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DRIVING RAIN TESTS WITH CAVITY-FILLED BRICK WALLS

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DRIVING RAIN TESTS WITH CAVITY - FILLED BRICK WALLS

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In Denmark, most one and two storey houses have the outer walls built of brick with a 7 - 13 cm cavity between the two leaves which are held together by steel ties, eight of them per square metre. Since the Second World War it is common to fill the cavity with an insulating material, the intention being to save fuel and make the house warmer. As one of the original reasons for building cavity walls was to prevent rain penetration, it might be feared that filling the cavity with some material would increase this risk. In order to investigate this, the Danish National Institute of Building Research carried out some tests which were reported by Rastrup [1] in 1957. The tests were performed using a brick wall 2,8 m high, with a film of water running down the outside and no wind pressure. However, since these tests were completed a number of new materials specially made for cavity wall insulation have come into use, and since, also, the test conditions used by Rastrup are generally considered to be too severe in relation to Danish weather conditions, it was decided to carry out new tests using the Norwegian type of artificial driving rain apparatus. This apparatus was built at the Thermal Insulation Laboratory of the Technical University of Denmark, and the tests were carried out at this laboratory in cooperation with the Danish National Institute of Building Research and the Laboratory of Danish Brick Manufacturers' Association.

The apparatus is shown in Figure 1. It consists of a closed box which can be sealed from the test panels, (eg, the brick wall shown in the left hand side of the figure). The artificial rain is produced by letting drops of water fall into a strong jet of air which throws them against the test panel. 16 pairs of air and water nozzles are mounted evenly spaced across the width of the test panel. A slide arrangement moves the nozzles up and down over the height of the test panel 3 times a minute. The angle of the air nozzles can be varied in both the horizontal and vertical planes so that all the angles of incidence of natural driving rain can be copied.

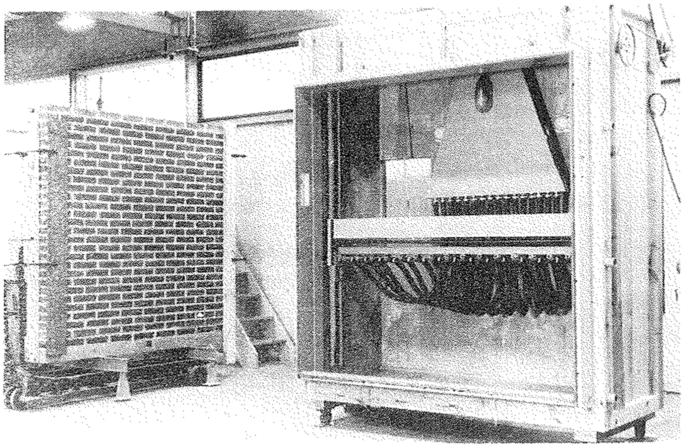

Figure 1. The artificial driving rain apparatus.

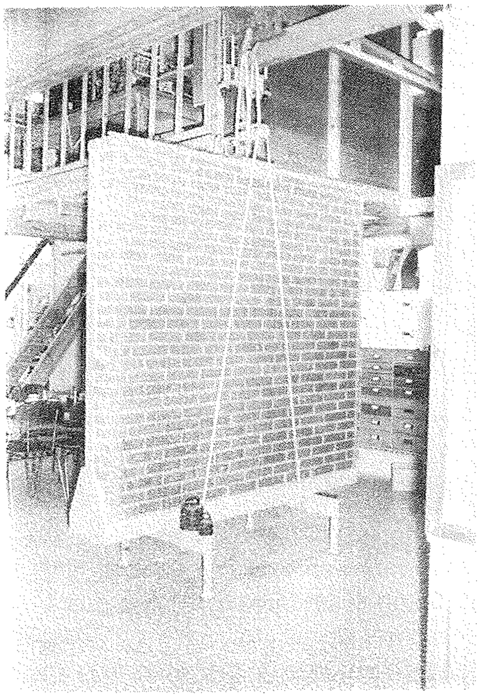

Figure 2. A test wall hanging in the hook of the balance.

A constant air pressure can be maintained in the range 5 - 80 mm H_2O and the amount of rain can be varied from 5 - 10 mm rain/hour. The quantities normally used on test were 22 mm H_2O and 7 litre/m^2h. Actual rain water was collected for the tests with the brick walls in order not to add lime to the walls. In Figure 1 it can be seen how the test wall is mounted on two steel trestles so that it can be handled with a low lifting-truck. Figure 2 shows a test wall hanging in the hook of a 2500 kg balance which weighs to an accuracy of $\pm$ 0,05 kg.

PURPOSE OF THE EXPERIMENT

The purpose of the investigation was to test different insulation materials to find their fitness for use in cavity brick walls exposed to driving rain. In order to test several materials simultaneously it was necessary to build several test walls which would be identical in construction and in resistance to driving rain. As the panels were only 1,87 m high and 2,02 m wide, it was scarcely possible to build a number of identical test walls with the same leakage as ordinary masonry. The laboratory therefore chose to build the test walls completely rain tight, and afterwards to drill holes in the bricks to obtain standard leakage rates. The size, number and placing of the holes could then be adjusted to give the required amount of water penetrating the test wall through to the insulating material. This amount should of course correspond to the rain penetrating ordinary masonry exposed to the Danish climate on open sites.

After a pilot experiment a method for building completely rain tight brick walls was developed, and it is as follows. A mortar bed is laid for one brick at a time, and the end of the brick is heavily buttered (for the complete filling of the vertical joint), and the brick then carefully placed in position. The brick, once it has sucked the water from the mortar must not then be moved, neither by hand nor by tapping. If the brick is not in line or not level, both the brick and the mortar must be removed and a new mortar bed spread and the brick again buttered. Only if the bond between the bricks and the mortar is not broken in any way, and if the horizontal and vertical joints are completely filled with mortar will the masonry be tight to driving rain. This method will not unfortunately be used in practice because great care and skill on the part of the bricklayer are essential to the result.

THE TEST WALLS

Five test walls were built of solid front wall bricks (1700 kg/m^3) using mortar with 7 1/2 % lime and no cement. The outside of the joints was scraped out to a depth of 12 - 15 mm and pointed with lime-cement mortar (1 part of cement mortar to 2 parts of lime mortar). The joints were tooled to a concave shape. After a drying period of 5 weeks the test walls had reached equilibrium in moisture content, but it was decided to wait 2 more weeks before commencing the experiment. The first part of the test was designed to show that the test walls were rain tight. They were exposed to driving rain (7 litre/m^2h by 22 mm H_2O) for one hour a day for a total of 4 weeks: after the first 2 1/2 weeks, 18 holes each 3.2 mm in diameter were drilled in the bricks, allowing 300 - 400 mls/day to penetrate.

After a drying period of 8 weeks the five test walls were again exposed to the artificial driving rain, this time for 3 1/2 weeks. This time the increase in weight of the test walls was about 2 kg less than the first, which corresponds to about 2 1/2 %. It is important, if reproducible results are to be obtained, that there is only a small difference in the increase in weight from exposure to exposure.

RAIN DISTRIBUTION IN APPARATUS

The ability of the apparatus to distribute the water evenly on the test panel was measured. In one of the masonry test panels a horizontal row of holes each 3.2 mm diameter was drilled in the bricks with a spacing of 2 cm, and to the back of each hole a short length of brass tubing 3 mm diameter was attached, so that the water penetrating each hole could be measured. Figure 3 shows the distribution of the water which collected in a 20 minute test run. In spite of some irregularities there

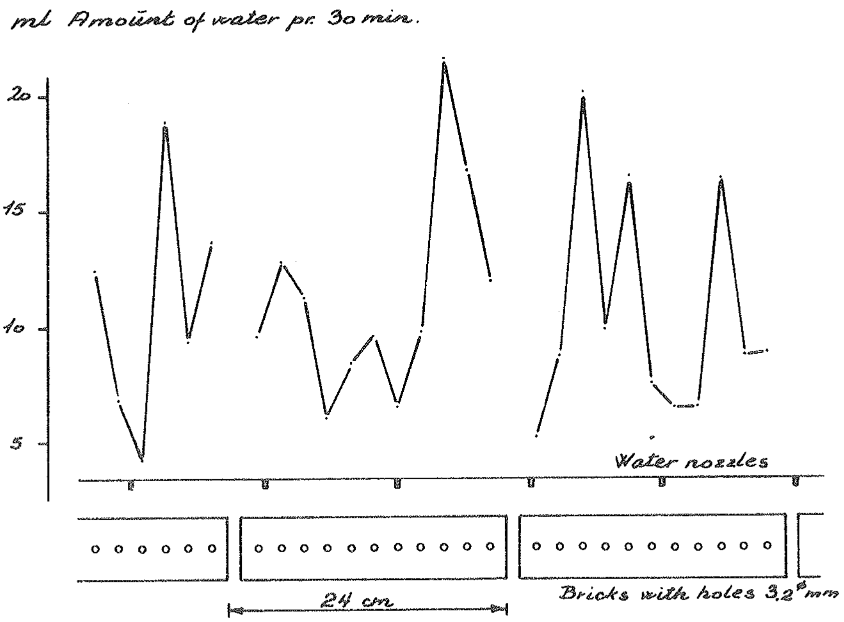

Figure 3. The water distribution of the driving rain apparatus.

is a marked tendency for get a minimum of water opposite the nozzles, and a maximum between the nozzles, the ration of minimum to maximum being 1:5. The brick wall used in this test was almost saturated with water so that nearly all the driving rain ran down the front of the wall in an unbroken film. When the slide with the nozzles moved upward, one could ascertain that the air jets blew the water from the areas it struck to areas in between the jets, and this is the reason why the water distribution was uneven. As a result of this experiment nothing was done to alter the distribution of the jets, but the original holes were sealed and a new set of twenty holes was drilled. The original set was drilled on a 24 cm module and as twice the spacing of the jets was 23 cm, this probably accounts for the very uneven water distribution. The new set was drilled on a 17 cm module.

TEST WALLS WITH ARTIFICIAL BACK WALLS

In order to reduce the weight of the test walls, a back wall consisting of a soft plate of masonite mounted on a wooden frame was used instead of masonry. Using this, rain penetration of the insulating material could be observed as soon as it reached the back wall. Figure 4 shows a cross section of a test wall with an 8 cm cavity. The artificial back wall can easily be dismounted so that the moisture absorption of the front wall, insulation material and back wall can all be determined separately.

During the driving rain test periods, the walls were wrapped in plastic foil to prevent too much moisture loss to the laboratory (at 20°C) in which they stood for 23 hours a day. Before wrapping, the moisture loss was about 2-3 kg per day, and after, about 0.2 - 1 kg per day, depending on the moisture content of the wall. A saturated test wall loses moisture not only by evaporation, but by water running out of it.

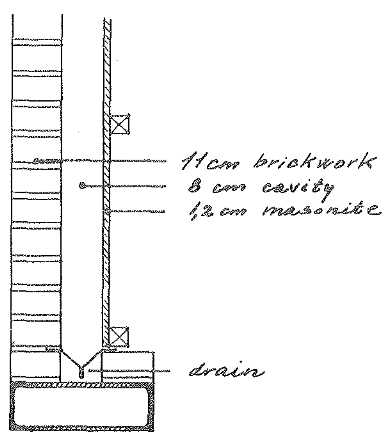

Figure 4. Cross-section of a test wall.

THE EXPOSURE PROGRAMME

First, each test wall was exposed to the driving rain for 1 hour a day (7 litre/m^2h by 22 mm H_2O) until the moisture content remained period-stationary with a period of a week. This took about 4 - 7 weeks. The test walls were weighed before and after each hour of rain, the water accumulating in the bottom of the cavity being measured. After this period, the walls were dried in the laboratory, which took from 4 to 6 weeks.

THE INSULATION MATERIALS

The following insulation materials have now been tested:

- Clay clinkers, expanded
- Glass Wool
- Polystyrene pearls
- Rockwool batts
- Rockwool granules
- Urea foam, injected I
- Urea foam, injected II
- Vermiculite, unimpregnated

All eight materials were tested twice, the first time the test wall was drilled with 20 holes of 4 mm diameter giving about 500 mls of water penetrating per hour of exposure, and the second time with 20 holes of 8 mm diameter giving about 1000 mls per hour. The other test conditions were unaltered. The increase in weight of the test walls is shown in Figure 5. The weight of the insulation material was measured before and after the driving rain period so that the moisture absorption could be determined. This is however not valid for the two test walls with urea foam since the foam when it is sprayed contains a considerable amount of water (50 kg/m^3) as solvent for the two components of which it consists. So after ten days hardening the test was commenced.

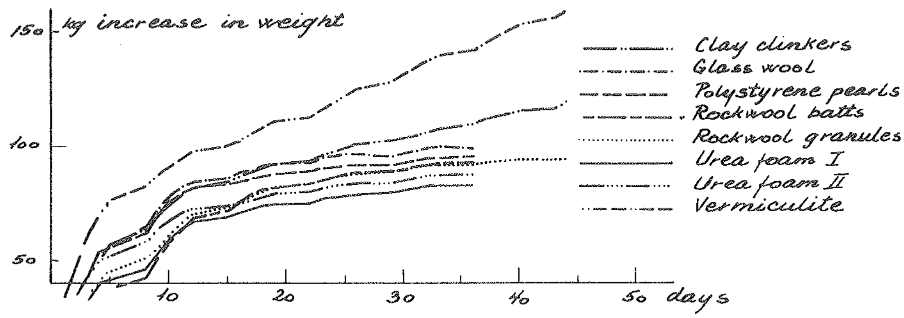

Figure 5. The weight increase of the test walls with insulation materials.

At the end of the rain period samples were taken of all the insulation material so that the moisture content could be determined by weighing before and after drying in the laboratory. Table No. 1 shows the results of these measurements for the materials used in the second (more severe) exposure. In the table are also shown the calculated densities.

Table 1. Test wall with 20 holes of 8 mm diameter.

	from the test wall		from the samples		
	density kg/m^3	moisture vol. -%	volume l	density kg/m^3	moisture vol. -%
Clay clinkers	380	5.2	0.47	330	2.4
Glass wool	14	0.006	2.6	17	0.01
Polystyrene pearls	18	1.0	2.0	16	0.005
Rockwool batts	30	0.09	2.2	44	0.007
Rockwool granules	82	0.3	2.3	80	0.04
Urea foam I	9		1.1	12.4	0.12
Urea foam II	9		0.95	11.5	0.21
Vermiculite	82	18	0.42	97	14

As can be seen from the table, there are discrepancies between the moisture contents of the insulating materials calculated in the two ways. A greater number of samples would have given a better determination of the moisture content as local difference would average out. From two of the materials, Clay clinkers and Vermiculite, very wet samples were taken during the same test. The moisture content of these two samples was measured as 16 and 36 volume % respectively. These figures correspond very well with those found by Rastrup [1] even though his test methods were different. The scatter of the results indicates the uncertainty of such driving rain tests, and it is our experience that only tests planned on generous lines will give reliable and comparable results - one of the reasons for this being that the test walls become more and more rain tight after every exposure to driving rain.

THE RESULTS OF THE TESTS

Generally speaking, six of the tested insulation materials: Glass wool, Polystyrene pearls, Rockwool batts, Rockwool granules, and Urea foam I and II absorb moisture only slightly when driving rain penetrates to the cavity in the brick wall, and as all these have a small thermal conductivity (0.03 - 0.035 kcal/mh°C for the pure materials) they are considered to be suitable for insulation of cavity brick walls. For the urea foams however, this only holds if the linear shrinkage can be

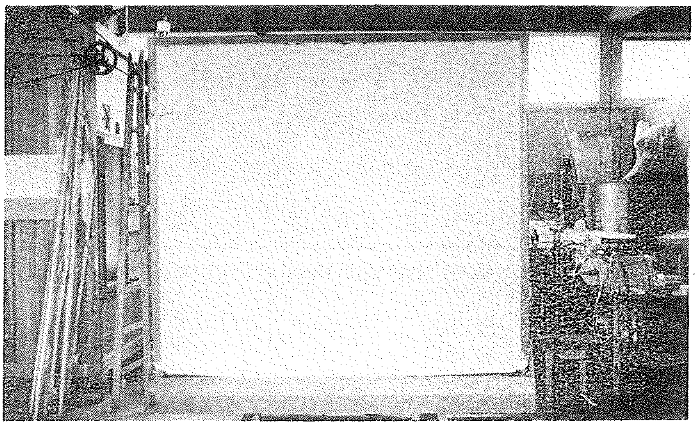

Figure 6. Urea foam I (back wall dismounted).

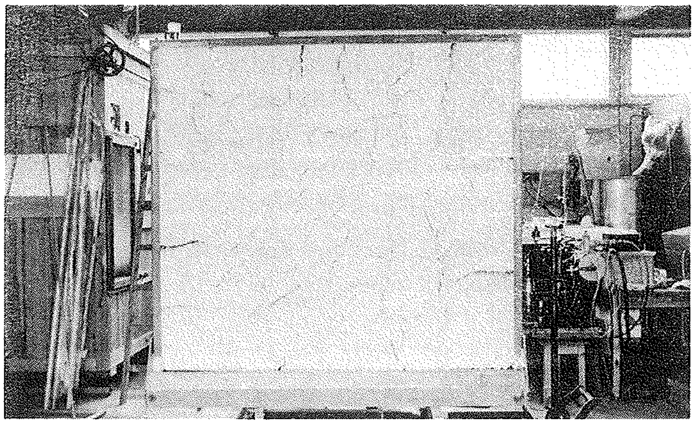

Figure 7. Urea foam II (back wall dismounted).

limited to a few percent. (See Figures 6 and 7). The remaining two materials, Clay clinkers and Vermiculite, absorb considerable amounts of moisture so that the increase in thermal conductivity is appreciable. Furthermore, these two materials, unlike the other six, may lead water from the front wall to the back, with the corresponding risk of moisture discolourations, and as they have a higher thermal conductivity (0.08 and 0.06 kcal/mh°C respectively) they are considered to be less suitable for cavity wall insulation in Denmark.

LITTERATURE

1. Rastrup, E., Regngennemslags virkning på løs fyld i hule teglstensmure. (The effect of rain penetration on insulation materials in hollow brick walls). VARME 1957: 1.