

Hazardous and deleterious building materials

This note offers a first point of reference and practical guidance to the identification and treatment of problems associated with some types of building materials. Bringing together the essentials of a wide range of different materials and forms of construction over the years that may have been found to be hazardous to persons or to the environment, may have been considered to be deleterious, might have been regarded as being problematical in some way, or would probably be labeled as deleterious if they had their chance again.

Giving advice on the nature of the material, its normal use, problem areas, methods of diagnosis and analysis, and methods of repair, this title also examines the history of the use of the materials in question and guidance to the ages and types of building most at risk. Deleterious Materials should be used with care as their presence can have an impact in some instances on future asset value and building viability.

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Asbestos

Many years before the science of mineralogy was evolved, the term asbestos was given to describe 2 distinct silicate mineral groups - the only common characteristic being their asbestiform or fibrous habit and what was thought to be an incombustible nature.

There are 6 naturally occurring minerals belonging to the 2 mineral groups:

- the serpentine group, containing chrysotile, or white asbestos (the fibrous form of the mineral antigorite);
- and the amphibole group containing the family of inosilicates, including crocidolite or blue asbestos (the fibrous version of riebeckite), amosite or brown asbestos (the fibrous version of cummingtonite-grunerite), anthophyllite, actinolite and tremolite.

Asbestos fibres, in general, are incombustible, resistant to acids (amphiboles) or to chemical bases (chrysotile), have very high tensile strength (stronger than steel) while being flexible (enabling knitting), are resistant to the action of moisture (they do not rot, so are very durable), and have very low thermal and acoustic conductivity coefficients making asbestos a good insulation material. The [Health and Safety Executive website](#) contains more information on Asbestos (see also [Enforcement](#)).

As a consequence of its versatility and relative cheapness, materials and components containing asbestos are commonly found in all but the most recent of premises. The [HSE](#) have detailed the following common types, listed here in order of decreasing ease of fibre release:

- sprayed coatings and laggings;
- insulating boards and insulating blocks;
- ropes, yarns and cloth;
- millboard, paper and paper products;
- bitumen roofing felts, damp proof courses, semi rigid asbestos-bitumen products and asbestos-bitumen coated metals;
- asbestos-paper backed vinyl flooring;
- unbacked (homogenous) vinyl flooring and floor tiles;
- textured coatings and paint containing asbestos;
- mastics, sealants, putties and adhesives; and
- asbestos reinforced PVC and plastics (see [Forms and products](#)).

It is carcinogenic if inhaled and can present a serious, sometimes fatal, risk to the health of those who come into contact with it, either inadvertently or by design. For this reason, the use of asbestos is no longer possible and work with the material is now one of the most highly regulated activities in the UK.

Asbestos materials that are sound, undamaged and not releasing fibres should not be disturbed. Their condition should be monitored on a regular basis. Where possible damaged materials should be repaired and then protected as necessary, provided that the repair or sealing will be durable and not likely to be disturbed. Only remove asbestos where repair is not possible or the material is likely to be disturbed.

Brick slips and brick panels



Popular in the 1960s and early 1970s, brick slips were seen as an easy method of concealing the exposed edges of a concrete frame at each floor level.

A failure to recognise the propensity of a concrete framed building to shrink created circumstances where the brick slips could be stressed and forced off the building, often with serious risks to health and safety.

The provision of movement joints above and below the course of slips is essential, but great care is needed to ensure that even the smallest amount of bridging of the soft joint does not occur.

Many slips were simply bonded in position, but inaccuracies in construction (often inevitable) lead to variations in the thickness of bedding materials. Sometimes a plane of weakness could develop between the mortar background and the concrete if ordinary mortar was used to bond the tiles. Mechanical fixings are desirable to ensure longevity.

Contamination of the reverse face of the brick slips (for example, with brick dust) or on the surface of the concrete (for example, with mould oil) could lead to poor adhesion.

Brick panels within either exposed concrete frames or supported on knibs can similarly be affected by unplanned shrinkage in a concrete frame. Damage can be severe and a need to renew the entire brick cladding is not unknown.

Calcium Chloride



When used as an admixture to concrete, calcium chloride acts as an accelerator, speeding up the setting of the concrete and its development of strength.

Calcium chloride was routinely added to concrete from the late 19th century until 1977, when its use as an admixture was effectively prevented under the (then) Concrete Code CP110 (see [Introduction](#)).

The corrosion of steel in concrete is an electrochemical process and relies upon the formation of an electrical cell in which water contained within the pores of the concrete acts as the electrolyte. The inclusion of calcium chloride ion into concrete increases the electrical conductivity of the concrete and with this, the likely corrosion rates. Sufficient quantities of chloride

ion can disrupt the passive layer around steel reinforcement, and if they exceed a threshold level can prevent the passive layer from being re-established. The steel can thus be put at risk of corrosion (see [Mechanism of corrosion](#)). A combination of carbonated concrete, damp conditions and a chloride content in excess of 0.4% by weight of cement is likely to cause corrosion. However, while chlorides are no longer added to concrete as an admixture, they could still be present as a result of poorly washed marine aggregates, or from exposure to de-icing salts, salt spray, sea water and the like. Chlorides can be absorbed into the body of the concrete by processes of absorption and diffusion. Potentially, concrete affected by external contamination sources is likely to be at more risk of corrosion. Treatment of chloride affected concrete is very difficult owing to the possibility of creating new corrosion cells at the boundary of the repair and the existing concrete. Methods of electrochemical treatment are becoming well established, with cathodic protection now a recognised method. Other systems of chloride extraction and migrating corrosion inhibitors have met mixed reviews and their effectiveness needs to be demonstrated by better performance data over time.

Calcium silicate brickwork



Calcium silicate (sand lime and flint lime) bricks are manufactured by mixing lime, sand and/or crushed siliceous or flint stone together, with enough water to allow the mixture to be moulded under high pressure. The bricks are then steam autoclaved so that the lime reacts with the silica to form hydrated calcium silicates. This results in durable bricks that are consistent in shape, size texture and strength).

Calcium silicate bricks complying with British Standards can give satisfactory service under a wide range of conditions of loading, exposure and dampness, both above and below ground, internally and externally. ([BS EN 771-2:2003](#) covers the specification of calcium silicate brick in brickwork constructions.)

In their natural form the bricks are moderately reflective and offer a good alternative to glazed brickwork for lightwell applications. Varieties of coloured, multi-coloured or textured bricks are available.

The bricks can be affected by a combination of salt contaminants - such as sodium sulphate, sodium carbonate and calcium chloride. Severe frost may also cause deterioration. However, in contrast to many clay bricks (or perhaps more correctly many cheaper clay bricks), calcium silicate bricks are resistant to sulphates, wetting and drying, and frost action. Exposure to sea spray can be harmful, while exposure to atmospheric carbon dioxide increases their strength and hardness.

Shrinkage is the most commonly perceived fault with calcium silicate bricks. Drying shrinkage should not be greater than 0.04%, but care needs to be taken during construction to ensure that shrinkage cracking is minimised later. Normal site procedures of covering and protection should be undertaken, but in contrast to clay brickwork, calcium silicate bricks should not be wetted during laying. If suction is too great, additional water can be added to the mortar (within reason) or very light wetting undertaken.

Vertical movement joints should be provided at intervals of between 7.5-9m, with the first joint from a return normally half that distance. To minimise the effects of movement, the ratio of length to height of masonry panels should not exceed 3:1. Careful selection of mortar for the work being undertaken is important and, as with many materials, the mortar should be generally weaker than the bricks themselves. If a mortar of too high a strength is selected, cracking, if it does occur, may pass through the brick rather than through the brick joints. With a weak mortar joint, there is a greater tendency for the bricks to shrink individually without stressing the wall as a whole - thus creating a multitude of small, insignificant cracks around brick units rather than larger cracks at greater intervals.

Thermal movement is likely to be about 1.5 times that of clay brickwork - the co-efficient of linear expansion being about 8×10^{-6} per deg. C (see [Thermal and moisture movements](#)).

A common fault in older buildings was to use calcium silicate bricks as a facing material with clay bricks as backing. Because of the propensity of the clay bricks to expand upon drying and the calcium silicate bricks to shrink, stresses inevitably built up, which caused fracturing.

Calcium silicate bricks have suffered adverse criticism over the years and are often unfairly cited as a deleterious material and excluded from use on commercial projects.

As a building material, bricks of this type are perfectly serviceable. Providing that suitable measures are taken to reduce the effects of shrinkage, there is no reason why they should not perform satisfactorily over the life of the building (see [Cleaning](#)).

Continental practice

The practice of discouraging calcium silicate bricks is unknown on the continent where that one industry exceeds the capacity of the whole of the UK brick market. There are around 169 members of the [European Calcium Silicate Producers Association](#). In Holland alone calcium silicate bricks account for around 38% of the UK masonry market.

Unfortunately, the bricks have acquired a tag in the UK, which has been perpetuated by a general lack of understanding of the material and its limitations together with an often misguided diagnosis as to the cause of cracking. Suggested causes ranging

from subsidence to corrosion of a steel frame are not uncommon and have often resulted in the expenditure of significant sums before the appropriate repair solution is put in hand.

Provided the correct precautions are taken in the design of walls constructed from calcium silicate brick there is no reason why satisfactory performance cannot be expected. So, it is unfair to prohibit the use of calcium silicate bricks, and their arbitrary inclusion in a deleterious classification should be challenged.

An appreciation of the material and its behaviour patterns, particularly in respect of shrinkage, is necessary so that faults can be diagnosed quickly and accurately without wasting time and money trying to prove that a structural problem exists.

Cem-Fil/GRC

Cem-Fil is a trade name describing a range of alkaline resistant glass fibres used as reinforcement in glass reinforced cement (GRC) products.

Originally developed by BRE and then marketed by Pilkingtons in the UK, Cem-Fil is now produced by a subsidiary of Saint Gobain. However, there are other manufacturers of alkaline resistant fibres, so avoid using the term Cem-Fil when defining GRC in generic terms (see [Introduction](#)).

Normal glass fibres degrade in alkaline environments such as concrete, but alkaline resistant varieties have been found to survive much better through the addition of zirconium dioxide.

The inclusion of chopped strands of glass fibre in to the cement matrix creates concrete with high impact and flexural strength, and enables thinner and therefore lighter components to be made.

Over time, the strength of GRC degrades, but provided that this is taken into account at design stage, this need not be a problem.

GRC is susceptible to moisture and temperature movements and so proper care in the design of fixings is very important.

Early GRC cladding panels tended to be large units, sometimes of sandwich construction - these exhibited a tendency to bow, particularly if curved units were used. Larger units are now considered to be less satisfactory.

GRC is now considered to be a highly versatile material, able to fulfil a wide range of service conditions and uses. Typical uses include claddings, planters, balustrade panels, sun screens, roof tiles, sheets and drainage channels.

Cement fibre slates



Cement fibre slates were first produced in the late-19th century using a process of laminating thin layers of a dilute matrix of asbestos and cement.

The asbestos slates grew in popularity and proved to be very durable. Asbestos proved to be an ideal material for reinforcement owing to the unique properties of the fibres.

However, concerns over health issues led to the abandonment of asbestos reinforcement and the search for alternative fibres from the early 1980s. Despite considerable research, no single fibre was found that could match the properties of asbestos and achieve such a level of durability.

Early uses of glass fibre proved to be unstable and highly unsatisfactory and the industry gradually settled on a proportion of cellulose and PVA fibres, which, although less efficient than asbestos, proved to be an acceptable alternative (see [Contemporary slates](#)).

Poor manufacturing process and failures in quality control can lead to problems of water absorption with subsequent curling and, in extreme cases, cracking. Fittings such as ridge tiles are made under a slightly different process and can distort quite badly if improperly fixed.

Inadequate nailing can also give rise to a problem of star crazing - a spider's web type crack pattern that can reduce durability (see [Star crazing](#)).

While unreinforced slates can be through coloured, some slates at the cheaper end of the market have a painted coating that can fade and deteriorate within 10-15 years or so. While visually displeasing, deterioration of the coating should not lead to a reduction in the performance of the slate.

CFCs (chlorofluorocarbons)

Chlorofluorocarbons (CFCs) were first produced in the early 1930s as a substitute for hazardous gases used in refrigerators.

They are colourless, odourless, non flammable gases containing carbon and fluorine together in many cases with chlorine and hydrogen (see [Introduction](#)).

CFCs were used in buildings in a variety of products including foam insulation, refrigerants, aerosol sprayed insulation and fire protection equipment (see [Properties and uses](#)).

Discarded CFC gasses from fridges, cooling equipment aerosols and building materials were found to collect in the stratosphere where they are broken down. The chlorine that is released catalyses the destruction of ozone in the ozone layer, a vital barrier against harmful UV radiation (see [Ozone depletion](#)).

In 1985 it was recognised that a transient hole had formed in the ozone layer above Antarctica and that the release of CFCs needed to be controlled. The alternatives to CFCs were HCFCs with the better known Refrigerant 22. However HCFCs are also seen to have global warming and ozone depleting potential.

A series of restrictions have been placed on signatories to the Montreal Protocol and EU member states. These effectively halted the production and use of CFCs and set limits on the continued use of the alternative HCFCs (see [The Montreal Protocol](#)).

Production and consumption of CFCs, halons and other ozone depleting chemicals has been phased out in industrialised countries. In the EU, HCFS are due to be phased out by January 2015 (see [Alternatives](#)).

However, buildings containing CFCs will remain in use for many years. While refrigerants will have to have been removed, foam insulation products will need to be disposed of carefully using an environmentally acceptable technology.

From 1 January 2001 recovered CFCs had to be destroyed (this policy also includes the reuse of foam insulation materials). Recovered HCFCs can either be destroyed or can be reused until 2015

Chlorides

While concrete as a material has been in use for centuries, it was not until the middle of the 19th century that serious experimentation with ferro concrete took place. Development continued through the early part of the 20th century, leading to the introduction of high alumina cement in 1924 and prestressed techniques in the years following the Second World War. During the post-war building boom, it became common practice to use calcium chloride as an additive to enable setting to take place quickly, and, in the case of precast concrete, to enable moulds to be struck earlier (see [Key points](#)).

The introduction of chloride ions into reinforced concrete can, if in sufficient quantity, result in a high risk of corrosion of embedded steel. There are 3 possible sources of chloride:

- introduced as an accelerator during the mixing process;
- introduced naturally, e.g. the use of unwashed marine aggregates;
- introduced as a result of external contamination, e.g. de-icing salt, exposure to salt spray.

Chloride-induced corrosion can be particularly difficult to deal with effectively. In certain circumstances 'pitting' corrosion can occur, with the steel effectively being eaten away without the formation of expansive rust. By cutting out affected areas and undertaking traditional hand-placed concrete repairs, a new corrosion cell is formed, with the consequent risk of corrosion occurring at the interface of the repaired area and the existing concrete (see [Repair methods](#)).

The introduction of calcium chloride as an accelerator was common until around 1978 and was particularly prevalent in the 1950s and 1960s. Similarly, buildings of this age often exhibited exposed concrete frames or elements of structure, which are susceptible to external contamination.

Coke breeze and filler joist construction (masonry and steel)



Developed as a method of constructing fire-proof floors in some of the early industrial mills, filler joist construction was popular in the second half of the 19th and first quarter of the 20th century. The system used a series of parallel steel joists with an infilling of breeze concrete (see [Introduction](#)).

Breeze concrete can have a high sulphur content, which in moist conditions can produce sulphuric acid. Steel embedded in breeze concrete is at acute risk of severe corrosion in moist conditions. It is not uncommon to find that the webs (or flanges) have been severely comprised.

Typical locations are the upper floors and roofs of factory premises constructed in the late-19th and early-20th centuries; as well as public buildings, such as banks, hospitals, schools and some housing schemes; and in a few cases, large private houses. Being a good electrical conductor coke breeze can permit large corrosion currents.

Concrete (deterioration)



In its natural state, with a pH level of around 12-13, concrete provides a good measure of protection to embedded reinforcement. The steel forms a passive layer that serves to protect it against corrosion. Once the pH level of concrete falls to 9-10, the passive layer is disrupted leading to the risk of corrosion. The actual risk depends upon a number of factors such as the presence of sufficient moisture and oxygen (see [Introduction](#)). Good quality, well-compacted concrete with a low water to cement ratio provides better protection than poorer, more porous mixes.

When exposed to the atmosphere, concrete is subject to attack from atmospheric carbon dioxide and sulphur dioxide in moist conditions. These acidic gases serve to lower the pH value of the concrete although sulphur dioxide usually only affects the surface. Carbon dioxide on the other hand diffuses into the body of the concrete, reducing its alkalinity in a zone gradually extending back from the surface. The process usually takes many years to reach the reinforcement, but when it does, disruption of the passive layer places the reinforcement at risk (see [Defects](#)).

Carbonation will advance quicker when the RH is in the region of 50-75%. Above or below this range the rate usually decreases. So the rate of carbonation will usually be greater within internal conditions.

A significant cause of deterioration in concrete is chloride attack. Chloride ions create conditions of high electrical conductivity in the concrete and thus increase the risk of corrosion. Chlorides attack the passive layer and are difficult to deal with using conventional hand-placed concrete repair methods (see [Sulphate attack](#)).

Chlorides were used as an accelerator in concrete up to about 1978 when their use was discontinued in the UK. However, concrete of any age is vulnerable to attack from chlorides arising from salt spray, de-icing salts and the like. Contamination from these sources can be potentially more damaging than with chloride that was used as an accelerator.

If the chloride concentration (usually expressed as a percentage by weight of cement) is high enough, pitting corrosion can occur. In this form of corrosion, the reinforcement is effectively eaten away without the formation of expansive rust. Pitting corrosion could be particularly dangerous in prestressed or post-tensioned structures because of the thinner sections involved. The effective treatment of chloride affected structures is difficult and it is probably best to use electrochemical methods, such as cathodic protection, to minimise the risk of further corrosion activity.

Concrete cladding

Heavyweight concrete cladding panels can function well in service, but are prone to the usual forms of deterioration arising from carbonation, chloride attack, low cover, etc.

Total failures are rare, but isolated failures are much more common. Older types of fixing can suffer from corrosion problems although it is often the concrete that fails before the fixing. Copper alloys were popular before the 1960s, but before the widespread use of stainless steel, some of the bronze alloys including manganese bronze, copper zinc alloy and high tensile brass suffered from stress corrosion (see [Introduction](#)).

Panels can suffer from the effects of frame shrinkages or deflections, and if fixings are unable to cope with the resultant movements, failures can occur. Panels usually have 2 support points unless fitted to a continuous floor edge, although some means of adjustment and levelling is usually needed. More than 2 support points can lead to misalignment and overloading of adjacent fixings. Thermal stresses can be high and must be accommodated by the fixing system (see [Fixings](#)).

Some forms of large panel contain insulation. These function as sandwich panels, but corrosion of (particularly) phosphor bronze ties between the inner and outer leaf can lead to the detachment of the entire outer face. So always ascertain the nature of the ties.

Sea dredged aggregates

Dredging for sand commenced in the UK in the mid 1920s in the Bristol Channel area. It has now grown to a major industry supplying not only UK needs but also those of Northern Europe, especially Holland and Belgium. Shortage of sands and gravels from inland quarries, coupled with environmental considerations has created a need for the use of aggregates dredged from marine sources. According to figures published by the Crown Estate, around 37.4mt were extracted from marine sources in 2004. Of this, about 1.5mt was used for beach nourishment schemes, whilst some 6.8mt were landed in the Thames area for use in the south east.

Marine dredged aggregates are essentially the same as terrestrial aggregates on a mineralogical level, and in UK waters for the most part are considered to be of normal reactivity as far as ASR is concerned.

Aggregates extracted from marine sources are a valuable natural resource - their continued extraction is essential in order to avoid the permanent depletion of terrestrial aggregates. Because the materials are obtained at sea, they can be loaded at coastal ports and avoid significant road or rail transport costs.

Resources of marine sand and gravel are of equal quality to their terrestrial equivalents. They are used in the same applications, commonly in concrete and concrete products and in sea defence roles. Continued extraction can however be sensitive from an environmental perspective although it is closely licensed and supervised.

While the materials can perform perfectly satisfactorily, in the past concerns were raised that the aggregate could have a high chloride content leading to a risk of chloride contamination and the risks of alkali aggregate reactions. However, providing proper precautions are taken, there is no reason to discourage the use of sea-dredged materials.

The issue was side-stepped effectively by requiring all aggregates to comply with BS 882 (which laid down limits for matters such as chloride content, reactivity and shell content). BS 882 was been replaced by BS EN 1260, which, when coupled with the Euro code for reinforced concrete (BS EN 206-1) places limits on total chloride and shell content.

As long as the aggregates satisfy the codes (which also set out regular testing and sampling routines) and the concrete mixes are designed within the guidelines set out in BS EN 206-1, there should be no cause to restrict the use of marine aggregates for constructional reasons.

Corrosion



Metals almost universally require some form of processing to make them useable (gold being the exception). The conversion from raw to finished product creates metastable conditions: over time and with the influence of moisture and oxygen a metal will tend to revert back to its original form - the process of corrosion.

Corrosion is an electrochemical process relying upon a flow of electricity between 2 sites - an anode and a cathode. The magnitude of the corrosion current dictates the rate of corrosion. Corrosion is usually initiated by a difference in the electrical potential of 2 metals in contact with an electrolyte (a galvanic couple), variations in the metallurgical state of the metal at different points on its surface, or local environmental differences, such as variations in oxygen supply. (See Introduction.)

There are a variety of different forms of corrosion including uniform, atmospheric, galvanic, microbiological, localised corrosion (of which there are various subgroups) and environmental assisted cracking (also with various subgroups).

Flow assisted corrosion can cause significant problems for engineering installations such as petrochemical works, affecting pipework, valves and the like.

Corrosion is not an inevitable process if appropriate precautions are taken. The correct selection of materials can avoid or reduce the effects of corrosion, while other measures such as surface coating, sacrificial coatings and cathodic protection can be used in appropriate conditions.

Crystalline silica

Crystalline silica is the generic name for a range of naturally and artificially produced minerals being predominantly composed of silicon dioxide. Silica and silicate compounds are very common and make up a majority of the earth's crust.

Quartz and cristobalite are common forms of crystalline silica and will be found in a wide variety of building materials including building stones, sand, concrete, bricks and tiles (see Introduction).

The release of dust particles from cutting, drilling and machining can generate large quantities of respirable dust which can lodge in the lungs over a period of time. Operations such as repointing can place workers at significant risk (see Construction activities).

Prolonged exposure to high levels of crystalline silica dust can produce very serious health risks, chiefly silicosis, a disease of the lungs. Even short term exposure (about 7 months) at very high exposure levels can lead to a very serious, progressive and terminal form of the disease. Workers suffering from silicosis and related problems are also at greater risk of developing lung cancers (see Health issues).

For these reasons, control limits on exposure have been set by developed countries. In the UK the current workplace exposure limit for respirable silica is 0.3 mg.m^{-3} as an 8-hour time weighted average (TWA), but there is every possibility that this will be reduced to 0.1 mg.m^{-3} during 2006 (see Statutory controls).

Precautions are therefore essential when working with materials that contain crystalline silica. The use of dust extraction systems and water suppression methods are vital, and if these cannot reduce exposure levels sufficiently, suitable alternative personal protection methods (respiratory equipment) will be necessary (see Minimising dust emissions).

Formaldehyde

Formaldehyde is a pungent, colourless chemical commonly used in water solution as a preservative and disinfectant. It is used in the manufacture of many timber-based building materials and household products, such as chipboard, plywood and medium density fibreboard.

Formaldehyde foam was used to insulate cavity walls, and following scare stories about the harmful effects of fumes it has generally been labelled as a hazardous or deleterious material (.

Formaldehyde gas may cause a variety of respiratory or allergy problems and is a known carcinogen - although links with cancer in humans are less certain. In the UK, the use of formaldehyde in building materials is common, but in some parts of Europe and North America, exposure to formaldehyde is considered more sensitively or even banned

Galvanised steel wall ties

Cavity walls are a form of construction dating back to the 19th century, often using wrought or cast iron ties to hold the 2 leaves together. They became popular in the inter-war years and were virtually standard construction post-war.

Until the early 1970s, wall ties often took the form of vertical twist types or twisted wire (butterfly) types. These were often galvanised, some to very poor standards. In 1945, standards for galvanising were published. However, the standards were reduced during the 1960s with the result that by the early 1970s widespread concern existed that tie corrosion was becoming a serious issue. In 1981, the standard for galvanising was increased threefold.

Research by the Building Research Establishment suggests that in the long term, all properties with galvanised steel ties will need to be repaired.

The rate of corrosion of the tie depends primarily upon its exposure to moist conditions and the presence of other contaminants, such as sulphur dioxide in industrial environments. One particularly aggressive form of construction was the use of black ash mortar which resulted in the early failure of zinc coatings.

Vertical twist ties can expand up to 4 times in volume when corroded, leading to significant distortions in the external fabric of a building. Twisted wire ties corrode, but generally do not exhibit the same disruptive effect upon the outer skin, meaning that the first anyone knows about the problem is when the outer leaf collapses - possibly during high winds.

Care is needed in the diagnosis of a tie problem as some symptoms could be mistaken for other types of defect. Similarly, great care is needed in the selection of appropriate forms of remedial tie to ensure that the properties of the tie (in terms of fixing, durability and flexibility) are matched with the demands of the property.

Wall ties are not the only components likely to be affected by zinc loss and therefore corrosion risk - components such as fixing cramps, restraint straps (where built in), lintel bearings, screws and brick joint reinforcement are all at risk.

Corrosion of wall ties is not confined solely to 1960s buildings. Cavity walls incorporating metal ties have been in use since the beginning of the 19th century and are common in dwellings built in the early 20th century in northern and western areas of the UK. However, during the 1960s it was common to use galvanised wire ties and, in some cases, vertical twist ties with substandard protection coatings.

The life expectancy of bitumen and zinc coatings on these ties is frequently well under the 60 years that was originally predicted. In fact, in 1981 [BS 1243](#) tripled the minimum allowed zinc coating thickness on wire ties.

According to the BRE, corrosion of wall ties could affect virtually all the cavity walled structures built before 1981

Glulam and box beams

Current laminated timber is constructed from stress graded longitudinal strips of timber, planed to a close fit and glued together using phenolresoreinol formaldehyde (PRF) adhesives. Individual strips are usually finger jointed.

Its relative low weight by comparison with steel and concrete means that self-weight is less of a constraint in design than other, heavier materials. A steel beam of equivalent bearing capacity would have a self-weight of around 20% greater than a laminated timber beam (see [Introduction](#)).

Being timber, glulam is likely to be affected by the same factors that would affect ordinary timber products: poor detailing, frequent wetting, exposure to aggressive chemicals etc. can have serious effects. Overloading of timber beams is a potential issue, either by excessive snow loads or unintentional means such as providing alternative, heavier roof coverings or roof mounted plant. If this is coupled with decay, the effect on the structure could be serious (see [Practical issues](#)).

Heavy snow in Germany and adjoining European countries in winter 2006 led to the collapse of a large number of timber buildings, some constructed with laminated timber and some being several decades old. Preliminary research suggests that regular planned maintenance inspections of glulam structures (and for that matter related structures such as plywood box beams) should be carried out. Investigations suggest a common problem with restrained shrinkage, curved beams and connections of cross girders (see [Structural issues](#)).

Strengthening of failed beams (or improvement of their load bearing characteristics) can be carried out by external plate bonding or post-tensioning with steel wires or rods. Carbon fibre or steel reinforced polymer are being used to good effect for plate bonding although these materials, because they are bonded to the timber, alter its appearance (

Man-made mineral fibres



Machine made mineral fibres (MMMF) is a generic term for a range of fibrous amorphous silicates [manufactured](#) from glass, rock, furnace slag and occasionally other minerals.

Broadly speaking there are 4 classifications of MMMF including:

- continuous filament (glass wool);
- insulation fibre - stone wool (rock wool or slag wool);
- ceramic fibre (or refractory fibre); and
- special purpose fibre.

Unlike asbestos fibres, MMMF tends to break into shorter lengths. Fibres below about 5 microns in diameter are considered to be respirable (i.e. capable of entering the lower portions of the lung). Those above 6 microns are not considered respirable. There is insufficient data to establish a relationship between the inhalation or ingestion of MMF and cancers, but laboratory studies in animals have produced carcinogenic symptoms in some cases.

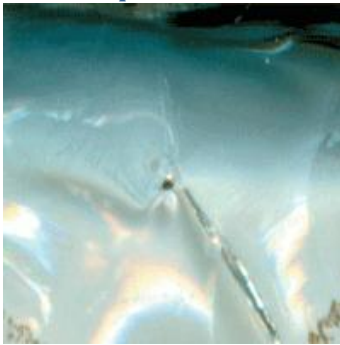
The health risks are greatest for workers likely to be producing or working with mineral fibres, but epidemiological studies have thrown up conflicting results, and currently there is considered to be insufficient data to draw meaningful conclusions as to proven risks. The risks to the general population are considered to be very small indeed.

Exposure to MMMF can cause dermatitis and itching, with some reports of eye irritation. The wearing of PPE such as masks and gloves should reduce the risks during normal handling.

In the UK, the HSE classifies refractory ceramic fibres and special fibres as Category 2 carcinogens (may cause cancer by inhalation), although there are some exceptions.

Mineral wools are classified as Category 3 carcinogens. These substances should be regarded as if they are carcinogenic to humans: there is sufficient evidence to provide a strong presumption that exposure to them may result in the development of a cancer. However, for mineral wools, derogations for classification are allowed if certain criteria are met. In practice, none of the commercial mineral wools currently on the market require classification as Category 3 carcinogens (see Measurement). The absence among workers of any established link between respiratory disease and exposure to airborne insulation wool fibres confirms the conclusions drawn by several national and international authorities that insulation wool products pose a negligible risk to humans.

Nickel sulphides



There have been numerous reported problems with the spontaneous fracture of toughened glass panels. Notable cases have included the failure of large overhead panels in shopping centres, failures at the Eurostar Terminal at Waterloo, the London Imax cinema and various other high profile buildings (see History).

Failures have resulted in some cases in the installation of temporary barriers, external temporary scaffolding systems or substantial re-glazing.

Nickel sulphide is one of several chemical contaminants that can occur during the manufacture of glass. There is some debate as to its origin, but it is thought that it is due to the mix of nickel and sulphate impurities within the glass batch materials, the fuels or even the furnace equipment, and this creates polycrystalline spheres that vary from microscopic to 2mm in diameter. All glass has some of these inclusions present - they are impossible to eliminate entirely and so they are not considered a product defect. In untreated (annealed) glass the imperfections are not a problem. But when glass is heat treated (toughened or tempered), the inclusions are modified into a state that transforms with temperature and time, and which is accompanied by an increase in volume.

In most cases this has little effect but, depending on size and proximity to the centre of the pane where the forces are greatest, this can eventually cause the glass to break.

There is a theory that for an initial period of approximately one year after manufacture there are relatively few breakages. After this, the number increases for up to several years, thereafter decreasing in frequency. There have been reported incidences where fractures have occurred more than 20 years after the installation of glass.

Although the safety risks are very small because of the risk of falling debris, it is desirable not to use toughened glass for sloped overhead applications. Alternative solutions would involve providing laminated glass or laminated toughened glass combinations.

'Heat soaking' is a quality controlled process that gives increased reassurance against the presence of critical nickel sulphide inclusions by subjecting the glass panels to accelerated elevated temperatures to stimulate the transformation of the crystals and thus initiate immediate failure. It is thought that this process identifies 90% or more of the glass that might have subsequently failed after installation.

Heat soaking does not change any of the physical properties of toughened glass, so there is no means of distinguishing whether or not if this process has been carried out.

Polychlorinated Biphenyls



PCBs are mixtures of elementary chlorine into biphenyl. They were produced from about 1929 but discontinued in the mid-1970s due to concerns over health risks and damage to the environment.

Typical uses were as oil in transformer installations, capacitors (in washing machines and ballast units for fluorescent lighting) and similar components-closed systems.

Significant quantities were also used in the production of so-called open systems, such as plasticisers for chlorinated rubber paints, mastic sealants, carbonless copy paper and for a time, chewing gum.

PCBs are toxic, and very persistent making them difficult to eliminate. They are hygrophobic (do not dissolve readily in water) and so can build up in fatty tissues in the body.

Health risks are varied but many health organisations consider that PCBs have the ability to cause cancer in humans. Control limits are in place in most developed countries and EU members pledged to eliminate them as far as possible by 2010.

Because they are so persistent, cross contamination of other building materials is possible. For example, while polysulphide mastics in movement joints may have been renewed, high levels of PCBs have been found in the concrete surrounding the joints - a factor that needs to be taken into account in future demolition and reuse of recycled materials.

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds (known as congeners) and are produced by introducing elementary chlorine into biphenyl. They are usually oily liquids or solids that are colourless to light yellow, although some PCBs can exist as a vapour. PCBs have no known smell or taste and are not produced naturally.

Commercial PCB mixtures were sold under a variety of trade names, the most common in the UK being the 'Arochlor' range.

According to the annual report of the OSPAR Commission 2000/2001, PCBs have been produced commercially since 1929, both for 'closed' uses (such as use as insulation and cooling fluids in transformers, dielectric fluid in capacitors and as hydraulic fluids); and for 'open' uses, such as grouting and sealants and as plasticisers in paints. Production in Europe was stopped in the mid-1980s (see PCBs, OSPAR, 2001), but it is estimated that over 1 million tonnes of PCB have been produced worldwide.

To begin with, and during the years of production, they were considered to be safe and were popular because of their extreme thermal, electrical and chemical stability. Until the mid-1970s PCBs were also used as caulking in polysulphide mastic for use in expansion joints in buildings.

Today, the release of PCBs into the environment arises from use, waste and waste disposal.

Vermiculite



Vermiculite is a naturally occurring mineral from a group known as hydrated laminar magnesium silicates. When heated, flakes of the material expand by as much as 30 times to form concertina-like particles - a process known as exfoliation. The resultant product is used in very many applications, including foodstuffs, horticulture and building.

Vermiculite is used in thousands of applications from light weight concrete, fire protection construction materials, intumescent applications, potting soils, texturisers in paints and coatings, and as nano-composites for films, coatings and barrier applications. Building applications include thermal insulation products, sprayed fire protection, thermal and sound insulation and insulating boards.

The material is inert and very absorbent, so it can be used for packing dangerous chemicals and for dealing with oil spills. It is mined in several parts of the world. One of the largest mines, the Libby mine, in Montana USA, produced a variety that was found to be contaminated with tremolite asbestos - the mine is now closed. Detailed studies of other sources of vermiculite have revealed no similar asbestos content, or a content so small as to be of no consequence..

Vermiculite can contain small fibres not unlike asbestos, but scientific investigations have failed to establish any particular link with cancer as a result of the inhalation. However, the material can produce silica dust, prolonged exposure to which can lead to the serious lung condition silicosis.. The general conclusions in the UK are that the material is safe to use, although normal and sensible handling precautions should be employed to control nuisance dust, exposure to the skin and eyes.

Commercially available vermiculites are virtually free of any asbestos or they contain only insignificant amounts similar to other products that are naturally occurring, but unreasonable doubts and reservations have persisted. Caution should be exercised when dealing with older materials that might have originated from a contaminated source and when handling it is necessary to take normal precautions to avoid the inhalation of nuisance dust.

Thin stone cladding



Traditionally, building stone was seen as a durable and robust material. Its properties were understood and building practices evolved to deal with particular characteristics of the material. It was used as a heavyweight form of construction - a structure in its own right - and this meant that large stones were used. These were able to accommodate the effects of thermal and moisture movements and were more tolerant of the use of incompatible materials, for example, iron cramps, which could corrode and cause localised damage.

However, stone was (and is) an expensive commodity. While traditionally it has been used as a load-bearing material, the advent of high-rise buildings and improved structural performance has dictated a different approach to construction, particularly since the Second World War. Gradually it began to be used as a facing material, often with a brick backing behind. Even these forms of construction were still fairly heavyweight, with stone of at least 100mm thickness being common.

Once framing was introduced in the early 20th century, designers lost little time in reducing the thickness of stone claddings yet further. Coupled with advances in cutting technology over the last 50 years or so this enabled stone to be cut to as little as 25-30mm for use as a facing material. This trend towards lighter weight buildings resulted in buildings that were inherently more flexible. Stone, recognised by its durability, was being expected to perform in ways that could result in significantly less durability than was first envisaged. Whereas older, heavyweight claddings were able to deal to some extent with the effects of thermal and moisture movements, thinner claddings can be more susceptible to damage.

Now it is not unusual to find stone panels of 30mm thickness – perhaps 10% of the thickness of stone used in the early stone buildings. Thin slabs with a slenderness ratio (height to width) of 75:1 are not unknown, although a more common ratio would be around 40:1.

While the ability to cut slabs much thinner enabled the economical use of stone as a cladding material, it also brought about problems of early failure. Notable examples are the Amoco building in Chicago, Grand Arc de la Defense in Paris and the Finlandia building in Helsinki, where the thin slabs were not able to accommodate the stresses that built up as a result of the anisotropic thermal expansion, with the result that severe bowing took place. This type of failure is commonly visible some 10–15 years after the completion of a building, but in some cases the phenomena has been observed after only one year.

In its natural form, stone is usually in compression, simply because of the weight of material bearing down upon it. When quarried, the resultant release of stress may lead to dimensional changes in the stone. Buildings constructed from load-bearing stone replicated some of the natural forces that the unquarried stone endured, but the current practice of using stone as a facing material, hung from the building, often creates tension forces - the opposite of the natural condition.

Proper design of fixings is critical to the long term durability of the cladding. The design of the fixing also depends on the nature of the stone cladding - whether it is hand-placed stack or half bonded or whether it is to act as a rainscreen. Panels used as rainscreens must be supported individually, whereas hand-placed finishes can derive some support from adjacent units as long as the bottom unit is properly supported.

Typical problem areas include detachment, cracking around fixings, cracking within the body of the panel, spalling around fixings, misalignment and bowing of panels.

Bowing of thin white marbles, especially calcitic marbles is a known problem and can be very harmful, usually leading to a need to re-clad. Panels of around 30mm thickness, particularly in some white marbles have been found to develop bowing characteristics. The movement is usually progressive and will ultimately result in failure. Typically, the process becomes noticeable after around 15 years.

Marble is usually made up of the minerals calcite and dolomite, with some having a higher proportion of either.

Both exhibit anisotropic tendencies - they expand and contract at different rates in different axes. Calcitic marbles tend to expand in two directions and contract in the third, while Dolomitic marbles expand in all directions but at different rates.

Thermal expansion of stone materials is inevitable, and temperatures of around 40–50°C are sufficient to initiate movement. Temperatures of this magnitude are often found on the facades of buildings in Europe. Summer temperatures in Europe are sufficient to initialise bowing or warping of panels.

Irreversible expansion creates stresses within the body of the marble and micro-cracking occurs around the boundaries of individual grains – in turn this increases the stone's porosity. Flexural strength decreases and porosity increases and the panels bow in either a convex or concave pattern.

Anisotropic movement also loosens the individual grains of marble leading to sugaring of the surface and gradual disintegration of the stone. The increase in porosity also makes the stone more vulnerable to the effects of atmospheric pollution and water, with decohesion of the fabric of the stone – termed sugaring – being the result.

Although limestones are durable they can be seriously eroded by the build up of calcium sulphate, the product of the chemical reaction between calcium carbonate and rainwater containing dissolved sulphur. The chemical is deposited on the surface of the stone to form a crust which eventually spalls off taking some of the limestone surface with it.

Some concerns have been expressed over the long-term durability of flamed granite, in particular whether the flaming process extends any pre-existing micro-cracking in the stone.

Volatile organic compounds

Volatile organic compounds (VOCs) come from a wide variety of sources, both natural and man made, including:

- trees (many trees and plants emit a wide variety of biogenically emitted VOCs);
- motor vehicles;
- solvents;
- industrial processes;
- food manufacture;
- soil refining, storage and distribution.

The Institute of Environment and Health defines VOCs as forming a large, diverse group of carbon-based compounds that are gaseous at room temperature but notes that the specific meaning of the term VOCs can depend on the analytical methods used to measure them. (*Volatile organic compounds (including formaldehyde) in the home*, Institute for Environment and Health, 1999)

The World Health Organisation classes VOCs as the group of organic compounds occurring in air that have a boiling temperature of between 50-100°C and 240-260°C.

Environment Agency data reveals that a majority of VOC emissions in the UK come from road transport and solvent use.

(Aerial emissions of volatile organic compounds (VOCs) by sector – Environment Agency)

VOCs are commonly used in industry for processes such as degreasing, thinning and dissolving. They can also be found in certain materials, such as, paint, inks and adhesives. The largest emissions of individual VOCs are of butane, toluene, pentane, propane, ethanol and 'white spirit'.

In buildings, typical sources are paints, flooring materials including carpets, vinyl and adhesives, particle boards, timber treatments, and solvents.

There is a gradual move to reduce VOCs, partly by legislation and partly by a growing environmental awareness.

There are several forms of VOCs, such as:

- acetone;
- trichloroethylene;
- isopropyl alcohol;
- methylethyl ketone; and
- white spirit.

Health effects

Most VOCs have no reported health effects even at elevated levels.

However, some can lead to sensory effects and general discomfort due to strong smells, irritancy or allergic reactions.

Headaches, nausea, dizziness and drowsiness can be experienced at extremely high levels.

Some are dangerous to humans. A minority of VOCs are known carcinogens, such as benzene and 1,3-butadiene, benzene being potentially damaging to DNA.

Environmental impact

The British Coatings Federation (BCF) considers that although the impact of household coatings on atmospheric pollution is very small (less than 2% of the total amount of VOCs emitted), manufacturers believe the amount of VOCs in decorative coatings should be reduced and consumers given the choice of using lower VOC-containing products. To inform purchasers of the VOC content of each decorative coating product, the BCF says coatings suppliers have introduced a labelling system with a 5-band classification - minimal; low; medium; high or very high.

VOCs are a precursor to ground level ozone - in sunny, still conditions and in the presence of nitrogen oxides, VOC emissions react to form ground level ozone. This is one of the components of summer time smog and harms human health, vegetation and building materials.

Ozone is a strong oxidising agent and at high concentrations, as well as affecting human health, it is known to damage building materials and adversely affect plant growth. Ozone is not emitted as a pollutant but its atmospheric concentration is raised by a photochemical reaction involving VOCs and oxides of nitrogen.

The Air Pollution Information System notes:

'When VOCs react with the hydroxyl radical (OH), they in turn are converted into reactive free radicals that react with nitric oxide. This reaction eventually leads to the production of ozone, and a recycling of free radicals to start the process over again. Both VOCs and nitrogen oxides are necessary for the production of ozone in sunlight.'

Defra's consultation paper for the proposed limitations to VOC emissions identified that ozone and its precursors can be transported over long distances, with the result that pollution may extend from around 100km to the whole troposphere. The South of England is affected by continental sources of ozone precursors and it is here that UK concentrations are highest. Maximum concentrations of VOCs occur downwind of a pollutant source and while urban and suburban areas can suffer high concentrations, urban areas tend to be less affected because of the chemical reactions that take place as a result of vehicle emissions. (See Consultation on implementation of Directive 2004/42/CE of the European Parliament and of the Council on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and

vehicle refinishing products and amending Directive 1999/13/EC, Air and Environment Quality Division DEFRA, March 2005.)

Measurement

There are 2 main methods of determining the levels of VOCs in indoor air:

- pumped sampling (this involves taking air samples over a period of 30 minutes to 1 hour, which can then be analysed using techniques such as spectrometry to measure peak concentrations); and
- diffusive sampling (diffusive samplers usually take the form of tubes or badges that can be left in the affected area for a set period of time and then examined in a laboratory. The system can be used to determine the peak concentration and a guide to the nature of the compound. However, badges cannot record variations over a time period.).

Legislation

The UK Government and the devolved administrations recognise that because of the transboundary nature of ground level ozone, any reduction of ozone concentrations requires an international approach. The Volatile Organic Compounds in Paints, Varnishes and Vehicle Refinishing Products Regulations 2005 implements the requirements of EU Directive 2004/42/CE (Paints Directive) on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes.

Emissions of VOCs from decorative paints and varnishes are not controlled under existing legislation. New obligations will apply to the products defined under Annex II Table A of the Directive and require:

- maximum content limits for solvents (VOCs) from 1 January 2007 (Phase I); and
- more stringent limits for the maximum content limits of solvents from 1 January 2010 (Phase II).

Currently, solvent emissions are regulated under the:

- Solvent Emissions (England and Wales) Regulations 2004;
- Solvent Emissions Regulations (Northern Ireland) 2004; and
- Solvent Emissions (Scotland) Regulations 2004.

The Control of Substances Hazardous to Health Regulations 2002 (COSHH) (as amended) require that health risks created by work involving hazardous substances should be assessed so that exposure can be prevented or controlled. This may include measurement to assess exposure and test the effectiveness of containment or ventilation, etc.

Wood preservatives

Wood preservatives comprise an active ingredient and a carrier system. There are a great many types of active ingredient available, some highly toxic or harmful to the environment. Carrier systems are usually either water, water/solvent emulsions or light organic compounds such as white spirit.

Water-borne systems can cause the wood to swell, while solvent-based systems, when applied under pressure or vacuum tend not to have the same effect (see Timber decay).

Preservatives can be applied by brush, spray or deluge systems, although these treatments rarely penetrate deeply into the wood meaning that vulnerable timber could be exposed if it splits or is sawn without further treatment to exposed edges.

Vacuum treatments are usually more effective and can be controlled and varied to suit the particular species of timber (see Types of preservative).

Under current UK legislation, most preservatives are classed as pesticides and are subject to statutory controls.

Creosote can no longer be used for a preservative function as it is harmful to the environment (see Toxicity).

There is a growing recognition that chemical treatments, particularly remedial treatments may not be necessary in all cases and that by adopting an 'engineered' solution it is often possible to deal with timber pests such as fungus or insect without recourse to chemicals. Keeping the moisture content of timber below about 18% is usually sufficient to kill off fungal growth.

Background

The mechanism of timber decay is complex and depends upon a number of different factors. Since the Second World War, the nature of timber, particularly softwood has changed and these materials are frequently less durable than their counterparts of 50 or more years ago. Whereas external joinery used at one time a reasonable proportion of heartwood, the demand for timber and the need for rapid production now means that a greater proportion of sapwood is utilised. The sapwood of many species is of poor durability meaning that once exposed to the weather it decays fairly quickly unless it is treated with some form of preservative treatment.

Over the years, the chemical industries have come up with a number of formulations of toxic chemicals, aimed chiefly at destroying the organisms that cause timber decay or destroying pests that feed on the wood. Unfortunately, treatment with preservative is no substitute for good design and the selection of appropriate timber in the first place.

Timber preservation companies have produced a variety of chemicals for use in remedial operations. They have a vested interest in using and specifying them, possibly regardless of the actual cause of the problem and in ignorance of the sometimes simple measures that can be put in place to deal with the problem at source. Products are available for either amateur or professional use and can range from brush applied solvents to pastes, phials or pellets for topical treatment or insertion. Generally, they comprise some form of biocide or active ingredient within a carrier system - usually a volatile compound or water-based spray.

Health effects

What is toxic to living organisms can also be toxic to humans and to wildlife that may come into contact with preservatives. For example, UK bat populations have declined sharply as a result of the almost routine treatment of roof voids against wood boring beetles. Health effects of exposure can range from sore eyes, nose and throat, coughing and sneezing, headaches,

nausea, skin rashes and lethargy. Some chemicals are known carcinogens, while others have been known to cause epilepsy or blood diseases.

Corrosion of metals

The NHBC Standards contain special precautions for the use of metal fittings that will be in contact with treated timber. Where copper-based preservatives are used it is important that metal fittings are not applied to the timber until the salts of the treatment have been 'fixed' - this normally takes about 7-14 days from treatment.

Metal fittings should be galvanised when they are likely to be affected by occasional dampness, but where wet conditions are expected (and the metal will be in contact with the timber) austenitic stainless steel is required. Mild steel and aluminium in contact with timber treated with copper containing treatments should be avoided as corrosion cells can be established. (NHBC Standards, Chapter 2.3, July 2004, S2.3-D5)

Mundic

Mundic is the old Cornish name for pyrites, a mineral found in abundance in some of the geological deposits in Cornwall and some parts of Devon.

In the early 20th century, waste products from the area's mining industries (tin, copper lead) were used to provide a cheap and local source of fine and coarse aggregate for the manufacture of locally produced concrete blocks and in-situ concrete (see [Introduction](#)).

The blocks were used primarily for housing, with some agricultural and light commercial uses. Commonly, the blocks were rendered - as part of a solid or a cavity wall

Some of this waste material contained unstable sulphides (pyrite being one of the main culprits), which deteriorated after the concrete became carbonated, and in damp conditions

There are 2 main [mechanisms of deterioration](#), both based around the oxidisation of sulphide minerals in the aggregate. The deterioration process is complicated, but results in the decomposition of the concrete and its expansion.

Parallel cracking along rendered block bed joints or map cracking of render finishes to in-situ concrete are a visual indicator of a problem.

Rendered surfaces reduce the rate of carbonation, so it is possible for cavity walls to deteriorate from the inside out. This means that by the time cracking and other visible manifestations of a problem have occurred the concrete is badly deteriorated. Not all mine waste products are troublesome, and there is a strong association between the location of certain mine workings and clusters of buildings with a Mundic problem.

Suspect buildings should be tested by taking core samples followed by a 2-stage petrographic analysis in accordance with [guidelines issued by RICS](#) and endorsed by the BRE.

Wood wool slabs or cement board



Wood wool slabs are manufactured predominantly from softwood shavings (wood wool) that have been coated and bonded with Portland cement and compressed to form low to medium density boards (see [Manufacturing process](#)).

Wood wool cement board (WWCB) is durable and resistant to rot and biological decay. Contrary to popular belief it does not degrade in moist conditions and can be used externally.

WWCB provides an ecologically friendly alternative to thermoplastic boards and resins. Its manufacture produces no harmful by-products and it has good thermal insulating properties - the substance can be bonded with other insulation materials to form composites of 2 or 3 layers.

One use of WWCB was as permanent shuttering to reinforced concrete, either in flat slab or ribbed construction. When used in this way, experience has shown that there is a risk of poor cover to the steel and hence loss of durability, possible reduction in strength, and loss of fire resistance. Buildings constructed from 1950 to the mid-1970s are most likely to be affected by this form of construction.

If permanent shuttering is discovered, intrusive investigations may be needed to determine the adequacy of concrete cover to the steel reinforcement. If voiding is present, the affected area can be exposed and repaired using hand-fixed concrete repair methods or, if over a larger area, sprayed concrete.

When used for other applications such as roof decking, WWCB performs well and should not be considered to be deleterious. The material is seen as a useful and cheap building product for affordable housing in developing countries, where low technology manufacturing can produce the boards using locally grown timber.

Lead



Lead is a unique metal being very soft and having little mechanical strength. For centuries it was used for roofing, water pipes, paints and in glazes on pottery and kitchenware. However, the material has long been known to cause health problems, with children and pregnant women particularly at risk. It is toxic in a cumulative way, teratogenic (causes embryos to be malformed) and carcinogenic.

Some historians have speculated that the downfall of Rome was due, in part, to the effects of gradual lead poisoning of the population from lead water pipes and lead glazed kitchenware. This may be supposition, but what is known is that in the 17th and 18th centuries, cider drinking populations in Devon suffered from severe abdominal pains with occasionally fatal consequences. During the late 1760s, Dr George Baker identified the problem as lead poisoning from the cider presses and the addition of lead acetate to cider. The processes were changed and confining the problem of 'Devon colic' to history.

Other substances have not imitated the unique properties of white lead in paint, but today, the use of lead based paint has been phased out in all but a few specialist applications, and lead in plumbing supplies, whether contained within pipework or solder in copper fittings, is no longer permissible in new construction or alteration. Significant quantities of lead still exist in buildings that were erected before controls were enacted, and so care is still required in the design and implementation of alterations and redecorations in circumstances where lead-based products have been used. Lead in paint has now been all but phased out except for specialist conservation work, but lead paint can remain and create a risk to health during redecoration or where it is likely to be chewed by animals or children.

The health effects of exposure to lead have been well known for many years, and gradually the use of this material has been controlled by legislation, leading to a general decline in exposure levels within developed countries.

While there is uncertainty over whether or not lead poisoning can lead to cancer, there is plenty of evidence to demonstrate that ingestion of lead (particularly in children) can affect development, reduce in IQ and have various behavioural effects.

Higher doses can lead to renal damage, nervous system damage, severe colic, and in some cases encephalopathy may develop, with headaches, confusion and seizures leading to death.

The main sources of contamination for humans are food, water supplies and paint finishes, and although the last two are now strictly controlled, dwellings constructed before about 1970 are at risk of having lead in plumbing systems.

In the UK, the key legislation appertaining to lead is the Control of Lead at Work (CLAW) Regulations 2002 and the Control of Substances Hazardous to Health Regulations (COSHH, as amended).

Lead in roofing is not perceived to have the same health risks. While normally regarded as a durable material, the life expectancy of lead roofing and flashings can be reduced considerably by failing to take into account the effects of thermal movement or by permitting condensation to form on its under surface.

To understand deleterious materials of the future, we must learn the lessons of the past - Trevor Rushton of Watts and Partners.

Deleterious materials perform in an undesirable way. We have considered high alumina cement, calcium chloride, asbestos and lead as deleterious or hazardous, but notwithstanding this, all materials have the capability of being in some way deleterious given the right circumstances.

With the drive to cut carbon emissions and provide a sustainable approach to construction, numerous new materials and construction methods are coming on to the market - many of which may indeed perform in ways that were not anticipated by the designer. How can we assess how well these innovations will perform?

The Duke of Wellington once proclaimed

"All the business of war, and indeed all the business of life, is to endeavour to find out what you don't know by what you do; that's what I called 'guessing what was at the other side of the hill'."

The following examples serve to illustrate Wellington's advice.

Don't take information at face value

In January 2010, a short piece in the Daily Telegraph discussed a research paper published in the American Chemical Society's Chemical Research in Toxicology journal.

The paper, Risks of Copper and Iron Toxicity during Aging in Humans (Ref. 1), drew attention to the possible risk of Alzheimer's disease resulting from exposure to water in domestic copper plumbing systems. The author concluded that people

with higher intakes of copper and a high-fat diet had 'lost cognition' more rapidly than expected, and that people over 50 should avoid drinking water from copper pipes.

However, before we consider the ramifications of banning the use of copper, let us look at one small fact the *Telegraph* chose to ignore - the research paper was what is called in scientific circles a 'narrative review'. This gives a comprehensive overview of a topic, but does not necessarily include all data. It is unclear how well the review covers the evidence, or whether it has omitted evidence that contradicts the author.

This review was also written by a single author, as opposed to being a collaborative effort, and may therefore be biased.

Furthermore, a majority of the studies covered in the review were animal- or cell-based studies, which means that their direct relevance to humans is limited.

Thus far, information is limited and it would be dangerous to base decisions upon limited and selective examples of research - but watch this space.

Don't overlook the obvious

The mercury from a single CFL is enough to pollute 30,000 litres of water beyond safe drinking levels

Compact fluorescent lamps (CFL) are considered to be 80% more efficient than conventional incandescent lamps, and governments globally are pushing to introduce them as a substitute for tungsten bulbs.

CFL bulbs contain up to 5mg of mercury per bulb. The mercury is required to produce ultraviolet light, which is then changed into visible light by a phosphor coating. However, the mercury from a single lamp is enough to pollute 30,000 litres of water beyond safe drinking levels (source: [Mercury Recycling plc](#)).

Under normal operating conditions, a CFL bulb should not break but experience and common sense tells you that breakages in the home are inevitable. Start investigating how to clean up and you will find some alarming advice. In the UK, the [Health Protection Agency](#) recommends, among other things (Ref. 2):

- vacate the room and keep children and pets out of the affected area. Shut off central air-conditioning system, if you have one
- ventilate the room by opening windows for at least 15 minutes before clean-up
- do not use a vacuum cleaner, but clean up using rubber gloves and aim to avoid creating and inhaling airborne dust as much as possible
- dispose of the fragments in a double-wrapped plastic bag and treat as hazardous.

Somehow I do not see the layman adopting this advice. And there's the problem - mercury will find its way into landfill. BSJ readers will recall a [recent article on PCBs](#) (Ref. 3) and the biopersistence of these materials - sound familiar?

Research by the [Maine Department of Environmental Protection](#) in the US has revealed that, depending upon the clean-up regime implemented, mercury concentrations can be extremely variable. Double re-sealable polyethylene bags did not appear to retard the migration of mercury adequately to maintain room air concentrations below action levels. Also, clean-up material may remain in the home for some period of time and/or be transported inside a closed vehicle, potentially exposing occupants to mercury vapour.

Given the difficulty of monitoring such precautions, one can see that uncontrolled disposal is a possibility, with at least *some* bulbs finding their way into landfill.

Expect the unexpected

In 2001, [BBC2's Newsnight](#) questioned the use of Incinerator Bottom Ash (IBA) as a secondary aggregate in road surfaces and building blocks on account of alleged high dioxin content. IBA is a by-product of industrial waste incinerators - it is essentially composed of those particles of ash that fall from a moving grate into a quenching pool.

IBA has been challenged by some environmentalists and it is possible that the material may yet be reclassified and treated as hazardous waste

The [Environment Agency's](#) current classification of IBA has been challenged by some environmentalists and it is possible that the material may yet be reclassified and treated as hazardous waste.

Foamed concrete is often used for void filling and roadway applications; it is a cement-bonded material made by blending an extremely fluid cement paste (slurry), into which is injected a stable, pre-formed foam. Not all foamed concrete products are the same; some contain IBA while others do not.

IBA often contains aluminium so that when it is used with cement, the aluminium reacts with the alkaline cement paste to produce hydrogen gas. In 'normal' concrete made with IBA aggregate, this 'off gassing' can cause swelling of the concrete and subsequent large spalling effects. If the IBA aggregate concrete is a foamed type for use as low density fill, the much greater porosity of the foamed mix will allow the small particle size of hydrogen gas to leach more easily from the mix in wet and hardened state.

In a recent incident, contractors had been filling an old well with IBA foamed concrete over three days. The well was contained within a building and capped with temporary metal plates. It is thought that sparks from cutting equipment led to the ignition of hydrogen gas produced by the concrete. Two workmen received serious foot injuries in the resulting explosion.

The results of the [HSE](#) investigation have yet to be published, but as a precaution, The [Highways Agency](#) has banned the use of foamed concrete containing IBA until such time as the material is deemed safe.

If something can go wrong...

In 2006, a fire at a site in Colindale consumed a six-storey timber-framed (TF) building in less than nine minutes. Last year, a fire on a site in Peckham was fanned by high winds and destroyed 39 new homes, spreading to flats in adjoining estates and a public house.

According to the ABI... the cost of fire damage in 2008 in the UK rose by 16% on 2007 to a record £1.3bn, i.e. £3.4m every day

Typical features of these fires are early structural collapse and fire spread to neighbouring buildings. But not only are TF buildings at risk during construction, the poor installation of fire stopping, plasterboard finish quality and cavity barriers can pose serious risks of fire spread in a completed building.

According to the Association of British Insurers, the insurance industry is increasingly concerned about rising fire losses: the cost of fire damage in 2008 in the UK rose by 16% on 2007 to a record £1.3bn, i.e. £3.4m every day (Ref. 4). New building techniques, including TF are highlighted as being a factor.

All of the above factors point to growing concern about the use of TF construction and recent rumours suggest that insurance companies will withdraw cover for these types of buildings.

Read the instructions: Building is now a process of assembly, with craft-based skills diminishing. However, it is vital that new systems are fully explained and understood throughout the chain. Not only does TF construction demand attention in respect of fire, proper consideration of shrinkage and load paths are essential.

For example, we are currently involved with repairs to a recently constructed block of 15 flats arranged over four floors. The building is of platform construction whereby the external walls are constructed of prefabricated timber panels bolted together on site. The timber panels support prefabricated floor and ceiling 'cassettes'.



Figure 1: Remedial work in progress to a TF building. The vertical load from the post in the centre of the picture was supposed to be transferred by a set of site-fixed studs below (now installed) but these were originally missing. The resultant distortion of the frame led to severe water penetration from a balcony. (© Watts Group/Trevor Rushton) The design was fully detailed by designers and required 'loose studs' to be inserted within certain internal wall panels to increase the load-bearing capacity of the panels to support point loads from the roof structure. The building was clad in brickwork.

Fairly soon after construction, residents were alarmed by distortion that began to occur in the building, windows no longer fitted and floors became uneven - in the most severe cases, differences in level developed of up to 75mm across a single room. The downward motion of the floors caused the external balconies to distort, with the result that water flowed back into the building.

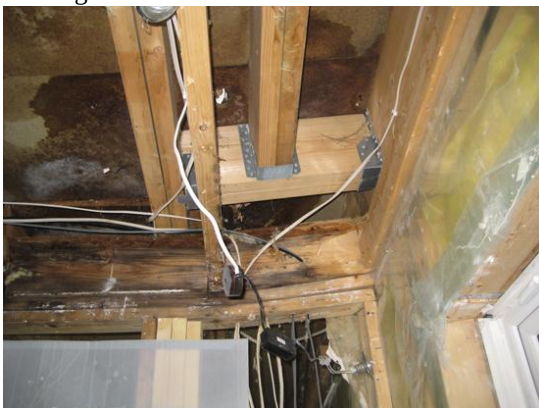


Figure 2: The same floor in the TF building seen from below. That the building merely distorted is testament to the flexibility of this form of construction. The vertical support studs have been installed as remedial work. (© Watts Group/Trevor Rushton)

The propensity of a TF building frame to shrink is well documented; suitable provision has to be made. However in this case, investigations revealed that many of the additional loose studs had not been fitted. Furthermore, some of the floor cassettes had been laid reverse-handed so that double-joisted sections no longer occurred beneath partitions or load paths. That the building did not collapse is testament to the inherent flexibility and strength of TF construction, but remedial work, involving decanting the flats is costing in excess of £0.5m.

Understand the need for water management: In Canada, a problem known as 'Leaky Condo Syndrome' led to the collapse of the British Columbian equivalent of the NHBC - the New Home Warranty Program in 1998. The syndrome involved the decay of TF houses arising from water penetration behind external wall insulation (EWI) systems.

Mineral wool, cellulose fibre and phenolic foam all have the capacity to retain water and, if coupled with a form of construction that resists drainage and evaporation, can lead to serious decay. Phenolic foam in particular contains acidic compounds that when released in wet conditions can have a very corrosive effect upon lightweight galvanized steel sheeting or structural elements. Applying impervious insulation and render systems to old walls can have harmful effects - it can prevent existing water management (breathability) of the fabric and exacerbate problems such as dampness, condensation and mould. The ability of the wall to release water is reduced and as a result, the increase in moisture content reduces the U-value. Problems such as these are typically encountered in older buildings without an effective DPC.

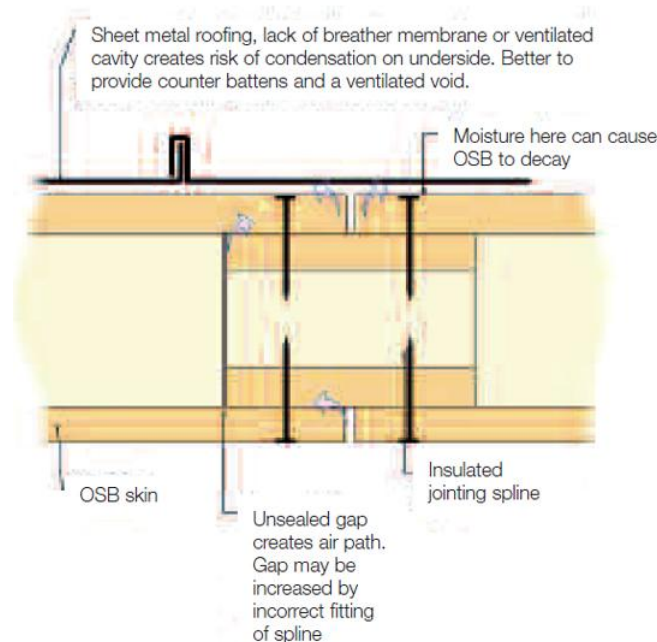


Figure 3: Although a common form of construction and one that can perform well in service, insufficient care in the sealing of joints can lead to air leakage and, in the right conditions, severe condensation on the underside of roof coverings causing the oriented strand board (OSB) to rot. Good construction systems can be given a bad name by poor assembly and detailing. (© Watts Group/Trevor Rushton)

NHBC Standards include detailed guidance to control the risk of rain penetration. For example, they require that external insulation systems over TF include a 15mm drained and ventilated cavity, and over light gauge steel frame a 15mm drained cavity. However, this is controversial and while the EWI industry acknowledges that in some cases a 'second line of defence' is needed, there are no recognised methodologies to determine when such a system would be required.

Furthermore, we come across plenty of examples where the render system has been used as the primary means of defence without auxiliary back up. Damage arising from normal wear and tear, alterations such as the insertion of vents and flues, new windows and the like all create potential for moisture penetration and waterlogging.

In Japan, where structurally insulated panel systems (SIPS) are popular, water ingress and decay problems have been encountered. These result from faulty or insufficient jointing techniques and a failure to seal the joints to prevent vapour transfer from the inside of the building to the cold outside face where it condenses on the sheathing around the joint. SIPS panels are becoming popular in this country, but unless the principles of water management and moisture control are properly understood and implemented, this sound method could become problematic.

The cases that I have outlined here are interesting in that they do not reveal 'new' defects or characteristics. However, what is of concern is the way in which previous lessons have not necessarily been learned, with the result that avoidable problems have been ignored or treated with a Nelsonian eye. Surveyors are well equipped to offer advice and it is worrying, for example, that of the key stakeholders selected to form the working party on the London Assembly's investigation into fire safety in tall and TF buildings, RICS is not represented.

My six principles are essentially matters of common sense - using what we already know to find out what we do not. Sadly, the catalogue of failures illustrates one fact that is often missed - that common sense is not common enough.

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Further information

- Ref. 1 Chemical Research in Toxicology journal, 2010 Feb 15;23(2):319-26
- Ref. 2 Fact sheet on mercury and compact fluorescent lamps, www.hpa.org.uk
- Ref. 3: A toxic legacy, BSJ, Jan/Feb 2010
- Ref. 4 Tackling Fire - A call for action, ABI, December 2009, www.abi.org.uk
- Investigating Defects in Commercial and Industrial Buildings can be purchased from www.ricsbooks.com
- Related competencies include: M008, T006, T013, T021 and T085