JSACE 2/25

Moisture Safety of the Construction with VCL Using Hygrobrid Technology

Received 2019/01/09

Accepted after revision 2019/05/02

Moisture Safety of the Construction with VCL Using Hygrobrid Technology

Martin Polikarpus

Siga Cover AG, Rütmattstrasse 7, CH-6017 Ruswil, Switzerland

Daniel Kehl

Büro für Holzbau und Bauphysik, Nixenweg 14, D-04277 Leipzig, Germany

Corresponding author: **kehl@holzbauphysik.de**

crossref http://dx.doi.org/10.5755/j01.sace.25.2.22422

Unventilated and green flat roofs with wooden construction and insulation between the rafters are used in new buildings. Due to the external vapour-tight construction, such roofs have no drying capacity on the outside. The scope of this study is to assess whereas the wood degradation in the wood or OSB caused by wood destroying fungus can take place as this can affect the structural function of the construction. Results show, that the 3rd generation moisture variable vapour control layer, which has additional function that the Sd-value changes according to the direction of the diffusion, has many application areas. The behaviour of the vapour control layer has a positive effect on the moisture balance of an external vapour-tight green roof. The moisture and direction variable performance of the 3rd generation vapour control layer has also a positive effect on the moisture balance of an external vapour-tight pitched roof. It is important to underline that presented results are valid for Central-European climatic conditions.

Keywords: building physics, diffusion tight flat roof, diffusion tight pitched roof, hygrobrid, moisture variable

Introduction

Unventilated and flat green roofs

Unventilated and green flat roofs with wooden construction and insulation between the rafters are used in new buildings. Due to the external vapour-tight construction, such roofs have no drying capacity on the outside. This is a typical application area for a moisture variable vapour control layer, which has a higher diffusion resistance in winter, when the inside air is dry, and a lower diffusion resistance in the summer, when the humidity is re-diffused and the room air is more humid. Since flat roofs are a standard in new buildings, the moisture from screed and plaster should also be considered.

Pitched roofs with vapour-tight underroof

The functioning roofs of old buildings can energetically renovated from the inside. In previous times, such roofs were often constructed with a vapour-tight underroof (e.g. bitumen sheeting on wooden framework). Therefore, the internal vapour control layer is of particular importance also in this type of construction.

ktu 1922

Journal of Sustainable Architecture and Civil Engineering
Vol. 2 / No. 25 / 2019
pp. 25-34
DOI 10.5755/j01.sace.25.2.22422

The scope of the simulations is to assess whereas the wood degradation in the wood or OSB caused by wood destroying fungus can take place as this can affect the structural function of the construction.

Methods

The simplified Glaser method according to DIN 4108-3: 2014 and SIA 180: 2014 is not applicable for external vapour-tight, green flat roofs, and vapour tight pitched roofs in wooden construction with inward laying moisture control layer. In addition, such a simplified method cannot be used to analyse different parameters in terms of building physics. In such cases, hygrothermal simulations could be used (EN 15026: 2007; WTA 6-2: 2014). The roof types can be examined and analysed using the software Delphin 5.9. These analyses will demonstrate the performance of the newly developed 3rd generation vapour control layer with Hygrobrid technology (3rd generation MVVCL). The vapour control layer is not only moisture variable but also direction variable, and it is compared in this examination with other moisture variable vapour control layers with small and large spread.

Vapour Control Layer

Moisture variable vapour control layer

There are currently many different moisture variable vapour control layers available on the market. The first generation of vapour control layers with moisture variable diffusion resistance has a small spread between high and low diffusion resistance (Fig. 1). Since then, they have been developed further, so that the 2nd generation vapour control layers have a larger spread of diffusion-equivalent air layer thickness (S_d-value) (Fig. 1).

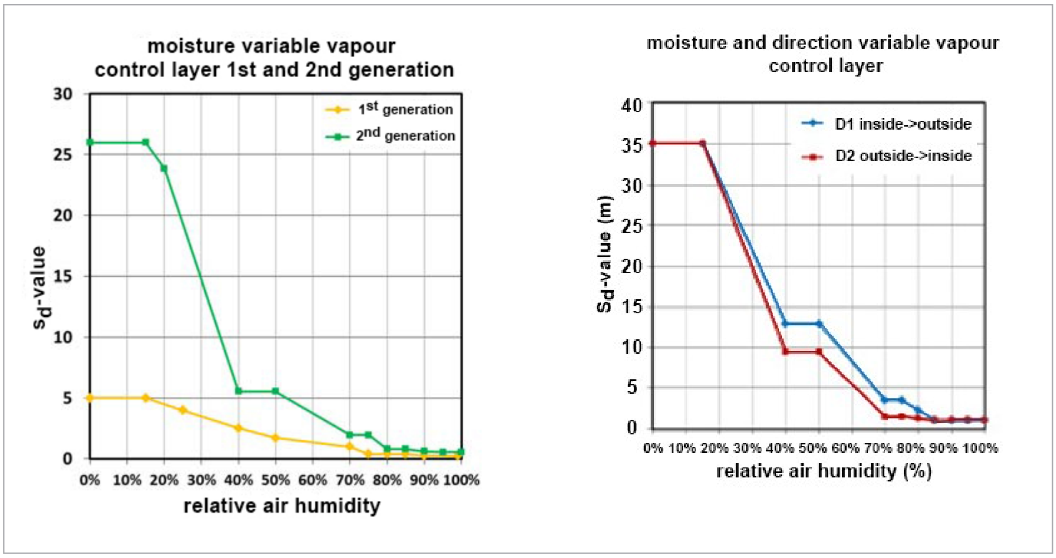


Fig. 1

Calculated Sd-value curves of the 1st and 2nd generation moisture variable VCL-s (left). Directional Sd-value curves of the 3rd generation VCL – blue curve: room → insulation; red curve – insulation → room (right)

Moisture and direction variable vapour control layer

Besides the moisture variability, this patented vapour control layer has an additional function – its material properties allow different S_d-value at the same ambient air humidity, according to the direction of the diffusion flux. This way, the effect of the moisture variability is strengthened. Moreover, the diffusion of the water vapour in the construction is reduced due to the elevated S_d-value (Fig. 1) at higher room air humidity (e.g. moisture from screed or plaster during construction phase). The presented curves are based on measurements carried out by TU Dresden.

Construction Calculations

Flat roof

External vapour-tight and green flat roof in wooden construction is simulated hygrothermally (Table 1). The roof is provided with a sealing (construction site seal) above the OSB panel with additional insulation of a further seal. As several studies have determined, construction of green roof has an unfavourable effect on its drying capacity. The section of a flat roof is shown in Fig. 2. Layer numbers correspond to Table 1.

Table 1

Structural building components of the calculated flat roof construction

Layer number	Description	Thickness [mm]	Thermal conductance [W/(m·K)]	Vapour resistance [-]
1	Green roof	–	–	–
2	Roof seal	1.0	2.3	100 000
3	On-roof insulation	120.0	0.028	100
4	Bituminous sheeting with aluminium insert	1.0	2.3	1500 000
5	OSB panel	22.0	0.13	165
6	Mineral fibre insulation cellulose insulation	240.0 240.0	0.035 0.040	1 1.5
7	Vapour control layer	0.16	2.3	800-35000
8	Air layer (batten)	25.0	0.18	0.46
9	Gypsum plasterboard	12.5	0.2	8.3

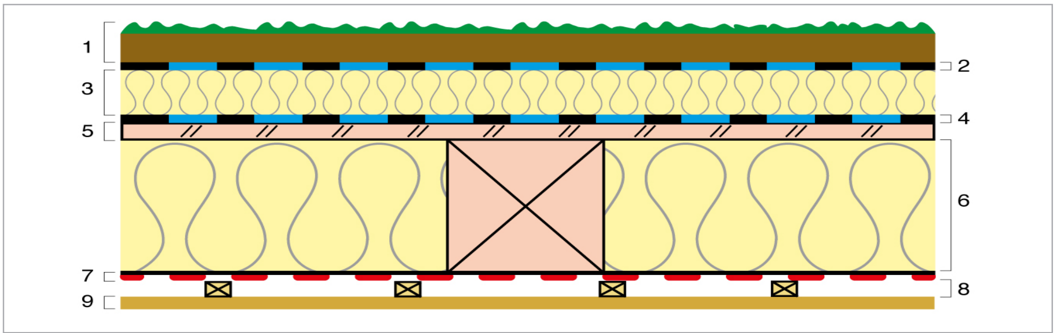


Fig. 2

Section of flat roof

Pitched roof

Unventilated and externally vapour-tight pitched roof with ventilated roof covering is simulated hygrothermally (Table 2). The roof is provided with an external vapour-tight underroof on solid

Table 2

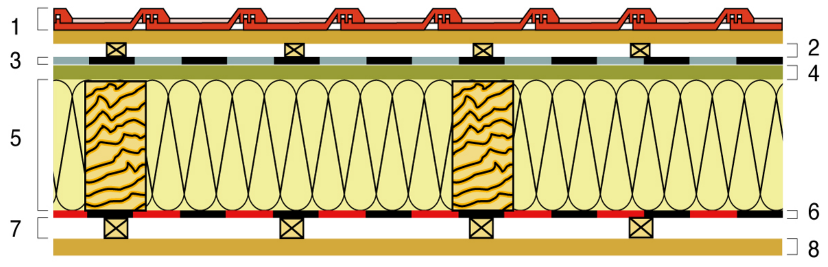
Structural building components of the calculated pitched roof

Layer number	Description	Thickness [mm]	Thermal conductance [W/(m·K)]	Vapour resistance [-]
1	Roof covering – red clay tiles	-	-	-
2	Air layer (counter batten)	-	-	-
3	Bituminous sheeting	2.0	2.3	100 000
4	Solid wooden formwork	22.0	0.09	130
5	Mineral fibre insulation cellulose insulation	240.0 240.0	0.035 0.040	1 1.5
6	Vapour control layer	0.16	2.3	800-35000
7	Air layer (batten)	30.0	0.18	0.46
8	Gypsum plasterboard	12.5	0.2	8.3

wooden formwork and represents the classic building standards of the 1960s and 1970s. The first studies have shown (Künzel 1998) that the external and internal climate, the inclination of the roof and the orientation are important influencing factors for the drying performance of the roof. Convection through leaks is an additional factor to consider. The section of calculated pitched roof is given in **Fig. 3**. Layer numbers correspond to **Table 2**.

Fig. 3

Section of pitched roof



Simulation Boundary Conditions

Boundary conditions used

The results of the hygrothermal simulations are always in connection with the applied boundary conditions (**Table 3**, **Table 4**).

Table 3

Boundary conditions for the hygrothermal simulations for flat roofs

Parameter	Description of boundary conditions
Outdoor climate:	Holzkirchen humidity reference year
Indoor climate:	Internal climate according to EN ISO 13788: / WTA 6-2:2014 - 20-25 °C and 35-65 % relative air humidity or building moisture
Surface transfer coefficient inwards:	Heat transfer resistance: 0,125 m^2K/W; Heat transfer coefficient: 8 W/m^2K
Source of humidity Airtightness:	Airtightness class B (q50 = 3 m^3/m^2h) Height of the air column in the building: 10 m Moisture load 250g/m^2y
Start/duration of the simulation:	01.10. / 10 – 15 years to a steady state
Starting humidity:	20 °C / 80% relative air humidity (cellulose: 50%)

Table 4

boundary conditions for the hygrothermal simulations of pitched roofs

Parameter	Description of boundary conditions
Outdoor climate:	Holzkirchen humidity reference year
Orientation:	North
Indoor climate:	Internal climate according to EN ISO 13788: / WTA 6-2: 2014 20-25 °C and 35-65 % relative air humidity
Surface transfer coefficient outwards: (convective component)	Heat transfer resistance: 0,08 m^2K/W Heat transfer coefficient: 12,5 W/m^2K
Surface transfer coefficient inwards:	Heat transfer resistance: 0,125 m^2K/W Heat transfer coefficient: 8 W/m^2K
Short-wave absorption coefficient a:	a = 0,6 [-] (Künzel 1998)
Long-wave emissions coefficient ε:	ε = 0,3 [-] (Künzel 1998)
Source of humidity Airtightness:	Airtightness class B (q50 = 3 m^3/m^2h) Height of the air column in the building: 10 m Moisture load 250g/m^2y
Start/duration of the simulation:	01.10. / 10 - 15 years to a steady state
Starting humidity:	20 °C / 80 % relative air humidity (cellulose: 50 %)

Explanation of the boundary conditions

Outdoor climate: Künzel (1998) has shown that with the external vapour-tight pitched roofs, the humidity of the outer wooden framework with the same roof inclination essentially depends on the outside temperature. The colder it is, the bigger the damage to the construction of the building could be. Holzkirchen, together with Hof, is one of the most critical sites and covers locations with an annual average temperature of at least 6.6 °C (in comparison Stockholm and Oslo has an annual average temperature of 6.8 °C with annual sun radiation difference of 2-4%). Since the climate data set in Holzkirchen (reference year for humidity) was of high quality for the simulation, this data set was used.

Moisture load and convection: The 22 mm thick wood and 22 mm OSB is divided into two layers in the simulation: 12 mm and 10 mm. The 10 mm layer is situated towards the inner side of the construction and moisture load of 250g/m^{2}y is applied to this layer. In this way leaks through convection are taken in account.

Green roof: Green roofs have an impact on the hygrothermal performance of the flat roof. As there is no validated material data set for the green roofs in Delphin 5.9, the climate data set was generated from temperature and relative air humidity. In addition, the flat roof described above is simulated using WUFI® including a 80 mm green roof (single layer substrate). The temperature and relative air humidity above the seal has been recorded and transferred into a climate data set for Delphin. The 80 mm layer of green roof is taken from the research project [IBP 2013] of Fraunhofer Institute for Building Physics and has been validated on various roofs in Europe (Leipzig, Vienna, Holzkirchen, Milan).

Built-in moisture: As the examinations of the Fraunhofer Institute for Building Physics show (Holm, Künzel 1999), the wet masonry walls with outside insulation dry between 2-4 years, depending on the insulation material (mineral fibre and EPS). Therefore, an assumption is made that the relative room air humidity only adapts to the normal indoor climate in the residential buildings in the course of three years as derived in the study by Zirkelbach, Holm in 2001 using room simulations.

Orientation: According to the orientation of the roof, the solar radiation onto the pitched roof is different - it is the highest towards the south and lowest towards the north. The pitched roof examined in this study is towards the north direction and is therefore in an unfavourable situation.

Evaluation Criteria for Oriented Strand Board (OSB) and Wood

Oriented strand board

In case of high material moisture, the strength parameters of OSB are reduced. This can lead to both a reduction of the load capacity and the usability (DIN 68800-2: 2012). This is to comply with the limit value of 18 M-%. According to the standard, it may be temporarily exceeded up to 20 M-%, if it can re-dry within 3 months.

Safety margin for OSB

The safety margin is determined by means of the limit value of 18 M-%. In this case, the smallest margin between the OSB moisture and the limit value in the steady state is calculated. If the value is negative, the limit is exceeded, if it is positive, then it is not exceeded. Definition of the safety margin for OSB are shown in Fig. 5.

In addition to the safety margin of the limit curve, the amplitude of the OSB is evaluated. Damage cases are known, where a bulge in the construction / pressing apart of the underlying walls appeared due to significant changes of moisture in OSB. Therefore, it is recommended in WTA MB E 6-8: 2015, chapter “Usability”, that the humidity fluctuation between summer and winter is to be constructively minimized (e.g. by additional external insulation).

Evaluation criteria for wood

For the assessment of wood moisture content, the so-called 20 M-% wood moisture criteria is often used. As stated by Kehl (2013), such a limit value is unsuitable for the evaluation of the hygrothermal simulation. In such cases, a detailed demarcation is needed, which couples the height and duration of the humidity with the temperature. For this purpose Kehl (2013) derived a limit based on Finnish investigations (Viitanen, Ritschkoff 1991). As a result of the study, no wood degradation took place following 12 months of storing wood samples with inoculated wood-destroying fungi in climatic conditions that lie on the limit value line.

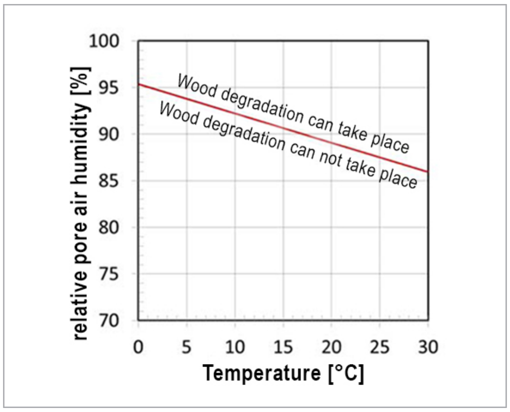


Fig. 4

Limit curve according to [WTA E 6-8 2015] for the evaluation of the pore air humidity and temperature under a 10 mm thick wood layer, which may not be exceeded in the daily average

Since the wood moisture content spreads due to different absorption isotherms in the individual programs, the wood moisture content is not evaluated but rather the relative humidity in the material (pore air humidity) is taken in account. This type of evaluation has proven itself in numerous simulations and can be found in the corresponding regulations (WTA MB E 6-8 2015). The temperature and relative pore air humidity in the wood (10 mm thick layer) is averaged over the day and represented in Fig. 4.

Safety margin for Wood

The safety margin is determined in Fig. 5, which shows the border limit and an example of the measured daily values for the 5th year. The smallest distance between the value pairs (temperature / relative pore air humidity in the material) and the limit curve in the steady state are calculated. In case of a negative value, the limit curve is exceeded, it may result in wood degradation by wood-destroying fungi; in case of a positive value it cannot. If the safety margin is very small, it must be observed, whether the long-term humidity level is low.

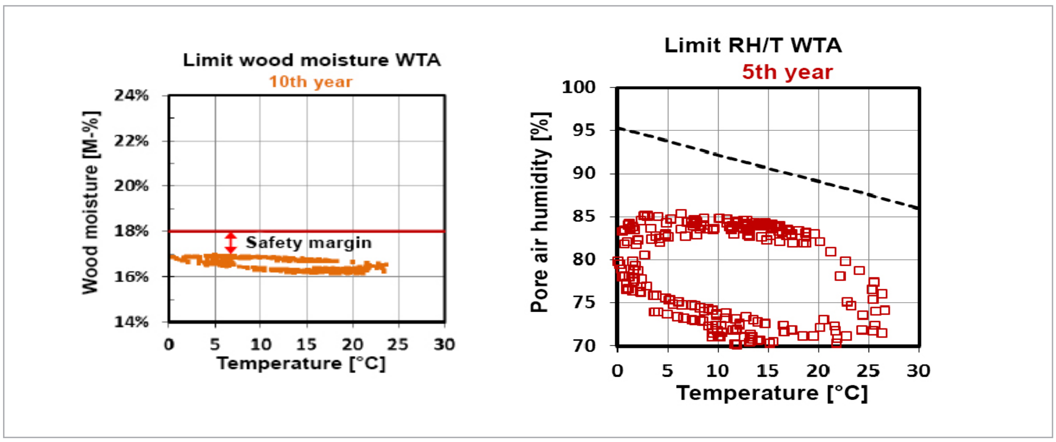


Fig. 5

Example for the definition of the safety margin between the recorded daily average of the wooden composite moisture and the limit value in the 10th year steady state (Left). Example of the definition of the safety margin for wood between the entered average daily values and the limit curve in the 5th year in steady state (right)

Results

Safety margin with mineral fibre insulation for flat roofs

The safety margins of the (OSB) moisture when using the different vapour control layers are shown in Fig. 6. When using mineral fibre insulation and considering the convection (LDK B, h = 10 m), the 3rd generation MVVCL has a safety margin up to 1.1 M-% compared to other vapour control layers. If the safety margin is negative then it exceeds the limit value.

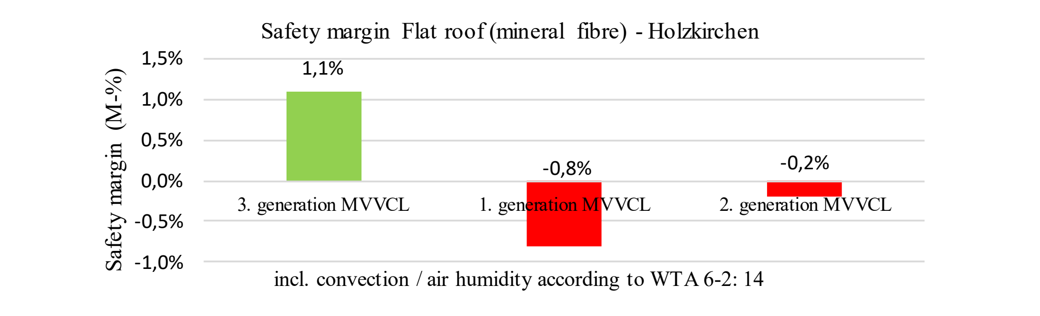


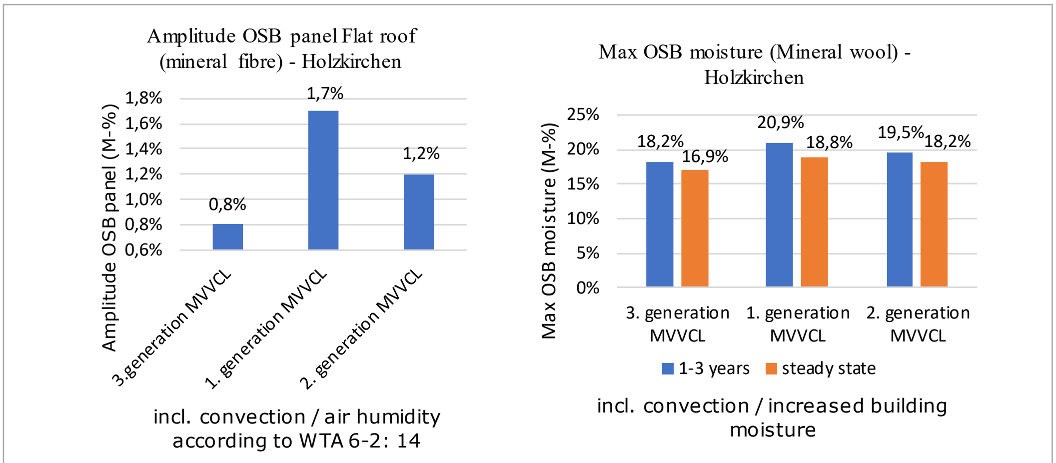
Fig. 6

Safety margin of an external vapour-tight flat roof with different vapour control layers and mineral fibre insulation. The 3rd generation MVVCL is the only one with a safety margin to the limit value. The others exceed the limit value of 18 M-%

Moreover, the humidity fluctuation of an OSB panel with 3rd generation MVVCL is lower, 0,8 M-% per year (see Fig. 7). Due to lower amplitude, the deformations of the OSB panel are also reduced.

Safety margin of moisture building

Since flat roofs are mainly used in new buildings, the moisture behaviour within the first few years after completion of the building is considered in Fig. 7. As already described above, the increased moisture building is taken into account within the first 3 years. Although the moisture and direction variable performance of the 3rd generation VCL slightly exceeds the limit (18.2 M-%), the duration of the exceedance is less than 3 months, which is permissible according to DIN 68800-2.



The lower the value, the less deformations resulting from it (left). Maximum material moisture of the OSB panel in the first 3 years following the production (with the estimated building moisture) and the long-term performance. With its moisture and direction variable vapour control layer, the 3rd generation MVVCL shows a strong inclination towards building moisture (right).

Fig. 7

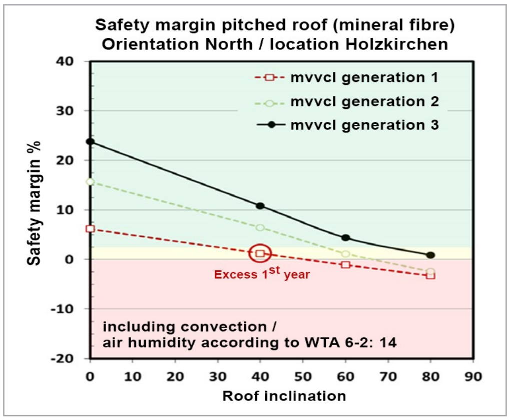
Humidity fluctuation of the OSB panel between summer and winter (amplitude)

Safety margin for pitched roofs

The roof is gradually tilted north, which reduces the solar short-wave radiation onto the roof and thus the re-drying capacity of the building component. The safety margin between the 3rd generation MVVCL and the moisture variable vapour control layer of the 1st and 2nd generation in conjunction with the roof inclination is shown in Fig. 8. If the safety margin is very small (yellow area), the data must be analysed more precisely. The steeper the roof inclination is, the lower the level of summer re-drying and thus the safety margin. Accordingly, the application area of the 3rd generation MVVCL in case of a north orientation is possible up to a roof inclination of 80° and thus also for steep mansard roofs.

Fig. 8

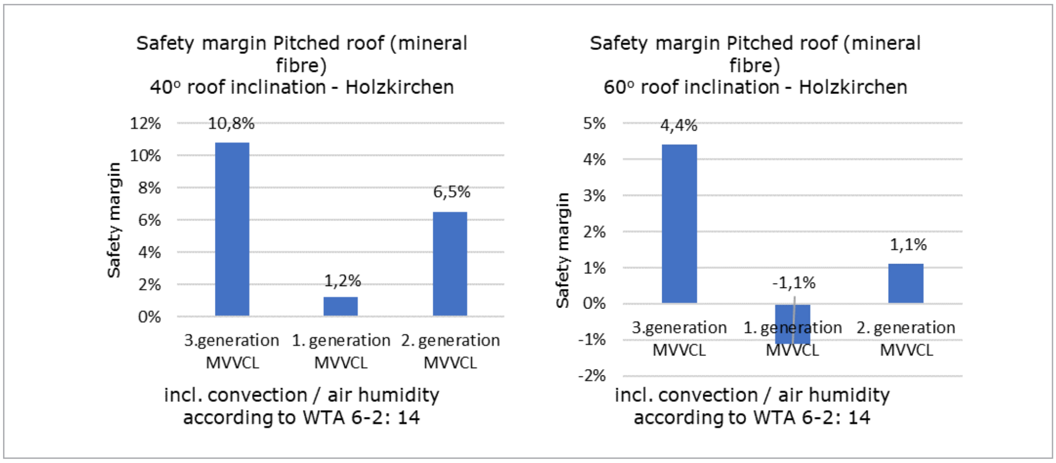
Safety margin of an external vapour-tight pitched roof (north orientation) with different vapour control layers in function of roof inclination (mineral fibre insulation)



The moisture variable vapour control layer of the 1st generation at 40° in a steady state has a small safety margin of 1.2 M-% relative to air humidity (**Fig. 9**). However, it exceeds the limit curve in the first year of the simulation. The moisture variable vapour control layer of the 2nd generation can be constructed up to a roof inclination of 60°. If cellulose is used in the roof construction instead of mineral fibre, the pitched roof with all the vapour control layers may only be constructed up to a roof inclination of 40°. In case of a 40° and 60° inclined, north-oriented roof, the safety margin of the 3rd generation VCL will be again compared with the moisture variable vapour control layer of the 1st generation and the 2nd generation (**Fig. 9**).

Fig. 9

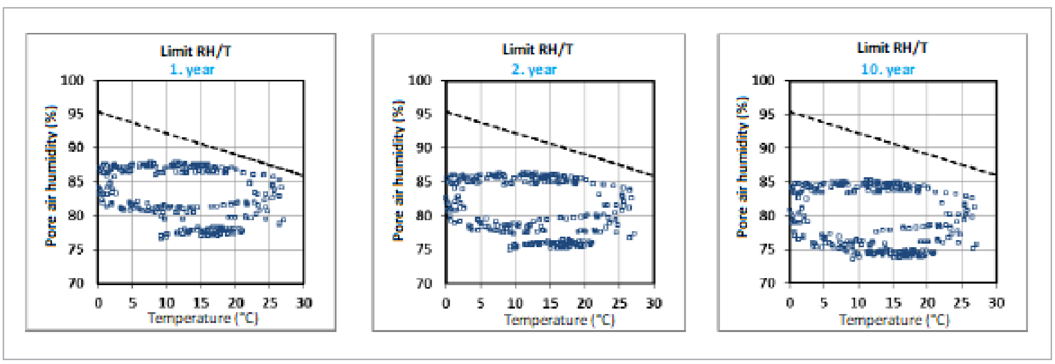
Safety margin of an external vapour-tight pitched roof (north orientation) with different vapour control layers in function of roof inclination (left: 40°, right: 60°)



Daily calculated pore air humidity/temperature values for 3rd generation MVVCL and the limit line for mould growth according to WTA-leaflet E 6-8 in 10 mm wooden formwork on 1st, 2nd and 10th year are presented on **Fig. 10** dealing with pitched roofs with mineral fibre insulation, North orientation 60° pitch. Delphin calculation results for development of the pore air humidity in a 10 mm thick wooden layer and the corresponding condensing limit value according to WTA-leaflet E 6-8 are given in **Fig. 11**.

Fig. 10

Evaluation of the pore air humidity/ temperature according to WTA-leaflet E 6-8 in 10 mm wooden formwork for 1st, 2nd and 10th year



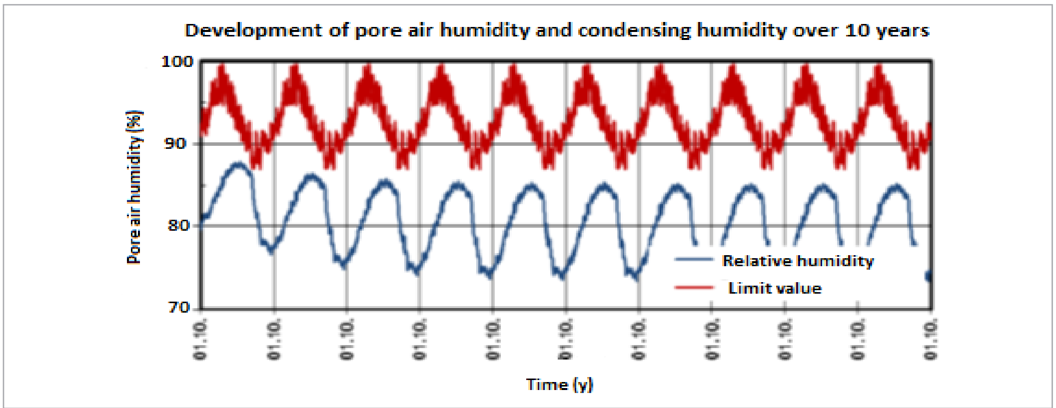


Fig. 11

Development of the pore air humidity in a 10 mm thick wooden layer and the corresponding condensing limit value according to WTA-leaflet E 6-8

Conclusions

The 3rd generation moisture variable vapour control layer, which has additional function that the S_d-value changes according to the direction of the diffusion, has many application areas. The behaviour of the vapour control layer has a positive effect on the moisture balance of an external vapour-tight green roof. Even in case of unfavourable conditions, there is still a re-drying capacity. As compared with the moisture variable vapour control layers of the 1st and 2nd generation, it has a high drying potential.

The moisture and direction variable performance of the 3rd generation vapour control layer has also a positive effect on the moisture balance of an external vapour-tight pitched roof. Even in unfavourable conditions (e.g. 80° - north – mineral fibre insulation - with convection), a re-drying capacity still exists. As compared to the moisture variable vapour control layer of the 1st and 2nd generation, the vapour control layer has a greater drying potential also in these constructions.

It is important to underline that presented results are valid for Central-European climatic conditions. Authors of this study have conducted numerous simulations for Northern-European climate (Oslo, Tromso, Stockholm, Helsinki) which will be presented in further research.

References

DIN 4108-3. 2014. Wärmeschutz und Energie-Einsparung in Gebäuden – Teil 3: Klimabedingter Feuchteschutz – Anforderungen, Berechnungsverfahren und Hinweise für Planung und Ausführung [Thermal insulation and energy savings in buildings – Part 3: Climate-related moisture protection – requirements, calculation methods and instructions for planning and execution], Beuth Verlag, Berlin 2014

DIN 68800-2. 2012. Holzschutz – Teil 2: Vorbeugende bauliche Maßnahmen im Hochbau [Wood protection – Part 2: Preventive structural measures in building construction], Beuth-Verlag, Berlin

EN 15026. 2007. Wärme- und feuchtetechnisches Verhalten von Bauteilen und Bauelementen – Bewertung der Feuchteübertragung durch numerische Simulation [Thermal and humid-technical behavior of components and components – Evaluation of moisture transmission by numerical simulation], Beuth-Verlag, Berlin

EN ISO 13788. 2013. Wärme- und feuchtetechnisches Verhalten von Bauteilen und Bauelementen – Raumseitige Oberflächentemperatur zur Vermeidung kritischer Oberflächenfeuchte und Tauwasserbildung im Bauteilinneren – Berechnungsverfahren [Thermal and humidity – related behavior of components and constructions – Room-side surface temperature to avoid critical surface moisture and condensation in the interior of the component – calculation method], Beuth Verlag, Berlin

Holm, A.; Künzel, H.M. 1999. Trocknung von Mauerwerk mit WDVS und Einfluß auf den Wärmedurchgang [Drying of masonry with MVVCL and influence on the heat transfer], In: Bauklimatisches Symposium, Dresden

IBP 2013. Hrsg.: Fraunhofer Institut für Bauphysik, Forschungsvorhaben: Ermittlung von Materialeigenschaften und effektiven Übergangsparametern von Dachbegrünungen zur zuverlässigen Simulation der hygrothermischen Verhältnisse in und unter Gründächern bei beliebigen Nutzungen und unterschiedlichen Standorten [Research project: Determination of material properties and effective transition parameters of green roofs for the reliable simulation of hygrothermal conditions in and under green roofs for any use and different locations], Eigenverlag, Holzkirchen

Kehl, D. 2013. Feuchtetechnische Bemessung von Holzkonstruktionen nach WTA - Hygrothermische Auswertung der anderen Art, Beitrag in der Fachzeitschrift Holzbau – die neue quadriga, Ausgabe 06-2013 [Humidity-related design of timber constructions according to WTA - hygrothermal evaluation of the other species, article in the journal Holzbau - the new quadriga, issue 06-2013], Kastner Verlag, Wolnzach

Künzel, H.M. 1998. Bedeutung von Klimabedingungen und Diffusionseigenschaften für die Feuchtesicherheit von Altbaudächern, In: Berichte aus Forschung und Praxis - Festschrift zum 60. Geburtstag von Karl Gertis [Importance of climatic conditions and diffusion properties for the moisture safety of old roofs, In: Reports from research and practice - commemorative publication on the 60th birthday of Karl Gertis], IRB-Verlag, Stuttgart 1998

SIA 180. 2014. Schweizerischer Ingenieur- und Architektenverein: SIA 180 – Wärmeschutz, Feuchteschutz und Raumklima in Gebäuden [Swiss Association of Engineers and Architects: SIA 180 - Thermal insulation, moisture protection and indoor climate in buildings], Zürich

Viitanen, H.; Ritschkoff, A-C. 1991. Brown rot decay in wooden constructions. Effect of temperature, humidity and moisture; Swedish University of Agricultural Scienses, Department of Forest Products, Report no 222, Uppsala

WTA MB 6-2. 2014. Hrsg. Wissenschaftlich Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege: Merkblatt 6-2: Simulation wärme- und feuchtetechnischer Prozesse [Scientific Technical Association for Building Preservation and Historic Preservation: Fact Sheet 6-2: Simulation of heat and humidity], IRB Verlag, München

WTA MB E 6-8. 2015. Hrsg. Wissenschaftlich Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege: Merkblatt Entwurf 6-8: Feuchtetechnische Bewertung von Holzbauteilen – Vereinfachte Nachweise und Simulation Zirkelbach, D.; Holm A. 2001. Trocknungsverhalten von monolithischen Wänden [Scientific technical working group for building conservation and historic preservation: Leaflet Draft 6-8: Humidity assessment of timber components - simplified evidence and simulation: Drying behavior of monolithic walls], In: IBP Mitteilung 389, Eigenverlag, Holzkirchen

About the Authors

MARTIN POLIKARPUS

Deputy Head of Application Engineering North Europe

Siga Cover AG, Application Engineering North Europe

Main research area

Building physics and material behavior

Adress

Rütmattstrasse 7, CH-6017 Ruswil, Switzerland
Tel. +41 41 499 69 69
E-mail: martin.polikarpus@siga.swiss

DANIEL KEHL

Consultant for building physics

Büro für Holzbau und Bauphysik

Main research area

Building physics and hygrothermal behavior

Adress

Nixenweg 14, 04277 Leipzig, Germany
Tel. +49 0341-52941138
E-mail: kehl@holzbauphysik.de