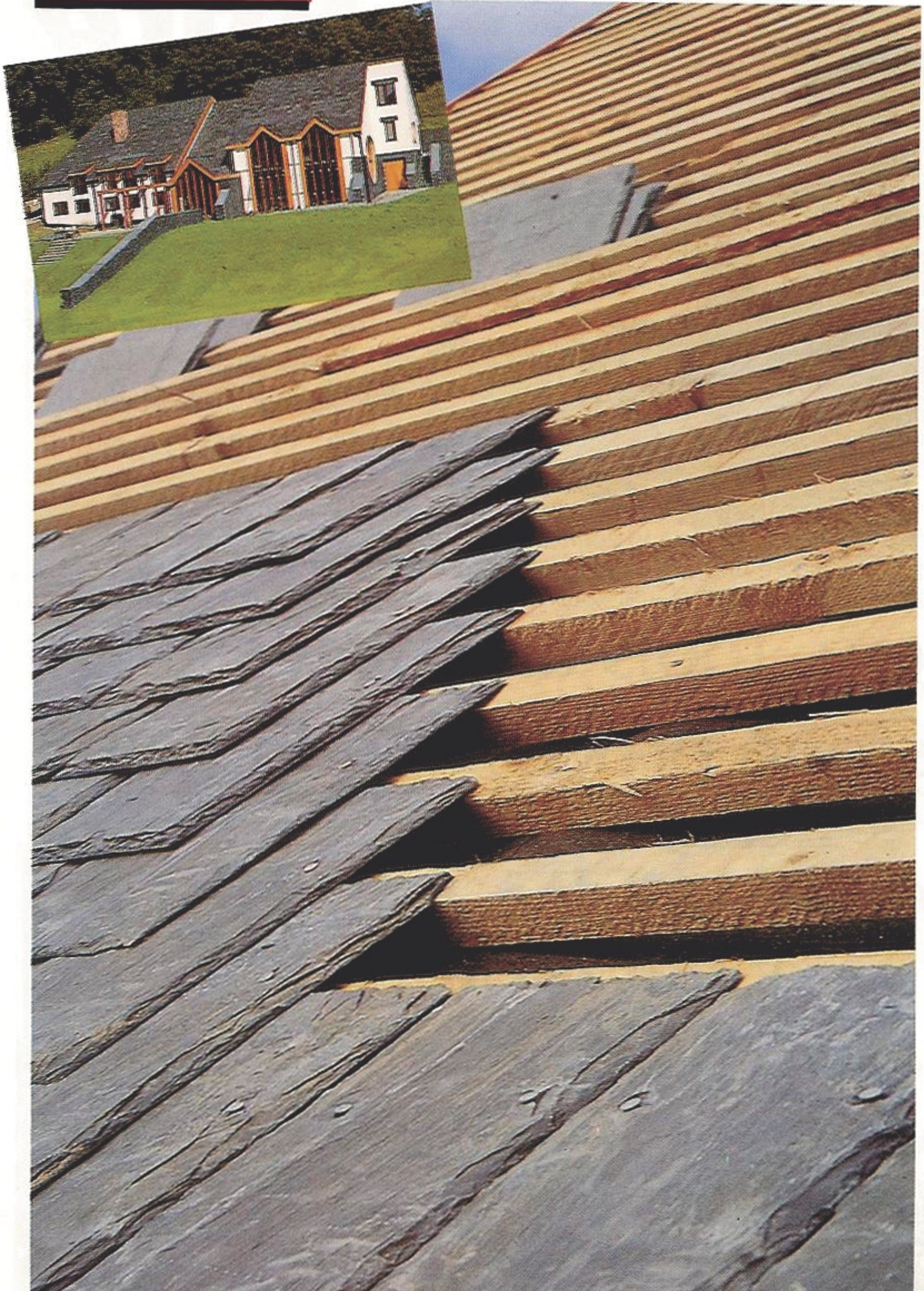


The

When slate is put onto a roof it is expected to stay there, unchanging and maintenance free, for many years. Some recent failures of imported slate have cast a shadow over the material in general. But slate is still the best material there is for roofing. Barry James Hunt explains why.*

The pictures left show Welsh slate from Cwt-y-Bugail Slate Quarries. The finished work is at Ystad Castell Morfa, in Harlech, Gwynedd.

* Barry Hunt is a senior geologist and stone specialist with the STATS group of companies, based in St Albans, Herts, which undertake a wide range of materials and construction investigations. Hunt has an interest both in finding out what has gone wrong when a building material fails, and in analysing materials so that problems do not occur. Much of his own research has involved investigating the reactions between different construction materials which may lead to premature breakdown. He has been particularly involved in the investigation of the reasons for staining and discolouration of stone.

changing face of slate

DURING the boom of the 1980s sales of slate went through the roof with a fourfold increase in demand. Until then, the British market relied almost solely on British suppliers who maintained generally small but high quality operations. As demand increased so did imports.

Slate was brought into the UK from countries as far afield as China and Brazil, although the vast majority (two-thirds) was from Spain. Generally, these various imported slates were cheaper than, but exhibited the same properties as their British counterparts when tested to BS 680 and by the beginning of the '90s almost half the slate used in Britain was imported.

Now, reports of slate failures are setting alarm bells ringing. The subject of one of the first big reports was the new headquarters for assurance group Colonial Mutual at Chatham, Kent, where up to 50% of the Spanish slates failed.

The types of failure varied from delamination and cracking to discoloration, with the suggested cause being the oxidation of a pyritic component naturally present within the slate. The questions which needed to be answered were: how the slate made its way onto the roof without being identified as being potentially defective; and how many constructions now contained such materials.

Sorting the wheat from the chaff seemed almost impossible as the materials now found to be defective appeared identical to many other slates with unblemished service histories.

The reasons why similar looking slates may perform so differently either under test or in service are often related to subtle geological differences and the problems of classification which may alter between different countries. These problems may be compounded by general quarrying terms which can over-simplify generic rock terms.

True slate is a microgranular metamorphic rock formed from the low-grade metamorphism of very fine grained sedimentary rocks. Most such fine sedimentary rocks were originally mudstones, including siltstones and claystones, although the classification may also include sedimented volcanic ashes.

The rock components are subjected to heat and pressure and may recrystallise. Eventually, slates will comprise a mixture of silica (quartz) and phyllosilicates (micas and chlorites). The phyllosilicates are platey (flat) minerals which are often formed at 90 degrees to the direction of pressure. The phyllosilicates therefore obtain a common orientation (or preferred direction) giving a strong foliation. The pressure is released when the slate is exposed at, or is close to, the earth's surface, and it expands and parts along the weakest direction, which is the foliation direction, to give a cleavage. The parting is still tight and essentially very strong.

Subtle differences in the slates occur when the original sedimentary rock-type itself exhibits differences in both composition and size of the constituents which lead to compositional and textural differences in slates. Furthermore, apart from the basic silica and phyllosilicates, a variety of other trace materials, including graphite, pyrite and calcite, may be present.

Incompletely metamorphosed slates show evidence of the original bedding races which can be preserved as 'ribbons', or differently coloured streaks cutting across the primary cleavage planes. Such bedding planes may be both lines of weakness and areas of either greater hardness or softness when compared with the slate matrix.

Other differences in slate come from the presence of nodules. In many slates there are calcite and/or pyrite concentrations. Some slates may be subjected to a second cycle of metamorphism in a different direction and then a second cleavage is formed at a different angle from the first. The lesser of the two cleavage directions may thus be referred to as the secondary splitting direction, or grain.

Slates have been used in Britain for more than a thousand years, with large, commercial quarries operating since the industrial revolution.

With such a long history of quarrying, those slates with defects have been identified and quarrying of them has ceased, leaving a few select ▶

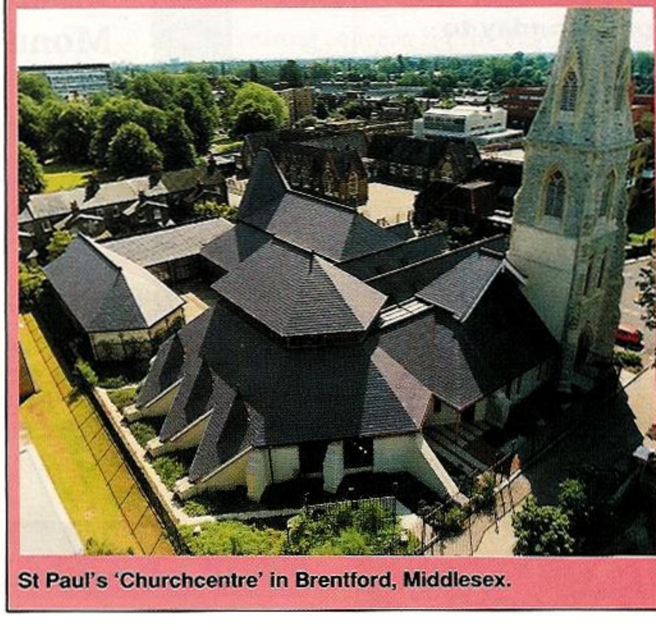
Slate spectacular on 'Churchcentre'

This is the latest in church worship. It is called a 'Churchcentre', where four churches in Brentford, Middlesex, have come together under one roof – and what a spectacular roof it is.

The original part of the building was a Gothic church, which has been substantially demolished and rebuilt, although the tower, a local landmark, was retained.

The Penrhyn roofing slate, from Alfred McAlpine Slate Products, was specified by architects Michael Blee Design of Lewes to complement the 56 different planes of the roof with their different pitches.

It was the expertise of Emerton Roofing (Western) Ltd, of Nantwich, which transferred the architect's designs into reality. Emerton Roofing were awarded a prestigious roofing award by the Worshipful Company of Tylers and Bricklayers for another project they had carried out.



St Paul's 'Churchcentre' in Brentford, Middlesex.

quarries to supply a high quality product.

Where slates are found to have been in existence somewhere for hundreds of years, inspection of such a location often highlights their slow deterioration. Usually minor spalling, loss of edges, delamination or partial discoloration of pyritic components may have taken place. Where pyrite has discoloured, this is often found to be a surface oxidation with fresh pyrite just below the surface.

Many imported slates come from quarries opened up in the past few years and do not have the experience of long exposure.

While old buildings roofed with slates from a local quarry may be put forward as shining examples of the quality of the material, ask yourself how the slates have been used; how thick they are; do they truly represent the currently quarried materials; how would they fare in a British location? This last question is the most difficult to answer, relying solely on tests and careful examination.

Although I have extolled the virtues of traditional supplies, don't forget that such supplies will alter with time due to the exposure of new materials and shifts in quarrying location. A simple change to a new quarry face may yield apparently similar slates to those previously quarried, but they might have intrinsically different properties. Often, a shift in quarrying to a higher level will mean working material that has been subjected to a greater degree of geological weathering.

With respect to the problems with Spanish slate, those which have been found to have deteriorated have been incompletely metamorphosed material, exhibiting distinctive bedding structures. Some deterioration in-service has been attributable to the attack of calcite inclusions by acids borne in rainwater.

A slate supplied from Mexico was reported to be mudstone, a rock with completely different properties from slate, which highlights the problems with classification.

Mudstone is a sedimentary rock comprising variable proportions of very fine clay and quartz and may or may not exhibit a fissility. It often splits erratically.

Some Italian slates, often referred to as Ardesia, are found to be slightly metamorphosed marls (metamorphosed mudstones containing a high proportion of calcite). On the other hand, the wide variety of often multi-coloured slate from India and China which looks quite unlike the uniform greys, greens and purples of British slates are often true slates, although others have been found to be quartzites.

Throughout the world there are recognised standards for the testing of roofing slates. The most recognisable standards are those originating from Britain, France, Germany and the United States, although countries such as Spain, which export large quantities of slate, do have their own standards.

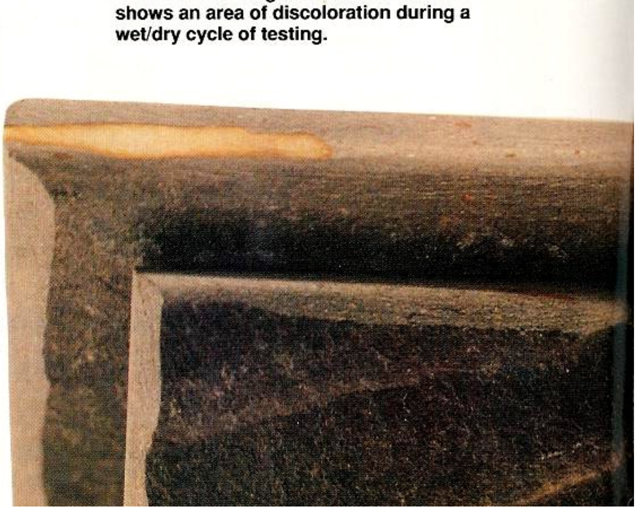
The specifications for slates used in Britain, whether supplied locally or imported, are limited, and to fully assess the potential performance of a given slate, tests used in other countries may be employed.

So why have some slates slipped the net and deteriorated in-service? From the various known tests standards it would appear that the tests carried out individually in different countries are inadequate to assess fully all the known or potential forms of deterioration. The various test methods employed in the UK, France, Germany and the US are summarised below.

BS8000:Part6:1990, Code of Practice for slating and tiling of roofs and claddings, refers to BS680:1971 which includes the only standard test available in Britain for slate roofing materials. BS680:1971 deals with size specifications and performance of slate in three tests: water absorption, cyclic wetting and drying and sulphuric acid immersion.

These tests were originally designed using quality Welsh slates and are relatively harsh – some well-known slates with excellent service records still ►

Some of the problems which can be encountered with slate. The picture at the top shows what happens when calcite inclusions burst as a result of mild acid attack. Above, the slate is showing signs of delamination as a result of acid immersion testing. And the slate below shows an area of discoloration during a wet/dry cycle of testing.



Burlington blue/grey and Westmorland green roofing slates form a distinctive and striking pattern on the Natural History Museum, London. The slate was supplied by Burlington Slate.

fail them. The Standard also stipulates that the grain should run longitudinally and not transversely as the waterproofing capabilities of the roof are less likely to be compromised if the slates split, which will typically occur along the grain if it does happen.

Advice on the selection of natural building stone is given in Building Research Establishment (BRE) Digest No 269, although it gives little further information concerning other slate features.

The French NF P 32-301 issued by AFNOR in August 1958 discusses the general characteristics of slate and specifies acceptance criteria for flatness, nodules, density, frost resistance, flexural strength (including loss of strength due to the effects of frost) and the presence of inclusions such as pyrite, calcite and iron oxide.

Both calcite and iron oxide are acceptable in minor proportions. Pyrite is not tolerated except where slates are to be laid with three thicknesses of full gauge and then only in a specific zone of the slate.

The Standard finally identifies a batch as compromising 5,000 slates and specifies that testing is to be carried out on every batch produced.

The German DIN 52 201, May 1985, Roof Slates, Terminology, Testing asks for a detailed petrographical examination and gives additional interpretation of the slate constituents with respect to potential strength and durability.

Other DIN tests include chemical analyses for annealing loss, carbon dioxide and combined sulphur, cyclical temperature and freeze-tha testing (to DIN 52 204 and DI 42 104 respectively), an acid te (DIN 52 206), the usual densi (DIN 52 102) and wat absorption (DIN 52 103).

The American ASTM C406-8 specification for slate roofir defines three grades of slate ar gives limits for water absorptio modulus of rupture, and weath resistance (ASTMs C121-9 C120-90 and C217-85). Th weather resistance test measur the depth of softening of sla when subjected to mild ac attack. It is also stipulated th slates should be free fro ribbons.

When you compare th different tests in differe countries it is evident that whi the British Standard tests a undoubtedly rigorous on certa physical and chemical characteristics, there are no criteria for any other features, such as the potential for pyritic oxidation or the character of slates. That is, is it a true slate and does it contain nodules, veins and other features which could lead to problems?

Both the German and French standards highlight problems with non-standard slate features but give little guidance about what can be done or any limits that could be applied.

Having compared the currently available tests for roofing slates and in the absence of one all-encompassing standard, I have produced my own suggestions for the assessment of roofing slate.

One final question remains: how good are the tests? The British Standard tests are rigorous, but why do some known quality slates still fail the water absorption criteria?

The water absorption rate is supposed to indicate the frost susceptibility of a slate. This was based on criteria devised in the past where it was found that those slates which appeared to be frost susceptible exhibited generally higher water absorptions.

It is now known that a high water absorption, although being a generally good guide, must not be taken alone as indicative of frost susceptibility, as this is also dependent upon factors such as pore and micropore size and distribution, the intercrystalline bonds and cleavage and other characteristics.

Furthermore, the water absorption test method itself has been shown to exhibit a high degree of relative error with corrections being required based on the different *adsorption* qualities (the level to which water clings to the surface) of the slates under test.

Similar, but often minor, problems are found with some of the other tests.

The proposed European CEN standards for roofing slate should eventually combine all the best aspects of the various tests. The standards should also give firm guidance as to their meaning.

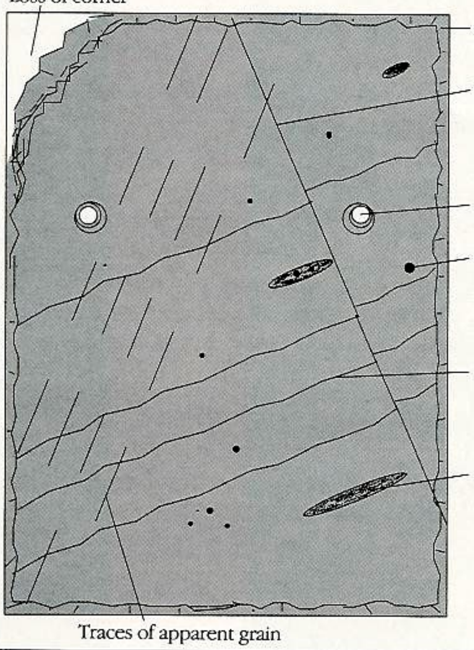
Presently, the proposed methods include water absorption, thermal cycling, a three point bend test, petrographical examination, flatness and dimensional stability, an optional freeze-thaw test depending on the water absorption results, and an exposure sulphate test. A draft for public comment is expected soon and hopefully the completed set of standards can be approved shortly thereafter.

But these tests alone, while being essential, may not accurately predict the performance of slate in-service. For this, proper geological consideration and the use of tests currently non-standard in this country are required.

It is hoped that the new European CEN standard will resolve the majority of the various test problems. However, until the procedure is available to all, the recent problems with the failure of slate roofs will not go away and may even increase. It is unlikely that the standards will be able to address problems such as discoloration and, again, specialist advice should be sought.

However, slate does not deserve the current stigma against it and should always be regarded as the first choice for any roof. □

General view of slate



Assessing roofing slate

In order to obtain the most appropriate information concerning the potential performance of a given slate and to ensure continued quality, the following procedures are recommended.

1. A professional geological appraisal of the quarrying location with selected slates being subjected to a full range of tests as outlined in items 4 to 10 below.
2. With continued quarrying operations the general quality of material should be monitored regularly, say every 5,000 slates as given in AFNOR NF P 32-301. The test regime for continual assessment would be as for items 4 to 6 below.
3. Where slate is imported or supplied from a source whose geology and overall quality is unknown or is unable to be easily obtained, it is suggested that a full range of tests is carried out, say every 50,000 slates.
4. A visual assessment of test samples should include notes on classification, grain, nodules, presence of potentially deleterious materials such as pyrite jointing, ribbons and any other physical characteristics.
5. Testing to BS680:1971. It is unwise to use slate with a water absorption rate over 1% and BS680 sets a 0.3% limit.
6. Slates either just passing or just failing the water absorption tests – ie falling between 0.5% and 0.8% – should be subjected to further cyclic, freeze-thaw testing. DIN 52 104, Method A and AFNOR NF P 32-301 are similar.
7. Petrographic examination, taking guidance from BS5930:1981 and ISRM Suggested Methods. This will enable a positive identification of the slate type and the presence of grain, any deleterious materials present, and the determination of microstructural defects.
8. ASTM C120-90 modulus of rupture (including modulus of elasticity) to determine bending strength. This test could be carried out on freeze-thaw tested specimens to look at the loss of strength.
9. Ad hoc chemical resistance to determine susceptibility of slate constituents to attack in a variety of different environments other than acid attack.
   - **a.** Lime water – pyrite reactivity
   - **b.** Metal alkalis (Na, K) – organic reactivity, potential for breakdown when subjected to cement-derived solutions.
10. Other testing and examination may include scanning electron microscopy (SEM), X-ray diffraction and X-ray fluorescence to look more closely at the slate constituents, their microstructure and other features. Wind tunnel testing may take place to look at the effectiveness of the fixing methods employed and the wind loading characteristics.