Chemical analysis of stucco plaster

Determining the composition of a stucco plaster can be useful when investigating cladding failure. However, recent BRANZ research shows that reliable results require more than simple chemical analysis.

By Neil Lee, BRANZ Concrete Scientist

When evaluating the causes of a stucco cladding failure, suspicion often falls on the mix composition of the plaster. A plaster with too little binder can be too weak to withstand wind and impact loads, while a plaster with too much will be highly mobilised and subject to shrinkage cracking.

In legal disputes the plaster's compliance with NZS 4251.1: 1998 *Solid plastering,* which is called up in the New Zealand Building Code as an Acceptable Solution for Clauses B1 *Structure,* B2 *Durability*, E2 *External moisture* and E3 *Internal moisture,* is often investigated. Table 3 of NZS 4251.1 specifies appropriate mix compositions, batched by volume. For the scratch and flanking coats of a stucco plaster, this is typically one part Portland cement, one part hydrated lime and six parts sand, with a slightly stronger mix permitted for the thin finish coat.

Tests determine composition

In principle, analysing a sample of hardened stucco plaster to determine its original batch proportions is fairly simple. The chemical make-up of Portland cement and hydrated lime can be considered approximately constant (see Table 1), or can be determined from manufacturer's records when ultimate precision is required. By chemically dissolving the cement and lime binder from a crushed plaster sample, the plaster's composition can be estimated by analysing the resulting solution.

The resulting plaster composition by mass can be converted to volumetric batch proportions using known or assumed bulk densities for the various plaster constituents.

Accuracy of tests vary

Despite this technique's apparent simplicity, a recent BRANZ research programme (funded by Building Research) examining the reliability of chemical analyses of stucco plaster revealed some concerning results. Samples of synthetic stucco plasters, batched under controlled conditions, were sent to five laboratories offering analysis of cementitious materials. Figure 1 demonstrates the difference in results between the laboratories for a stucco sample with a simple known composition of 1:1:6 parts by volume of GP cement, hydrated lime and quartz sand respectively. The graph plots the variance between the mass of silica, lime and sand present, determined by the chemical analyses and the true result. Figure 2 takes the additional step of converting this data back to equivalent volume proportions at batching, to facilitate comparison with mixes proportions specified in NZS 4251.1.→

Table 1: Composition of stucco plaster components.

Plaster constituent	Soluble CaO	Soluble SiO_2	Bulk density
Portland cement	63.5%	21.8%	1,450 kg/m^3
Hydrated lime	75.7%	<1%	575 kg/m^3
Sand	nil (assumed)	nil (assumed)	1,675 kg/m^3 (typical)

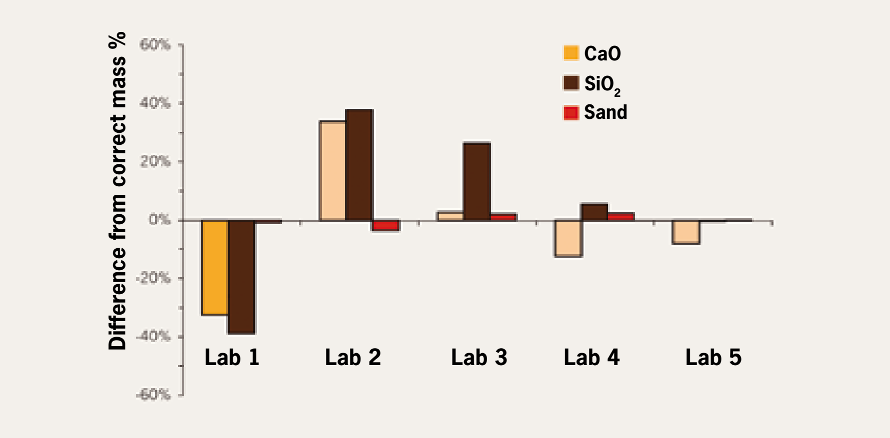

Figure 1: Accuracy of chemical analyses from various laboratories for a test sample of 1:1:6 stucco plaster.

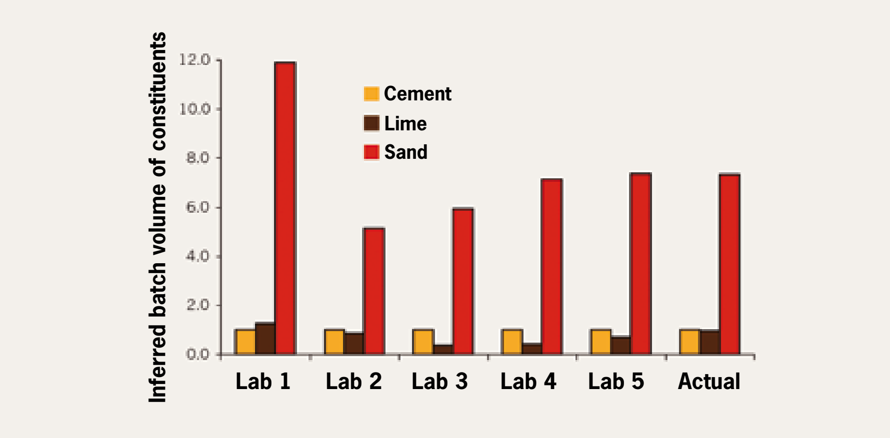

Figure 2: Plaster batch volumes inferred from the chemical analyses.

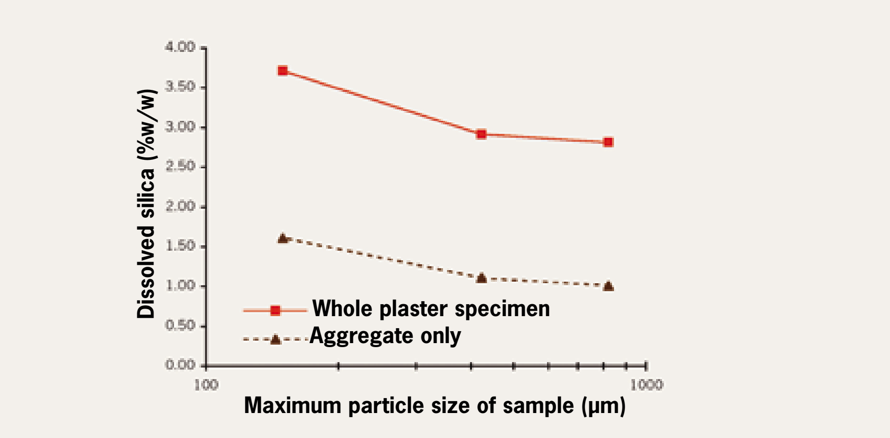

Figure 3: Measured soluble silica, as a function of particle size, extracted from stucco plaster and its constituent aggregate when subjected to an alkaline dissolution procedure.

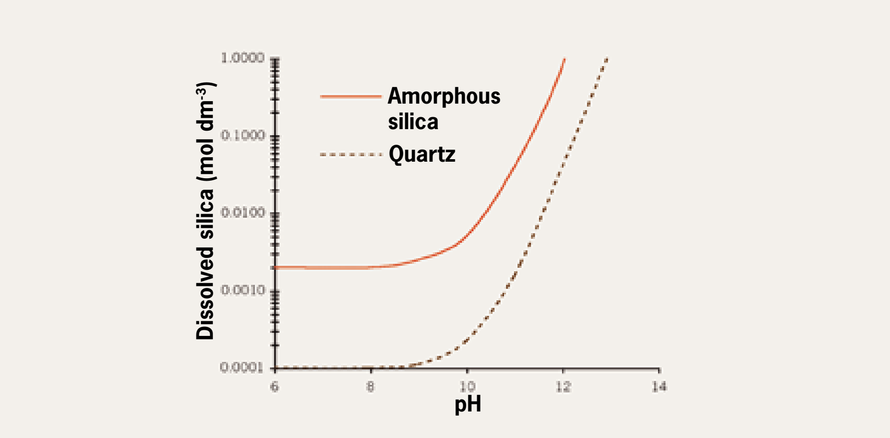

Figure 4: Maximum solubility of SiO_2 polymorphs as a function of pH (after Brownlow, 'Geochemistry').

While some laboratories performed well, there are clearly a number of results that could not be relied on for a fair determination of Code compliance. Similar patterns were observed with stucco samples prepared at other ratios of cement, lime and sand.

Technical skills in decline?

There are a number of possible explanations for this variation. One possibility is simply technical capability. The laboratories in the study used long-established test methods such as AS 2701–2001 *Methods of sampling and testing mortar for masonry constructions* and BS 4551–2: 1998 *Methods of testing mortars, screeds and plasters: Chemical analysis and aggregate grading.* Both methodologies rely on the analyst's classical bench-top 'wet chemistry' abilities. It is likely these skills are declining with the increasing reliance on instrumentation and automation for routine chemical analyses.

Soluble aggregate may distort results

The research also raised doubts that the aggregate remains insoluble during the dissolution of the binder phase. The standard test methods employ a dilute acid solution that will also readily dissolve limestone aggregate, or the fragments of shell commonly found in marine sand. The additional calcium liberated by this reaction can significantly distort the value calculated for the hydrated lime content of the plaster.

Alkaline alternative evaluated

Because of this potential interference, BRANZ has been working with a New Zealand laboratory to evaluate the suitability of an alternative alkaline dissolution procedure. The rationale for this is that aggregates containing minerals soluble under alkali conditions are not routinely encountered in New Zealand (they are usually found in lake sediments from tropical regions).

Some success has been achieved but the determination of silica in the plaster is sensitive to how much the test sample is ground prior to dissolution (see Figure 3). This is difficult to control accurately in the course of a routine analysis.

This sensitivity is not totally unexpected, because the solubility of all forms of silica is known to increase dramatically when the pH of a solution increases beyond 9 and the dissociation of silicic acid is no longer suppressed (see Figure 4). Unfortunately, this additional SiO_2 can significantly interfere with the analysis since the calculation of the quantity of Portland cement present (and hence also the excess of CaO that equates to hydrated lime), depends directly upon this value. Also, soluble silica is present in plaster in small quantities relative to calcium, and is more sensitive to potential error.

BRANZ recommends

BRANZ suggests wherever possible individual samples of the plaster constituents (cement, lime and especially the sand) should be analysed in parallel with the whole plaster sample. This will permit the analytical results to be adjusted to account for their contribution to the soluble silica and calcium concentrations measured.

If this cannot be done, a petrographic analysis (thin-section microscopy) is necessary to evaluate the aggregate for any mineralogical characteristics that could potentially interfere with the subsequent chemical analyses. The petrographic examination may also furnish useful information about the sand grading, air void system and chemical or physical instabilities due to alkali-silica reactivity, freeze-thaw damage or moisture movement. A reasonable case can be made that the use of chemical results alone is not sufficient to completely evaluate a hardened stucco plaster. Indeed ASTM C 1324, the American standard for the examination and analysis of hydraulic cement-based mortars, plasters and stucco, specifically notes that 'Interpretations and calculations of chemical results are dependent upon results of the petrographic examination. The use of chemical results alone is contrary to the requirements of this method'.

Both petrographic and chemical analyses require relatively elaborate equipment and a high degree of skill and experience on the part of the analyst to obtain satisfactory results. Potential clients should seek reassurance that their chosen laboratory possesses this degree of capability. Documented participation in inter-laboratory round-robins or specific ISO 17025 accreditation for these classes of tests are possible methods of demonstrating this.

Don't rely on chemical analysis alone

The accuracy and precision with which inferred plaster batch proportions can be confidently reported appears to be poorer than the theoretical limits of the analytical chemistry techniques employed. Such results can be useful adjuncts to indicating the cause of failures in stucco and other solid plasters. However, caution should be exercised before making claims of Code non-compliance solely on the basis of chemical analyses, particularly where only limited numbers of analyses are undertaken without the benefit of a supporting petrographic examination.

Other causes of failure

Any plaster failure investigation must consider all the pertinent information available, including the constituents used, conditions on site, contiguous materials and specification requirements. Experience suggests stucco failures due to gross misproportioning are comparatively unusual. The main reported problems of shrinkage cracking and poor inter-coat adhesion typically result from deficiencies in application procedures, such as the absence of suitable movement control joints, or the use of a poorly graded sand with a high fines content resulting in a highly mobilised mix. These can be diagnosed without recourse to chemical analysis. ◖