BRE Digest

Concise reviews of building technology

Digest 361

May 1991

CI/SfB (J4)

Why do buildings crack?

This Digest examines the causes of cracking in buildings and shows, with descriptions and illustrations, the visible results of a wide range of problems. The Digest is a key to other, more specialised, BRE Digests and other publications and does not contain a complete solution to every cracking problem. It aims to broaden the understanding of the factors responsible and increase the likelihood of correct diagnosis and repair. Avoidance of some of the pitfalls will minimise future trouble in new buildings and lead to better design and workmanship.

This Digest replaces Digest 75 which is now withdrawn.

Most buildings develop cracks in their fabric. This often happens soon after construction when many materials are drying out; sometimes it occurs later Most early cracking is not structurally significant but it may be aesthetically offensive and rain penetration may be increased. It is easily repaired and unlikely to recur to any great extent. Only rarely does cracking indicate a reduction in structural capacity. Much can be done to minimise or even avoid cracking by recognising that movement of building materials and components is inevitable and must be allowed for in design.

Diagnosis of specific causes of cracking is often difficult; every building is unique and several factors may combine to produce the observed defect. Before repairs or remedies are considered, the following must be ascertained:

- the causes of cracking;
- their effect on the performance of the building;
- whether movement is complete, incomplete, or cyclic (eg seasonal).

The movements responsible for cracking are summarised in Table 1.

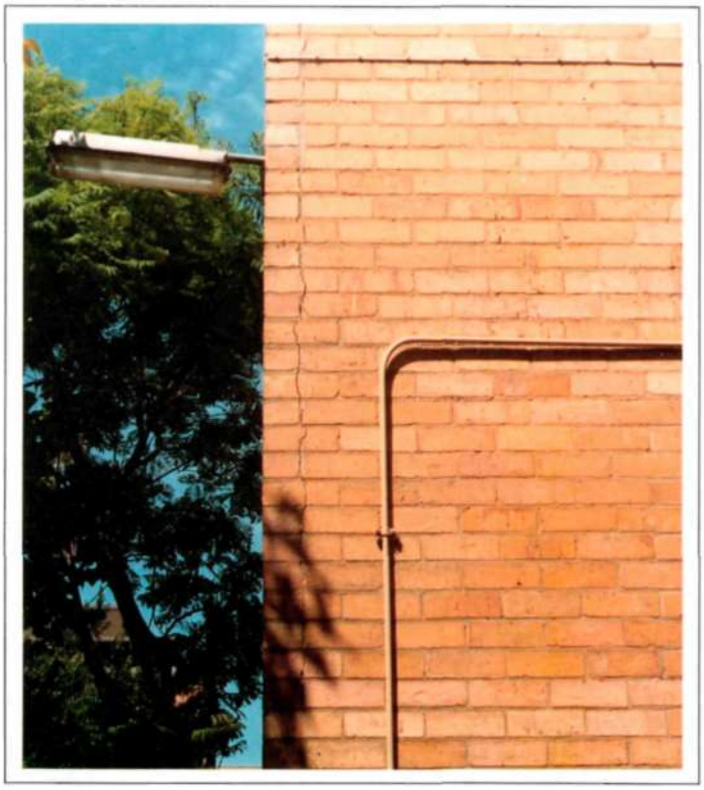

Fig 1 Wall ties have prevented free movement

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EXTENT OF MOVEMENT

With most building materials, the normal cyclic (reversible) movements arising from seasonal or diurnal moisture and temperature changes will give a maximum movement of between 0.25 and 0.5 mm per metre length. Non-porous materials, such as metals, glass and most plastics, are affected only by temperature; porous materials, such as brick, concrete and timber, are affected by moisture as well. Timber has a very high moisture movement across the grain. Some plastics have very high thermal movements; they may also be swelled by solvents.

The scale of movements arising from most chemical effects or ground movements cannot be predicted reliably. Moisture expansions of fired clay products can be predicted and are usually designed for on the basis of an expansion of 1 mm per metre length over the life of a structure.

Table 1 in Digest 228 gives a list of design values for predictable movements of most building materials.

THE EFFECT OF MOVEMENTS - HOW DO CRACKS OCCUR?

Cracks can be considered as occurring either between or within components. An example of the first is shown at the corner of the building in Fig 1 where the wall ties have prevented free movement of the return. Figure 2 shows this schematically: cyclic thermal movement of block A permanently displaces block B and produces a crack in the structure without, necessarily, inherent failure of either component. Owing to ingress of debris into cracks, movement of B could be progressive.

Tension cracks can occur in a long wall by 'ratcheting'. This is shown in Fig 3 where:

1 - the wall expands owing to solar heating or wetting/condensation in winter;

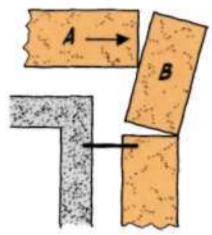
2 - since the compressive stress is insufficient to crush the wall material but is sufficient to overcome the frictional force between the wall and the damp-proof course, the wall slides along;

3 - when the wall cools or dries out, it shrinks and goes into tension; since its tensile strength is only a fraction of its compressive strength and is lower than the frictional resistance of the dpc, the wall cracks;

4 - eventually, the crack partly fills with debris and the process repeats itself, thus gradually widening the crack.

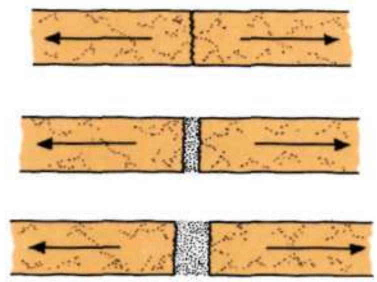
The observed deformation is frequently at right-angles to the forces or movements producing it. Movement of about 0.5 mm in a 3 m panel can produce a bulge of about 25 mm out of plane - Fig 4. The theory and detail of such movements, eg in cladding units subjected to vertical compression, are covered more fully in Digests 227,228 and 229.

Figure 2



Cracking within components involves the strength of the material much more directly. When building components are restrained, their strength is often exceeded by stresses arising from movement in the materials: cracking results. In practice, therefore, good design is based on an understanding of both the strain tolerance of the materials and the movements involved and avoids the development of harmful levels of stress by controlling and limiting restraint. Structures with materials fully restrained in compression but well within their compressive strength may be more stable and less likely to crack than those allowed to move freely. This may be the preferable design option in some cases. Prestressed concrete is a well known example of the calculated application of this design technique.

Figure 3



Internal restraint is supplied by the component itself when differential movements occur in the component (eg as a result of drying from one face only, or of different temperatures on opposite faces). Distortion, and often cracking, then follows. This is more likely to occur in thick materials or components, and those which are insulated or have moisture barriers so that the temperature or moisture differential between the opposite faces is high. Sandwich panels are a classic case where the differential stresses can reach very high levels and cause serious damage or self-destruction - Fig 5.

Figure 4

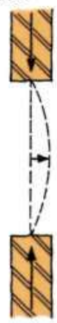
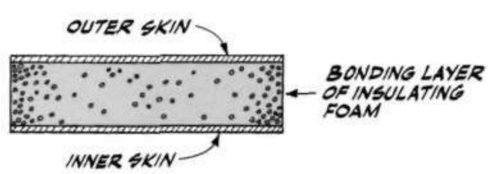


Figure 5



DIAGNOSIS

The cause of cracking cannot always be determined with absolute certainty from a single viewing. Inspection may have to be repeated at intervals to establish the duration and nature of the movements responsible. Movement or crack monitoring may be necessary to see whether the problem is still active. Standard methods for monitoring are given in Digests 343 and 344. Diagnosis can be greatly helped by a thorough knowledge of the history of the components and of the building. The likely causes should be checked for consistency with the number, width, depth, length, location and direction of cracks and the probable modifying effects of restraint. There are a few general observations that can be useful.

- Foundation movement will normally cause damage to all structural elements supported including floors and *both leaves* of a cavity wall. Cracks from foundation movements are often very large: widths of 5 to 25 mm are not uncommon.

- Problems with materials that affect only one leaf of a cavity wall do not normally result in cracks in the other leaf except where the ties or other linking elements cause unintentional restraint. An example of this is wall ties installed near or on returns; this can cause vertical cracks on the quoin - Fig 1. Code of practice BS 5628 and DAS 115 advise against this practice.

- Cracks from thermal and moisture movements are generally between 0.5 and 5 mm wide.

- Thin panels will bow out of plane very easily; normal thickness brick or concrete walls that are fully restrained and axially loaded do not bow easily. If brickwork in older buildings is bowed, it is usually eccentrically loaded, often eccentrically supported and often has no lateral support (ie no ties where the floors span parallel to the wall). In modern brickwork, bowing is more likely to be due to sulphate attack or construction inaccuracies.

- Random cracking of concrete slabs, concrete units or cement-based renderings can be the result of a number of mechanisms; chemical, petrographic or x-ray analysis of the affected material is usually needed to establish the cause.

SIGNIFICANCE OF CRACKING

Cracking can affect a building in a number of ways. If severe, it may result in a loss of stability, in rain penetration and air infiltration, heat loss and reduced sound insulation. All of these mean a loss in the efficiency of the building. Cracking may not be severe but it is often unsightly and unacceptable to occupants. Correct diagnosis will decide whether a satisfactory repair is possible or, in extreme cases, economically worthwhile and whether the requirement is only aesthetic or is necessary to maintain structural safety.

Digest 251 contains advice on the assessment of cracking and the appropriate action in relation to damage caused by ground movement. Digest 329 covers cracking due to wall tie corrosion.

ILLUSTRATED EXAMPLES

The problems summarised in Table 1 are illustrated either by typical examples or by expanded explanation.

TEMPERATURE CHANGES

Extreme cases may result in obvious damage. Figure 6 shows brickwork punched out by steel roof trusses which expanded during a fire. Cracking by ratcheting of long sections of lightly loaded walls and claddings is relatively common but can be avoided by providing frequent movement joints.

Figure 6

The thermal movement of flat roofs exposed alternately to the sun and the night sky can be large: about 5 mm for every 10 m with concrete. It continues for the full life. Movement is often restrained at some point, for example where the roof abuts another building or where a lift shaft or stair well is carried up through the roof slab. The effects of movement are then concentrated elsewhere.

Figure 7 shows how walls at right-angles to the long axis of the roof, and furthest from the restrained parts of the slab, are cracked by rotation of the part in contact with the underside of the slab. In addition, the tops of walls running in the direction of the long axis have cracked in shear. These two types of cracking are often complicated by the tendency of the slab to bow upwards in the centre when its top surface is hotter than the underside.

Repairs are unlikely to be durable unless the roof movements are reduced. Practical considerations usually limit remedial measures to improvement of above-roof insulation and provision of reflective surface treatment. In new buildings, inverted roofs, joints and separation of internal walls from roofs can help to prevent trouble. More guidance is given in Digest 312.

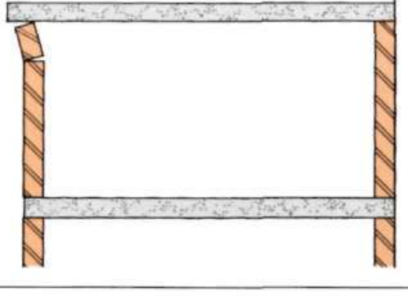


Figure 7

INITIAL DRYING OUT OF MOISTURE AND WETTING AND DRYING

Portland cement products, autoclaved aerated concrete, sandlime units and timber products.

Shrinkage cracking is probably the most common form of cracking found in buildings. It affects many building materials: sandlime bricks, lightweight concrete products, plain concrete slabs, some plasters, rendering and timber.

Shrinkage increases in concrete products with increasing cement content and water contents. The initial shrinkage can be 50% greater than movement caused by subsequent wetting and drying. Dense aggregate concrete usually has less shrinkage than lightweight aggregate concrete. Most of the movement is due to the cement paste but some aggregates are shrinkable themselves - Digest 357. Calcium silicate brick walling (Digest 157) behaves like concrete and should be designed as such.

Figure 8 shows a typical tension failure of a calcium silicate wall at an unreinforced weak point: a window opening. Autoclaved aerated concrete (AAC) materials have shrinkages of the same order but their low tensile strength demands careful design. Over-strong mortars will encourage the formation of such large obvious cracks by bonding the units together very firmly and increasing the overall shrinkage. A weaker mortar will allow distributed microcracking which copes with the movement without disrupting the integrity of the wall. Guidance is given in Digest 342.

Figure 8

The familiar map pattern cracking shown in Fig 9 is typical of drying shrinkage, a commonly reported failure in dense cement-sand external rendering. These renderings are often applied to exclude rainwater, but in practice fail to do so because they shrink and crack. Another cause of rendering failure is the use of over-strong renderings on weak backing materials, such as AAC and traditional lime-plastered, soft brick and mud walls. The strong render shrinks and curls, breaking the bond near the surface of the weaker backing material. It then spalls off. In new work, the strength of each successive coat of a render system should be lower than the previous coat (or the same strength but thinner).The damp conditions necessary for sulphate attack may be set up in exposed locations. Note the difference between the map pattern and the pattern of cracking associated with sulphate attack.

Figure 9

Timber has a high shrinkage across the grain when it dries from a seasoned moisture content down to an equilibrium content of around 12 to 15% in normally heated buildings. In timber frame systems, the horizontal timber elements in the frame (floor joists and horizontal rails etc) amount to about 300 mm per storey and are in the load path. This can lead to an overall shrinkage of the frame of up to 6 mm per storey. This does not usually cause problems with lightweight cladding supported by the frame but can cause differential movement if the cladding is supported by the foundations. Typical problems are:

- interaction via wall ties which can push out the masonry;
- at windows fixed to the frame where the cill will be rotated if a soft joint is not provided between the base and the opening in the masonry;
- at the heads of windows where the lintel supporting the masonry over the opening is attached to the timber frame.

Designing for movement of brick cladding to timber frame is discussed in DAS 75 and 76.

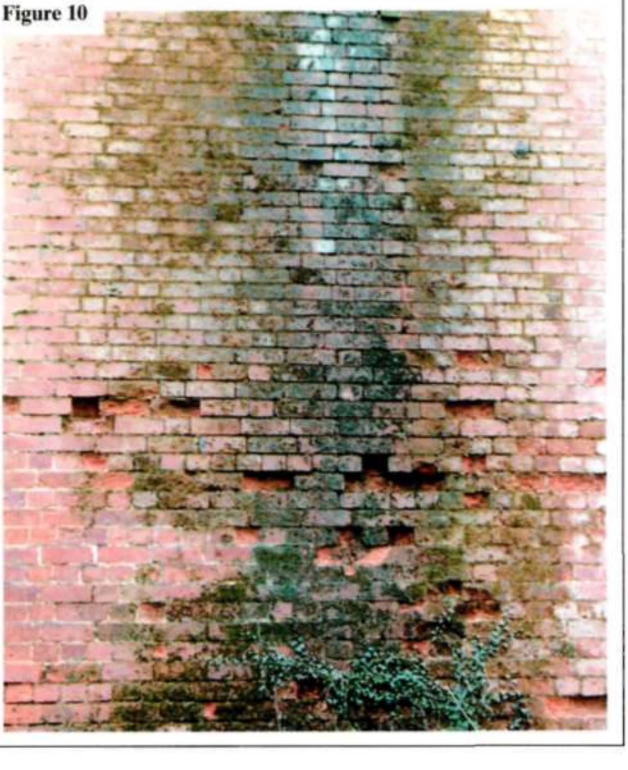


Figure 10

LOSS OF VOLATILES

This is a shrinkage process associated with the loss of solvents from paints, some mastics (such as putties) and some sealants. Shrinkage is an inherent characteristic of these products so. if performance is critical, a non-solvent-based alternative should be used.

FREEZING AND THAWING OF ABSORBED WATER

This is a deterioration mechanism which can affect all porous materials exposed simultaneously to saturation by moisture and temperature fluctuations about 0°C. It is caused by the expansion that occurs when liquid water at 0°C cools to ice at - 4°C. Ice forms first in the pores nearest the surface; the remaining water trapped inside may have nowhere to expand as the temperature of the inside falls. This produces a bursting force which causes the surface layers of materials to spall off. Materials with low absorption are clearly likely to be less affected but so are those with a wide range of pore sizes because they very rarely fully saturate under normal conditions.

This process usually causes destruction of materials in-situ by a process of spalling or crumbling and only rarely does it result in large-scale cracks in structures. Figure 10 is typical of the damage to porous materials repeatedly frozen while saturated with water. It is probably a contributory cause to the failure of free-standing boundary walls, parts of the building envelope between the ground and the ground level dpc and roof parapets. These are likely to suffer near their base due to rising damp, splash-up and run-off of rain from higher levels.

In the UK, foundations in occupied buildings are rarely damaged by frost heave in the soil and damage is usually confined to severely exposed parts of buildings founded on predominantly chalky and fine sandy soils.

In some of these soils there may be a build-up of ice layers which cause the foundations to lift, but even then only in exceptionally severe winters. Figure 11 shows some fairly typical effects. The house was newly built on chalky soil, with chalk fill under the floor slabs. It was unoccupied - and therefore unheated - and the parts most affected were those most exposed.

Further guidance is contained in Digests 63, 64 and 67.

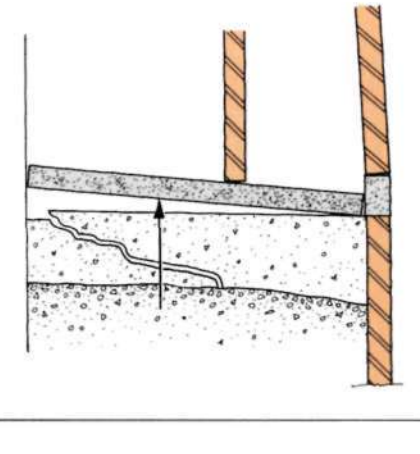


Figure 11

SUB-SURFACE CRYSTALLISATION OF SOLUBLE SALTS

(Crypto-efflorescence or salt attack)

Efflorescence is the process where absorbed water in porous materials first dissolves indigenous soluble salts, creates them by a chemical reaction or carries them in from a contaminated source (such as the ground) then deposits them as crystals on the surface as the material dries out. Crypto-efflorescence is the process where the crystallisation process takes place below the surface and the volume changes induced cause damage similar to frost damage. It is usual for this process to generate local spalling rather than large-scale cracking.

SULPHATE ATTACK

Sulphate attack is a reaction between water solutions of soluble salts, usually sodium, potassium or magnesium, and a constituent of Portland cement (or hydraulic lime). If saturation is extreme and persistent, calcium salts can also cause the problem. In brickwork, it is usually the mortar or cement rendering that is attacked and clay bricks are the source of the soluble salts; salts can also arise from groundwater in contact with earth retaining walls or from leaching of gypsum plaster. The reaction is an expansive conversion of tricalcium aluminate (C^A) to ettringite. This leads initially to cracking and spalling of mortar/render but eventually to gross expansion of the masonry; causing movement, bowing, arching and general disruption.

For serious attack in clay brickwork, all of five conditions must be satisfied:

- soluble sulphate content of bricks above 0.5%;
- C_3A content of cement above 8%;
- permeable mortar;
- wet for long periods;
- moisture interchange between brick and mortar/rendering.

If significant salts are not present in the bricks, failure occurs only if sulphates are introduced by contamination.

The reaction occurs only when masonry is wet for long periods; it does not, therefore, normally affect the area between the damp-proof course and the eaves because this is partly sheltered and warmed by heat leaking from the building. Parapet walls, free-standing external walls and retaining walls are vulnerable, especially if the coping detail or waterproofing is leaky.

Rendered brickwork can be a problem. A correctly designed, applied and finished rendering should protect brickwork against rain entry in all but the most severe exposure. Dense, impervious renderings with too high a cement content often give trouble because they shrink and crack and let in water (Fig 9) and because they prevent evaporation of water from the wall. In Fig 12, a defective coping admitted rainwater into a boundary wall and the dense rendering prevented evaporation. The cement in the mortar was attacked first, causing expansion of the bed joints and typical horizontal cracking of the rendering. Provided stability has not been impaired and the coping is waterproofed, the rendering could be replaced by a weak, porous rendering based on sulphate-resisting cement, isolated from movement of the brickwork by metal lathing over breather paper.

Digest 196 gives advice on rendering; Digests 89 and 250 discuss sulphate attack on brickwork and concrete.

Sulphates can be produced from the oxidation of pyrites and other sulphides. Deterioration of building blocks and other concrete made using mine waste generally known as *Mundic* has occurred in Cornwall and Devon. This is apparently caused by the instability of some pyritic and/or slatey rock constituents. Further information is given in *Advice on certain unsound rock aggregates in concrete in Cornwall and Devon.*

Sulphate attack of ground-floor slabs is quite common, usually as a result of using inappropriate fills. Hardcore or fill containing appreciable amounts of sulphate must not be used below concrete floor slabs. Gypsum products are sometimes inadvertently used in hardcore, but the most widespread reported cases of failure have involved burnt colliery shales, often referred to as *red shale.* These often contain considerable quantities of soluble sulphates. Figure 13 shows how sulphate attack of the underside of the concrete slab can cause it to arch and crack, and the walls to bulge. In cases like this, if the stability of the structure is unimpaired, the fill could be replaced by sulphate-free material: not by re-use of the broken floor slab which may be contaminated with sulphates.

Floor heave can be caused by the use of steel slags, pyritic shales, magnesite bricks and some older high-sulphate blastfurnace slags.

Hardcore is discussed in Digest 276.

Figure 12

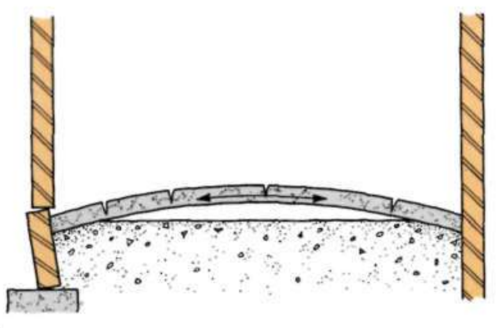


Figure 13

CORROSION OR OXIDATION OF STEEL

This is a very common problem affecting fixings, reinforcement and structural steelwork buried in porous building materials which become damp. The main problem is the formation of hydrated iron oxide, commonly called rust, which involves a four-fold increase in volume. The volume increase can cause movement, spalling or cracking of the materials in contact with the metal. The most common failures are in houses with steel wall ties (Fig 14) and concrete reinforced with carbon steel and either contaminated with chlorides or carbonated by atmospheric CO_2 - see *Carbonation* and Fig 15.

More details of the process are given in IP 12/90, IP 13/90 and Digests 263 and 264. Advice on repairs is given in Digests 265 and 329.

Figure 14

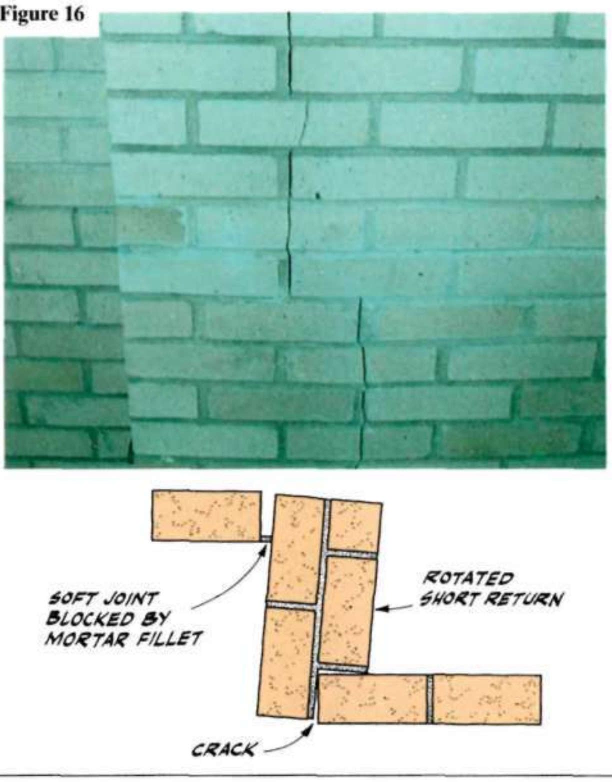
Figure 15

MOISTURE EXPANSION OF FIRED CLAY PRODUCTS

The initial moisture expansion of clay products after firing can be substantial and, for practical purposes, is irreversible because it is a chemical adsorption process unlike the normal reversible moisture movement. The process is very rapid just after the product has cooled after firing; the rate then falls off with time but can continue for 20 years or more. Materials vary markedly: London stock bricks, for example, have low expansion and underfired shales a particularly high expansion. For most simple designs, however, a single figure of 1 mm/m is used for the expansion of clay brickwork.

New walls are particularly susceptible to damage by horizontal moisture expansion if they contain short returns. In Fig 16. the damp-proof course, acting as a slip joint, allowed the brickwork above the dpc to expand with no significant restraint and the brick return in the wall was rotated and cracked. Figure 1 shows a related problem where the short return was restrained by wall ties. The problem can be reduced in new work by not placing ties too near to returns - DAS 115. The only satisfactory remedy is to install a

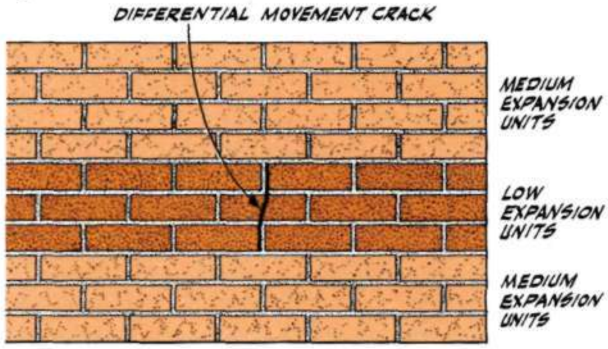
Figure 16



movement joint to allow for any subsequent expansion. In some cases this can be achieved by widening the existing crack but often the brickwork must be restitched and the joint placed elsewhere. The stability of the modified structure must be checked before such work is carried out and additional ties or supports may be necessary.

Another problem arises from differential expansion of different units bonded together into one structure. A contemporary example of this problem is the combination of low-expansion decorative string courses of contrasting colour within high-expansion

Figure 17



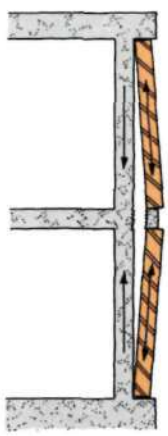
brickwork of another colour. The difference in colour will also result in different thermal movements. The result is that the expanding mass of brickwork puts the string courses into tension and they crack - Fig 17.

BS 5628: Part 3 does not identify this case since all clay units are deemed to perform the same in this respect. But BRE workO has shown that the expansion can vary by a factor of 5:1, or even more, between different types of clay bricks. Similar problems occur where clay bricks are used as a make-up string in concrete masonry, and where diaphragm walls with a concrete inner and clay brick outer are bonded at the webs. If different materials are to be combined in a single structure, their respective movement characteristics must be considered; if they are significantly different, the specification or the structure design must be changed to accommodate the movements, for example by inserting slip planes. Most clay brick manufacturers can supply movement data for their own products.

Vertical moisture expansion of brickwork can also cause trouble in conjunction with drying shrinkage of in-situ concrete walls or columns. In Fig 18, the moisture expansion has put the infilling brickwork under eccentric compression. The resulting stress was relieved by outward bowing of the brickwork. The magnitude of the forces involved is illustrated by the way in which the intermediate nib was pulled away. Weathertightness and stability were impaired and a satisfactory repair required rebuilding the damaged elements.

Advice on this problem and suggested repairs are included in DAS 2 and Digest 359.

Figure 18



CARBONATION

This is a chemical reaction between carbon dioxide gas in the atmosphere and alkaline components of building materials (such as sodium, potassium and calcium hydroxide, and silicates in cement-based products, sandlime bricks and AAC). The effect is to convert the strongly alkaline material (pH 12 to 14) to a weakly acid state (pH 8). The process is progressive from the outer skin inwards at a rate largely dependent on the porosity, taking one or two years to penetrate 50 mm in exposed AAC blocks but 50 to 100 years for 25 mm in well-compacted concrete. The rate is affected also by the moisture content; it is fairly slow in very dry walls and in fairly damp walls, and most rapid in walls in the humidity range 50 to 75% (normal internal conditions in the UK).

The process has two implications:

- it destroys the passive layer on the surface of carbon steel reinforcement and fixings, allowing corrosion to occur;
- it induces volume changes, generally reported to be shrinkages, in the first few years of the life of porous products so that any resultant effects on walls cannot be distinguished from initial drying shrinkage which occurs in the same timespan.

Data on rates of carbonation are given in IP 6/81 and on inhibiting coatings in IP 7/89.

ALKALI SILICA REACTION

This is a reaction between certain forms of silica (silicon dioxide) contained in aggregates for concrete and alkalis (sodium and potassium) present in set Portland cement paste - see Digest 330.

The process occurs only in the presence of moisture: generally, the wetter the conditions the worse is the effect. Normal winter condensation can provide sufficient moisture. The products of the reaction are usually of greater volume; this results in an expansion and causes random 'map cracking' at the surface and has the effect of weakening the resistance to tensile and shear forces.

HYDRATION OF OXIDES AND UNSTABLE CLINKER AGGREGATES

This is common in fired clay bricks where particles of calcium oxide and, occasionally, magnesium oxide form during the firing process. They react expansively with moisture to form the respective hydroxide and often spall small pieces from the surface. The typical failure is termed 'lime popping' and is of aesthetic rather than structural concern. Figure 19 shows an extreme example of a lime pop originating from a larger than normal particle that passed a faulty sieve.

Occasionally, clinker aggregates cause popping or general expansive failures of concrete blocks due to hydration processes or through moisture sensitivity of excessive unburnt coal - see BRE Report BR 105 and BS 3797.

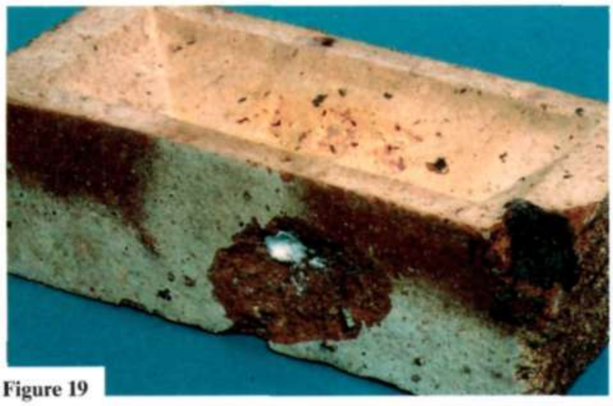


Figure 19

IMPOSED LOAD EFFECTS

Suspended reinforced concrete floor slabs deflect under their self-weight and superimposed loads; this must be expected. Occasionally, however, drying shrinkage in an asymmetrically reinforced slab can contribute markedly to further deflection. In Fig 20, shrinkage has been accentuated by the inclusion of shrinkable aggregates in the concrete. The resulting additional deflection has removed support from the foot of the wall above, and cracking has occurred. In cases like this it is extremely difficult to say how many factors are collectively responsible for cracking (poor design and workmanship may also contribute); still less is it possible to say what each has contributed in producing the defect. The inclusion of this example is a reminder of the difficulty of clear-cut diagnosis of the causes of cracking in practice.

Overloads occur most commonly where loads are concentrated on to a small area via a joist, beam or joist hanger. Joist hangers result in particularly high stresses on the outer fibre of the wall adjacent to the load and failures have been recorded.

FOUNDATION MOVEMENT

The most common cause of foundation movement is due to shrinkage or swelling of clay soils.

All clay soils shrink when dried and expand when wetted. These volume changes tend to be worse for the stiff plastic clays that are common throughout the South of England. Their location and behaviour are described in Digest 240. In these soils, seasonal volume changes can produce vertical movements in open ground of 25 mm or more. The effect is normally restricted to the surface layers and is likely to be only a few millimetres at 1 m depth. The process is reversible and cracks which form during a dry spell will often close during the winter.

Foundations can move either as a result of the loads applied to the ground by the building (settlement) or as a result of external factors that act independently of these loads. Varying amounts of foundation movement (differential movement) distort the building and can cause damage.

Foundation settlement is likely to be tolerated by the building provided the loads do not exceed the 'allowable bearing pressure'. Values given in BS 8004 suggest that most natural soils in the UK, except loose sands, very soft clays and organic soils, are capable of supporting typical low-rise building loads (up to 75 kPa). Special care has to be taken when building on made ground or fill - Digests 274 and 275.

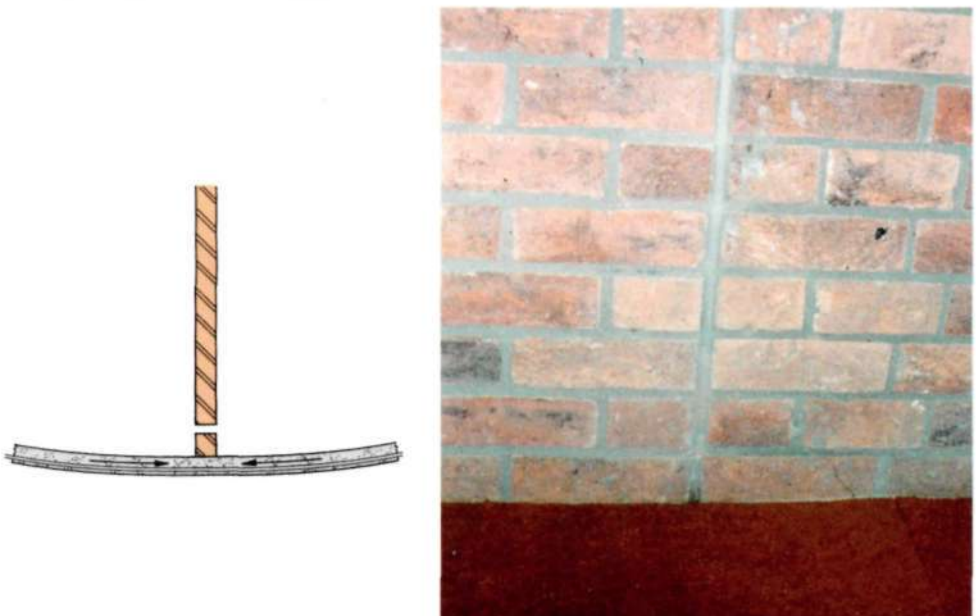


Figure 20

The possible causes of foundation movements that are independent of the applied load include:

- frost heave;
- changes in groundwater level;
- erosion by flowing water, adjacent excavation, landslides, coastal erosion;
- subsidence associated with swallow holes or mining activities;
- settlement of made ground.

Figure 21 shows a failure in flats on a filled quarry where some of the piles in the foundation did not reach to the quarry floor and slipped during a period of heavy rain.

Removal of moisture from the ground by trees tends to exacerbate the seasonal volume changes - Digest 298. Typically, ground movements associated with large trees are about four times those measured for clear ground. Trees also have a long-term effect because the winter rainfall may not fully replace all the moisture lost in the growing season. The region of permanently desiccated soil so formed expands as the tree grows, producing settlement over an increasing radius; it can reach depths of to 5 to 6 m.

Figure 22 shows typical damage due to clay shrinkage exacerbated by nearby trees.

If a tree is removed, the moisture returns to the soil slowly causing it to expand (heave) by as much as 150 mm. Because the effect of the tree is localised, the movements generated in nearby foundations are differential and can be much more damaging than uniform movements.

VIBRATION

There is little hard evidence for serious damage by vibration, except from extremes such as the effects of explosions, blasting in mines and earthquakes.

Digest 353 gives some guidance on acceptable levels and how to measure the intensity.

Figure 22

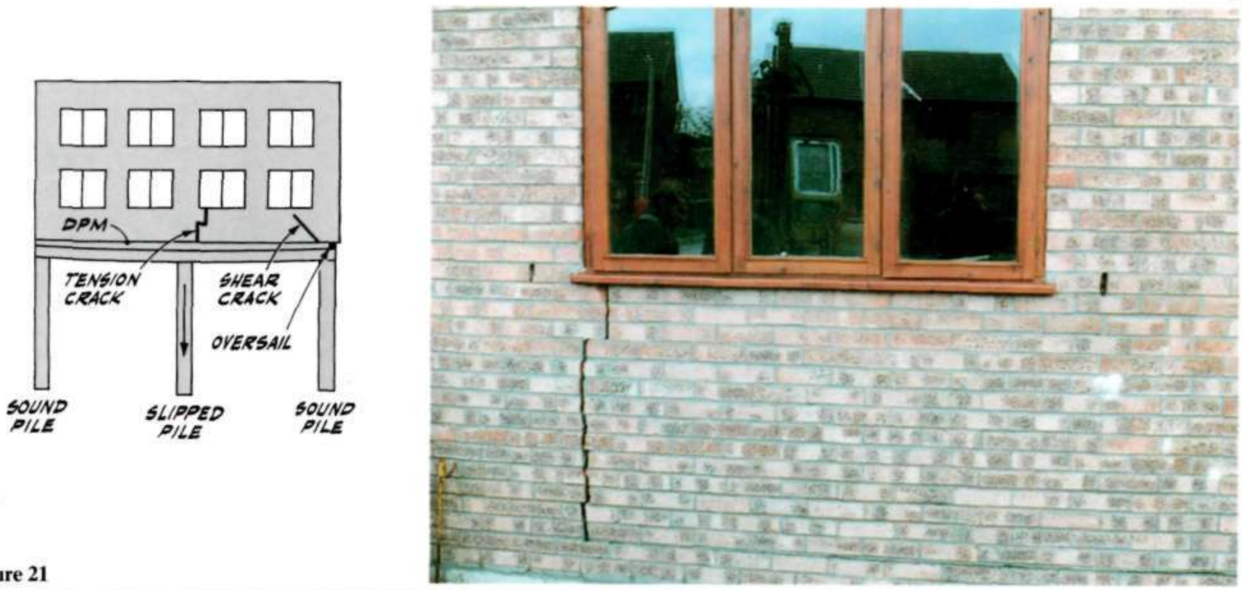


Figure 21

Table 1 Movements and principal causes

Action	Effect and duration	Materials affected	Components affected
Physical changes			
Temperature changes	Expansion and contraction. Continuous daily and annually.	All materials except special ceramics and alloys.	Walls and roofs, especially well-insulated dark cladding and south-facing roofs.
Initial drying	Shrinkage over weeks or years.	Mortar, concrete, aerated concrete, sandlime units, timber.	Large, low aspect ratio masonry walls; timber frames and floors; large concrete frames.
Wetting and drying	Expansion and contraction. Seasonal and weather-related; intermittent for life of material	Most materials, especially timber, porous concrete products, shrinkable clay soils especially if affected by large trees.	Timber and concrete directly exposed to weathering; shallow foundations on shrinkable clay soils.
Loss of volatiles	Shrinkage over hours to years. Irreversible.	Solvent-based (paints, mastics, plasticised plastics).	Finishes; movement joints; sealants.
Freezing and thawing of absorbed water	Expansion; internal damage; spalling. Intermittent related to weather.	Porous materials, especially fired clay products, natural stones, weaker concrete materials, soils.	Walls and roofs exposed to high levels of driving rain and associated freeze/thaw action; services and very shallow foundations in soil subject to freezing.
Sub-surface crystallisation of soluble salts (crypto-efflorescence)	As above with associated salt staining.	Porous materials, especially fired clay bricks and tiles and natural stones which contain salts or are subject to contamination from the environment.	Walls; roofs; floors subject to wetting and drying cycles and structures in contact with contaminants such as groundwater, sea water, effluents, acid rain.
Chemical changes			
Sulphate attack	Permanent expansion over months to years.	Portland cement and hydraulic lime mortars; concrete; blocks.	Structures that remain wet for long periods, eg exposed walls, slabs.
Corrosion, oxidation	Permanent expansion over months to years.	Metals, especially mild and high tensile steels.	Fixings, especially in exposed structures; reinforcement in carbonated or contaminated concrete.
Moisture expansion of ceramics	Permanent expansion over decades; worse in young structures.	Fired clay bricks and tiles. Due to a chemical reaction with atmospheric moisture.	Slender brick walls (especially cladding and parapets); tiled floors and walls.
Carbonation	Permanent shrinkage over one to 50 years depending on porosity.	Porous concrete and calcium silicate products.	Walls, especially where they are weakened by openings.
Alkali silica reaction	Irreversible expansion over many years.	Concretes containing reactive aggregates and sufficient alkali.	Concrete that remains wet for long periods, eg slabs, bridges, dams, earth retaining structures.
Hydration of oxides and unstable slag aggregates	Permanent expansion over months to a few years.	Usually occurs as particles of unhydrated lime or magnesia in fired clay bricks. May occur in slag aggregates not complying with BS 1047.	Most common as aesthetic spalling of fair-faced brickwork. May be a contributory cause of volumetric moisture expansion in some bricks and concrete blocks. Heave of floor slabs above unstable fills.
Imposed load effects			
Dead and imposed loading on structure within design limits	Elastic (instantaneous) and creep deflection over years.	All materials in the load path.	Seldom causes cracks.
Structural loading	Elastic (instantaneous) and creep deflection over years.	All materials in the load path.	Walls subject to concentrated loads, eg where joists and joist hangers bear.
Loading of ground/ foundations	Consolidation. Settlement over months to years.	Especially silty or peaty soils and any made ground.	Mainly walls of brittle material where differential settlement occurs.
Differential soil movements			
Settlement, mining, subsidence, swallow holes, land slips, soil creep, earthquakes	Differential settlement. Can occur at any time in the life of a building.	Foundation strata.	Walls and floors. Usually affects both leaves of a cavity wall but cracking is different due to different loading and restraints.
Vibration			
Traffic, machinery, sonic booms, mining, explosions	Oscillating strain fields.	Brittle walling materials.	Probable cause of damage to bridges and buildings near transport facilities, but difficult to prove.

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Printed in the UK and published by Building Research Establishment.

Price Group 3. Also available by subscription. Current prices from:
BRE Bookshop, Building Research Establishment, Garston, Watford, WD2 7JR (Tel: 0923 664444).
Full details of all recent issues of BRE publications are given in *BRE News* sent free to subscribers.

ISBN 0 85125 476 4

Printed in the UK for HMSO Dd.8339212, 6/91, CH0, 38938