PREDICTION MODELS OF THE WATER VAPOR DIFFUSION BEHAVIOR OF WOOD-BASED PANELS

Norbert Ruether¹, Heinz Peters², Roland Kronen³

ABSTRACT: Wood-based materials for construction have to possess moisture protection characteristics, but the parameters influencing those characteristics were largely unknown. Within the project the influence of the parameters density, particle size, type of adhesive and level of adhesive content on the water vapor diffusion behavior of wood based panels was investigated. The results led to prediction models of the water vapor diffusion behavior of wood based panels.

KEYWORDS: buildings physics, water vapor diffusion, wood based panels, prediction models

1 INTRODUCTION

Wood-based materials for construction have to possess moisture protection characteristics. These characteristics, however, are influenced by many different parameters which were largely unknown. This led to widely differing μ-value specifications being listed for comparable products in official regulations. This causes planning offices to regularly make false assumptions and interpretations for construction situations. The literature research prior to the project provided no explanation for this, so a systematic investigation of the influences of each parameter seemed necessary.

2 TASK OF THE PROJECT

The task of the project was to design prediction models for the water vapor diffusion behavior of wood based panels. With these models, manufacturer of wood based panels can calculate the behavior to water vapor diffusion without measuring the value.

3 METHODS

At the Fraunhofer WKI pilot plant laboratory boards were prepared by varying the parameters density, particle size, type of adhesive and level of adhesive content systematically.

The diffusion resistance was ascertained in accordance with ISO 12572.

1 Norbert Ruether, Fraunhofer WKI, Bienroder Weg 54E, Braunschweig, Germany. E-Mail: norbert.ruether@wki.fraunhofer.de

2 Heinz Peters, Fraunhofer WKI

³ Roland Kronen, Fraunhofer WKI

4 RESULTS

During the project it became clear that the parameter type of adhesive has no significant influence while others had a considerable influence. The density, for example, has an exponential effect (see Figure 1). This, combined with the fact that the density of wood-based materials has a relatively large variance, explains why there were great differences in the specified values. The results of the investigations in this project also show that the μ-values measured cannot be reliably interpreted if the density of the test specimen is not accounted for at the very least. Besides the density, the particle size and the level of adhesive content also have a considerable influence under each different set of conditions.

For OSB the over-proportional increase in μ-value characteristic for exponential functions can be seen in the density range between 400kg/m³ and 700kg/m³. It is...
therefore in the range which typical wood-based materials have as a density.

While the density correlates very well with the $\mu$-value, the logarithmical influence of the particle size is very difficult to model, so specific models were created in this project for common particles such as fibers, chips and strands. The influence of the level of adhesive content, however, correlates with the density and the particle size such that the models for describing the $\mu$-value display two summands.

The first describes as

$$\mu_1 = a + b \cdot e^{\left(\frac{\rho}{\tau}\right)}$$  \hspace{1cm} (1)

the exponential influence of the density. The second, as

$$\mu_2 = d \cdot \left(\frac{\beta}{f}\right)^{1.5} \cdot \left(\frac{\rho}{g}\right)^2$$ \hspace{1cm} (2)

describes the influence of the level of adhesive ($\beta$) content in relation to the density ($\rho$).

The factors $a$ to $g$ for each wood-based material type are listed in Table 1. The density should always be entered in kg/m$^3$ and the level of adhesive content as a percentage. The proportion of hydrophobic agents should be added to the adhesive content. As wood-based materials can possess different particle sizes, densities and adhesive contents in different layers, the models are differential in practice, i.e. have to be applied specific to each layer.

### Table 1: Factor values

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value of the factors by boards made of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fibers</td>
</tr>
<tr>
<td>a</td>
<td>5</td>
</tr>
<tr>
<td>b</td>
<td>0.1</td>
</tr>
<tr>
<td>c</td>
<td>150</td>
</tr>
<tr>
<td>d</td>
<td>0.1</td>
</tr>
<tr>
<td>f</td>
<td>10</td>
</tr>
<tr>
<td>g</td>
<td>100</td>
</tr>
</tbody>
</table>

### 5 CONCLUSIONS

The models are not precise mathematical physical models. They have been empirically calculated on the basis of test results. Error estimation has shown that the results have an error level of around +/-10% and that measurements show a similar error range. As the adhesive content in a diffusion sample and within a layer cannot be precisely ascertained and the particle sizes can differ greatly even within a layer, the difference between the measurement and the calculation can be even bigger than that stated above. However, a $\mu$-value as shown above can be expected on average, meaning that the $\mu$-value can be predicted with sufficient precision for a production batch.

Comparing the results of the diffusion measurements with small samples with a diffusion face of around 54cm$^2$ to those with a 250cm$^2$ diffusion face, it can be seen that the smaller test specimens produce greater deviations from the average (especially when there are inhomogeneous materials in the face) than their larger counterparts. ISO 12572 specifies that the diffusion resistance value has to be the (arithmetic) average from 5 samples. This approach, however, does not take into account that the process involves parallel-“connected” resistances from a physical point of view. Face ($A_{ges}$) of a wood-based material consists of many small aligned faces ($A_i$). Thus, the face $A_{ges} = \Sigma A_i$. Each partial face has its own diffusion resistance. As these partial faces lie next to each other, the diffusion resistance of the overall face ($R_{ges}$) is ascertained as the total resistance of several “parallel-connected” resistances. The equation is

$$\frac{1}{R_{ges}} = \Sigma \frac{1}{R_i}$$  \hspace{1cm} (3)

This equation shows that the partial faces with a very low resistance can significantly impact the total resistance. In the case of fiber panels, these (microscopic) partial faces with very low diffusion resistance are very evenly distributed across the face due to the particle structure. The bigger a particle’s face (fiber – chip – strand – veneer), the more likely it is that partial faces occur which have a very low diffusion resistance.

### ACKNOWLEDGEMENT

The investigations were founded by the Bundesministerium für Wirtschaft und Technologie (Federal Ministry of Economics and Technology) via the Arbeitsgemeinschaften industrieller Forschungsvereinigungen (German Federation of Industrial Research Associations), reprented by the internationalen Verein für technische Holzfragen (Association for Technical Issues related to Wood).