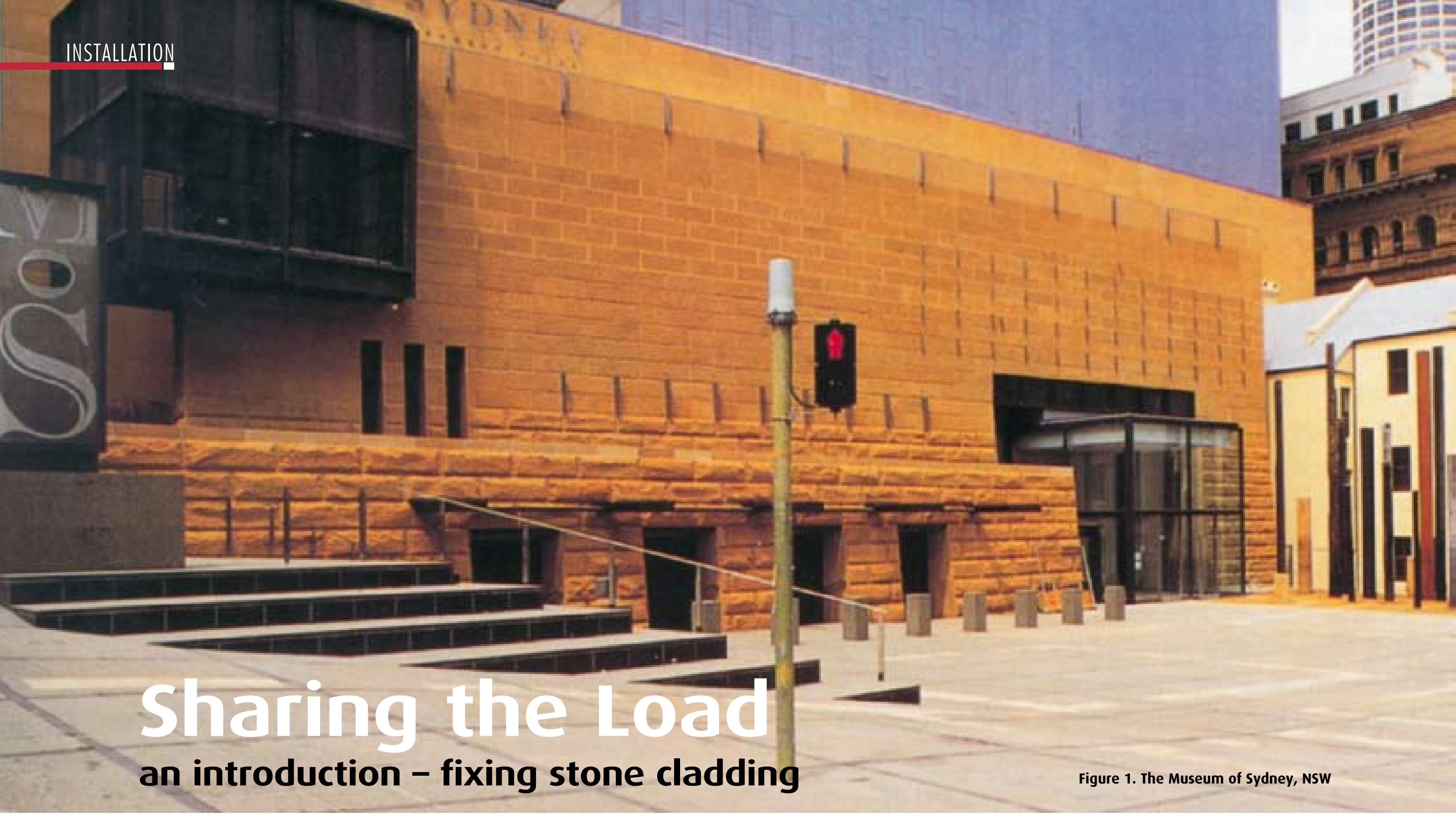

Sharing the Load

an introduction – fixing stone cladding

Figure 1. The Museum of Sydney, NSW

by David West and Pein Lee

This article provides an introduction to the fixing of stone cladding. It is intended to provide an overview of the different ways of fixing stone cladding to buildings. It is not a comprehensive 'how-to' manual – although we propose to take a more detailed look at some of the most important methods of fixing stone cladding in future issues.

Transferring Loads

Before we look at ways of fixing, we need to discuss briefly the primary factors acting on the stone cladding and its fixings.

The fundamental question when we fix stone is how we transfer loads back down to the ground. There are many loads to be considered, but in essence, the main ones are as follows:

1. **Gravity (dead load)** – the self-weight of the stone unit – and the potential for it to drop to the ground.
2. **Wind** – the changes in air pressure around the building – and the potential for the stone unit to be pulled off the building.
3. **Earthquake** – the movement of the ground beneath the building – and the potential for these vibrations to shake the stone unit off the building.
4. **Temperature** – the changes in dimension of the stone unit with changes in temperature – and the potential for these changes in dimension to generate localised pressure on the stone units
5. **Impact** – contact between people or vehicles and the stone cladding – and the potential for damage or displacement as a result.
6. **Movement** – differential change in dimension between the structure and the cladding – and the potential for these changes in dimension to generate localised pressure on the stone units

Of these loads, we generally manage to select fixings and install the stone cladding to accommodate the gravity (dead) and wind loads satisfactorily. Because earthquakes are an infrequent occurrence in Australia, and the magnitude of loads arising from earthquakes in Australia are comparatively low, satisfactory design for wind load will usually mean that the fixings are capable of resisting the earthquake loads.

Most failures we have seen involving stone cladding have arisen from temperature or other movement causing localised pressure on the stone units. This can then cause the fixings to fail, or the stone panels to fail at the connection point (anchorage) with the fixing.

In summary then, the three critical loads that must be considered in the fixing of stone cladding in Australia are:

- dead loads
- wind loads
- movement loads

Fixing Methods

We can look at methods of fixing stone cladding with regard to a number of different aspects. We can consider the substrate to which the stone units are attached; we can look at the type of fixing that is used, and how it connects into the stone unit; or we can consider the manner in which the fixing system accommodates the loads discussed above. As each aspect will tend to favour different methods of fixing, we've tried to combine these aspects in the following summary of stone fixing methods.

Self-supported Ashlar

When the individual stone units are stacked one on top of another, so that their own weight is transferred down to the ground through the stone units below, we say that the wall is self-supporting. Typically, this method of installation requires thicker units of stone, such as ashlar blocks of sandstone or limestone. Such walls are capable of standing without any other form of fixing, but in that case, will have little resistance to wind and earthquake loads. Consequently, Australian standards require that self-supporting ashlar walls have lateral fixings to provide support against wind and earthquake loads. These lateral fixings can take many forms, from simple brick ties, to a range of other embedded metal cramps, dowels, or pins. In traditional construction, lateral restraint was sometimes provided through interlocking construction with a brick back-up wall.

This method of fixing is common in buildings of the early 20th Century, and in domestic construction. It is sometimes still used on larger buildings, as in the sandstone walls to the Museum of Sydney built in the mid 1990s (Figure 1.).

This method is limited by the requirement to transfer dead loads down through the stone cladding, which means that movement loads are not readily accommodated. This means that large areas, and in particular, tall facades, are not suitable for this method. Buildings with varying structural systems and substrates are also less suited to the use of self-supported ashlar.

Mortar Spots And Wire Ties
As stone units used in cladding became thinner, internal stone fixing techniques using plaster spots and wire ties moved out into the weather, and mortar spots (or pads) and wire ties were used to fix stone cladding. In this instance, the stone units were still stacked, so that the dead load was taken back down to the ground. However, the thin stone units were unstable without lateral support, so that they were packed out from the wall behind using mortar spots or pads, and tied back to the wall behind using copper wire ties.

This method of fixing is often found on buildings from the mid 20th Century, although a modified version of it became popular during the 1980s and 1990s using epoxy adhesives instead of the mortar, and stainless steel wire instead of copper.

This method is also limited by the requirement to transfer dead loads down through the stone cladding. It is really only appropriate for small areas of cladding on simple buildings.

Shelf Angles And Cramps
The introduction of steel shelf angles to support the dead load of the stone units allowed stone cladding to be fixed to much larger areas of wall. In many ways, the shelf angle became a 'false ground', and so this is a refinement of the two systems described above. Provided that the shelf angle was strong enough to carry the load of the stone above, this system allowed the use of either of the systems above on much larger areas of wall. However, it was still constrained by the inability to accommodate movement, and despite the use of movement joints at shelf angle locations, many stone cladding failures have occurred with these systems.

Mechanical Fixing
The ultimate refinement of these fixing systems was to support each individual stone unit with its own shelf angle and cramp arrangement. Initially, these were distinct fixing types, and each stone panel had two shelf angles toward the base of the panel, and several cramp fixings to provide lateral support. However, refinement to simplify the fixing process led to the design of fixings that were able to provide a combination of dead load support and lateral restraint through the one component. These are commonly known as fixing brackets. In the simplest form, these can be rods or small angles through which a pin or dowel is placed at the end. The stone unit sits on the rod or angle, and is restrained by the pin or dowel being placed in a hole or slot in the side of the stone unit. There are, however, hundreds of different variations on these mechanical fixing brackets – in fact, almost as many variations as there are buildings using stone cladding!

An advantage of this system is that the fixing brackets can be placed in the joints between stone units and provide support to two adjoining panels.

Accommodation of movement still remains critical with this system, and unfortunately, this is often not understood by the installers of stone cladding using mechanical fixing systems. It is important that there is movement capacity in a vertical direction between the underside of a fixing bracket and the top of the panel below. This doesn't just mean a gap – it means that the fixing pin or dowel must be able to slide in and out of the hole or slot in the top of the stone below. It is also important that there is movement capacity in a

Mechanical fixing, Exchange Centre, Sydney, NSW

horizontal direction between adjoining panels, especially where there is a long run (greater than 3-4 metres).

This brings us to the great dilemma of stone fixing – whilst the installers use epoxy adhesives at the fixing locations to ensure that the front face of the stone units stays flush and aligned, and the stone units stay in the correct position, this means that the stone units are locked together and unable to move. There have been many attempts to get around this dilemma – we've seen or heard of systems that use:

- sleeves on the pins or dowels
- greased pins or dowels
- sealant in lieu of adhesive
- loose pins or dowels
- adjustable brackets

These all work – the biggest problem is the perception that they cost more money and take longer to install. We'd like to challenge that perception – would anybody like to discuss this with us further?

Precast Cladding
Another approach to fixing stone cladding that developed during the 1960s is the composite construction of precast concrete units faced with stone panels. These are manufactured by placing the stone units face down in the moulds, and pouring the concrete on top of them. Of course the reinforcement cages and fixings for the stone panels need to be put in place before the concrete is poured.

Fixings for stone-faced precast are typically angled dowels or pins set into holes drilled in the rear face of the stone units. In order to provide interlock with the concrete behind, these may be spring or butterfly shaped clips, which may or may not be tied to reinforcing members. A key component of this system is the provision of differential movement capacity between the precast concrete unit and the stone unit. Recommended practice involves the use of a slip membrane, and compressible sleeves around the pins or dowels into the stone unit.

This approach is generally adopted where the construction approach has identified benefits in the use of precast concrete cladding on the building, rather than as a design solution for the fixing of stone cladding.

Strongback Truss
During the 1980s, as thin granite cladding suddenly became the façade of choice for most architects, new methods of fixing stone were developed. One such new system was the strongback, or truss. Here, stone units were fixed to a steel truss which was then hoisted into position onto the side of the building. In essence, very similar to a steel version of a precast concrete cladding panel, these strongbacks could be larger and comparatively lighter.

The fixing brackets used with this system must not only accommodate the basic loads, but they must also be able to accommodate the loads arising during transport and erection on the building of the strongback truss.

Curtain Wall Systems
By far the most common way of installing stone panels on tall buildings in Australia now is the incorporation of the stone unit into an aluminium curtain wall system. In this situation, the stone panel is treated in a similar way to a pane of glass or a sheet of aluminium, and installed into an aluminium framed panel in the factory for later erection on site.

In this situation, the stone is usually restrained by aluminium extrusions set into slots cut on two edges of the stone unit, although the use of structural silicone has occurred on a small number of buildings. Concern on the part of certifying authorities about the long-term performance of structural silicone has meant however that all stone panels are mechanically restrained as well.

Ventilated Cladding Systems
A development in Europe that has really only been used here for a small number of ceramic unit clad buildings is the ventilated cladding system. In this case, fixings are set into the rear face of the stone panel, usually using an undercut fixing type, and a clip attached. The panels, with clips, are then hung onto a lightweight metal framing system on the face of the building, and the joints left open.

This approach offers many benefits, in that the connections between the fixings and the stone panel are amongst the strongest possible, and each panel is 'hung' independently from the sub-framing. It does require, however, that the sub-framing is fixed very accurately, as the alignment of the stone panels is dependent on the alignment of the sub-framing.

Lightweight Panels
In order to avoid the issues associated with the weight of stone panels, a number of lightweight panel systems have been developed, typically using an aluminium honeycomb backing adhered to the rear of a very thin (<10mm) sheet of stone. These panels can then be fixed to the building in a number of ways.

Whilst there are enormous benefits in using lightweight panels in lift cars and on ships, concerns over the long-term durability of such systems have meant that they have not been widely adopted for external cladding.

The fixing of the stone in lightweight panels is essentially adhesive – and this is discussed further below.

Adhesive
The use of adhesives for installation of stone units is widespread. The most common application is the installation of stone tiles using tile adhesive systems, usually latex-modified cementitious adhesives. The use of filled epoxy adhesives is also common, particularly for smaller units and smaller-scale installations.

Adhesive fixing of stone relies on the bond – typically a mechanical bond rather than a chemical bond – between the rear face of the stone and the adhesive, and between the adhesive and the substrate. Key factors in the strength of this bond include the surface texture of the stone, absence of dust or surface films, and the type of adhesive used.


Strongback truss, Federation Square, Melbourne VIC.


Ventilated cladding systmes are proving very successful in many markets.

Theoretically, adhesive systems can be proven to work for the fixing of stone cladding. In practice however, there are so many factors that can affect the strength of the adhesive fixing that the risk of failure is substantially greater than for mechanical fixing systems. Consequently, specifiers and designers are reluctant to use adhesive fixing systems.

There is also concern about the long-term durability of adhesive fixing systems, and as most of the adhesives in the market have less than 30 years demonstrated performance, this is difficult to resolve.

Summary
There are many ways to fix stone cladding. Different methods are suitable for different situations. The following table summarises the general suitability of each of the methods described above for three common external cladding situations:

Fixing System	Single-storey construction	Low-rise (up to 4 storeys)	High-rise
Self-supported ashlar	√√√	√	X
Mortar spots and wire ties	√	√	X
Shelf angles and cramps	√	√	X
Mechanical fixing	√√√	√√√	√√√
Precast concrete cladding	X	√	√√√
Strongback truss	X	√	√√√
Curtain wall	X	√	√√√
Ventilated cladding	√	√√√	√√√
Lightweight panels	√	√	X
Adhesive	√	X	X

X – not suitable; √ – can be used, with care; √√√ – suitable

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