<u>Analysis of missing points with diffusion barriers</u>

Hans Peter Leimer
BBS INGENIEURBÜRO

1 Problem:

With light weight construction types, like timber framed or timber panel housing, light- gauge steel constructions, roof structures consisting of timber or light-gauge steel you always have to deal with convection of humidity in areas of cross-section.
There also is a danger with non-elaborated pitched roofs. These constructions are well known and often realized in European countries like GB, Scandinavia, Benelux, and also in southern Europe.
For any type of construction, in general, a diffusion respectively wind barrier is placed on top of the heat-insulating layer from inside the room. Defective barrier parts which may have been caused by damages or imperfect overlapping, respectively inperfect tightness along the rims or penetration give way to humid warm air from inside the rooms into areas of cross section due to differences in pressure.
In a context of a steadily increasing use of reinforced felts which are open to diffusion, we have to deal with the question in what respect the interior diffusion barrier is advisable, respectively how defective spots can still have an effect.
In the following the influence of clefts/defective spots in diffusion barriers on the clampness-behavior of the roof cross-section is to be determined. For this purpose different tests were carried out on a model cross-section.
While “Corovin”/Peine was interested in the pre-examinations, “Braas”/Oberusel showed interest in the further development of reinforced felts with strong diffusion open qualities.

2 Preparations for the experiments:

A timber-frame (1*1 m²) was installed into an external wall of an airconditioned test room. The timber frame is divided in two rafter areas of a steep roof construction with ‘rafter 1’. It is possible to create a defined missing spot in both rafter areas. As defined missing spot inside the diffusion barrier as well as in the plasterboard a 150 mm Ø KG-pipe was installed in each case in order to reduce them by means of an adapter band.
The frame was constructed in such a way that diffusion or convection through any other side ways could be excluded.
The outside climate was not influenced, but the unit was protected against rain. With the help of air-conditioning systems, the climate inside was kept almost constant.
Three different experiments called A, B and C are presented in this context. These 3 experiments differ from each other in the following way: the draft through the unit as well as the outer reinforced felt were varied. Two reinforced felts, first a high diffusion open ‘HDUSB’ (s_d= 0.03m) and second a diffusion tight barrier ‘DDUSB’ (s_d=3.0m) were compared.

Flow velocities were measured with the help of a ‘Thermo-Anemometer’ (measuring range 0.0000-1.000 m/s). Measuring the resistivity, the humidity of timber was determined (gravimetric confirmation measurement).

3 Pre-experiment A:

3.1 Construction of experiment A:

Experiment A is characterized by an outside positioned HDUSB. There is just one missing spot, which is reduced up to 50mm.

Rafter-field 1	d [cm]	Rafter-field 2	d [cm]
outside		outside	
Reinforced felt (Multidenier) Insulation of mineral fibre Diffusion barrier Plasterboard	 20 1,25	Reinforced felt (Multidenier) Insulation of mineral fibre Diffusion barrier Plasterboard	 20 1,25
Missing point	∅ 50 mm	No missing point	
inside		inside	

Table 1 Arrangement in layers test A

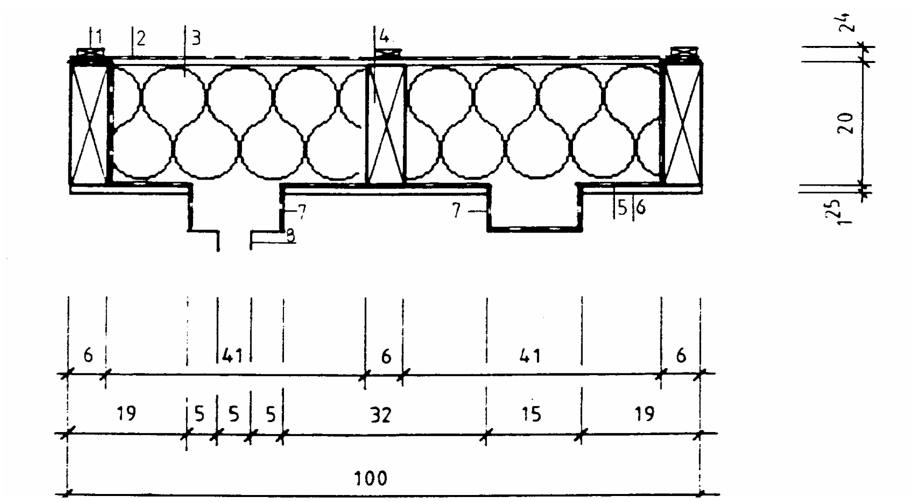

Illustration 1 model construction

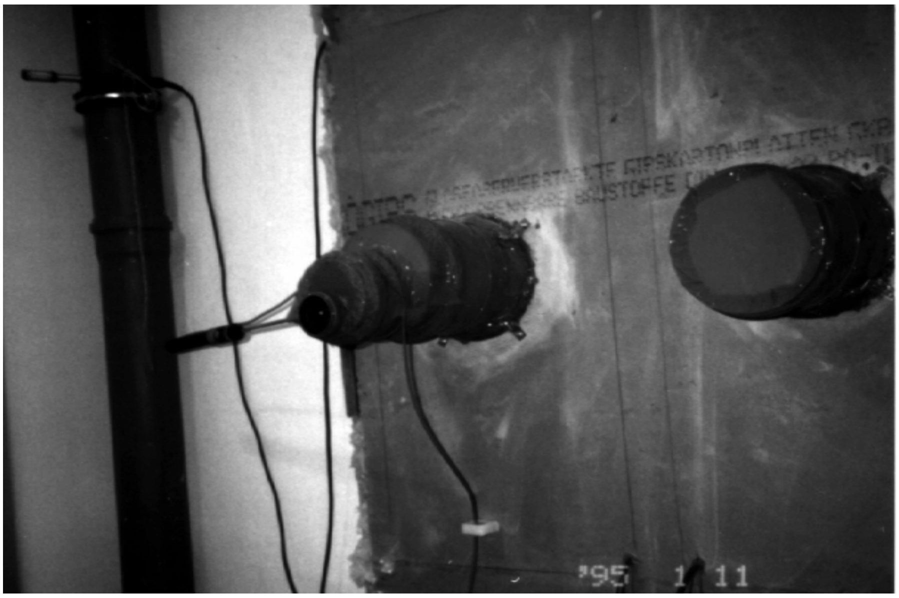

Illustration 2 Model – inside view

3.2 Margin parameters

3.2.1 Points of measurement:

Following parameters were registered (see illustration 3):

Point of measurement	Design ation	Humidity of timber	Height of building unit (beginning inside) [mm]
1	UU20	**U**ndisturbed rafter field	20
2	UG20	**D**isturbed rafter field	20
3	UU100	**U**ndisturbed	100
4	UG100	**D**isturbed	100
5	UU180	**U**ndisturbed	180
6	UG180	**D**isturbed	180
7	diverse	Temperature of building unit	
8		Speeds of air current	

Table 2 Points of measurement

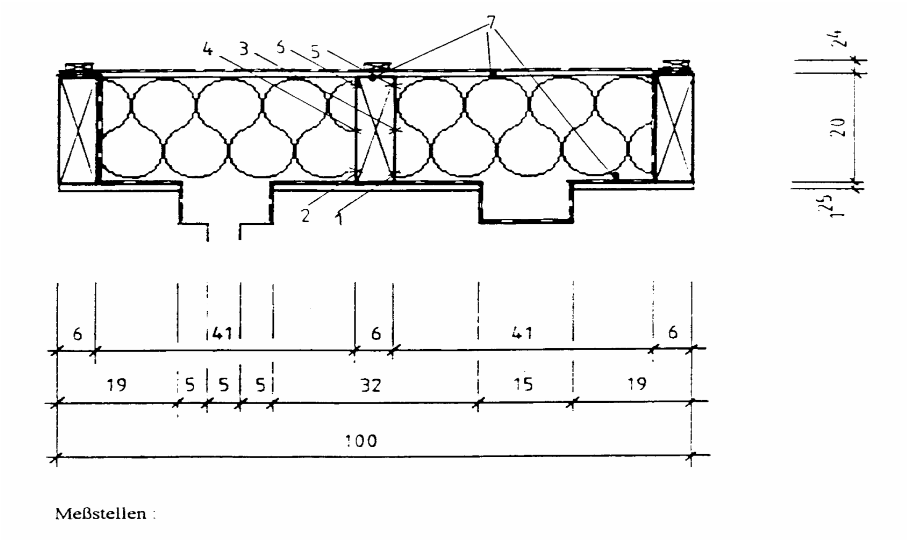

Illustration 3 measuring points for timber humidity and temperature

3.2.2 Climate and duration of experiment:

The experiment was performed during the winter period for about 853 hours. The outside - and inside climate was determined as indicated below:

		Temperature [°C]	Relative humidity [%]
Outside climate	Average	+ 1,0	85
	Maximum	+ 12,5	98
	Minimum	- 8,0	70
Inside climate		20 ±2K	50 ±10%

3.3.3 Results and interpretation:

The tested variant showed the following different humidity values in timber:

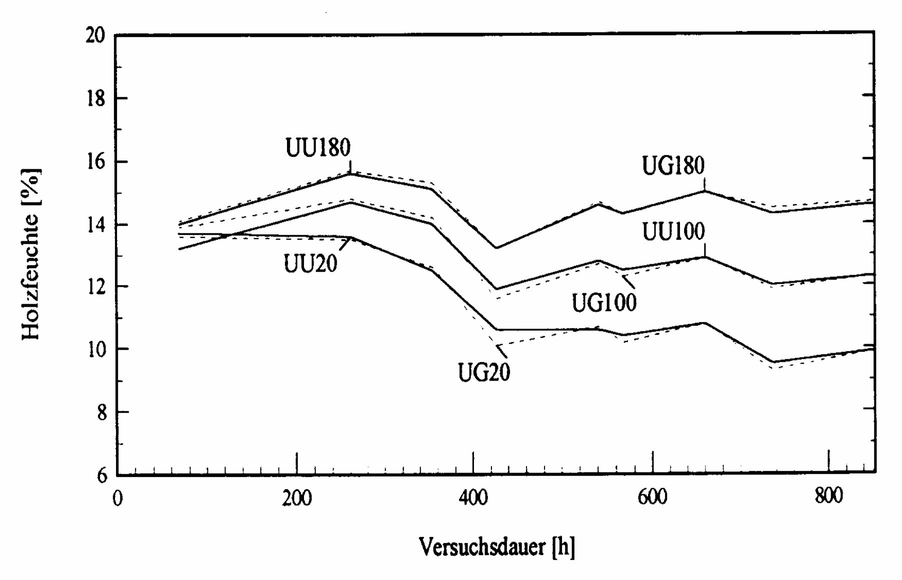

Illustration 4 Humidity values in timber

During the test speeds of air currents were measured from 0.0 ... 0.03 m/s, 0.01m/s on average.

One strining results with the humidity measuring of timber was that the values for the disturbed as well as for the unidsturbed rafter field were roughly the same at the same depth. You can see that the timber humidity values on the inside of the missing spots are considerably lower than on the outside ones.
One can assume that a missing diffusion barrier has no significant influence on the humidity of timber when using a HDUSB.

4 Pre-experiment " B ":

4.1 Construction of experiment:

In this test the missing point was expanded up to Ø 150mm.
Furthermore the second field of rafters, in which a new intermediate beam was added ("test-rafter 2") got a missing point (Ø 50mm). A formwork and a DDUSB were fixed outside. In order to advance the convection streaming, a hole was cut into the construction.

Rafter field 1	d [cm]	Rafter field 2	d [cm]
outside			
Reinforced felt HDUSB		Reinforced felt DDUSB	

		Formwork	1,5
		Air gap	5,0
Insulation of mineral fibre	20,0	Insulation of mineral fibre	15,0
Diffusion barrier		Diffusion barrier	
Plasterboard	1,25	Plasterboard	1,25
Missing point	∅ 150	Missing point	∅ 50
inside		Inside	

Table 3 Arrangement of layers test B

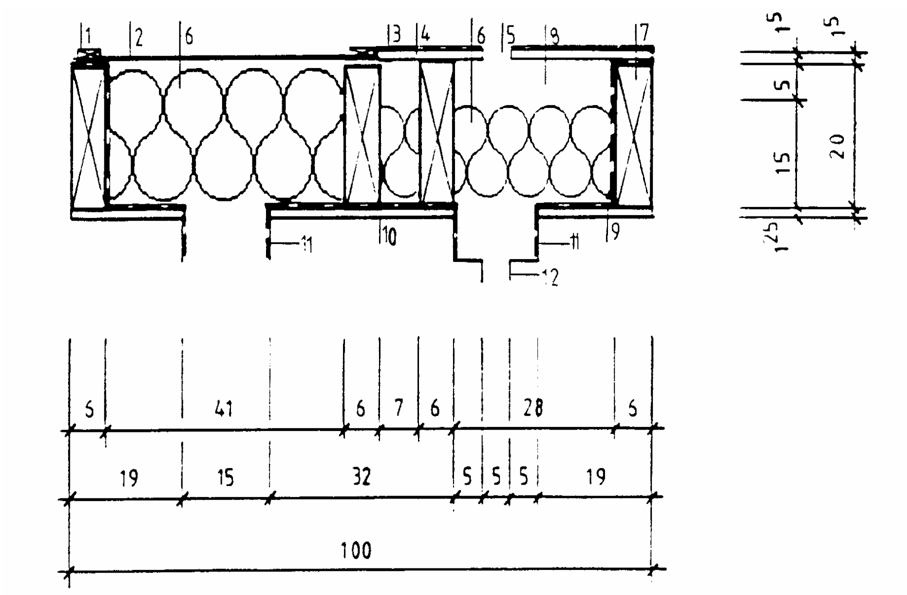

Illustration 5 Construction of the model

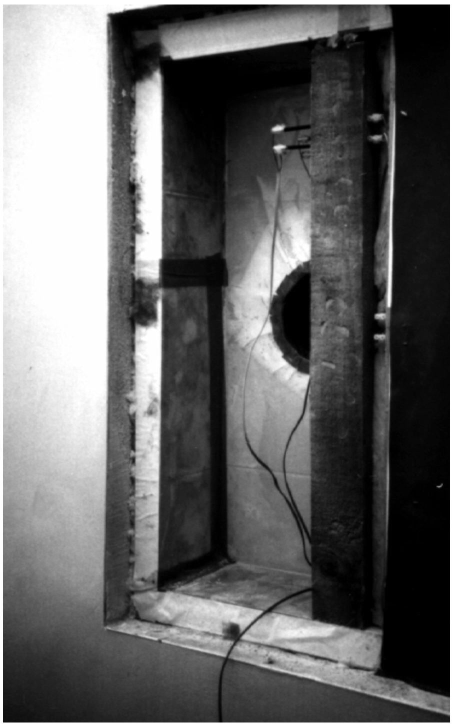

Illustration 6   Model (without insulation) – elevation from outside

4.2 Boundary parameters

4.2.1 Points of measurement:

Following parameters were registered (also see illustration 7):

Point of measuremen t	Name	Humidity of timber	Height of building unit (from inside) [mm]
1	UB20	Diffusion open USB	20
2	UD20	Diffusion tight USB	20
3	UB100	Diffusion open USB	100
4	UD100	Diffusion tight USB	100
5	UB180	Diffusion open USB	180
6	UD180	Diffusion tight USB	180
7	UU100	Undisturbed rafter field (Diffusion tight USB)	100
8	UG100	Disturbed rafter field (Diffusion tight USB)	100
9	UU180	Undisturbed rafter field (Diffusion tight USB)	180
10	UG180	Disturbed rafter field (Diffusion tight USB)	180
11	USchO	Upper formwork	200
12	USchU	Humidity of timber of the formwork below	200
13	diverse	Temperature of bulding unit	
		Speeds of air current	

Table 4   Points of measurement of experiment B

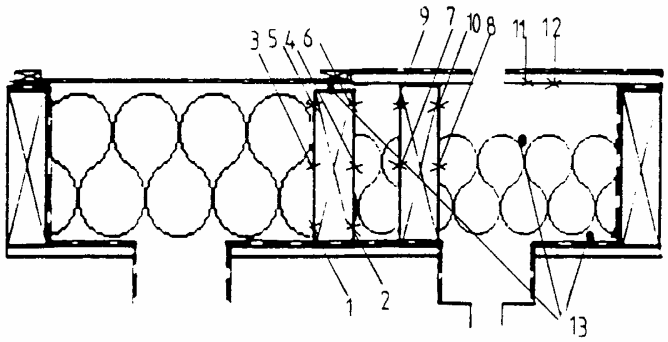

Illustration 7   Points of measurement for timber humidity and temperature

4.2.2 Climate and duration of experiment:

The experiment was performed during the winter period for about 1372 hours. The outside - and inside climate was like this:

	Average	Temperature [°C]	Relative humidity [%]
Outside climate	Average	+ 5	80
Inside climate	Maximum	+ 10.5	92
	Minimum	- 1.0	55
		21 ±1K	50 ±7%

4.2.3 Results and analysis:

Following humidity values of timber were found for the tested variant:

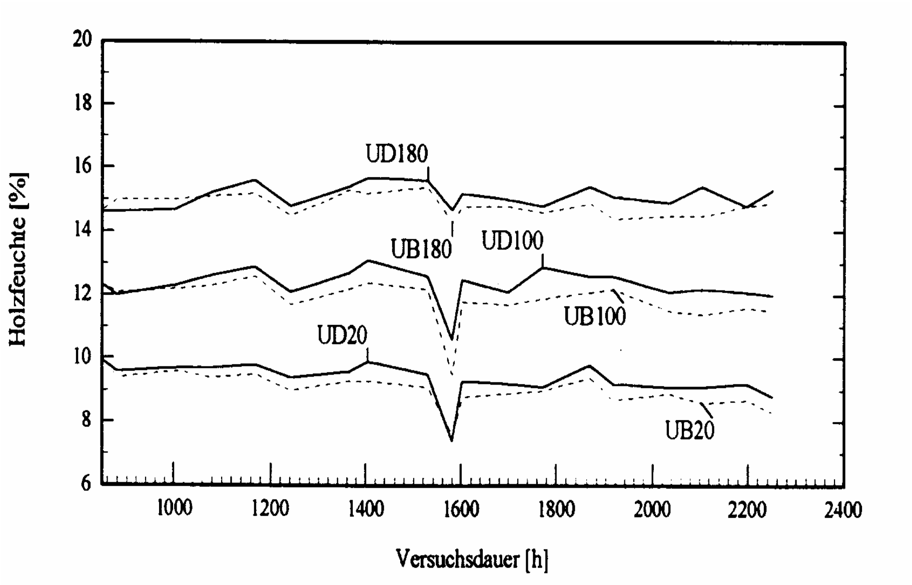

Illustration 8 Timber of humidity of tested rafter 1 (illustration 30)

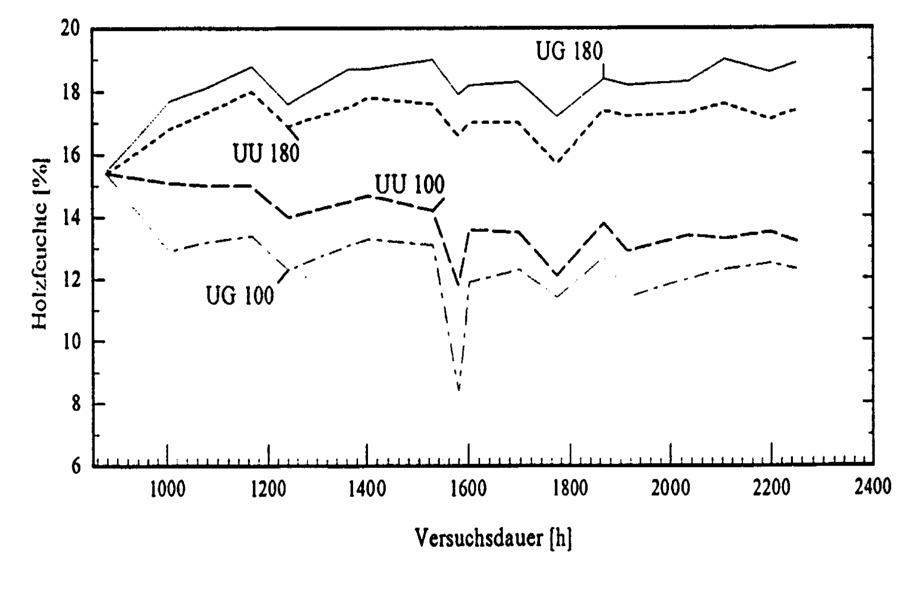

Illustration 9 Timber of humidity of tested rafter 2

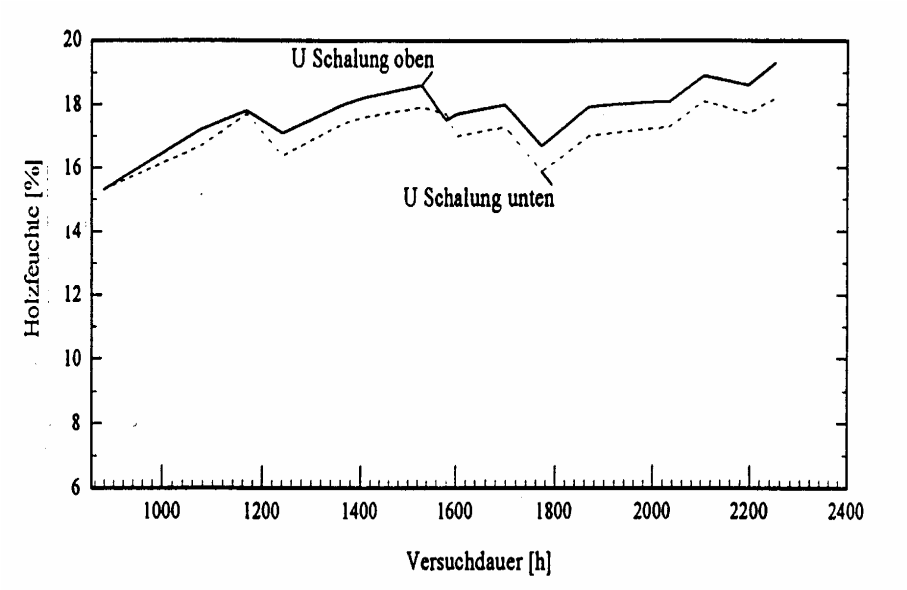

Illustration 10 Timber of humidity in the formwork

During the test speeds of air currents were measured from 0.0 ... 0.4 m/s, of 0.01 m/s on average (including considerable fluctuations).

In comparison to test A, the humidity values of timber in test rafter 1 (illustration 8) show us unchanging tendencies that means the humidity values keep constant, resp. there is a slight reduction. The maximum humidity of timber stays below 20 per cent. The measurement data concerning the side with the diffusion - open USB are insignificantly lower than on the other side where a diffusion tight - panel is fixed.

Illustration 9 shows impressively that the humidity of timber of this construction, especially with the building part depth of (180mm), is higher than in the first field of rafter. At the end

of the test the increase of humidity has not visibly stopped. The humidity of timber within the disturbed rafter-area is about 1.5 % higher than on the side of rafter gap.
The humidity of timber of the formwork (see illustration 10) continuously rises, although 20 % have not been reached at the end of the test.
The upper value is approximately 1 % above the lower one.

5 Main experiment:

5.1 Experimental set-up:

In order to generate a forced convection, a defined draft was blown into the construction-unit by a fan. The fan has a performance of (number 10, illustration 11) 6 m³/h. It was switched on in intervals, first 2*15 min/h, later on 1*15 min/h. Through a pipe system, the draft was guided into the building unit.
In both rafter areas a wooden formwork was placed on the outer sides. Whereas a diffusion-open USB (‘Multidenier’) was fixed in field 1, a diffusion tight USB (‘PVC’) was attached to field 2.

Rafter field 1	d [cm]		Rafter field 2	d [cm]
Outside			Outside	
HDUSB		>	DDUSB	
Formwork	1,50	>	Formwork	1,50
		>	Air gap	5,00
Insulation of mineral fibre	20,00	>	Insulation of mineral fibre	15,00
Diffusion barrier		>	Diffusion barrier	
Plasterboard	1,25	>	Plasterboard	1,25
Missing point with fan	∅ 150		Missing point with fan	∅ 150
inside			Inside	

Table 5 Assembly of layers in experiment C

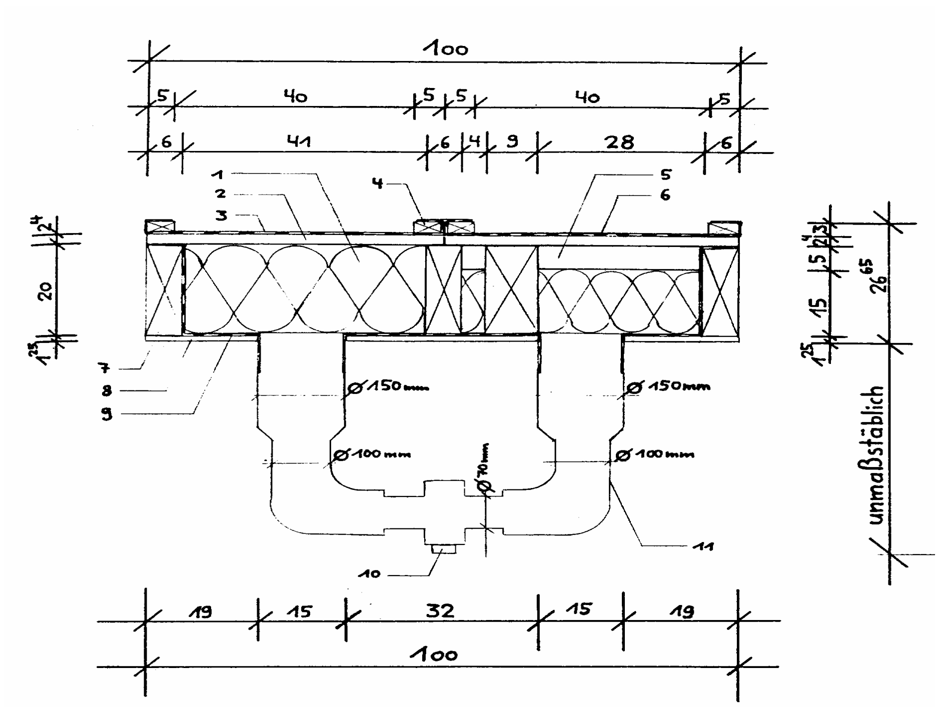

Illustration 11 Construction of the model

5.2 Boundary parameters:

5.2.1 Points of measurements:

Following parameters were registered (also see illustration 12):

Point of measurement	Name	Humidity of timber	Height of building unit (from inside) [mm]
1	UB20	Diffusion open USB	20
2	UB100	Diffusion open USB	100
3	UD100	Diffusion tight USB	100
4	UB180	Diffusion open USB	180
5	UD180	Diffusion tight USB	180
6	USB 20	Rafter gap (test rafter 1)	20
7	USB 100	Rafter gap (test rafter 1)	100

8	USD 100	Rafter gap (test rafter 2)	100
9	USB 100	Rafter gap (test rafter 1)	180
10	USD 180	Rafter gap (test rafter 1)	180
11	UBO/UBU	Upper formwork (Diffusion opened USB)	200
12	UDO/UDU	Formwork below (Tight diffusion USB)	200
13	Diverse	Temperature of bulding unit	
		Speeds of air current	

Table 6 Points of measurement of experiment C

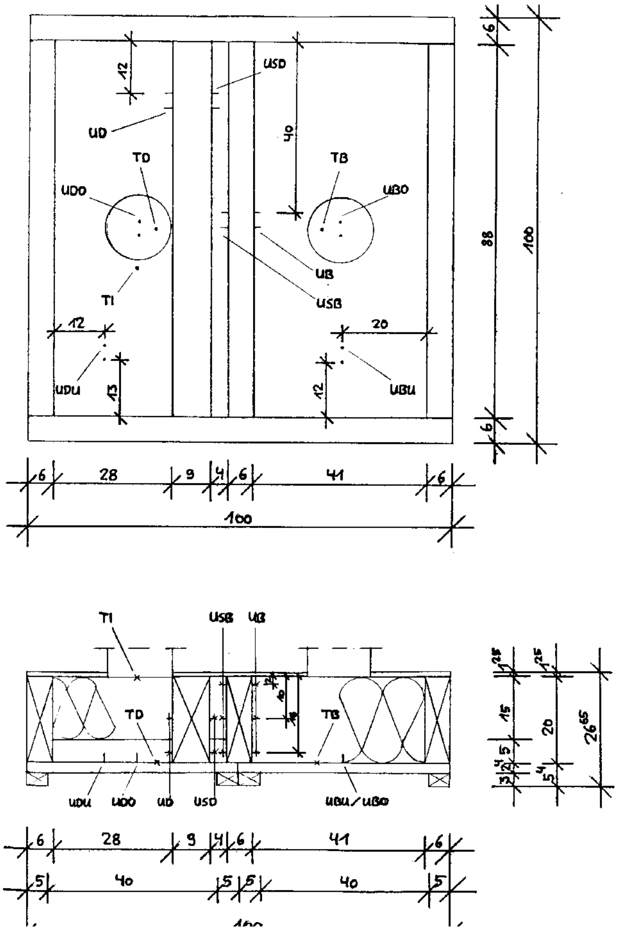

Illustration 12 Points of measurement for timber humidity and temperature

5.2.2 Climate and period of experiment:

This experiment was carried out during the winter-period for 1776 hours. The outside- and inside climate was determined as follows:

		Temperature [°C]	rel. Humidity [%]
Exterior climate	average	- 1	65
	maximum	+ 10.0	88
	minimum	- 10.0	45
Ineterior climate		21 ±2K	50 ±10%

5.2.3 Results and analysis / evalution:

The following humidity values of timber were found for the tested variant:

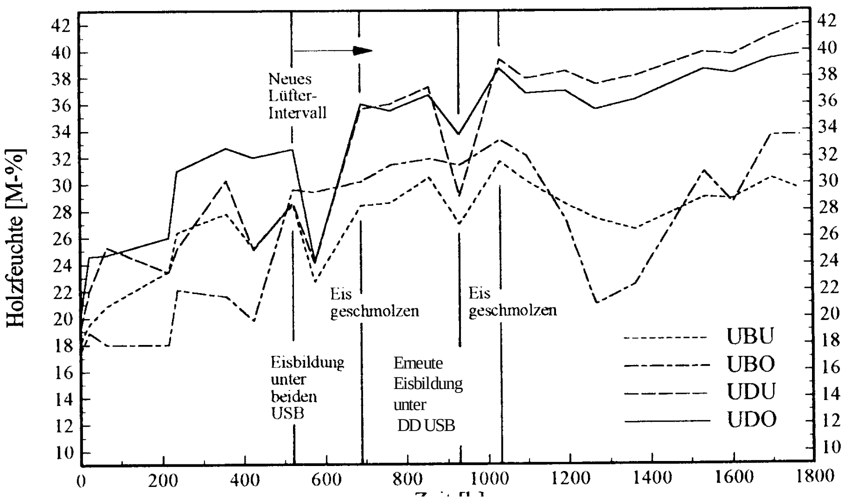

Illustration 13 Humidity of timber with the formwork

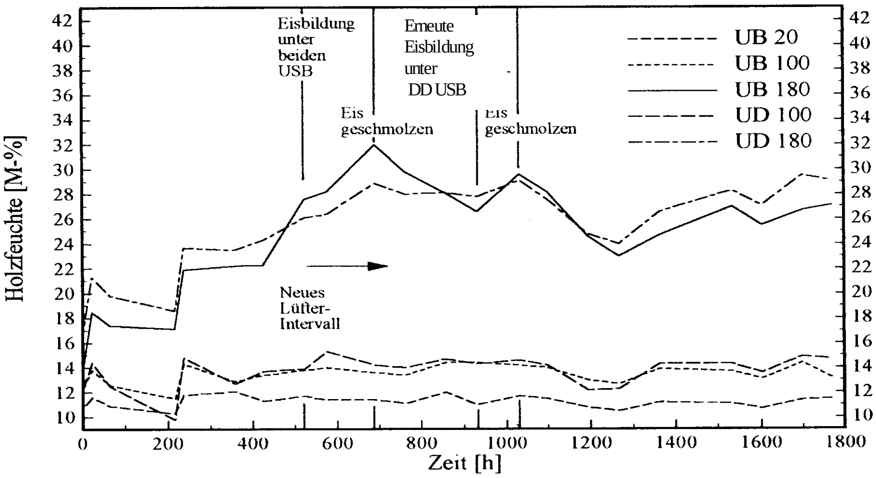

Illustration 14 Humidity of timber in rafter

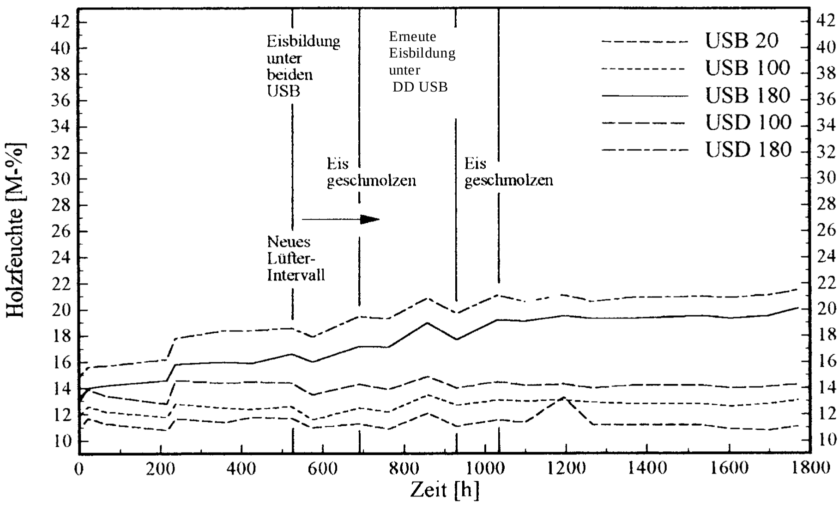

Illustration 15 Humidity of timber in rafter gap

The air stream, created by a fan, can reach speeds ranging from approx. 0.144 to 0.289 m/s, depending on the flow resistance with in the individual rafter fields, i. e an average of approx. 0.036 to 0.0072 m/s with intervals of 15 min/h.

Humidity measuring of formwork timbers indicated values which are exclusively above fibre saturation! During the cold winter period ice formed underneath the two reinforced felts. However, the formwork of the diffusion open USB (UB_) dries under more favourable climatic conditions, whereas the other formwork UD_ continuously gets damper.

This observation is supported by the fact, that when opening the construction after roughly 2500 hours in the beginning summer period, the formwork UB_ was dry whereas the tight diffusion barrier showed a highly developed mould formation.

Obviously the outer values (180mm) are close to fibre saturation. This can be concluded from the development of humidity in the rafter timber. The other measurement data clearly show less humidity.

Since this construction can be described as an almost closed system, the timber humidity values in the rafter gap are distinctly lower. The outer measurement data show a humidity of timber of about 20 % (tendency: slightly increasing).

As a result it can be said that a high windproofness of the construction is enormously important.

These results emphasize the prior importance of high wind-proofness of the construction.

6 Summary:

The tests show us the following results:

1. When using a high-diffusion open and steam proof USB, a convection of humidity, caused by small missing points, is no problem if there is no chance of building a “Luftwalze” in the element and/ or if the air can not stream from the inside to the outside (requiring a high tightness of the building on the outside).
2. Larger missing points in diffusion barriers lead to considerably higher humidities of timber; they re not critical when using HDUSB.
3. With increased humidity convection due to a state of vaste untightness in areas of cross-section of building parts, for example caused by / as a consequence of incorrect connentions, roof windows etc., condensate and ice may occur, no matter if the USB used is diffusion open or diffusion tight.
4. If using HDUSB the cross section dries up faster.