

## MOISTURE PROPERTIES OF PLASTER AND STUCCO FOR STRAW BALE BUILDINGS

### Introduction

Straw bale walls for houses have been used since the introduction of the mechanical baler in the early 1900's. Although straw bale (SB) houses were popular for a short while in a local area of Nebraska, they lost favour for nearly half a century. There has recently been a rebirth in SB construction and interest. In many cases the interest stems from the highly insulating, simple, and sustainable nature of SB walls.

The classic and time-proven straw bale wall assembly consists of straw bales with 25 to 50 mm thick mineral-based stucco skins applied directly to both faces of the straw bale. The stucco skin of modern SB buildings is often made of steel mesh reinforced cement stucco skins applied directly to the straw bales. This coating provides a finish, a weather barrier, an air barrier, fire protection, rodent and insect control, and some structural properties.

CMHC supported a study of the moisture properties (water vapour permeance and liquid water absorption) of stucco skins commonly applied to straw bale walls. The influence of water repellents and elastomerics on vapour permeance and water absorption was also investigated. Knowledge of these properties will aid the selection of straw bale stucco finishes, and can be used to calculate (using manual methods or CMHC's EMPTIED program) the moisture-related performance of straw bale walls.

### Test Program

The project involved applying a range of different stucco mixes directly to straw bales, cutting samples from the bales, applying various coatings if applicable, and then conducting vapour permeance and capillary absorption tests.

### Test Samples

Test samples covering a range of realistic stucco mixes were chosen after discussion with many people on the Internet-based CREST Straw bale building list. The samples are listed in Table 1. All samples were mixed using volume proportions.

Standard Type 10 Portland cement was used. The elastomeric coating was a high-quality acrylic based product—(Maxicyrl, by Sto Industries, [www.stocorp.com](http://www.stocorp.com)). The siloxane (Sikagard 70 by Sika) was a 5% by weight solvent-based product. A local chemical supply company provided the calcium stearate. Finding a source for this chemical required considerable effort and may make its use in plasters difficult. The paints were of average quality interior grade (tradename: CIL Dulux), purchased at Canadian Tire. The linseed oil was a double-boiled product (by Recochem).



**Table 1: Test Samples**

Test Label	Description
A	1:3 Cement: Sand
B	1:1:6 Cement: Lime: Sand
C	1:2:9 Cement: Lime: Sand
D	1:3 Type S slaked Lime: Sand
E	Clay: Sand “earth plaster”
	<b>Variations</b>
A1	As A with an elastomeric paint
A2	As A with siloxane treatment
B1	As B with linseed oil treatment
B2	As B with an elastomeric paint
B3	As B with a siloxane penetrating repellent treatment
B4	As B with calcium stearate (2% by weight of cementitious components)
B6	As B with alkyd (oil) primer and paint
B5	As B with latex primer and paint
B6	As B with oil paint and primer
C1	As C with linseed oil treatment treatment
D1	As D but with slaked Type S quicklime

## Test Setup and Procedure

Vapour permeance was measured using procedures similar to ASTM E96. The E96 method was modified to measure the vapour permeance of a sample with 75%RH on the outside and 100% on the inside (an average humidity of 87.5%). These conditions simulate the situation of wet straw on the exterior of a straw bale drying to the exterior in a humid climate.

Capillary suction can most simply be measured from water uptake tests. Standard tests include the EuroNorm TC 89/WG10 N95 and the German DIN 52617. These tests place the sample in contact with water to a depth of 1 to 2mm. The rate of absorption is calculated from the weight gain measured at several points over a 24-hour period.

## Results

The test results are summarized in the Table 2.

The vapour permeance of pure cement:sand stuccos is rather low. This means drying will occur relatively slowly. The addition of lime resulted in a significant increase in vapour permeance (see Figure 1).

Linseed oil appears to have a small but beneficial effect on the water uptake of the 1:2:9 and 1:1:6 samples. It also reduces vapour permeance somewhat. More research on samples with thicker coats of linseed oil should be conducted.

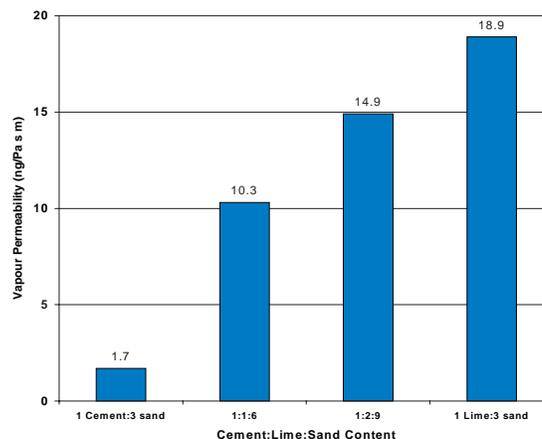
The calcium stearate treatment reduced the vapour permeance of the sample significantly and did not reduce the liquid water absorption significantly. Hence its use does not offer any advantages.

Both the siloxane and elastomeric treatments reduced the water absorption dramatically and had little effect on the vapour permeance. The siloxane was much more effective.

**Table 2: Summary Results**

Sample	t [mm]	Vapour Permeance [ng/Pa*s*m <sup>2</sup> ]	Permeability [ng/Pa*s*m]	Water Absorption [kg/m <sup>2</sup> *s <sup>1/2</sup> ]
<b>Cement:Sand</b>				
A - 1:3 datum	43.5	39	1.7	0.038
A1 - 1:3 elastomeric	39.5	40	—	0.0085
A2 - 1:3 siloxane	41.0	40	—	0.0004
<b>Cement:Lime:Sand</b>				
B - 1:1:6 datum	35.0	295	10.3	0.092
B1 - 1:1:6 linseed	36.0	223	8.0	0.067
B2 - 1:1:6 elastomeric	32.5	244	—	0.015
B3 - 1:1:6 siloxane	41.0	203	8.3	0.0006
B4 - 1:1:6 calcium stearate	53.5	81	4.3	0.101
B4 - 1:1:6 calcium stearate	44.0	142	6.2	0.083
B4 - 1:1:6 calcium stearate	53.5	41	2.2	0.093
B5 - 1:1:6 latex paint	36.5	203	—	0.020
B6 - 1:1:6 oil paint	40.0	41	—	0.014
<b>Cement:Lime:Sand</b>				
C - 1:2:9 datum	50.5	295	14.9	0.110
C1 - 1:2:9 linseed	50.5	259	13.1	0.105
<b>Lime:Sand</b>				
D - 1:3 Datum	33.5	565	18.9	0.127
D - 1:3 Datum	35.5	529	18.8	0.173
D1 - 1:3 Quicklime	32.0	459	14.7	0.161

Note: Vapour permeability is a material property, expressed independently of material thickness, in units of ng/Pa\*s\*m. Vapour permeance is a measure of the ease of vapour flow through a specific layer, in units of perms (ng/Pa\*s\*m<sup>2</sup>). Permeability and permeance are analogous to thermal conductivity and thermal conductance respectively. Metric permeance can be converted to US Perms by dividing by 57.4.

**Figure 1: The Influence of Lime Content on Vapour Permeability**

## Conclusions

Cement:sand stuccos are not very vapour permeable.

The addition of lime to a stucco mix greatly increases vapour permeance but also increases water absorption. Pure lime is 10 times more permeable than cement stucco.

Siloxane treatments appear to work very well – they do not noticeably reduce vapour permeance but they do dramatically reduce, almost eliminate, water absorption. The use of siloxane can be recommended based on these tests.

The quality elastomeric product tested has a high vapour permeance and low water absorption. Note that not all elastomeric coatings have these properties. The performance of these products after a year or two of exposure should also be investigated.

As other research has shown, paints can be used as vapour diffusion retarders. The application of a coat of latex paint and primer to a 1:1:6 stucco will reduce the vapour permeance to about 200 metric perms (3 US perms). While not a vapour barrier by code definitions, this level of vapour permeance will often be sufficient to control wintertime diffusion-related condensation.

An application of oil-based paint and primer to stucco will reduce the permeance of a 1:1:6 stucco to below the 60 metric perm (1 US perm) level assumed to constitute a vapour barrier by North American codes.

Linseed oil is not a very effective water repellent but does not affect vapour permeance. Thicker layers and more coats should be investigated. The calcium stearate additive did not appear to reduce water absorption but did reduce vapour permeance.

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A full report on this project is available from the Canadian Housing Information Centre at the address below.

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