The Effect of Leakage through the Sealant in the Cup Test Method

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SUMMARY:
Cup tests based on the EN ISO 12572 standard are widely used to measure the water vapor transmission properties of construction materials. The method is said to be simple, doesn’t require any expensive equipment and produces results with minimal input. Despite the simplicity of the procedure there have been problems with producing similar results between different research institutes. Therefore it seems that the cup method can be sensitive to errors and human mistakes. A number of factors may affect the accuracy of the results. One source of error is the sealing of the sample inside the cup.

The water vapor permeability test method has been developed and the accuracy of the method improved. During the development of the method, errors caused by leakage have been studied more thoroughly. The leakage amount through the sealant was investigated with cup tests by blocking the moisture flow through the material with a sheet of aluminium. The results show that the amount of leakage depends on the position of the aluminium sheet. Also if the edge of the material is sealed with tape to prevent the intrusion of sealant inside the material, the tape may increase the leakage because of poor adhesion between the tape and the material. When measuring the water vapor permeability of a vapor tight construction material, the effect of the leakage through the sealed edge becomes larger and if care is not taken while installing the sealant the measurements may be inaccurate.

1. Introduction

Most commonly the water vapour permeability is measured according to the EN ISO 12572 standard using wet or dry cup tests. In Figure 1 is shown the principle of the wet cup test.

FIG 1. The principle of the wet cup test.
A specific relative humidity is created inside a cup by using a saturated salt solution. The specimen is placed inside the cup supported onto a threshold. The edge of the specimen is sealed with a vapour tight wax. The cup is placed inside a climate chamber. The difference in humidity by volume inside and outside of the cup creates diffusion through the specimen. Water vapour is only able to move through the material. Density of moisture flow rate can be measured by weighing the cups periodically and by using the Equation 1.

\[
g = \frac{\Delta m}{A \Delta t}
\]

Where
- \( g \) density of moisture flow rate \([\text{kg}/(\text{m}^2\text{s})]\)
- \( \Delta m \) change in weight \([\text{kg}]\)
- \( A \) open area \([\text{m}^2]\)
- \( \Delta t \) change in time \([\text{s}]\)

The water vapour permeability values can be determined with Fick’s law using the density of moisture flow rate (Equation 2).

\[
g = -\delta_v \frac{\partial v}{\partial x}
\]

Where
- \( g \) density of moisture flow rate \([\text{kg}/(\text{m}^2\text{s})]\)
- \( \delta_v \) water vapour permeability \([\text{m}^2/\text{s}]\)
- \( v \) humidity by volume \([\text{kg}/\text{m}^3]\)

Even though the test procedure seems simple there have been problems producing similar results between different research institutes. For example the round-robin test that was organized during the Annex 41 (Whole Building Heat, Air and Moisture Response) showed variation of results even though the materials were the same and the methods and the results should have been identical (Roels 2008).

The sources of uncertainty in water vapour permeability measurements have been studied in many institutes (Hansen 1990, Bomberg 1989). According to these sources, errors may result from for example barometric pressure changes, surface diffusion resistances at the specimen surfaces, air layer thickness inside the cup, RH oscillations, errors in measuring instruments, calculation technique or sealing edges.

In this paper the errors caused by leakage through the sealed edges have been examined more thoroughly.

2. Measurements

The primary purpose of the research was to investigate the water vapour permeability of an adhesive. During the research, also errors caused by leakage and their influence on the results have been studied more thoroughly. The amount of leakage through the sealant was investigated with cup tests by blocking the moisture flow through the material with a sheet of aluminium. The influence of the position of the aluminium plate was also taken into consideration. In some cases the edge of the specimen was sealed with an aluminium tape to prevent the wax from intruding between the specimens (Figure 2). The influence of the tape on the leakage was also investigated.
2.1 Specimen

Six different types of test series were tested. All of the test series consisted of three parallel and identical test specimen. Descriptions and pictures of the test series are shown in Table 1.

<table>
<thead>
<tr>
<th>Nro of Test Serie</th>
<th>Description</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Two sheets of gypsum board (reference test)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Layer of adhesive between two sheets of gypsum board</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sheet of aluminium between two sheets of gypsum board</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sheet of aluminium on top and on bottom of two sheets of gypsum board</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Layer of adhesive between two sheets of gypsum board&lt;br&gt;The edge of the specimen is sealed with aluminium tape</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sheet of aluminium between two sheets of gypsum board&lt;br&gt;The edge of the specimen is sealed with aluminium tape</td>
<td></td>
</tr>
</tbody>
</table>

The water vapour permeability of the adhesive was determined by using the first and the second test series. The amount of leakage through the sealant was investigated with the third and the fourth series. The fifth and the sixth series were done to find out the influence of the tape.

2.2 Test cup

The test cups were circular dishes made from 1.25mm thick aluminium plate. The dimensions of the test cup are shown in Figure 3.

![FIG 3. The dimensions of the test cup [mm].](image-url)
The specimen was placed inside the cup supported onto a threshold. The edge of the specimen was sealed with a vapour tight wax. The wax consisted of 40% microwax and 60% paraffin.

2.3 Test environment

During the measurement the cups were stored in a climate chamber. In the climate chamber the relative humidity was 33% and the temperature 23°C. A constant relative humidity of 75% RH was created inside the cup with a sodium chloride salt solution. The average relative humidity was therefore 54% RH.

The test cups were weighed on average three times per week. The scale was Precisa ES 2220M Executive precision scale. The reading of the scale was 0.001 g.

3. Results

3.1 Water vapour permeability of the adhesive

The density of moisture flow of test series 1 (two sheets of gypsum board) and test series 2 (layer of adhesive between two sheets of gypsum board) are shown in Table 2. In this Table is also shown the water vapour resistance values of the two test series.

<table>
<thead>
<tr>
<th>Density of moisture flow rate [g/(m²s)]</th>
<th>Water vapour resistance [Zv [s/m]]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS 1 (Two sheets of gypsum board)</td>
<td>1.3E-6</td>
</tr>
<tr>
<td>TS 2 (Layer of adhesive between two sheets of gypsum board)</td>
<td>2.3E-7</td>
</tr>
</tbody>
</table>

The water vapour resistance of the adhesive alone was determined by using the equation

\[
Z_{adh} = Z_{gb+adh} - Z_{gb}
\]  

Where 

\[
Z_{adh} \quad \text{water vapour resistance of adhesive [s/m]}
\]
\[
Z_{gb+adh} \quad \text{water vapour resistance of adhesive and gypsum board (test series 2) [s/m]}
\]
\[
Z_{gb} \quad \text{water vapour resistance of gypsum board (test series 1) [s/m]}
\]

The water vapour resistance of the mere adhesive is therefore 3.5E+4 [s/m]. This converted to a µ-value (water vapour diffusion resistance factor) equals 1577.2 [-].

3.2 The amount of leakage through the sealant

The amount of leakage through the sealant was investigated with cup tests by blocking the moisture flow through the material with a sheet of aluminium. Two different types of leakage tests were performed. The first one had a sheet of aluminium between two sheets of gypsum board (the same position as the adhesive). The other had aluminium sheets on top and on bottom of the two sheets of gypsum board.

The density of moisture flow rates of these two test series can be seen in Table 3.
TABLE 3. Density of moisture flow rates of test series 3 and 4.

<table>
<thead>
<tr>
<th>Density of moisture flow g [kg/(m²s)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS 3 (Sheet of aluminium between two sheets of gypsum board)</td>
</tr>
<tr>
<td>TS 4 (Sheet of aluminium on top and on bottom of two sheets of gypsum board)</td>
</tr>
</tbody>
</table>

The results show that the leakage amount is greater in test series 3, where the moisture flow is only blocked with a sheet of aluminium between the two sheets of gypsum board.

3.3 The influence of leakage to the water vapour permeability

Also the influence of leakage to the water vapour permeability values was investigated. This was done by correcting the density of moisture flow rates with the amount of leakage. A following equation was used:

\[ g_{\text{fin}} = g - g_{\text{edge}} \]  \hspace{1cm} (4)

Where  
- \( g_{\text{fin}} \) corrected density of moisture flow [kg/(m²s)]  
- \( g \) density of moisture flow of main series [kg/(m²s)]  
- \( g_{\text{edge}} \) density of moisture flow through the edge of the cup [kg/(m²s)]

The corrected water vapour permeability was then calculated by using the corrected density of moisture flow rates. The corrected values were determined for gypsum board and the adhesive alone to see how the effect changes when considering a vapour tight material compared with a very vapour open material. The results can be seen in Figures 4 and 5.

FIG 4. The influence of the leakage to the water vapour permeability of gypsum board.
FIG 5. The influence of the leakage to the water vapour permeability of adhesive.

The results show that the influence of the error caused by leakage may become significant when considering vapour tight materials.

3.4 The influence of aluminium tape to the leakage amount

In the EN ISO 12572 standard is written that molten sealants may penetrate into porous materials and introduce errors to the effective area under test. The edge of the specimen is therefore in these cases advised to be sealed with tape or an epoxy resin. In this research the influence of the taping was under investigation. In two test series the edge of the specimen was sealed with an aluminium tape to prevent the wax from intruding between the two sheets of gypsum board. The influence of the tape can be seen in Figure 5.
According to the results (Figure 5) the leakage through the edge of the specimen increased significantly when the edge of the specimen was sealed with aluminium tape.

4. Conclusion

Leakages through the sealant in cup tests may cause significant errors to water vapour permeability values if they are not taken into consideration. The errors can be taken into account by measuring the moisture flow through the seal with an additional test series where the moisture flow through the material has been blocked with for example an aluminium plate. The amount of leakage can then be reduced from the main results.

When evaluating the amount of leakage the original specimen type should be taken into account. The position of the aluminium plate has a strong impact on the amount of leakage and the final results.

The sealing of the specimen with a tape is not advisable. The tape sealed on to the edge of the specimen may increase the leakage through the sealant because of poor adhesion between the tape and the specimen. If there is a risk of molten wax penetrating a porous specimen and the edge of the specimen is sealed with tape or epoxy resin the amount of leakage through seal should be investigated with additional test cups where the moisture flow through the specimen is prevented.
5. Acknowledgements

These investigations considering the amount of leakage through the sealant have been performed in connection to a research project carried out for an industrial company. The objective of the main research was to measure the water vapour permeability of different adhesives.

References


