**INTRODUCTION**
The function of mortar in masonry walls is to bond the individual bricks or blocks together to form a single element to:

- resist movement and stress; and
- (in external walls) provide a weatherproof barrier.

The bond between the mortar and the masonry units is one of the most important properties of masonry construction, particularly when it is non-loadbearing such as in low-rise buildings.

Most masonry walls are at times subject to forces such as raking from wind, minor settlement of foundations and, in some instances, more-severe forces resulting from earthquakes. It is the development of tensile strength (ie the ability to resist elongation) that is crucial, and that makes bond strength a priority in masonry construction.

Weak mortar (ie inappropriate mixes or diluted mixes with excessive water) with a lower than desired bond strength will inevitably lead to cracking in masonry construction. Such failure limits the ability for the redistribution of stresses, thereby increasing the possibility of major failure once severe or extreme forces are encountered.

Effective bond strength will enable the mortar to accommodate thermal changes (expansion and/or contraction of units) and to minimise any penetration of water into a building and/or permeation toward structural building elements susceptible to damage by water.

**THE BOND** between the mortar and the masonry units is one of the most important properties of masonry construction.
This datasheet draws on recent research by the University of Newcastle and the CSIRO (partly funded by the Cement and Concrete Association of Australia) to determine the main factors influencing masonry bond strength. This research project incorporated:

- an Australia-wide survey of site practices;
- testing of various types of bricks [clay, concrete and calcium silicate] and mortar composition;
- a study of the mechanism of bond-strength development.

The research findings are outlined on the following pages.

In all aspects of building construction, the outcome is influenced both by the materials used and the workmanship. The main points to note when undertaking masonry construction are:

**DOs**
- Match mortar to the masonry units
- Use adequate cement content
- Use lime as appropriate
- Use clean sand
- Batch mortar accurately
- Mix mortar for at least six minutes.

**DO NOTs**
- Do not overdose with air entrainer
- Do not use detergent
- Do not use a shovel to measure mortar ingredients
- Do not place long runs of bed mortar
- Do not rework stiff mortar into the mix
- Do not pre-wet masonry units.

(See Practical Considerations for amplification of these points)

**RESEARCH FINDINGS**

The research project referred to overleaf revealed that the effect of the major factors on mortar bond strength are:

**Masonry Units** In Australia, masonry units are made from clay, concrete or calcium silicate. Typically, the only property defined by the manufacturer is compressive strength, which has no bearing on the bonding properties of masonry. Surface characteristics and suction are the most important properties in determining bond capability. The three basic masonry material types differ in their surface characteristics, pore structure and suction properties, and it could therefore be expected that different mortars would be required for the development of optimum bond strength. The Australian Standard AS 3700 Masonry Structures provides different deemed-to-satisfy mortar mixes for each masonry type, but does not recommend specific mixes as optimum, nor does it recommend the mortar strength for use with various types of units.

The research quantified the differences in bond strengths achieved with various mortar/masonry unit combinations. As can be seen in Figure 1, higher bond strengths were achieved with clay bricks than with concrete or calcium silicate bricks, while pressed clay bricks performed better than extruded clay bricks. (Note that the reason for the presence of holes in extruded clay bricks is often assumed to be to produce an interlocking action with the mortar, whereas it is purely a manufacturing consideration.)

![Figure 1: Mix and masonry unit effect on 7-day flexural bond strength](image)

**Mortar Mix** The primary mechanism for the development of bond strength is cement hydration (the chemical action initiated when water is added to cement). High cement-content mortars are thus beneficial, as shown by the research in which a considerably higher bond strength was achieved using a 1:1/4:3 (cement:lime:sand) mortar than when using a 1:1:6 mortar.

The use of lime in mortar mixes (particularly for clay brickwork) was established as being beneficial in that it improves the plasticity of the mortar. The recommended mixes are 1:1:6 for general purpose work, 1:1/4:3 for high-strength work and 1:2:9 for small structures.
The surveys (carried out as part of the research) revealed a wide range of mixes to be in common use for all types of masonry units, with no clear pattern of consistency within or between States. The recommendations in various manuals and codes of practice published over the last twenty years were either unknown or largely ignored. In particular, there was much less use of lime than expected and little understanding of the best mixes for use with concrete and calcium silicate units. (The best mixes for use with these have consistently been shown to be those using clean, sharp, well-graded sand with no clay content and incorporating a water thickener.)

The survey also showed that it is common for builders to use an identical mortar for laying both clay and concrete units, despite the clear evidence that tailoring the mix to the specific type of unit enhances bond strength.

Sand  The research showed that the movement of fine particles [cementitious components and fine sand] towards the brick/mortar interface while the mortar is still fluid is extremely important in developing bond between the mortar and the masonry units.

Sand should be clean and free of clay content. Clay or ‘fire-clay’ should not be added to the sand as this markedly reduces bond strength.

The proportion of fine particles should be towards the upper limit of 10% often recommended, while the proportion of coarse particles should not exceed 1%. It is recommended that the maximum difference between the amount passing any two successive sieves be 50%, and that the difference between the amount passing the 150-µm and 300-µm sieves not exceed 25%.

Cement  The tests on the three types of bricks using three cement types (portland and fly-ash and slag blends) showed that the cement type had less impact on bond strength than did the brick type and the mortar mix. Adequate bond strengths were achieved with each cement type.

Admixtures  The survey showed that the use of air entrainer is widespread and that detergent is the next most common workability enhancer, despite the fact that AS 3700 prohibits its use. The tests revealed the need for the use of air-entraining admixtures to be carefully controlled, since overdosing severely reduces the bond strength achieved. For at least twenty years, the use of water thickener to enhance bond strength with concrete and calcium silicate units has been recommended. With particular types of sand, they can also enhance bond strength in clay brickwork. The survey revealed, however, that water thickeners are used only in NSW and Queensland, and even then to only a limited extent.

Curing  As is the case with concrete, mortar benefits significantly from being properly cured (ie the rate of moisture loss restricted) for some days after placing. Curing (eg by covering the wall with a plastic sheet) not only improves bond strength but also limits the incidence of micro cracking, improving the watertightness of both the mortar and the masonry structure as a whole.

Workmanship  Several aspects of workmanship have been identified as contributing to poor performance of masonry structures. Lack of attention to gauging mixes in correct proportions, the incorrect addition of air entrainers and the preparation of units for laying were all recognised as major contributing factors to reduced bond strength. Practices such as pre-wetting of concrete and calcium silicate units were found only to promote excessive shrinkage, efflorescence and inevitably reduce bond strength. To control high suction it is preferable for a water thickener to be included in the mortar. Most importantly, the mortar should be matched to the suction of the units, by means such as the addition of lime to the mix.

PRACTICAL CONSIDERATIONS  

Materials

■ Bricklayers should ensure that the mortar composition matches the masonry units. Factors to be considered include type of units and their suction characteristics, sand grading, inclusion of lime and the use of admixtures.

■ Water-thickening admixtures should be used where appropriate, eg in mortar for concrete units.

■ When using air-entraining admixtures, the manufacturer’s recommendations should be followed. In particular, overdosing should be avoided since it reduces bond strength.

■ Detergents, drinks, sugars and the like must not be used to improve workability as they destroy bond strength. (They are specifically banned by the Australian Standard AS 3700.)

■ Lime contributes to the volume of fines in the mortar, thus enhancing workability and cohesion and promoting adhesion at the mortar/masonry interface.

■ Only clean, sharp sand free of clay should be used. Clay (fire clay) should not be added to the sand or to the mortar as this reduces bond strength.
The simplest way to batch mortar accurately is to use a mixer of known volume. After placing into it the required volume of cement and lime (i.e., a certain number of bags), it can then be filled with sand and a suitable quantity of water. The amount of water can be dictated by workability requirements since—up to this amount—it is beneficial to bond strength.

A minimum mixing time of six minutes is recommended—strength and colour variations may result from shorter mixing times. While there is no recommended maximum, it is particularly important that mortars containing air-entraining admixtures not be over-mixed if excessive air-entrainment and subsequent very low bond strength are to be avoided.

Poor construction practices such as incomplete filling of joints, and laying pressed bricks with the frog down adversely affect bond strength.

Placing too great a length of mortar in a course before placing the bricks on it results in the loss of too much moisture to the lower course and consequently weakens the bond to the upper course.

Dampening or wetting of units prior to laying reduces the suction of the unit and leads to poor bond—it is preferable to proportion the mortar to match the suction characteristics of the units.

Any disturbance of the units more than a few seconds after placement should be avoided. Such movement causes a rounding of the upper surface of the mortar bed thus prejudicing the bond at the interface adjacent to one or both faces of the unit—the most critical areas under out-of-plane bending forces.

**IMPORTANT SAFETY INFORMATION**

When handling and using cement or fresh concrete, avoid skin contact. Wear suitable protective clothing.