elevation

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Stone failure influences
Cladding surveys
Specifying galvanising

Taylor

natural stone

an appraisal of selection factors

Following the success of the society's first city walk in London 2007, the formula of social event preceded by some interesting lectures was followed. This time the theme was stone.

*Talks were given by ********** on **********, David Ellis of Sandberg talked about failure modes and influences on failure; then Tim Yates from BRE talked about **********.*

In this issue, David Ellis discussed stone failure in more detail.

The use of natural stone has increased at a phenomenal rate over the last decade due primarily to advances in cutting technology. The ability to cut large thin stone panels to high tolerances has allowed a much wider utilisation for external cladding and permitted architects to develop evermore innovative designs.

Advances in stone panel manufacture have also necessitated a much more detailed understanding of the behaviour and performance of stone as a construction material.

In the first instance stone is a natural material and not a manufactured product. As such, it has to be appreciated that its performance characteristics are dictated by subtle variations in structure and composition, all of which can affect design.

bedding and rift

One of the most important considerations is the orientation of bedding (layers in sedimentary rocks) or rift (mineralogical alignment in igneous or metamorphic rocks). This orientation within a cladding panel has a direct influence on stone strength in relation to wind load, fixing load support and restraint, and weathering durability.

Many stones are cut and sold in two directions by suppliers (natural bedded and face bedded) as different visual appearances can be achieved. It is therefore fundamental to understand the bedding or rift orientation of the stone to be supplied to a project in relation to test data, particularly when the stone is being supplied from overseas.

Figure 1 shows the bedding or rift in relation to origin in a block and subsequent usage in a cladding panel. It is typical UK practice to cut stone natural bedded, whilst in Europe typical practice is to cut face bedded.

test orientation

Once the stone cutting direction has been established, it is then paramount to determine whether supplied strength test data is applicable (i.e. has the stone been tested in the correct orientation in relation to the direction panels are to be cut for the project). Figure 2 shows how flexural strength test specimens are orientated and subsequently loaded in relation to bedding and rift. The two solid lines at the top of each specimen represent the upper rollers of a

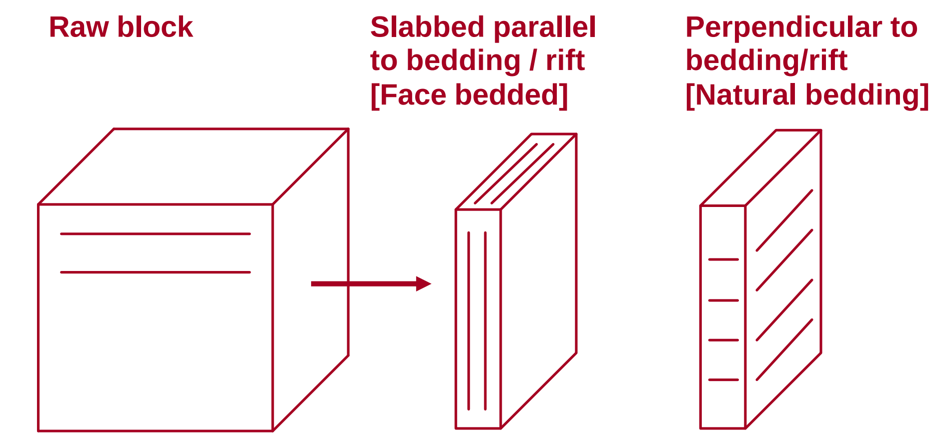


Figure 1 Bedding & rift orientation in relation to usage

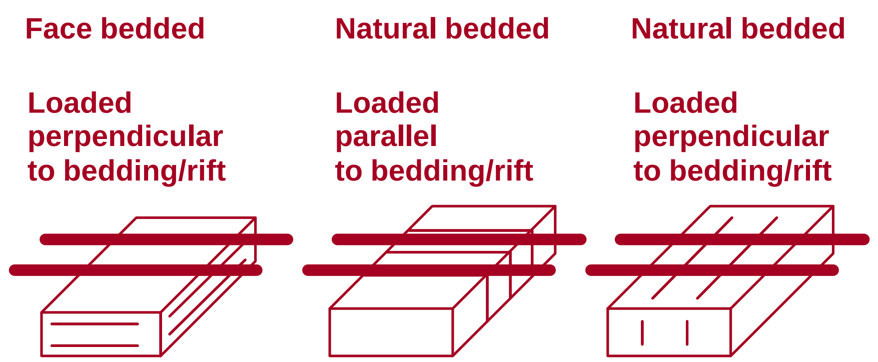


Figure 2 bedding and rift influence on

4-point flexural strength constant moment loading arrangement (BS EN 13161).

The same concerns arise with fixing tests. Figure 3 shows the importance of bedding and rift orientation in test specimens prepared for breaking load at dowel hole tests (BS EN 13364). The same considerations would be applicable to other fixing types, e.g. kerf / slot, undercut anchor.

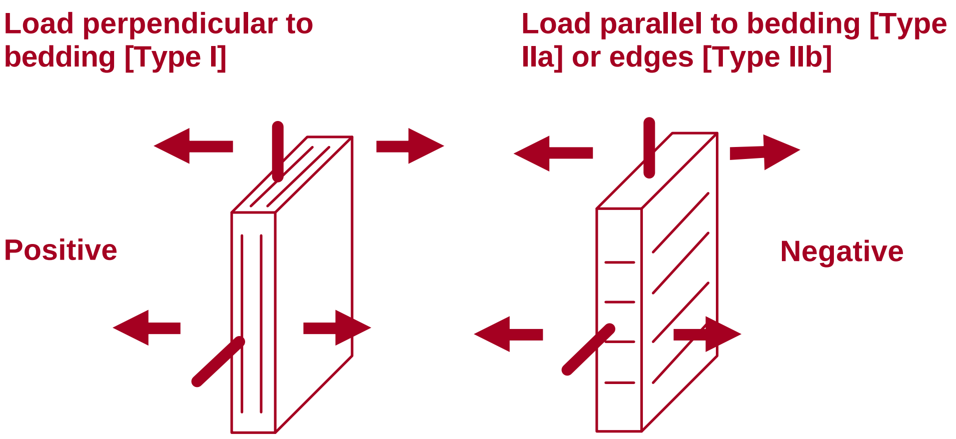


Figure 3 Breaking Load at Dowel Hole

test specimen condition

Current BS EN strength test methods (BS EN 12372 - Flexural strength under concentrated load, 3-point ; BS EN 13161 - Flexural strength under constant moment, 4-point ; BS EN 1926 - Compressive strength) only assess stone in an oven dried condition.

It is a well known fact in rock mechanics that stone strength can reduce from the dry to the saturated condition. For some rock types (e.g. granites) the loss can be negligible, however in some sedimentary rocks

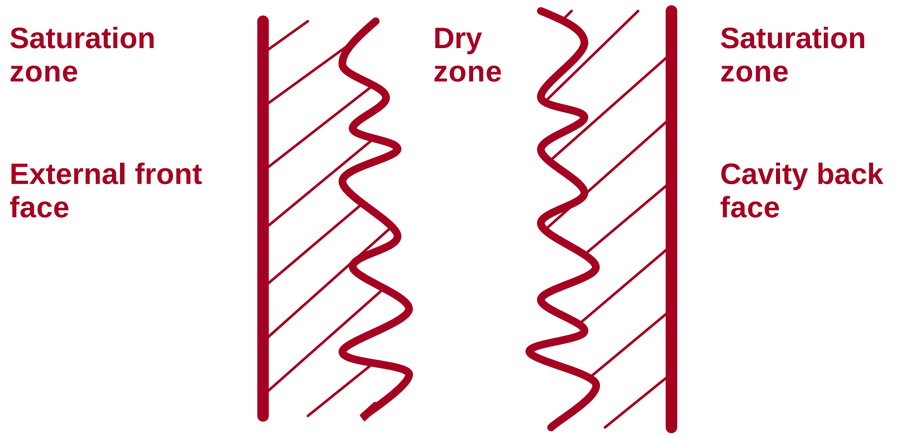


Figure 3 Strength difference: wet/dry

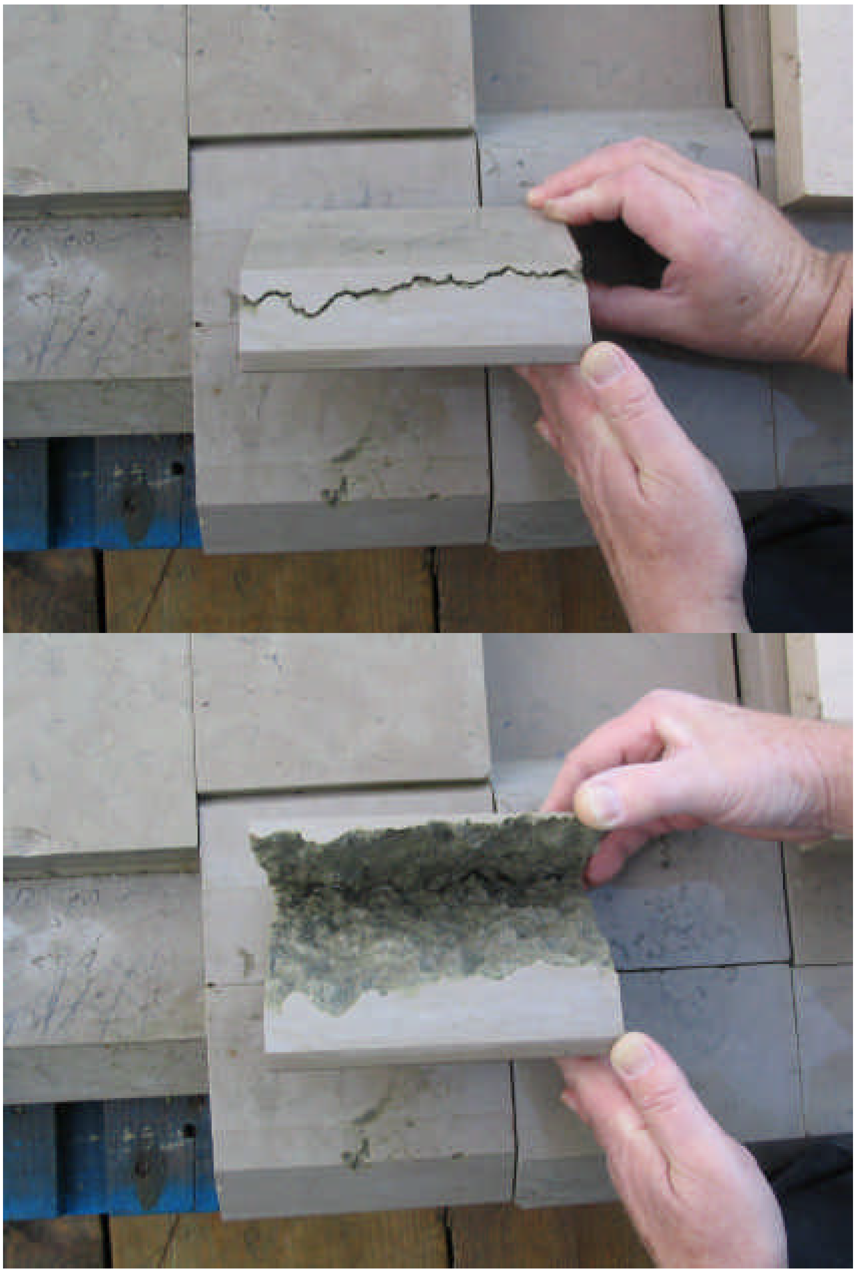


Figure 5 Stylolite failure plane

the strength reduction can reach 70% or more. Whilst it can be argued that it is unlikely that a stone will become fully saturated when used for an external envelope, it is not unreasonable to assume a moisture content approaching 50% when water saturation occurs at both the front and back surfaces of a cladding panel in a drained cavity, as shown in Figure 4.

It is therefore of paramount importance the facade engineer has a clear understanding, or seeks specialist advice, on how stone is cut and tested to ensure that any potential strength reduction is considered in the design calculations and associated factors of safety adjusted accordingly.

fabric of the material

The appraisal of natural stone for use in facades must consider the structure and fabric of the material, as many rock types have specific features that can impact on stone performance.

Some features are inherent and are related to origin or subsequent development over geological time, whilst others are introduced through extraction and secondary processing methods.

stylolites

These features occur in limestones and typically appear as irregular suture-like boundaries or 'zig-zag' lines in the face of a cladding panel, though it should be remembered that they can also occur in the plane of the panel (i.e. hidden) dependent upon whether the stone is cut natural bedded or face bedded. They are formed in a rock mass by pressure-controlled solution followed by immediate local redeposition.

Stylolites are important features since they contain detritus along the suture lines. In some cases the detritus is inert, forms a strong bond between the background rock mass either side, and is not a cause of concern. Sometimes however the suture line is composed of clay minerals which can have a significant effect on panel integrity and durability performance [figure 5].

Micro cracks and cracks

All granites are micro cracked, a fact that often surprises many engineers. This is an inherent feature related to their geological development and in the majority of cases is of no concern.

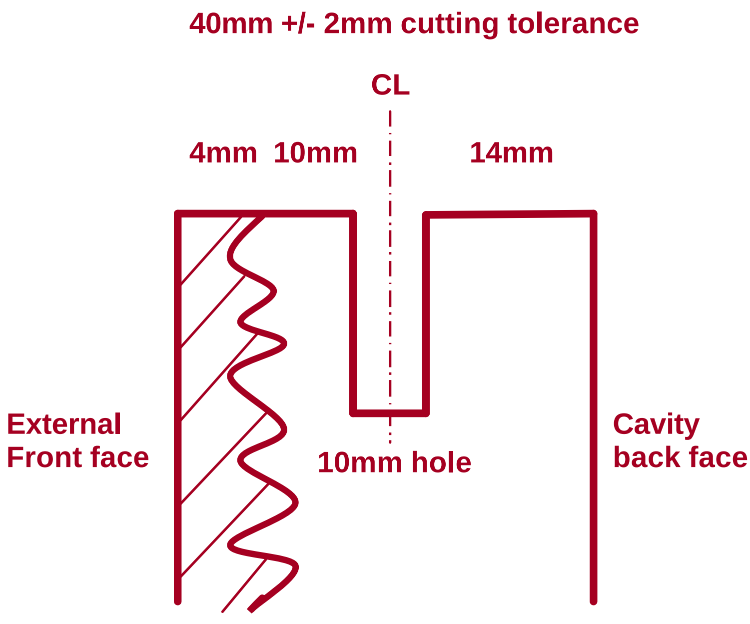


Figure 6 Thickness loss over fixing

Cracks (linear features that run say over 100mm and do not form part of the mineralogical background) are of greater significance however, since they impact immediately upon the integrity of a cladding panel. Cracks can occur naturally within the rock mass where they are often related to joint development or in-situ structural movement and are of critical concern.

Blasting is the principal mechanism whereby cracks are generated in to the rock mass. Whilst blasting is now very rarely utilised in the UK or Europe for dimension stone extraction, the practice is widely used in countries where more exotic stones are sourced (e.g. India, China, South America).

The presence of blast induced cracks can be easily verified using dye penetrant techniques.

It is also important to remember that cracks can be formed during stone processing. In particular, the use of percussion hammer drilling to form support or restraint fixing holes can cause significant damage to the stone and compromise stone performance under subsequent wind loading.

surface finishing

Flame texturing of granite is often undertaken in order to aesthetically enhance the surface of cladding panels.

This process is based on high temperature gas jets traveling over the stone surface that create a rapid thermal shock and shatter the near surface zone. Dependent upon the degree of application secondary micro cracks can be created that penetrate to considerable depth (e.g. 4mm).

Panel integrity can be significantly compromised where the effective stone thickness is reduced by up to 10%. Furthermore there is a significant effect in relation to stone thickness over fixing points under negative wind loading [Figure 6].

Next issue:
Marble and thin veneer panels

David Ellis is a chartered geologist and engineer

Natural bedded sandstone panels

Taylor

Cladding Inspections

A Primer for the Façade Engineer

by Phil King of Arup Facades

Background

Buildings were once built only from the materials that were locally available. More humble buildings were mud, thatch and timber; whilst churches, castles and rich merchant's houses might be stone from the local quarry. There were a few notable exceptions perhaps - Stonehenge where stones were rolled cross country - but generally local sources proved both practical and economic; and such things as building regulations and architectural awards had not yet come to the fore to precipitate wider choices of materials.

As transport developed from ox cart to canals, railways and into modern road haulage, the travelling distance of building materials increased. In parallel with this, advancing technology also changed the selection and performance of the building materials available. The result is that the buildings that we are asked to survey today might include historic stonework (the mud and timber ones having mostly fallen or burnt down) through to a vast range of 20th century materials from around the world.

Mistakes have always been made in the choice of materials. The older ones have long since failed (sometimes though the accompanying lessons are forgotten and the mistakes become repeated); the more recent mistakes are still there in our contemporary building stock. This may include such things as asbestos, structural use of high alumina cement, detailing without drips and movement joints, and inadequate cover to reinforcement in concrete. The list is a long and sorry one but it is core to our business.

A survey framework

It is of course impossible to cover within a short article, the full range of cladding systems and all the ills that can befall them. However, regardless of the cladding type and the purposes of the survey, the things a client asks us to find out often boil down to the same series of simple questions:

- What is it?
- What does it do?
- What condition is it in?
- How long will it last?
- How much will it cost to look after?

A checklist of information that needs to be gathered and symptoms to look out for, applicable to all sorts of cladding will be useful as a starting point for surveyors by providing a systematic framework for their visit to a building.

Any tool that helps gather the information must be worthwhile. The benefits will be more comprehensive reports for clients and reduced need to go back again to look at something that was forgotten first time around.

The approach

Information is collected by looking at the building, looking at its documentation and talking to people who know a bit about it. Begin by making long range visual inspections from pavement level. Look at whole elevations and take photographs of each for later reference. Is the building's form compact such that the floor area is contained within the minimum surface area of cladding? Whilst this conserves heat, it also reduces natural light penetration. Is the façade highly articulated?
Changes of direction, interfaces and special details are potentially more troublesome than the standard details of flat areas of cladding. Identify the different types of cladding and look for areas that warrant closer inspection. These might be selected for being typical or atypical, accessible or because something you see alerts you. The south west corner is often a good place to choose. In the UK this catches the prevailing wind, rain and sunshine.

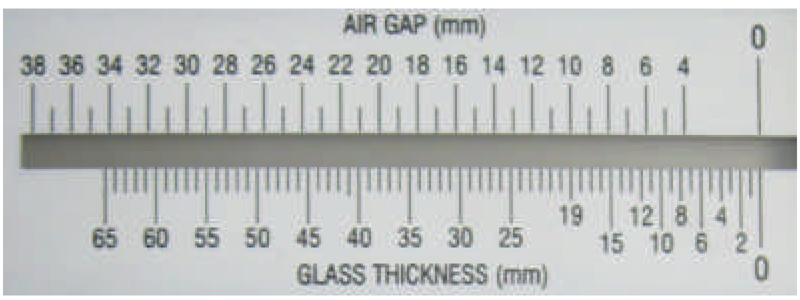
A chat to the building manager over a cup of tea usually comes next. What's the history of the building? What documents are available? Are there any leaks? Do people complain of frying in summer and freezing in winter? How often are the windows cleaned? Does the maintenance access system work? Has any glass ever broken, why and how was it replaced?

Document review must involve checking the lease to see what obligations it contains in relation to the cladding. Typically, there will be requirements for cleaning and maintaining elements and not causing nuisance or safety issues from bits dropping off. Whilst the precise wording is paramount, sometimes the spirit needs to be considered instead. Instances have been encountered of lease requirements to polish the brass, clean the stonework and repaint the timber windows for a building which was in fact clad with glass and aluminium! Some solicitors really should get out more and have a look at the building before drawing up leases!

Check the asbestos register and consider how this affects your inspections. The other obvious documentation is the O&M manual if this exists. Sometimes it turns out to be just a dusty cardboard box in the basement full of jumbled M&E drawings, trade literature and invoices for bulk supply of toilet paper from 1987. Persevere though; it can be worthwhile, yielding cladding drawings, specifications, warranties, and maintenance, repair and alteration records. Buried treasure!

A walk around a typical floor will reveal whether the glazing is single or double glazed, toughened, filmed or laminated. Pocket laser gauges such as those available from Merlin, can measure the glass thick-

Merlin glass measuring device



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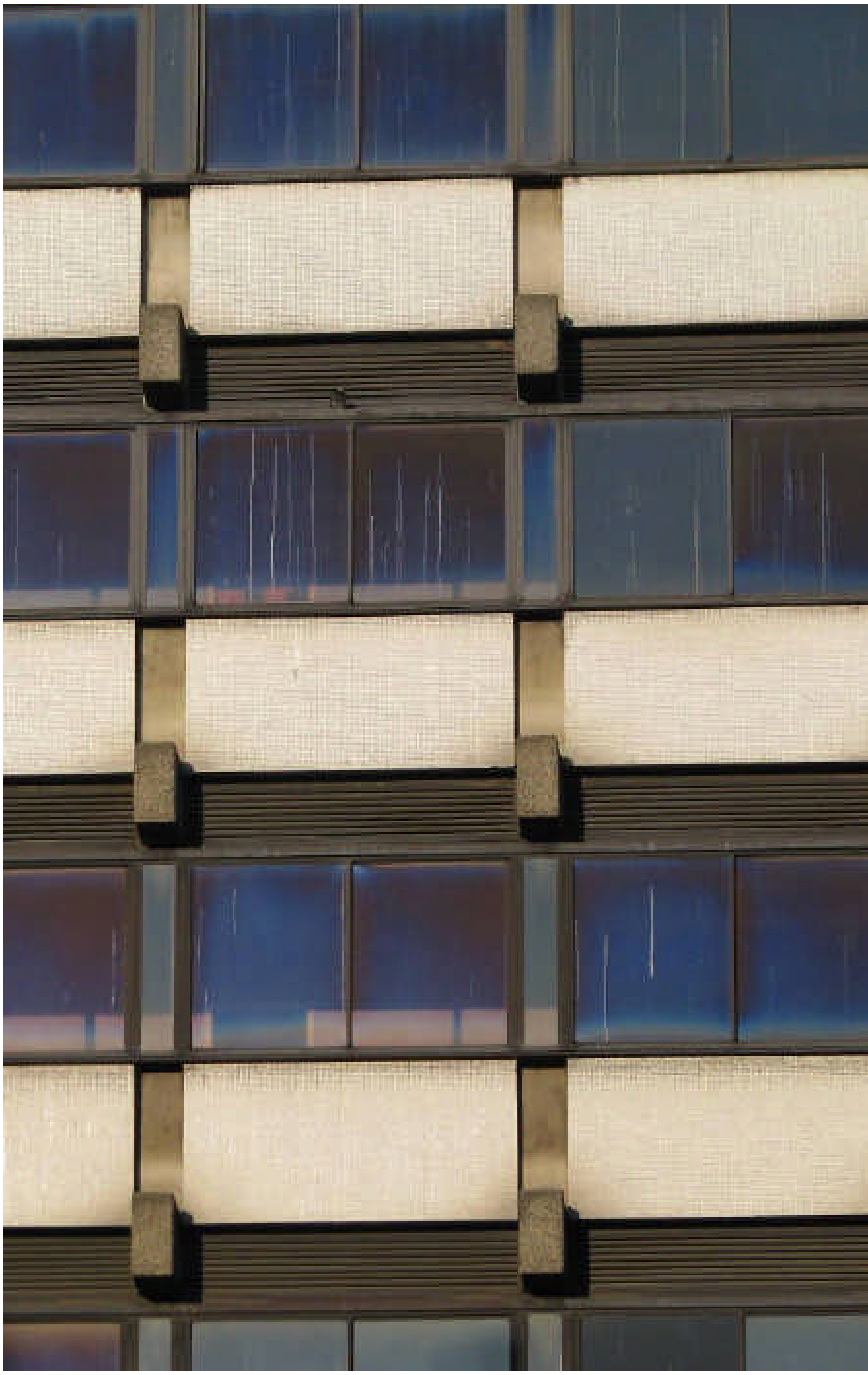
nesses and air gap width with access from inside the building only. Record whether the glazing can be replaced from inside or outside.

Look for ceiling tiles stained by water penetration, draughts or obtrusive traffic noise break-in. Look through the windows onto any adjacent cladding you can see. Try opening a few windows (carefully, in case their hinges are broken) and assess the condition of ironmongery, reach distance and operating force. Check for window cleaners' eye bolts. Have a look into the ceiling void, behind perimeter trunking and under raised floors for cladding anchor brackets, fire stopping or any signs of leakage. Observe clues such as whether occupants use the window ledges for storing things without fear of them getting wet and listen to what they might want to tell you. Some occupants will explain in great detail everything they know about the cladding (and lots more!).

The next stage is to inspect the selected areas close up from outside. This can also explore whether access is provided that reaches all parts. Inspection may be possible from a terrace or by dangling in a cradle or cherry picker. At this stage the integrity of the cladding and the condition of finishes should be assessed. What to look for during this external inspection will depend upon the type of cladding one is dealing with: provision for movement, glass type, stone fixings, wind loads leaky details, nickel sulphide, concrete spalling, finishes breakdown, brickwork movement, gaskets and sealants and so on. These cannot be covered briefly so they will have to wait for another time…

Conclusion

In conclusion, the observations made and information gathered still need interpretation before a report can be written to answer the client's questions listed earlier. We are not attempting to cover interpretation within this short article. Detective work and reference to specialist knowledge will still be required to produce the final report on the cladding.



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Blooms in the glass coatings of a tired old facade

Diary

9 February 2009
SFE Middle East Conference
LeMeridian Airport Hotel, Dubai

5 March 2009
SFE Annual General Meeting
RIBA Portland Place, London

25 June 2009
SFE City Walk
Commencing Euston, London

18-21 October 2009
Glassex and Interbuild
NEC, Birmingham

Feedback

Please submit comments, articles, case studies, technical features, diary dates, or any other newsworthy items to the editor, Mark Taylor at :
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www.facadeengineeringsociety.org

Hot Dip Galvanising

Using the ISO standards for specifying coatings

The European and international standard covering hot dip galvanising is EN ISO 1461 – ‘Hot dip galvanized coatings on iron and steel articles - specifications and test methods’.

A specification can be set out as a visual and performance standard, where the look and the minimum performance the coating must achieve is laid out; or a prescriptive specification, where the means to achieve the desired criteria is specified. Most of ISO 1461 is set out descriptively, i.e. laying down basic standards of quality, coating type, purity of the zinc, thickness, inspection and testing criteria.

It also sets out information to be provided by the specifier to the glavaniser, including information about the base metal, special requirements of coating thicknesses, details of areas requiring higher quality for connections, and after treatments such as painting or powder coating. The standard defines basic visual acceptance criteria of the finish, but the specifier can embellish with further requirements. For instance, one basic requirement is for the surface to be smooth. Smoothness is a relative term and the specifier should not expect the same quality of smoothness as mechanically wiped articles, such as sheet, tube or wire. The chemistry of the steel is the main influence on both coating thickness and appearance. The galvanizer may add several different additives to their galvanizing bath to enhance the coating appearance by making it shiny, spangled or minimizing the reactivity of certain steel chemistries.

Storage stain, white areas of zinc oxide and zinc hydroxide corrosion products that go on to become stable zinc carbonate, caused by close storage or wrapping, are not considered criteria for rejection by the standard, providing the coating thickness is meets acceptance criteria. Wet storage stain can be usually be removed with a nylon brush, but the specifier may pronounce this to be a rejection criteria if the finish on the item is to achieve a particularly high standard.

Interestingly, adhesion performance is not covered, as it is inherent in the process. Zinc/iron alloy layers form between the two metals. These layers are inherently tough, in some cases harder than the steel upon which they are formed.

Of prime importance is the coating thickness, which ranges from 35/45μm (minimum local thickness/minimum mean thickness) for steel <1.5mm thick to 70/85μm for steel =6mm thick. Thickness is ensured by agreement of references areas and defined tests.

Limits are placed upon uncoated areas and renovation by zinc thermal spaying is defined, but the specifier can again, define specific means of repair or improvement. Perhaps the most vital piece of information to communicate in the specification is the required design life of the component. The galvaniser can turn to the more prescriptive guidance on the use and performance of hot dip galvanizing contained in EN ISO 14713 - 'Protection against corrosion of iron and steel in structures - zinc and aluminium coatings - guidelines'. This contains tables coating thicknesses required to achieve various ‘Life to first maintenance’ times for several metal protection systems used in a variety of environments. Specifiers of projects in the UK can use more accurate data provided by the Millenium Map available from the Galvanisers Association

Hot dip galvanised components will fare better than paint only ones in this marine proximity facade

Taylor