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Properties and Advantages of Pre-Blended Stucco

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Abstract
A skilled tradesman will know the optimum ratio for producing good quality, workable stucco, but this optimization does not always happen in the world of lowest bid. Applicators and designers need to consider other approaches to manufacturing stucco, such as the use of pre-bagged, pre-blended stucco comprising sand, cement, fiber reinforcement, and other admixtures.

Introduction

Portland cement stucco is traditionally made on-site by mixing sand, cement, lime, and water before being applied to a prepared building surface. The amounts of each raw ingredient are specified on a volume basis by codes and standards, as in ASTM International C 926, *Specification for Application of Portland Cement Plaster*, *Uniform Building Code (UBC)* Chapter 47, "Installation of Walls and Ceilings Coverings," or local building codes.

These volume-based standards allow for significant variation in the amount of materials used. For example, a basic recipe for plaster scratch coat is:[1]

> 1 part portland cement, 0 to three-quarter part lime, 2.5 to 4 parts aggregate (by volume)

However, it is not enough to just pick any combination of raw materials fitting into the recipe above to get good stucco. A skilled tradesman will know the optimum ratio for producing good quality, workable stucco. Experienced applicators fine-tune their proportions to account for locally available materials, climate conditions, and local practice. Unfortunately, this optimization does not always happen in the world of lowest bid, and less-than-perfect stucco can be the result.

Applicators and designers need to consider other approaches to manufacturing stucco to meet the increasingly higher demands placed on building products and wall systems. Many changes have taken place in construction since the days these codes and practices were developed, and modern wall systems are more easily damaged by even minor water leakage.

In the future, higher demands may also be placed on stucco cladding in seismic regions. Structural engineers have been reluctant to exploit the strength of stucco cladding in seismic design, likely because the specifications are broad and difficult to strictly enforce. As such, designers are uncertain whether they can rely on stucco's strength and attachment. This is unfortunate, as there is considerable strength and energy absorption potential in a stucco cladding.

Pushing stucco's frontier

Many components are necessary to take stucco wall cladding to a higher level of performance. In the rainy, cool weather of Vancouver, British Columbia, designers mandate a 19-mm (0.75-in.) strapped drainage cavity behind the stucco, occasionally combined with a pre-blended stucco concentrate (only sand and water added on-site). However, this still leaves the addition of sand a major variable.

The gradation of the sand allowed by code can vary significantly, meaning the amount of water needed will vary, as will the amount of subsequent cracking. (Most codes still allow the substitution of stucco sand for fine masonry sand when either the former is unavailable or good results can be shown.)

The author recently carried out a test program on a pre-blended stucco comprising sand, cement, fiber reinforcement, and other admixtures. The product is ready for use after adding water and mixing, and because it is manufactured under controlled conditions, it is possible to optimize mix design and exploit technological advances in the field of admixtures. For example, water-reducing admixtures and micro-fibers are added to reduce shrinkage cracking, while a water permeability-reducing admixture is added to reduce the rate of water penetration. High quality air-entraining admixtures improve workability and freeze-thaw durability without compromising water permeability or strength.

Test program

Three types of stucco were evaluated: a) control pre-blended bagged stucco; b) pre-blended stucco with integral waterproofing additive;[2] and c) a typical building code mix.

Product B is pre-blended, bagged stucco containing all ingredients, including sand in a 36-kg (80-lb) bag. It contains fiber for shrinkage control and a system of water-reducing, plasticizing, and air-entraining admixtures optimized for stucco applications. An advanced version of the stucco includes a crystalline waterproofing admixture technology[3] (henceforth known as 'integral waterproofing additive,' or IWA).

The test program had several specific objectives:

- Determine the effectiveness of IWA in reducing the water permeability of the pre-bagged stucco.
- Determine the overall quality of pre-bagged stucco compared to a typical building code stucco.
- Evaluate properties such as mixing and application characteristics, water requirements, plastic and drying shrinkage cracking potential, compressive strength, setting time, and water permeability.
- Determine the permeance (breathability) of the pre-bagged stucco with and without IWA and compare it to typical building code stucco.

(Note: Permeance measures the rate of vapor flow through a material. A higher permeance promotes faster drying of a wet wall. The objective is to determine whether the pre-bagged stucco adversely affects the rate of wall drying [with or without IWA]).

Sample preparation

The site-batched stucco was made in accordance with typical code requirements using the specified materials and proportions (*i.e.* ASTM C 926). Two versions of the building code (BC) control mix were made:

- BC-1: 1 part cement: 0.45 parts lime: 3.6 parts sand (by volume)
- BC-2: 1 part cement: 0.21 parts lime: 3.3 parts sand (by volume)

The mix design for the pre-bagged stucco is proprietary and, therefore, unavailable. The mix can be generally summarized as containing portland cement, sand, lime, fibers, and other admixtures meeting the requirements of ASTM C 926-98A (as per the manufacturer's information). Three other mixes contained 2.0 percent, 2.5 percent, and 3.0 percent of the integral waterproofing additive by mass of cementing materials.

Forms for stucco panels were 350 mm wide by 2400 mm long by 19 mm deep (14 x 93 x 0.75-in.). The bottom of the form was lined with two layers of 30-min building paper and stucco wire mesh. Stucco wire was nailed down in two rows at 200 mm (8 in.) o.c.

The first five mixes were cast on the same day. BC-2 was cast five days later to confirm the results of BC-1.

The stucco was mixed in a mortar box. Water was added to achieve a workable mixture. Stucco was re-tempered as necessary at 20 minutes, at which point it was applied into the wooden forms. Forms were filled horizontally and stucco applied in one layer using a steel trowel. The surface was given a wood-float finish.

The panels were allowed to cure inside a warehouse with no moist curing. BC-1 had excessive plastic shrinkage after 24 hours, so another building code mix was made with slightly different mix proportions. BC-2 was fog sprayed during the first three hours, but some plastic shrinkage developed.

Panels were cored to obtain samples for testing after about three weeks. A diamond drill was used to remove 170-mm and 94-mm (6.7-in. and 3.7-in.) diameter cores for the test program. Care was taken to avoid coring through crack locations in building code mixes (with minor exceptions).

Following coring, samples were cleaned of cutting debris and allowed to dry freely in lab air until time of testing.

Water demand and workability

Water requirement, or water demand, is the amount of water needed to give the stucco a workable consistency so it can be adequately applied in the field. As shown in Table 1, the building code mixes required more water and had a higher water-cement ratio than any of the pre-bagged mixes. Admixtures in the pre-bagged stucco result in less water needed for equal workability. The higher water-cement ratio building code mix will result in a more porous and permeable, higher shrinkage, and less durable product. The addition of IWA had a negligible effect on water requirements.

The workability of all pre-bagged mixes was very good. The integral waterproofing additive did not affect the workability of any of the mixes. The pre-bagged mixes (with or without IWA) were all easier to trowel than the building code mixes, but all mixes finished well.

Setting time

Setting time (Table 2) was determined using Gilmore needles on three of the five stucco mixes. Fresh stucco was cast in 15-mm deep, 89-mm diameter (0.6 x 3.5-in.) plastic molds and kept in 100 percent relative humidity (RH) until setting time measurements were carried out. Slight delays in set for both pre-bagged stucco mixes were noted.

Plastic and drying shrinkage

Plastic shrinkage cracking occurs when the stucco is still fresh or shortly thereafter, and results from water evaporation or its absorption into a porous substrate. Plastic shrinkage can be made worse by insufficient mix water and poorly optimized mix design. Rapid reacting cements may also play a role, but the addition of fibers can restrain plastic shrinkage cracking. Photos 1 through 4 show the stucco panels at 27 days old for all mixes except BC-2 (which was 22 days old).

Extensive plastic shrinkage cracking was observed in BC-1 and BC-2, recognizable as typical random pattern cracking. Many cracks were shallow and did not fully penetrate through the stucco thickness; however, cracks widths were quite wide, up to 1.6 mm (0.06 in.) in many cases. A minor (100-mm [4-in.] long) plastic crack was observed in the 2.5-percent stucco. No plastic cracks were observed in the pre-bagged control, 2.0-percent, and 3.0-percent mixes.

Drying shrinkage cracking results from water loss in the hardened concrete, and is displayed in high water content mixtures. One such crack occurred in each of the pre-bagged control, 2.5-percent, and 3.0-percent panels. No such cracks occurred in the 2.0-percent panel, nor were any observed in the building code mixes (although existing plastic cracks very likely became wider due to drying shrinkage).

Compressive strength

Compressive strength testing was completed on 50-mm (2-in.) cubes. Samples were moist cured at 22 C (72 F) until time of test. Compressive strengths for all mixes (Table 2) were more than adequate for the requirements of a stucco cladding. In fact, compressive strength test results are surprisingly high for the building code mix. This may explain why those panels cracked so readily (*i.e.* too high cement content). The 2.0-percent stucco had a moderately higher strength than the pre-bagged control stucco. This is consistent and expected behavior for the integral waterproofing additive.

Low-pressure (standpipe) water penetration test

A low-pressure (standpipe) water penetration test was developed specifically to observe the permeability of the stucco in relation to typical building construction. Cored samples from the test panels were cleaned and dried in lab air until the start of testing. The test apparatus is shown in Figure 1 and Photo 5. The stucco sample was set on two layers of 30-min building paper and plywood. A 100-mm (4-in.) diameter standpipe was caulked onto the stucco sample and a constant pressure of 200 mm (8 in.) of water applied.

Two methods were used to determine the rate at which water was passing through the stucco samples. The first was visually observing the wetting pattern on the underside of the sample. The second was measuring the moisture content of the plywood base (using an electrical, resistance-based moisture meter). The purpose of the epoxy paint was to prevent water from short-circuiting under the caulking. Two cycles of testing were completed when the stucco was 57 days old and 98 days old. Results are shown in Figures 2 to 5.

Through absorption and capillary suction, water quickly penetrated the building code stucco. Moisture appeared on the downstream side soon after the water's first contact with the surface. The rate of wetting was much greater than other stucco mixes.

The moisture content on the plywood gave a general indication of permeability (the rate of moisture transmission through the sample). The building code mix also had higher plywood moisture content than the other samples.

The stucco samples containing IWA had superior or similar waterproofing performance compared to the pre-bagged stucco without it. This was true for both the rate of wetting and the moisture transmission rate. The 2.0-percent and the 3.0-percent mixes were distinctly better than the pre-bagged stucco. The 2.5-percent mix was only marginally better overall than the pre-bagged stucco, and only marginally poorer in some individual parameters.

(Note: The 2.5-percent stucco had slightly poorer compaction during application as evidenced by some wire mesh showing on the base, underscoring the importance of proper application methods to fully compact the stucco and embed the wire lath reinforcing.)

All mixes showed a reduction in absorption and permeability between first and second cycles. In general, IWA stucco showed a greater reduction in absorption and permeability (with time) than either the control pre-bagged or building code mixes.

The amount of wetting of the plywood after 72 hours is minimal for all types of stucco. The moisture content of the plywood never exceeded the 19 percent moisture content level often used in building codes to delineate between wet and dry conditions.

High pressure water permeability testing

The water permeability test apparatus is shown in Figure 6. Pressure was delivered using pressurized nitrogen over water (separated by an impermeable bladder). Supply pressure was controlled and measured with gages and the nitrogen supply regulator. The water supply was de-aired to reduce gas bubble accumulation in the samples. The water flow through the samples was collected and weighed on a mass balance. The collection containers were partially filled with oil to limit the evaporation of water passing through the samples.

Two pressure cycles were completed: when the stucco was both 57 and 98 days old. Four specimens of each stucco mix were tested. Very little flow could be obtained on the second cycle of tests and extremely high pressure was necessary to obtain any wetness on the downstream surface. Several samples did not show any evidence of water penetration on the second cycle.

The test cell was open on the downstream side, so it was possible to measure the percentage of the surface that was damp. Results of area of wetness are shown in Figures 7 and 8. Water flow through the stucco was collected and water flow rate for the first cycle is shown in Figure 9. There was insufficient water flow to take a measurement in the second cycle.

The following general conclusions can be made with respect to the high-pressure water permeability test results:

- Flow rates for all stucco mixes were highly variable between samples of the same type, making it difficult to reach firm conclusions about the high-pressure water permeability data.
- Results from the first testing cycle show relatively high flow rates at low pressure when compared to permeability values of normal concrete. This is likely typical for stucco, even of good quality.
- The rapid initial wetting behavior of the building code control mixes observed in low-pressure testing was also observed in the high-pressure test.
- A sharp reduction in permeability was noted from the first to second cycles in the high-pressure test. This was not observed in the low-pressure test, and may be due to pore structure changes resulting from high-pressure water, which suggests the importance of using test pressures similar to actual field conditions (*i.e.* lower pressures).

Wet/dry cup permeance test

Wet and dry cup permeance tests measure the rate of water vapor flow through stucco. In the wet cup, the water vapor flows from a near 100-percent relative humidity condition to a 50-percent RH condition. In the dry cup, water vapor flows from a 50-percent RH condition to a near zero percent RH condition. The test configuration is shown in Figure 10 and results in Table 3.

The permeance values of all the stucco samples were relatively close, indicating the samples were generally more ‘breathable’ than those with other published values. The permeance of the building code stucco was the lowest (lowest vapor flow rate), which is surprising given the water permeability of this mix was the highest, and both liquid water and water vapor would be expected to travel through the same flow capillary tracts. The IWA samples had only slightly lower permeance than the pre-bagged control samples.

(Note: All stucco mixes were tested without a finish coat, some of which will reduce stucco breathability.)

Conclusions

Superior physical properties were observed in the pre-bagged stucco when compared to the building code stucco mixes, and the integral waterproofing admixture provided additional performance benefits to the pre-bagged stucco.

There is no doubt good site-batched stucco can be made using building code mix designs. However, pre-bagged stucco offers the ability to manufacture a product under more carefully controlled conditions using modern material innovations. This not only provides more consistent final results, but enables the creation of a superior building product. A better product will broaden the utility of, and confidence in, stucco.

Notes

[1] ASTM International, ASTM C 926, *Standard Specification for Application of Portland Cement-Based Plaster,* 1998.
[2] The portland cement plaster (stucco) was manufactured by TradeCraft under the name Waterguard in conjunction with Pakmix of Seattle, Washington.
[3.] The crystalline integral waterproofing admixture (IWA) was manufactured by Xypex Chemical Corporation.

Table 1: Mix Designations and Water Requirements

Mix ID	Description	Water/cementing material (W/CM)
BC-1	Building Code Control #1	0.84
BC-2	Building Code Control #2	0.83
WG-0	Pre-bagged control (Weatherguard)	0.52
WG-2	Pre-bagged plus 2.0 % integral waterproofer	0.52
WG-2.5	Pre-bagged plus 2.5 % integral waterproofer	0.52
WG-3	Pre-bagged plus 3.0% integral waterproofer	0.53

Table 2: Compressive Strength and Setting Time

Mix ID	Compressive Strength (psi)				Setting time (hr:min)	
	7 day		28 day		Initial	Final
	MPa	psi	MPa	psi		
BC-2	24.7	3580	29.0	4210	5:20	8:40
WG-0	16.3	2360	18.5	2680	5:40	10:05
WG-2	22.1	3210	23.8	3450	6:30	10:35

* setting times are approximate and sensitive to “between operator” error.

Table 3: Summary of Permeance Values

Mix I.D.	Wet Cup		Dry Cup	
	Perm	(ng/Pa•s•m^2)	Perm	(ng/Pa•s•m^2)
BC-2	14	800	7.0	400
WG-0	19	1080	7.8	450
WG-2	17	950	7.3	420
WG-2.5	19	1070	-	-

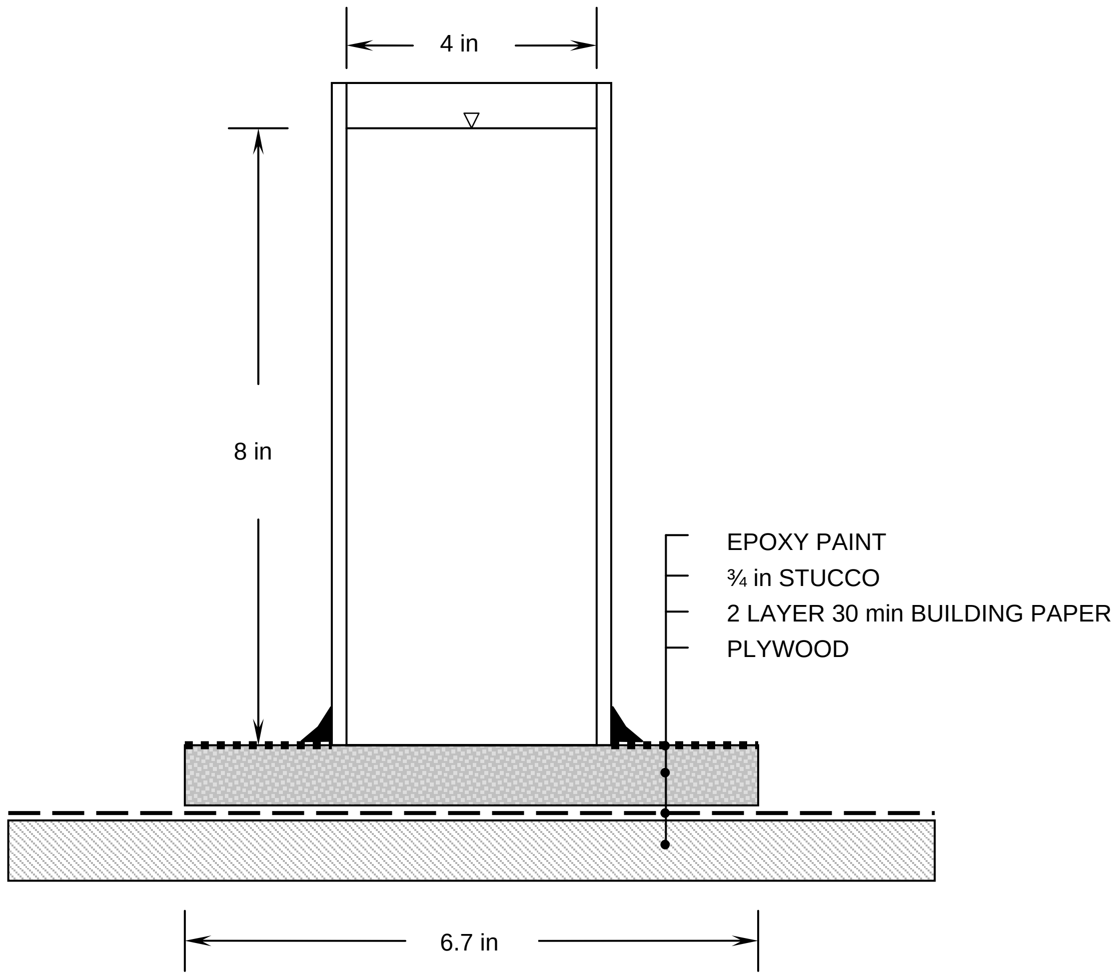


Figure 1: Low-pressure (standpipe) pressure test apparatus

Figure 2: Area of wetness on back side of stucco - First cycle
Low-pressure - standpipe test

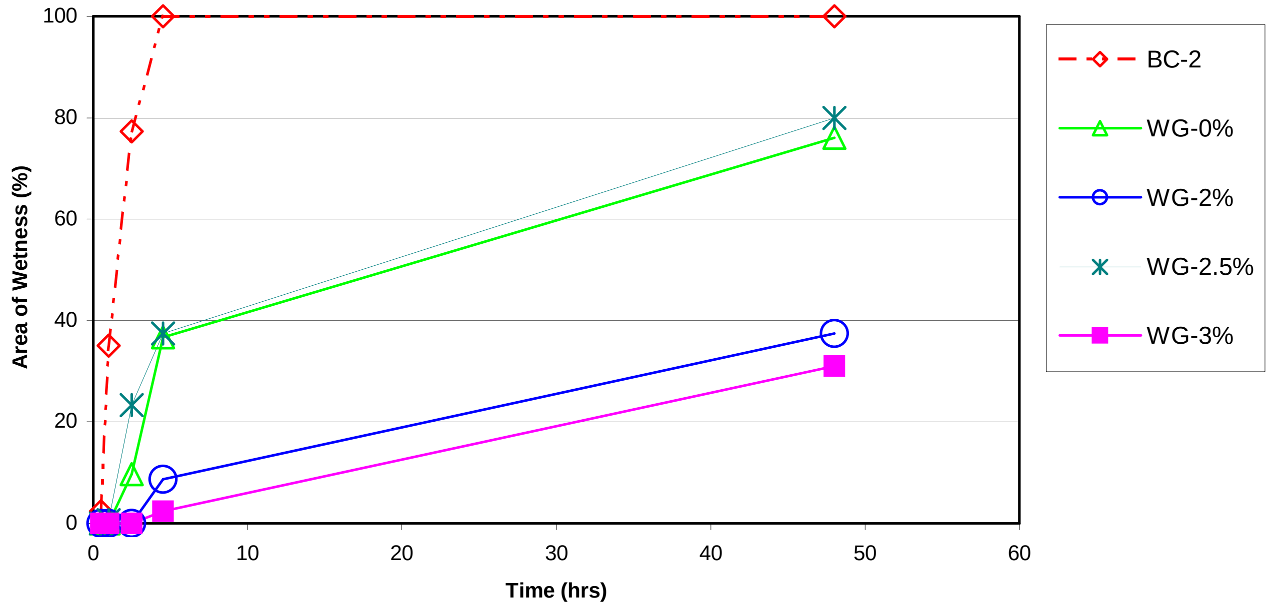


Figure 3: Area of wetness on back side of stucco panel - Second cycle
Low-pressure standpipe test

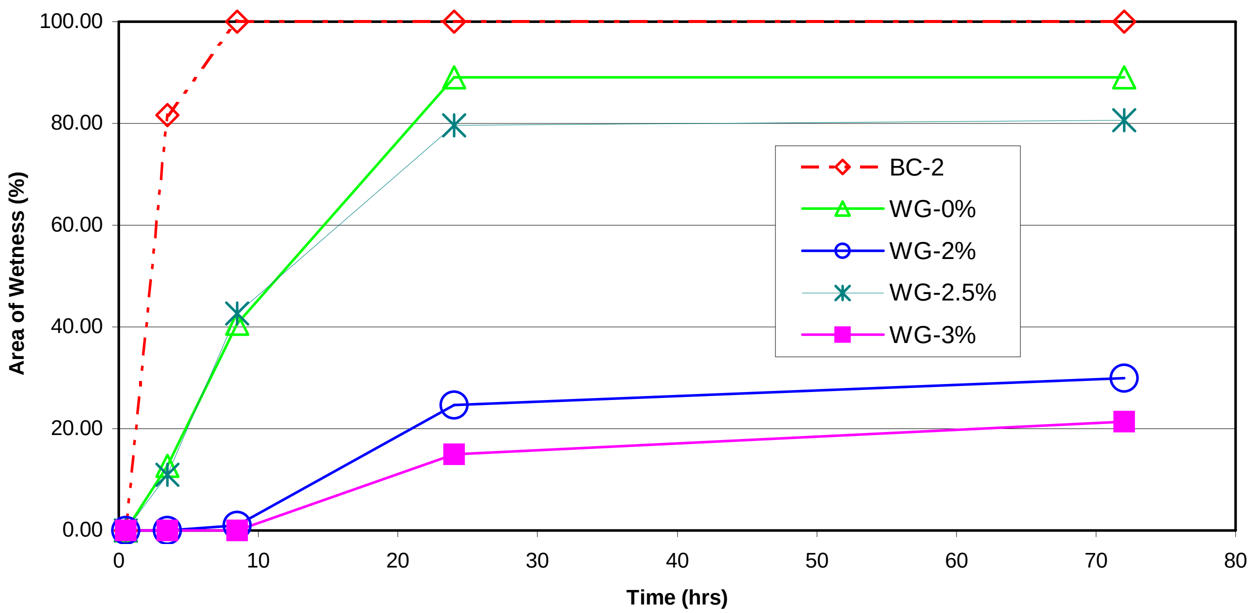


Figure 4: Plywood moisture content vs Time - First Cycle
Low-Pressure - Standpipe Test

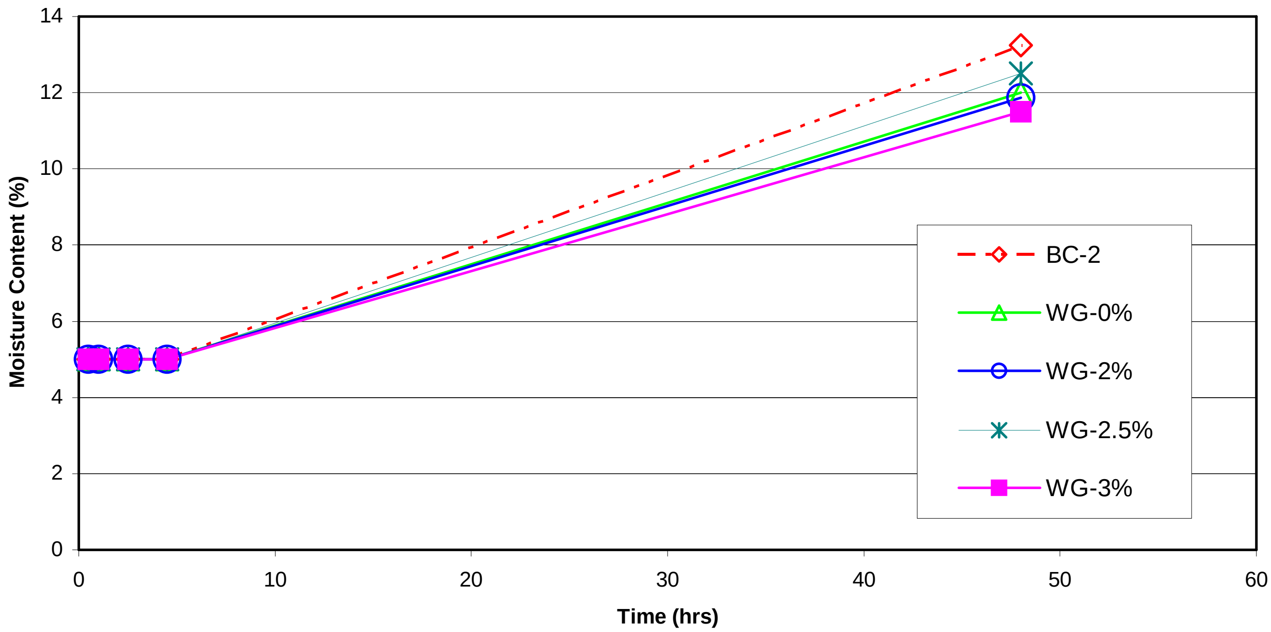
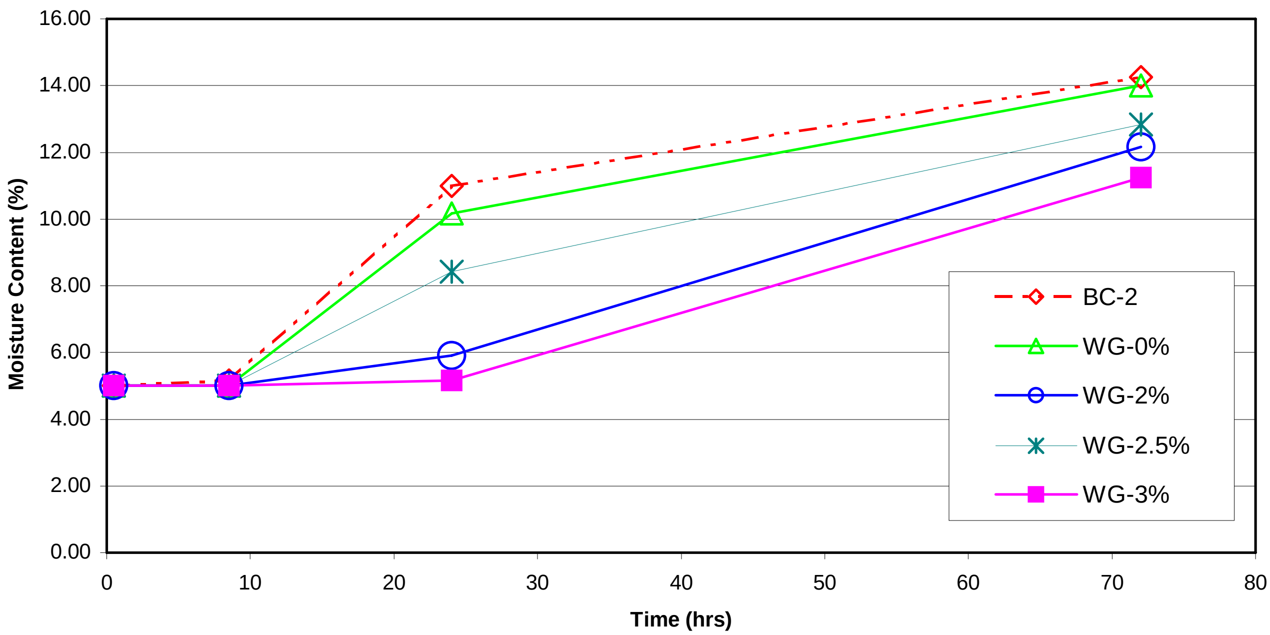


Figure 5: Plywood moisture content vs Time - Second Cycle
Low-Pressure - Standpipe Test



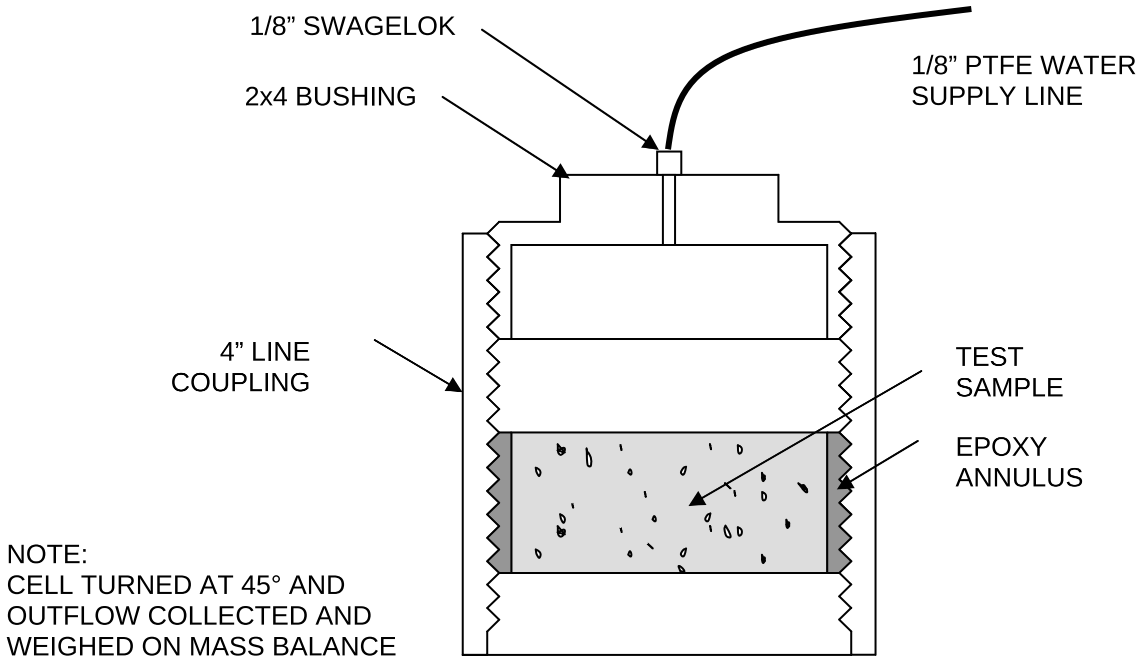


Figure 6: High-pressure water permeability apparatus

Figure 7: Area of Wetness of back side of stucco - 1st Cycle
High-pressure test

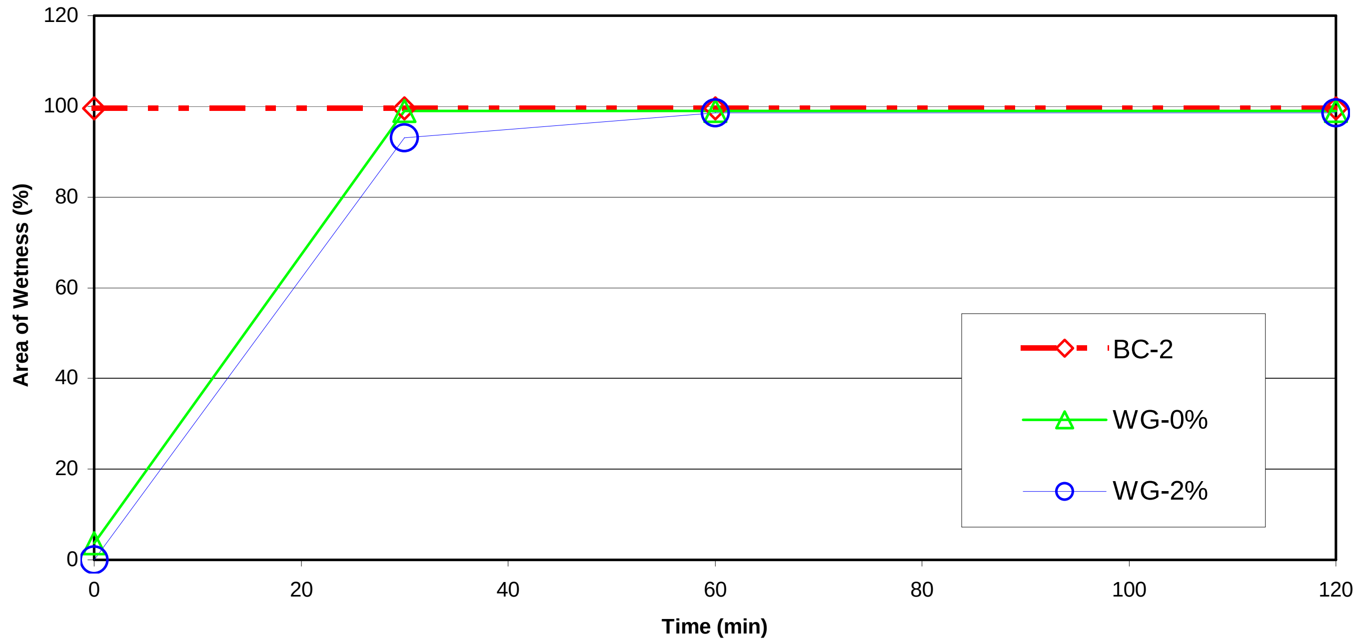


Figure 8: Area of Wetness on back side of stucco - 2nd Cycle
High-pressure test

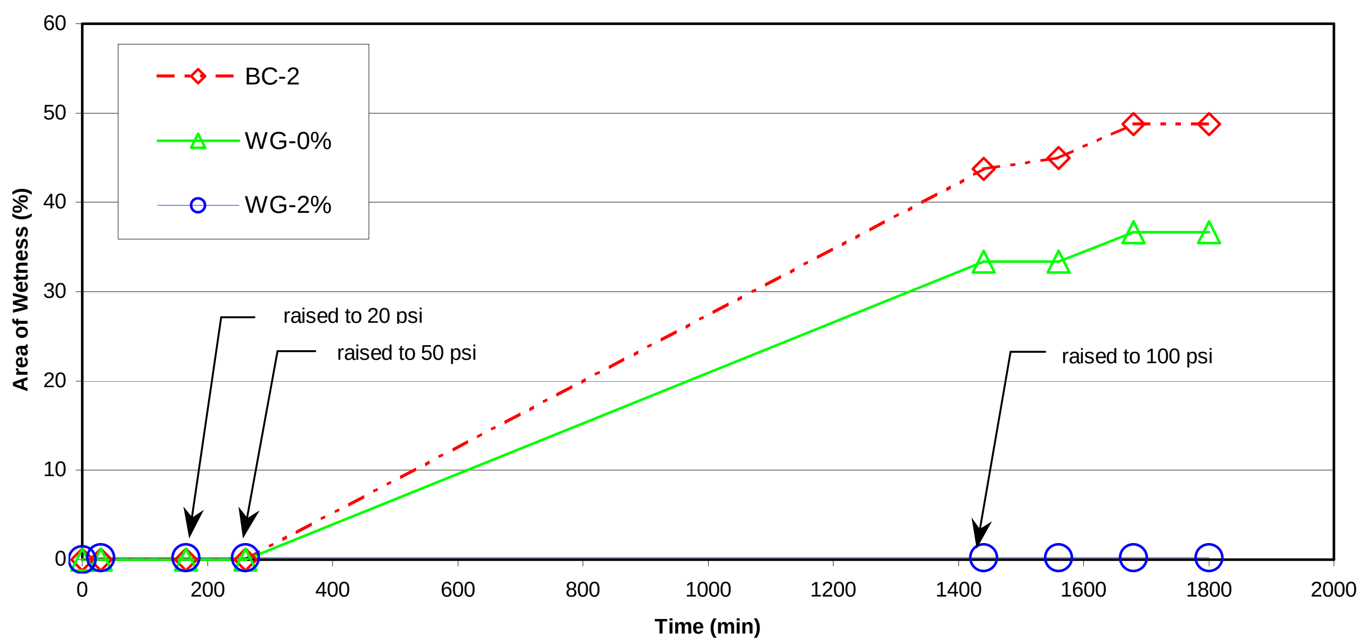
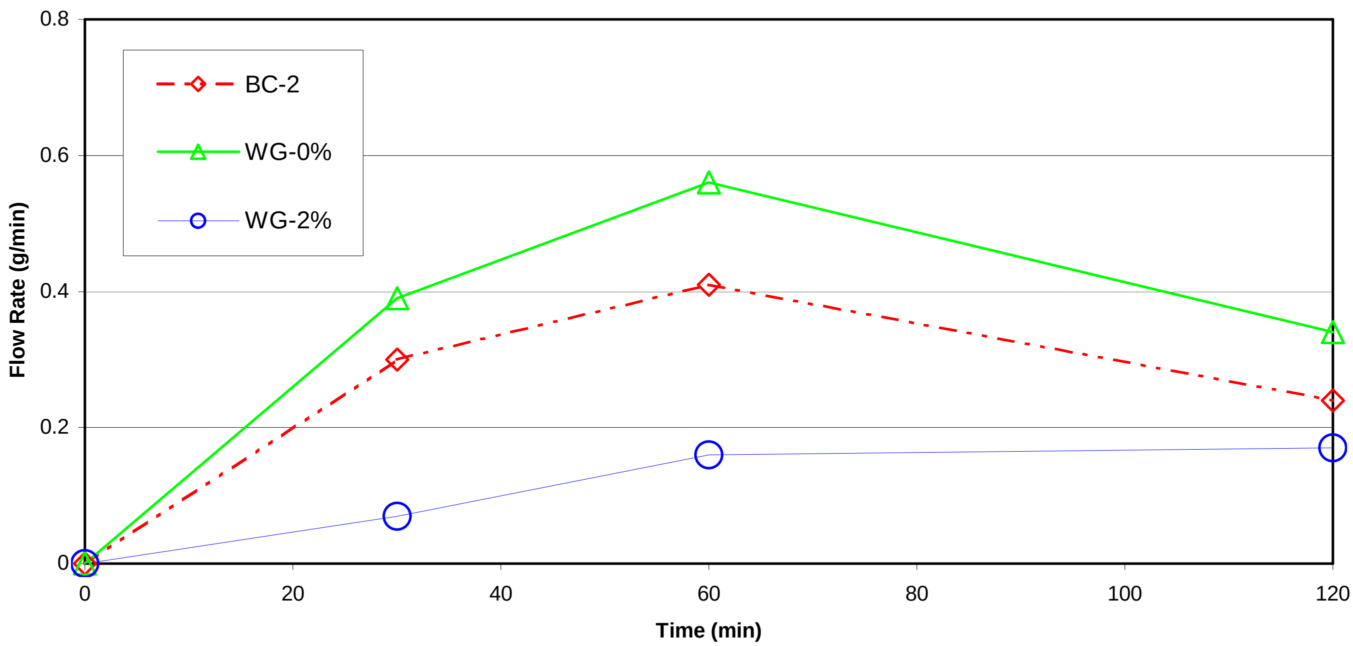


Figure 9: Water Flow Rate- 1st Cycle
High-pressure test



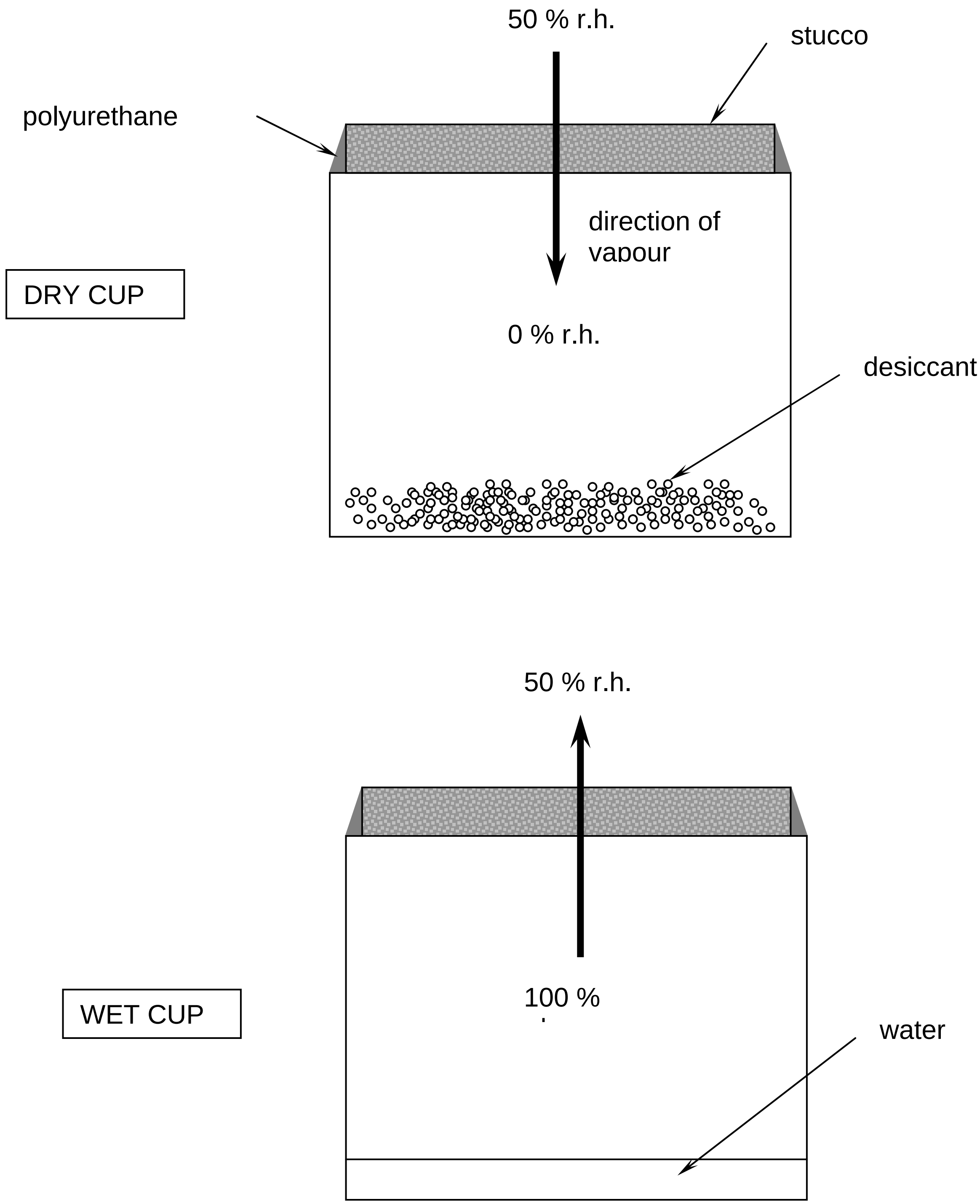


Figure 10: Wet Cup – Dry Cup Test Apparatus

Photo 1

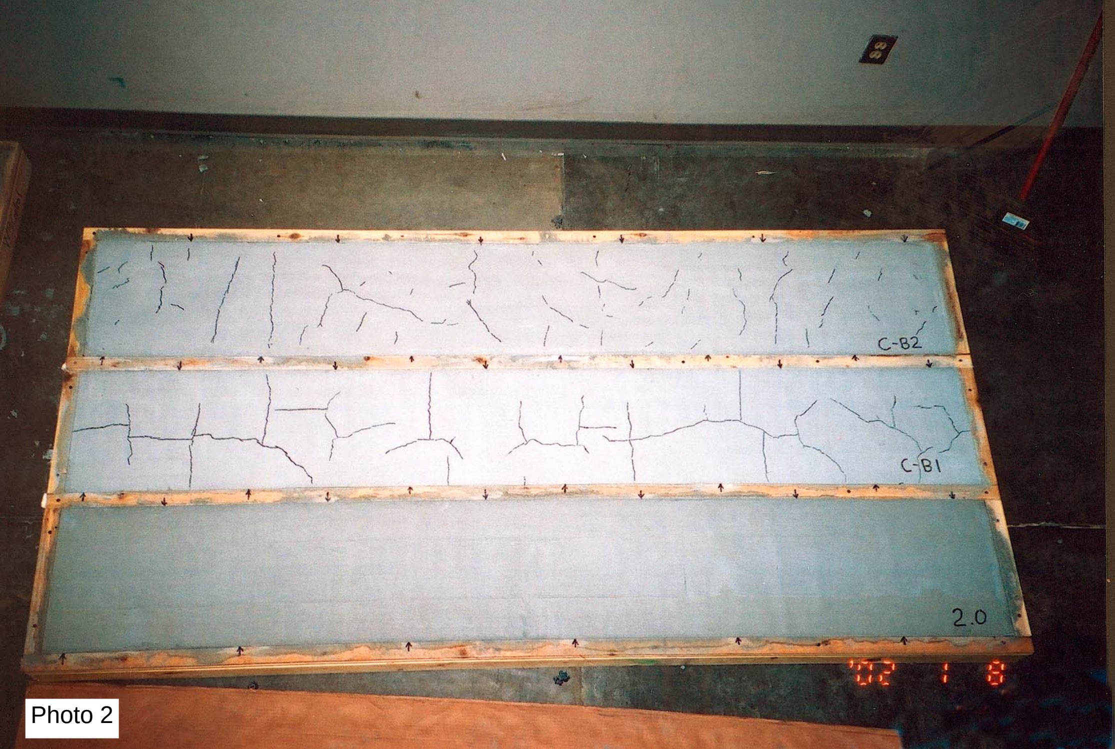


Photo 2

Photo 3

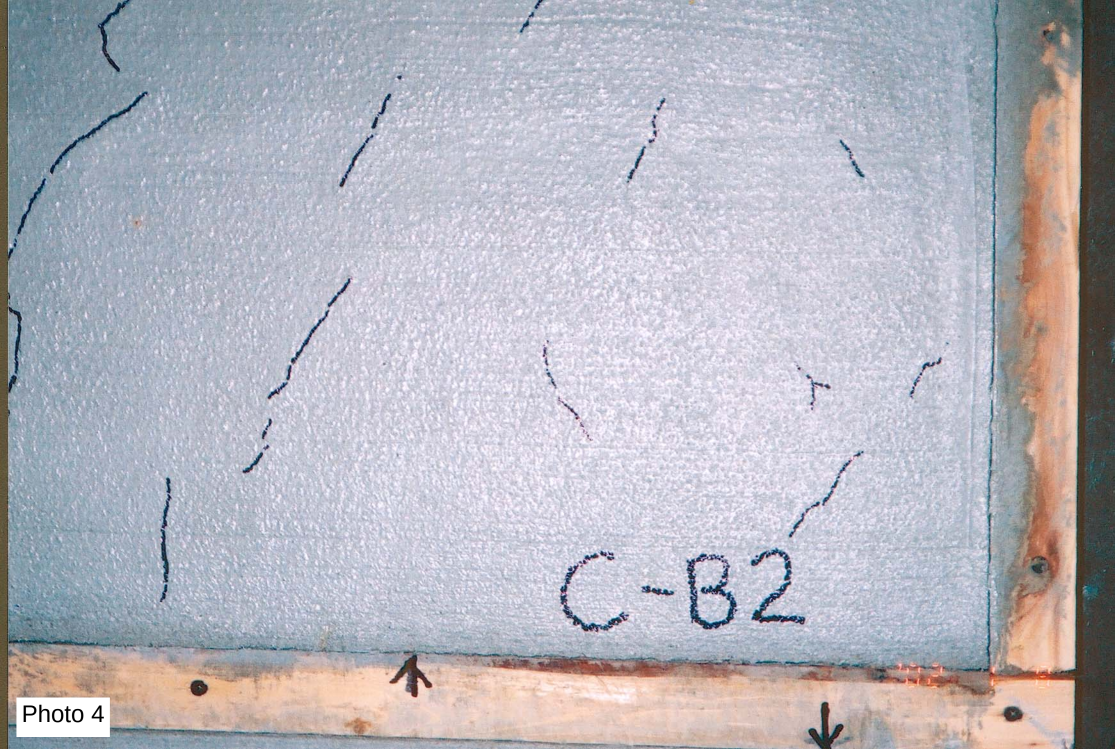


Photo 4

Photo 5