).

The digital calliper has an electrical socket. This can be used to record observations together with crack identification numbers on a hand-held digital recorder. Down-loading to a computer is possible so that data can be stored and movements presented in tables and graphs. Such a system is justified only where a large number of observations are involved and is beyond the scope of this Digest.

Photography and video
General photographs of a building are useful to preserve an immediate impression of the type of structure. They can also show incidence of roof distortion and tile movement.

More detailed photographs of areas of damage can complement the sketch records and can often show the extent of any repairs that have already been made. No attempt should normally be made to estimate the width of cracks from simple photographs as an alternative to direct measurement. If, however, a good close-up photograph of an identifiable crack had been taken earlier, it is sometimes possible to make a fair estimate of the width of the crack at that time. This is done using the magnifier-with-graticule to compare the width of the crack with the known dimension of a brick or block.

High-resolution computer-assisted photogrammetric and video techniques are being used to obtain reasonable resolution of crack widths on inaccessible structures but they are very expensive to use and outside the scope of this Digest.

Other BRE Digests

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Supplement: specifications and suppliers of equipment

This list covers all items marked (*) in theDigests. Prices are at September 1995, exclude VAT, and should be checked with the manufacturer or supplier before purchase. Delivery charges may be added in some cases. Sufficient details of each item for ordering purposes are contained within quote marks ‘ - - - ’.

Avongard Ltd can supply some of the items as noted below, in addition to their own products — enquiries to Avongard Ltd.

Addresses and telephone numbers are listed on page 2.

(1) STEEL RULE:
'Rabone Steel Rule, Pattern 47R 150 mm. Product No. 0-35-422.'
Stanley Tools. Stanley stockist tool merchant.
Telephone Stanley Tools for local agent. £3.54.

(2) PLASTICS CRACK MEASURING RULE:
'Crack width gauge.' Avongard Ltd. They sell direct to user. £3.85.

(3) PLASTICS TELL-TALES:
Avongard Ltd. There are several versions of tell-tales. Telephone Avongard for a descriptive leaflet and price list. They sell direct to user. £4.75 to £11.65 each according to type.

(4) DEMOUNTABLE MECHANICAL GAUGE:
'Model MD Demec mechanical strain gauge—100 mm gauge length, complete with Invar reference, and setting out bar.' Mayes Instruments Ltd. They sell direct to user. £530. A ‘NAMAS’ certificate of accuracy is available for an extra £160 at time of purchase. This is not considered necessary for use described in this Digest.

(5) DRILLED LOCATION DISCS:
'6.3 mm diameter stainless steel locating disc for demec.' Mayes Instruments Ltd. They sell direct to user. £52 for 400. Smaller quantities from Mayes Ltd are available only at time of gauge purchase. Or via Avongard Ltd, £27 for 100.

(6) DIGITAL CALIPER:
'Mitutoyo Digimatic Electronic Caliper range 150 mm code No. 500 —133U.' Mitutoyo (UK) Ltd. Obtain from local stockist or agent, usually a tool merchant. Telephone Mitutoyo for local agent. £84.90.

(7) SPIRIT LEVEL:

(8) SCREWS:
'Brass un-plated slotted round-head woodscrews size No 6 × 1 1/4 inch long to BS 1210:1963 Table 8.' Obtain from tool or fixings merchant. £0.94 per 100, but more expensive for smaller quantities. Where longer screws are required use No 6 × 1 1/4 in or 1 1/4 in; or No 8 × 1 1/2, 1 1/4 or 2 in. Some of these sizes are BS non-preferred and are not stocked by all suppliers. Do not use ‘twinthread’ woodscrews which do not have a smooth cylindrical portion below the head.

(9) WALL DRILL (for use with wall plug):
'Rotary masonry drill size 4.5 mm.' For rotary (non-impact) drilling in soft to medium brickwork, blocks and tiles. £2.78.
'Rotary-impact masonry drill size 4.5 mm.' For rotary-impact drilling in concrete, engineering or other hard bricks or stone. £2.78. Obtain from tool or fixings merchant, or DIY store.

(10) WALL PLUG:
'Rawlplug plastic plug Cat No. 67-008.' Rawlplug Ltd. The plugs are colour-coded green and supplied in clusters of 10 around a plastics identity plate marked ‘4.5 mm drill: Nos 4, 6, 8 screw’. Obtain from tool or fixings merchant. Telephone Rawlplug for local agent. £2.10 for box of 100 plugs. If a different wallplug is required a full insertable in a suitable depth of hole to allow the 10 mm of screw length to be glued direct to the wall without intervention of the plug material (Digest Fig 10).

(11) EPOXY RESIN GLUE:
‘Araldite ‘two-tube’ standard adhesive in the blue pack.’ Ciba-Geigy Plastics. Obtain from tool or fixings merchant, hardware or DIY store. £1.95 per pack — about 40 g. Or via Avongard Ltd, £3.55.

(12) WALL DRILL (for use without wall plug):
'Rotary masonry drill size: 4.0 mm.' £2.78.
'Rotary-impact masonry drill size 4.0 mm.' £2.78.
For notes on use of the types of drill and for suppliers see item 9.

(13) MAGNIFIER:
'Basic Magnifier Ref MAG6 complete with case' or 'Basic Magnifier with torch-handle illuminator Ref MAG6TR.' Also required is 'Graticule Ref M6T3 (Black).' Graticules Ltd. They supply direct to user. £45 for the basic magnifier and £66 for the illuminator version. The black graticule is generally satisfactory and costs £23; they also stock white or red for special application at a price of £40. To order, change colour specification using reference number above.

(14) PEN:
'Staedtler Pancolor permanent black superfine pen Ref 303S-9.' Staedtler (UK) Ltd. Obtain from local drawing office suppliers. Telephone Staedtler for local agent. £1. Or any make of similar writing of 0.3 mm.

(15) WATER LEVEL:
‘Akwamasta one man water level.’ Wedgewood Developments. They supply direct to user and via agents. Telephone them for details. £48.
ADDRESSES AND TELEPHONE NUMBERS

Goods should be obtained from suppliers as noted under each item on page 1. In case of difficulty telephone the manufacturer for name of local agent or stockist.

AVONGARD Ltd
61 Down Road, Portishead, Bristol BS20 8RB.
Tel: 01275 849782. Fax: 01275-848062.

CIBA-GEIGY PLASTICS
Duxford, Cambridge CB2 4QA.
Tel: 01223-832121. Fax: 01223-838404.

GRATICULES Ltd
Morley Road, Tonbridge, Kent TN9 1RP.
Tel: 01732-359061. Fax: 01732-770217.

MAYES INSTRUMENTS Ltd
Vansittart Estate, Arthur Road, Windsor, Berkshire SL4 1SE.
Tel: 01753-620237. Fax: 01753 832430.

MITUTOYO (UK) Ltd
Joule Rd, West Point Business Park, Andover, Hants SP10 3UT.
Tel: 01264-353123. Fax: 01264-354883.

RAWLPLUG Co. Ltd
Skibo Drive, Thornlibank Industrial Estate, Glasgow G46 8JR.
Tel: 0141-638-7961. Fax: 0141-638-7937.

STAEDTLER (UK) Ltd
Pontyclun, Mid-Glamorgan CF7 8YJ.
Tel: 0443-237421. Fax: 0443-237440.

STANLEY TOOLS
Woodside, Sheffield S3 9PD.
Tel: 01742-768888. Fax: 01742-739038.

WEDGEWOOD ENGINEERING DEVELOPMENTS
35 St. Tydfils Avenue, Merthyr Tydfill, Mid-Glamorgan CF47 0NP.
Tel: 01685-377808. Fax: 01685-383401.