Report : Laboratory tests and modelling to investigate the effect of flooding on mineral wool cavity insulation batts in masonry walls

Prepared for: Mineral Insulation Manufacturers Association

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Executive summary

This report discusses a series of tests that were carried out by Glasgow Caledonian University to establish the effect of immersion in flood water on a) the structural integrity, and b) the residual moisture content after draining and the consequential effect on the thermal performance, of mineral wool batts in a masonry cavity wall.

Mineral wool batts were in immersed in water in a Perspex tank, replicating a typical wall cavity, for various periods and then left to drain over several days. Weighing determined the residual moisture content.

Modelling to ISO 10211:2007 was used to determine the effect of raised moisture content on addition heat loss at typical wall/ground floor junctions. Modelling to EN 15026:2007 was used to investigate the time that batts in a masonry wall might take to dry after flood water had drained away

The results showed

- Glasgow Caledonian considers the test procedures used and the results provided in this report to provide a robust scientific assessment of the likely performance of mineral wool cavity wall insulation batts when subjected to flooding.
- Mineral wool cavity wall batts are not structurally damaged, dislodged or susceptible to gaps or voids when subjected to simulated flooding.
- Mineral wool cavity wall batts regain their tested thermal conductivity once the simulated flood has receded.
- Walls insulated with mineral wool cavity wall batts do not retain significant quantities of water once the simulated flood has receded.
- Walls insulated with mineral wool cavity wall batts dry out at largely the same calculated rate as walls with empty cavities once the simulated flood has receded.
- The residual flood water in the wall incorporating mineral wool cavity wall batts has no significant effect on the thermal performance calculated for the overall building).
- Mineral wool cavity wall batts do not increase the calculated risk of condensation or mould following a flood.
- The mineral wool cavity wall batts tested are suitable for use in cavity walls, which may be liable to flooding (noting the observations below).

Besides the simple consequences of immersion in water, two other effects made be important.

- Strong currents of water from a swollen river or the impact of large waves in a coastal flood can damage a building and potentially disrupt the insulation. However it is unlikely that mineral wool batts within the cavity of a wall that remains intact will be disrupted. If the wall or building collapses, the position of the insulation is irrelevant.

- More significant problems may be caused by pollutants carried by the floodwater. This can be salt from seawater, agricultural chemicals from run off from fields and, most importantly, sewage from overflowing or backed up sewers.

1. Introduction

Flooding of buildings is becoming increasingly common in the UK because of a) the changing climate and rising sea level and, b) pressure to build on flood prone areas such as flood plains and coastal regions. Besides the short term distress caused by flooding, it can have long term impacts on the habitability and even the structural integrity of buildings. This can lead to major insurance costs and long term disruption to people's lives as they have to leave their house while it is dried and repaired. A considerable amount of work has now been undertaken, sponsored by the government and the insurance industry, to investigate ways of protecting individual buildings from flooding, to make them more resilient to flooding and to reduce the time before the building can be reoccupied and the cost of subsequent repairs.

The performance of the outer walls of a building is particularly important in the event of a flood, in relation to the wall itself and any insulation present in walls built with cavities.

However, little scientific research data has been made publicly available to describe the effects of a flood on cavity wall insulation. This lack of robust data makes it difficult to assess the suitability of different insulation materials and systems for use in buildings, which may be liable to flooding.

This investigation has therefore been carried out to evaluate scientifically the effect of flooding on the physical integrity and subsequent performance of mineral wool cavity wall insulation batts. The investigation particularly focusses on the effect that immersion in flood water may have on the structural integrity of mineral wool insulation batts, the potential for the batts to become dislodged and the on-going thermal performance of the construction after the flood has subsided.

2. Project approach

The project discussed in this report was designed to investigate the effect that immersion in water has on mineral wool batts within a simple wall cavity.

Some initial tests were carried out by simply immersing 300 mm square samples cut from the batts in a tank of water, to examine their structural integrity, and assess how much water they took up and released. However the main series of tests were carried in a specially constructed Perspex tank, which contained three batts arranged as they would be in a cavity wall. Water was introduced into the tank over about 20 minutes to simulate a flood plain flooding characteristic. The batts were left immersed for various periods to investigate whether times of immersion affected their subsequent performance. After immersion, the water was drained from the batts, which were then left in the tank for various periods to investigate whether further draining took place over the following days.

The effect of the residual moisture content of the batts after draining on the thermal conductivity of the mineral wool was used to calculate the heat loss through a wall/ground floor junction, and assess its effect on the overall heat loss from a house.

The advanced hygrothermal model, WUFI, was used to estimate time that flooded batts in a masonry wall would take to dry once the flood water had drained away.

3. The materials tested

Four different materials received from the manufacturers were tested. All consisted of cavity batts 100mm thick, 1200 mm long and 450 mm wide. Three of these were glass wool with densities ranging from 20 to 48 kg/m^3 and thermal conductivities ranging from 0.032 to 0.036 W/mK. The fourth material was rock wool, with density 39 kg/m^3 and conductivity 0.037 W/mk. All the materials had been treated with water repellents.

4. Testing complete batts in a model wall cavity

4.1 The test tank

After discussion with the insulation industry, a test was devised in which insulation was installed in a Perspex tank, which could be flooded and drained from below. After immersion for a period the water was drained off and the residual water content of the insulation determined by weighing.

A diagram of the test tank is shown in Figure 1. The overall dimensions of the tank were 1650mm deep, 1200mm across and 100mm wide. Three 1200 mm long 100mm thick batts are laid as shown in the diagram, with the middle batt cut in half. Five steel wire wall ties are included in the positions shown between the batts. The batts are supported on a wire mesh grid, with an open space below which allows water to be introduced from below and allows the batts to drain freely.

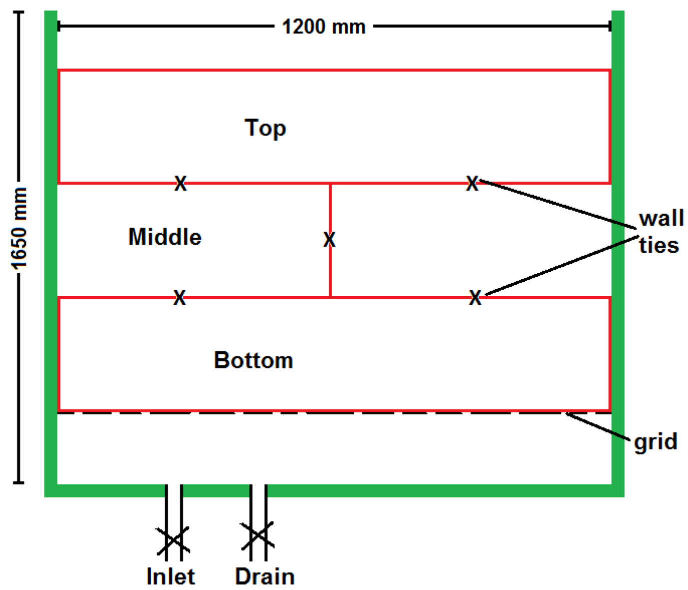


Figure 1 – Diagram of test tank

Figure 2 shows the tank before installation of the insulation,

Figure 2 – Views of the tank before installation of the insulation

Figure 3 shows the tank with insulation installed. The insulation was restrained from the top by jamming strips of XPS between the sides of the tank and below the top line of bolts.

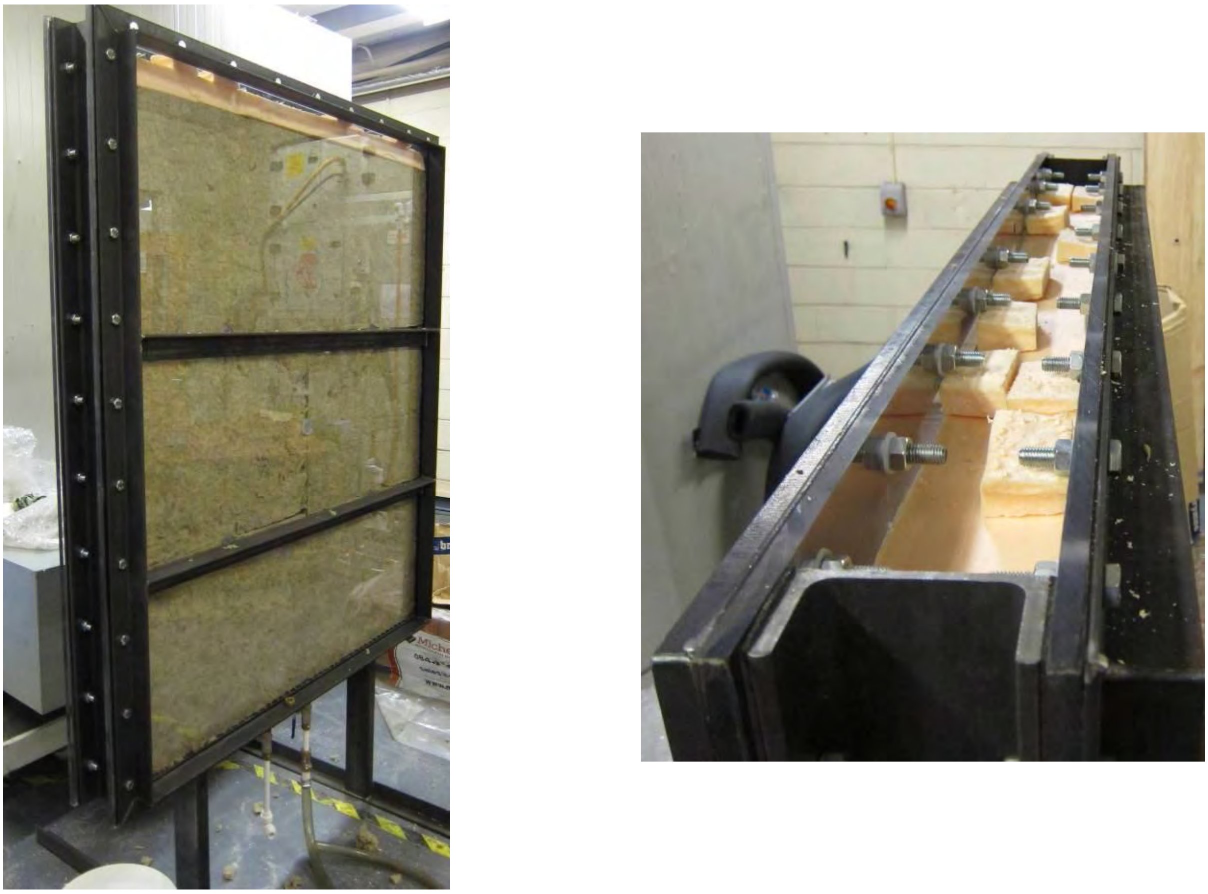


Figure 3 – Tank with insulation installed and restrained from the top

In each test, the tank was filled with water from below, over about 20 minutes, so that there were no currents within the tank to disrupt the insulation. As the water rose within the tank, the level of the wetted insulation lagged behind the water level, as shown in Figure 4, and took 2- 3 minutes to 'catch up'.

Figure 4 – Water level and wetted insulation as tank filling

4.2 The Test Procedure

After various trials the following basic test regime was carried out:

1. Three batts were weighed as delivered, to give the initial 'dry' weight, m_0 in kg.
2. The volume of each batt, V m^3, was determined by measuring the dimensions
3. The batts were installed in the tank and flooded from below, usually to the top of the topmost batt; it was necessary to add more water over the next couple of hours to maintain the water level as air came out of the insulation. In some cases the tank was flooded only up to the top of the middle or bottom batt.
4. The insulation was left flooded for various periods, generally 2 – 5 days.
5. The water was drained off until no more was flowing.
6. The system was left to drain further for various periods from 2 to 15 days, water continued to drain off for about 24 hours, very little further came off after that.
7. When the top two batts were removed from the tank, no further water drained from them; they were then weighed to give m_1.
8. It could be seen that the lowest ~10cm of the bottom batt remained extremely wet, even after several days draining. If the bottom batt was removed most of this water drained out and was lost. Therefore, to enable the mass of water in this wet layer to be determined the bottom batt was turned on end and allowed to drain for 6 hours, the water coming off was collected and weighed to give m_3.
9. The bottom batt was taken out and weighed, to give m_1; m_3, the water collected when the batt was turned on end was added to m_1 to give m_2.

The weight of water retained in each batt was determined by subtracting the 'dry' weight, m_0, from each of weights.

$m_{w1} = m_1 - m_0$ was the weight of water retained after complete draining of all three batts

$m_{w2} = m_2 - m_0$ was the weight of water retained in the bottom batt before it was turned on end

Then the weights were divided by the volume of the batt to give the moisture content in kg/m^3

Dividing the weight of water by the dry weight, gives the percentage water content by mass, kg/kg.

$\mathbf{w_1 = m_{w1}/V \quad w_2 = m_{w2}/V}$

$\mathbf{u_1 = 100 \cdot m_{w1}/m_0 \quad u_2 = 100 \cdot m_{w2}/m_0}$

4.3 Summary of a typical test

Three batts were installed in the tank at 0930 14/12/2012. The tank was flooded to the top; further water was added to top up over rest of the day.

The tank was drained at 0805 19/12/2012 after an immersion time of 4.94 days.

The tank and insulation were left to drain until 0815 3/1/13 i.e. 15 days

The top and middle batts were removed, and the bottom batt stood on end and drained till 1440, 6 hours, 8.805 kg of water were collected. Table 1 shows the results from this test

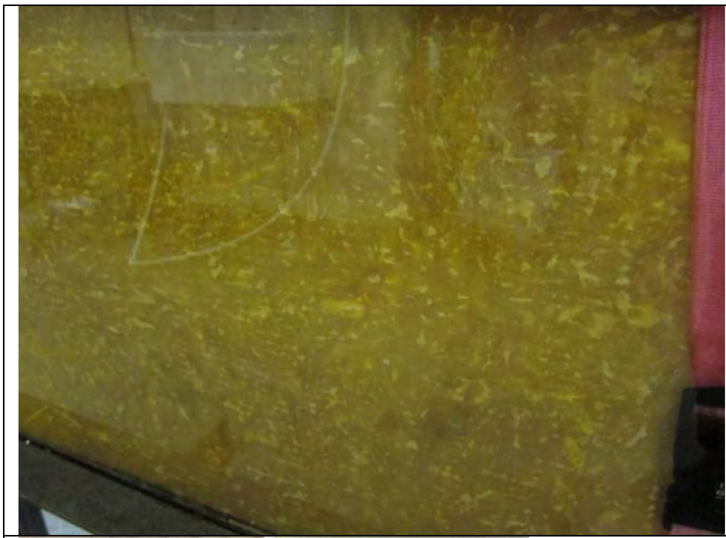
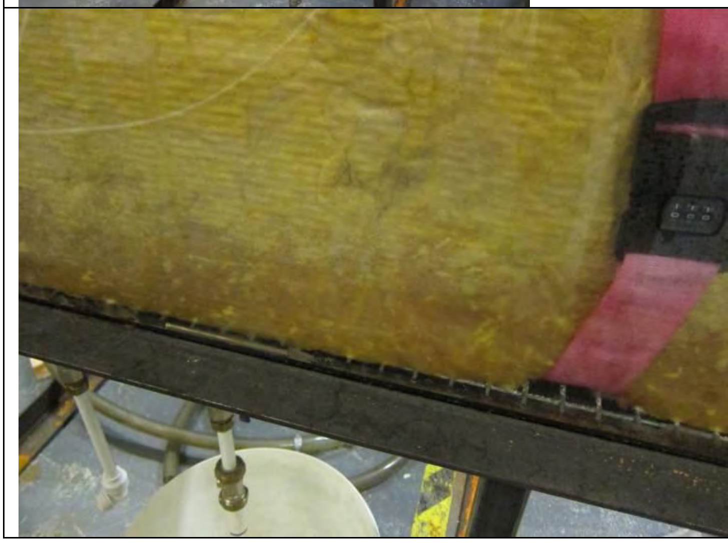
Table 1 – Summary of results from test

	Dry batt m_0 kg	Wet batt m_1 kg	Water m_{w1} kg	w_1 kg/m^3	u_1 %by wt
Top batt	1.764	2.884	1.12	20.74	63.5
Mid batt	1.834	3.194	1.36	25.19	74.2
Bottom batt 1	1.732	5.057	3.325	61.57	192.0
Bottom batt 2	1.732	13.862	12.13	224.63	700.3

Bottom batt 2 before standing on end - Bottom batt 1 after standing on end for 6 hours

The sequence of pictures below shows the test.

	Insulation before flooding The pink and blue luggage straps are to enable the insulation to be removed without dismantling the tank!
	Tank full after five days immersion
	After 5 days of immersion, the water level has fallen slightly due to release of air

	base of tank after five days immersion
	Tank immediately after draining
	Base of tank after draining for 6 hours

	Base of tank after draining for 6 hours
	Top of tank after draining for 6 hours

	Bottom batt stood on end
	Bottom batt removed from the tank after being stood on end
	Bottom batt removed from the tank after being stood on end

Figure 5 – Sequence of images of tank test

4.4. Results from the tank tests

Table 2 summarises the results from the tank tests. Immersion depth refers to the depth of water in the tank – 1 up to the top of the bottom batt, 2 up to the top of the middle batt etc.

Table 2 Summary of the results from the tank tests

Test	Insulation	no of batts	immersion depth	Immersion Time	Drain Time	Top batt %mc	Mid batt %mc	Bot Batt %mc	Top batt kg/m^3	Mid batt kg/m^3	Bot Batt kg/m^3
1	A	3	2	2 hrs	30mins	0	106	454	0.0	37.6	161.7
2	B	3	2	1 day	1 day	2	104	403	0.2	10.3	89.9
3	B	3	2	2 days	5 days	1	108	414	0.2	10.8	86.7
4	C	3	2	1.8 days	6 hours	0	100	194	0.0	19.7	76.0
5	C	3	3	4.8 days	7 hours	212	117	140	80.7	45.6	55.0
6	C	3	3	5 days	8 days	78	83	130	29.6	32.2	51.4
7	D	3	3	5 days	15 days	64	74	192	20.7	25.2	61.6
8	D	1	1	4.8 days	2 days			184			59.6
9	D	1	3	3.8 days	2 days			176			54.7

The result of Test 5, with the very high top batt moisture content, is anomalous, and did not recur..

The different materials produced similar results:

1. The 'structural integrity' of each of the batts was preserved after immersion, i.e, there was no sign of slumping and they continued to fill the cavity after immersion and after the subsequent draining.

2. When the flooding was taken up to the top of the middle batt, the water content of the top batt did not increase at all; i.e. there was no sign of a 'capillary rise' into the dry batt.

3. The moisture content of the top and middle batts after flooding and draining was 70 – 100% by weight, or 30 – 50 kg/m^3. Their appearance is no different from before flooding.

4. The moisture content of the bottom batt after draining within the tank was 400 – 600% by weight or 150 – 300 kg/m^3. Most of this water concentrated in the bottom 100mm of the batt. When the batt is turned on end and the water drained out, the remaining moisture content is 150 – 200% by weight or 60 – 100kg/m^3.

5. The moisture content after draining is unaffected by the immersion time, if it is more than 2 – 3 hours.

6. If only one batt is installed in tank the result is that same as for the bottom batt when all three batts are installed.

4.5 Testing of a vertical sample

Following discussions with industry, a test was carried out with one batt stood on end in the tank to confirm that the persistently wetted layer in the bottom 10cm recurred.

Figure 6 – Sample flooded in Tank

The sample shown in Figure 6 was immersed completely for two days, and then left in the tank to drain for three days.

Figure 7 – Base of sample after 3 days draining

When removed from the tank the overall moisture content was 80.8 kg/m^3

A series 10 cm slices were cut from the base of the sample (Figure 3) and weighed individually

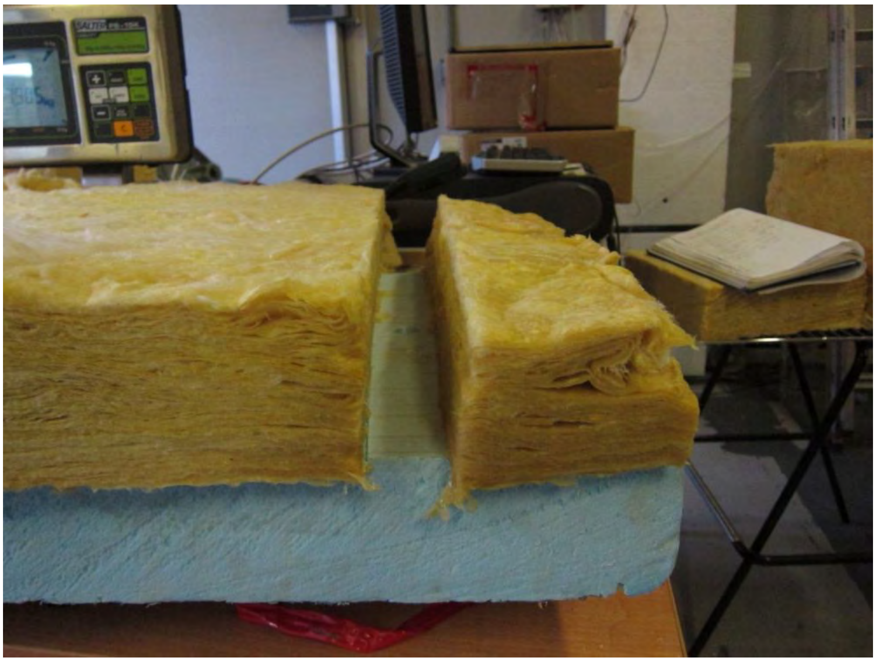


Figure 8 – 10cm slice cut from base of the batt

This gave the moisture contents in Table 3, which shows the exceptionally high moisture content in the bottom 10cm.

Table 3 - Moisture content of 10cm slices

Cm from base	**Moisture content Kg/m^3**
0 – 10	552.2
10 – 20	168.7
20 – 30	39.3
30 – 40	22.9
40 – 50	26.9
Remainder of batt	22.9

5. Small sample testing

The tank tests described above are time consuming and use up a large amount of insulation. To obtain information more rapidly a series of tests were carried out, in parallel with the tank tests, on smaller samples 300mm square cut from the batts.

Samples were cut from a batt, immersed in a tank of water for various periods, then removed and allowed to drain while standing on one edge on a grid. Once water had stopped flowing, they were weighed and then stood in beaker with one corner downwards; this caused further draining and the batts were weighed again once all this had ceased. This is shown in the images in Figure 9.

	300mm square sample cut from batt
	Sample during immersion
	Sample draining on grid

	Sample draining on grid
	Sample draining further in beaker

Figure 9 – Sequence of images of small sample test

Table 4 and Figure 10 show the final moisture contents after the two stages of draining. There is a good deal of variability in the results, with no trend up to two hours immersion. The one test with longer immersion for almost two days, did lead to a significantly higher moisture content. The final moisture contents are much higher than those from the tank test, probably because this test did not involve the long period (2 – 5 days) of draining.

Table 4 – Summary of small sample tests

Immersion time: minutes	% by mass	kg/m^3
15	360.0	112.0
30	316.4	106.9
60	530.1	156.7
60	428.0	125.6
120	414.8	124.4
120	371.4	115.6
2490	626.7	208.9

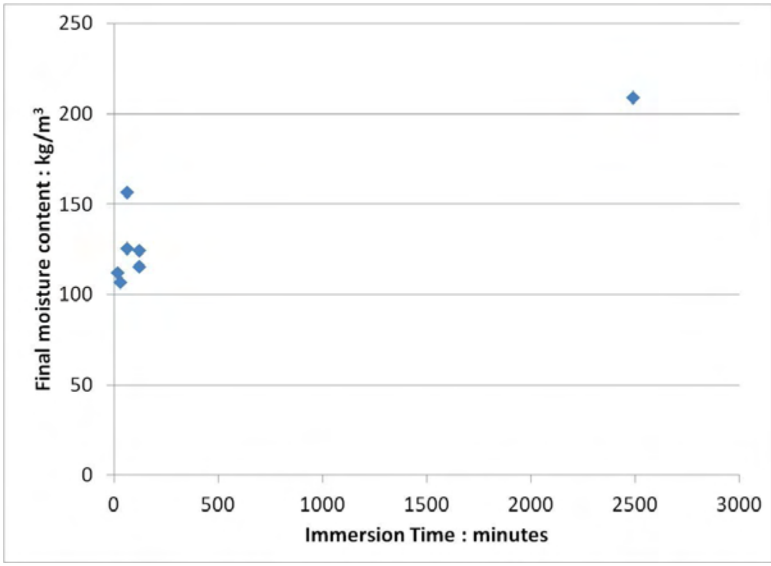


Figure 10 – Results of the small sample tests

6. The effect of residual moisture content on the thermal performance of a building

6.1 Effect on thermal conductivity

The effect of flooding on the thermal performance of the building can be estimated from the variation of thermal conductivity with moisture content. The German software, WUFI, which is widely used for calculations of heat and moisture movement in constructions, contains a database of the properties of a wide range of materials, as a function of their moisture content. The values of thermal conductivity of mineral wool are shown in Figure 11.

This is fitted by: $\lambda = 0.04 + 2.708 * 10^{-5} * mc + 5.941 * 10^{-7} * mc^2$

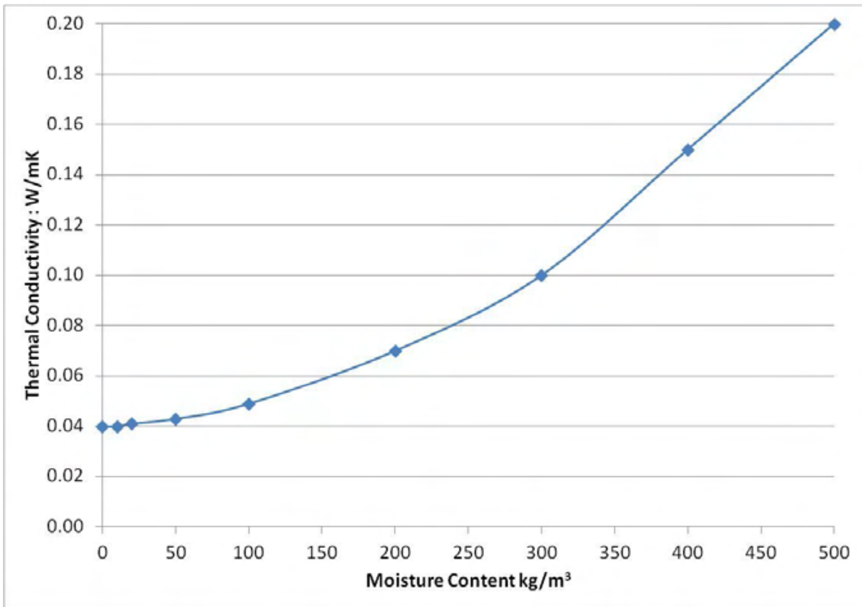


Figure 11 – Thermal conductivity of mineral wool against moisture content (WUFI database).

Table 5 shows the effect of the raised moisture content in the test described in Section 3.5 on the conductivity of the different 10cm sections of the batt.

Table 5 – Moisture content and resultant thermal conductivity of 10cm slices cut from a vertically immersed batt

cm from base	Moisture content Kg/m^3	Conductivity from WUFI database W/mK
0 – 10	552.2	0.236
10 – 20	168.7	0.061
20 – 30	39.3	0.042
30 – 40	22.9	0.041
40 – 50	26.9	0.041
Remainder of batt	22.9	0.041

The conductivity of the bottom 10cm of the batt is significantly raised by the moisture content, that of the next 10cm slightly raised, and the rest is unaffected.

6.2 The effect of a wetted section of insulation on heat loss

The effect of the 10cm section of wet insulation on heat loss from the building could be estimated by calculating the local U-value of the wall. However, as the wet section is part of the junction between the ground floor and the wall, where heat loss is strongly affected by multi-dimensional flows, it will be more realistic to calculate the effect on the ψ-value of the junction.

Heat loss at junctions, over and above that through the adjacent plane areas, is represented by the ψ-value in W/mK, with the total heat loss through all the junctions given by the sum of the products of the length and ψ-value of all the junctions, $\Sigma L\psi$. The total fabric heat loss is then given by $\Sigma AU + \Sigma L\psi$ W/K. In housing, $\Sigma L\psi$ is typically about 10% of ΣAU.

The risk of condensation and mould growth on the internal surfaces, associated with 'cold-bridging', is quantified by the f-value or temperature factor, given by (Ts – Te) / (Ti – Te), where Ts is the lowest internal surface temperature, and Ti and Te are the internal and external air temperatures. Studies in a number of countries have shown that the f-value should be above 0.75 to minimise the risk of condensation and mould.

Wet insulation, with raised thermal conductivity near a junction will raise heat loss and therefore the ψ-value, and lower the surface temperature and therefore the f-value. The effect of this has been analysed in two junctions, between an external filled cavity wall and a solid ground floor and a suspended floor. In both cases there is a 100mm wall cavity, fully filled with mineral wool, down to the DPC, with plastic foam insulation below that. The effect of raising the conductivity of a 100mm strip of mineral wool just above the DPC, from 0.037 W/mK up to 0.25 W/mK, was investigated. The effect of varying the conductivity of the inner leaf blockwork was also investigated.

Details of the two ground floor models analysed with TRISCO, the thermal analysis software that complies with BS EN ISO 10211, are shown in Figure 12. The full models extend much further out into the ground, than is shown, in accordance with BR 497.

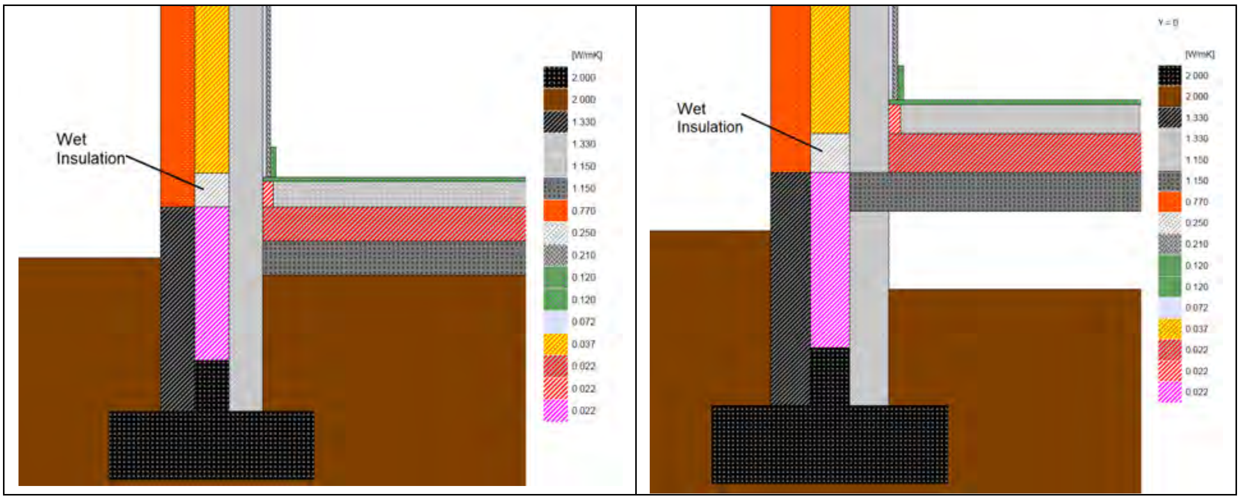


Figure 12 - Ground floor models analysed

Figure 13 shows the ψ-values from the suspended floor; increasing the conductivity of the 100mm strip of insulation, increases the ψ-value of the junction by 15 – 20% depending on the conductivity of the inner leaf.

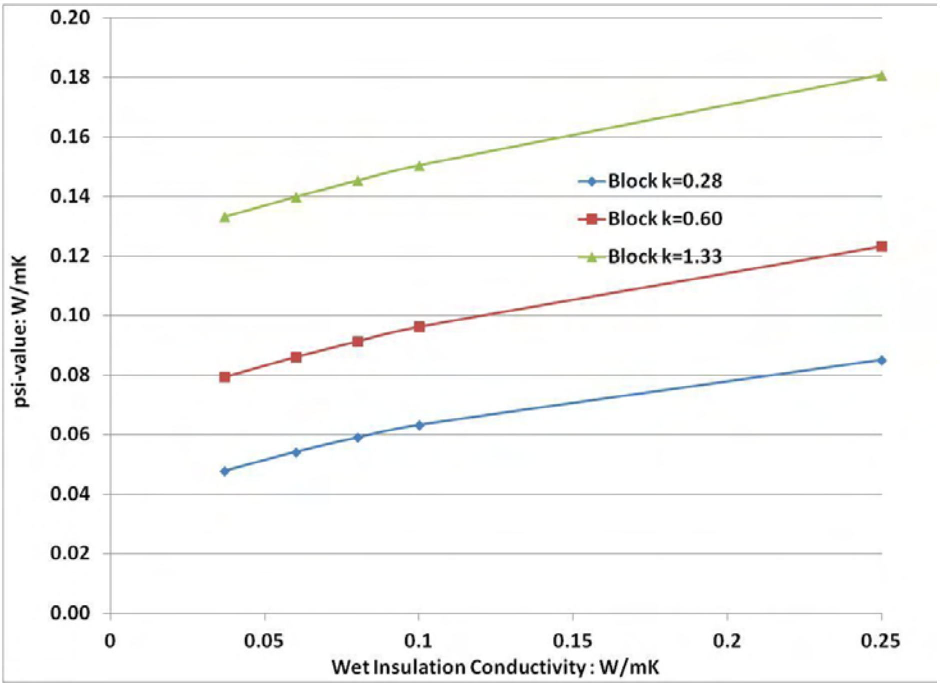


Figure 13 – Calculated ψ-values for the suspended floor

Figure 14 shows the f-values from the suspended floor; as expected the values decrease as the conductivity of the wet insulation rises, however they remain well above the limit of 0.75.

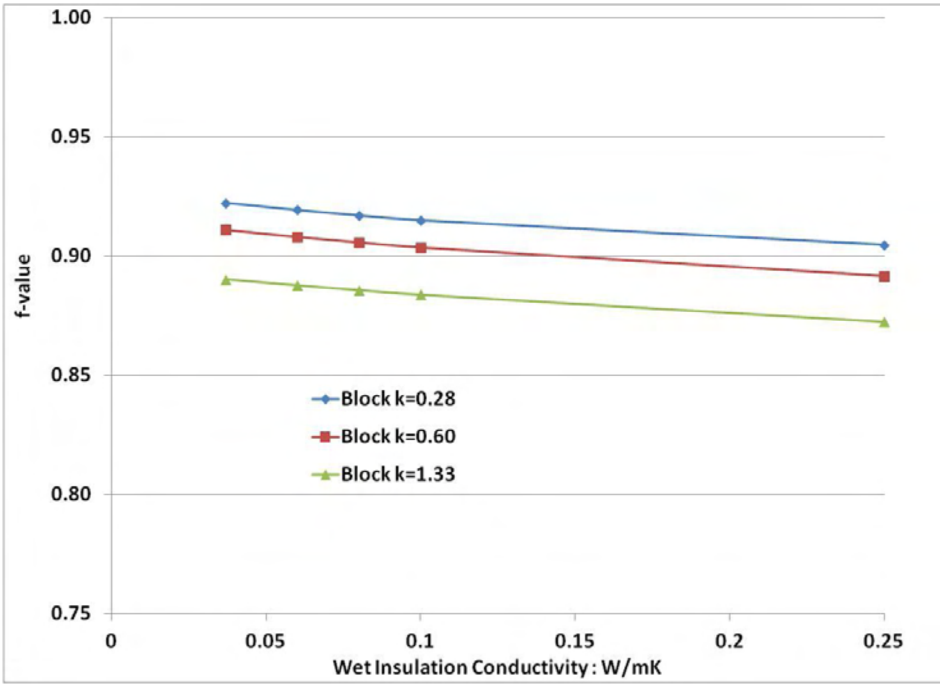


Figure 14 – Calculated f-values for the suspended floor

Figure 15 shows the ψ-values from the solid floor; increasing the conductivity of the 100mm strip of insulation, increases the ψ-value of the junction by 50 – 70% depending on the conductivity of the inner leaf.

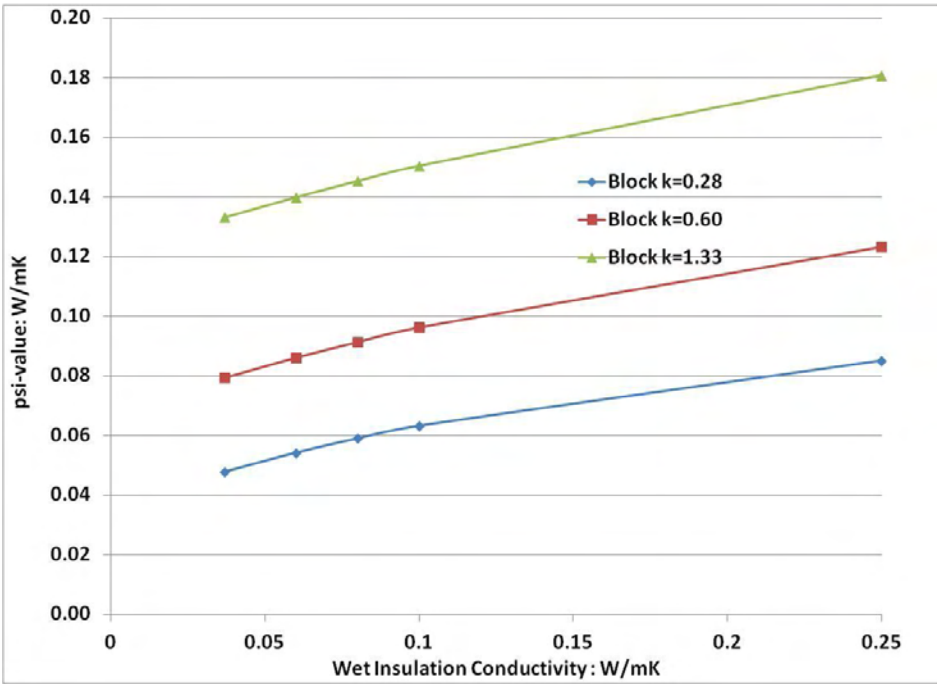


Figure 15 – Calculated ψ-values for the solid floor

Figure 16 shows the f-values from the solid floor; as expected the values decrease as the conductivity of the wet insulation rises, however they remain well above the limit of 0.75.

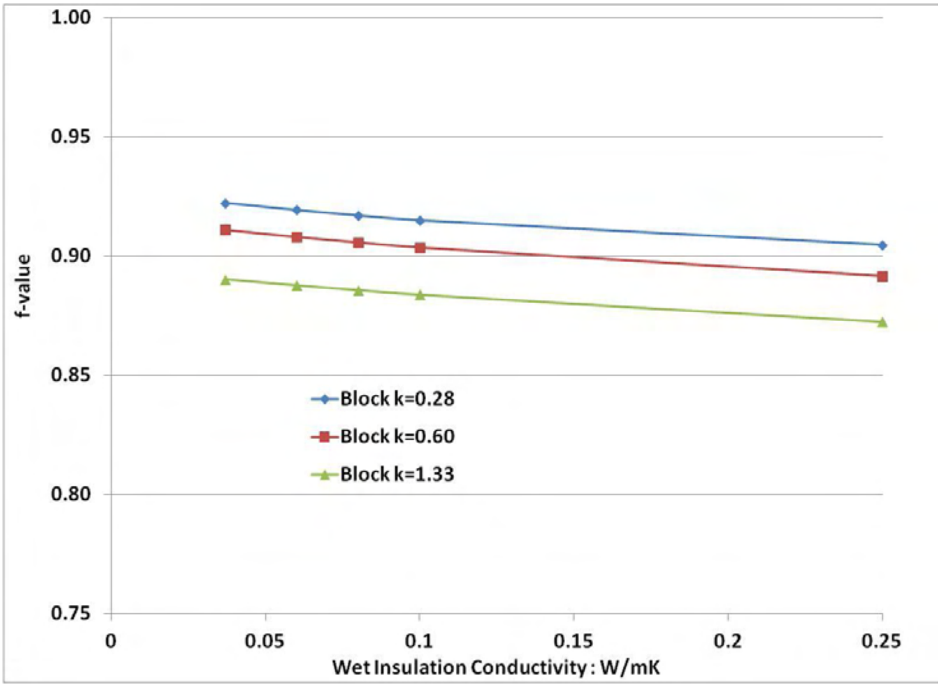


Figure 16 – Calculated f-values for the solid floor

The overall effect of this 10cm strip of wet insulation on heat loss from the house can be assessed by calculating the contribution of the different heat loss paths in a typical detached house, shown in Table 6.

Table 6 - Contribution of different heat loss paths

Plane areas	**A m^2**	**U W/m^2K**	**AU W/K**	**% of total**
Walls	197.72	0.28	55.4	25.8
Windows	15.68	2	31.4	14.6
Doors	5.0	2	10.0	4.7
Ground Floor	81.6	0.17	13.9	6.5
Roof	81.6	0.15	12.2	5.7
Total			**122.8**	**57.1**
Junctions	**L m^2**	**Ψ –value W/mK**	**Lψ W/K**	
Ground floor/wall	36.4	0.055	2.002	0.9
Internal floor/wall	36.4	0.0009	0.033	0.0
Eaves	20.4	0.08	1.632	0.8
Gable	16	0.078	1.248	0.6
Corners	24	0.06	1.44	0.7
Internal wall/wall	24	-0.006	-0.144	-0.1
Jambs	32.4	0.01	0.324	0.2
Lintels	13.2	0.03	0.396	0.2
Sills	13.2	0.013	0.172	0.1
Total			**7.10**	**3.3**
	ach		**W/K**	
Ventilation	0.5		**85**	**39.5**

Total			214.9	100.0

With dry insulation, the ground floor/ wall junction, with a ψ-value of 0.055 W/mK, is contributing 0.9% to the total heat loss. If the moisture content of the wet insulation is high raising the conductivity to 0.25 W/mK, the ψ-value rises to 0.07 W/mK, with this junction contributing 1.2% to the total heat loss. The total has risen to 215.5 W/K an increase of 0.27%. The percentages are similar for the other floor types and block conductivities.

7.0 WUFI Model of drying wet insulation in a cavity wall

7.1 WUFI modelling

The flooding tests have shown that, even after many days of draining, there is a residual high moisture content in a layer about 10cm high in the bottom of batts that have been immersed. The advanced German hygrothermal analysis software WUFI, which complies with BS EN 15026, has been used to estimate how long this layer might take to dry.

The dimensions and the materials in the model are shown in Figure 17. It is assumed that the cavity between two masonry leaves is fully filled with mineral wool down to the concrete base. The bottom 100mm of mineral wool and the adjacent masonry could be saturated with water at the start of each WUFI run.

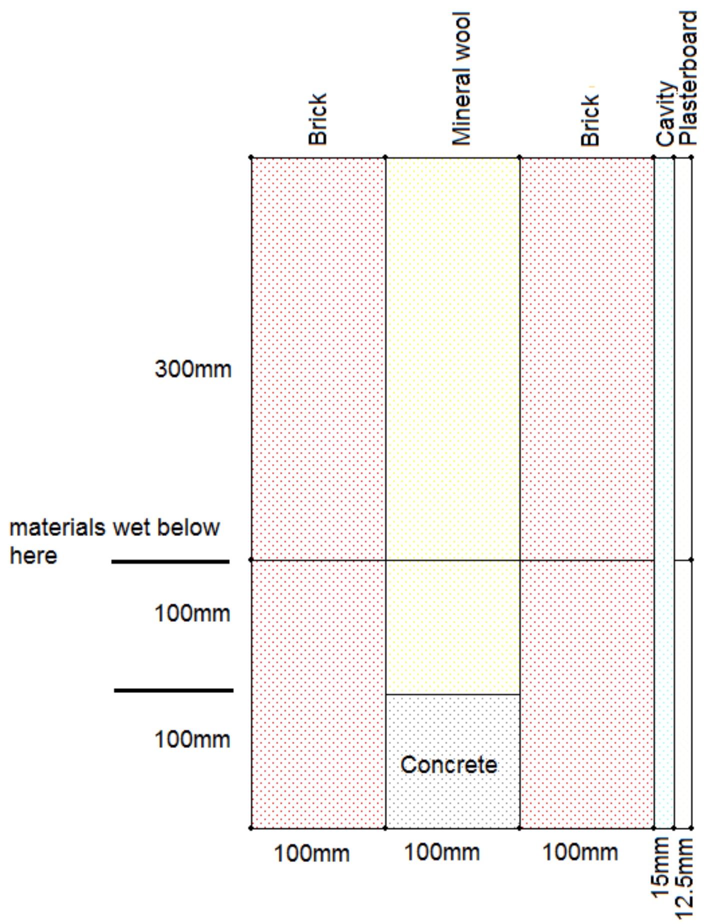


Figure 17 – Materials and dimensions of WUFI model of cavity wall

The external climate was a year from Glasgow repeated twice, starting on October 1st. Initially the internal climate was as defined in BS5250 for a class 3 densely occupied house, i.e. the internal temperature is assumed to be 20°C, with a high internal moisture load, which falls with increasing outside temperature. Subsequently, the effect of dehumidification, with a raised internal temperature and constant, low internal relative humidity, was investigated.

The wall was assumed to be west facing either fully exposed to driving rain or fully sheltered.

The properties of the brick, mineral wool and concrete from the WUFI database are summarised in the figures below.

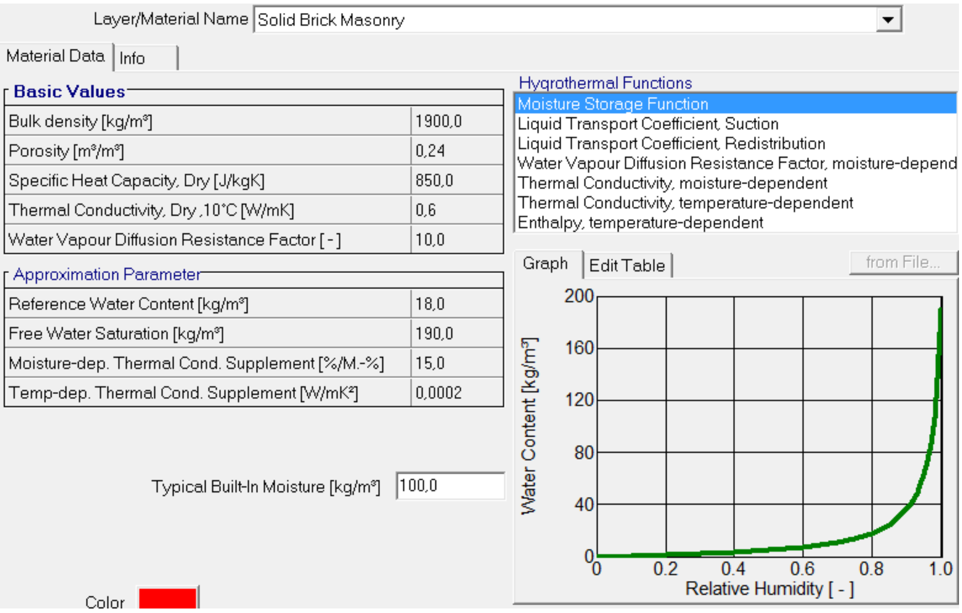


Figure 18 - Properties of brick from the WUFI database

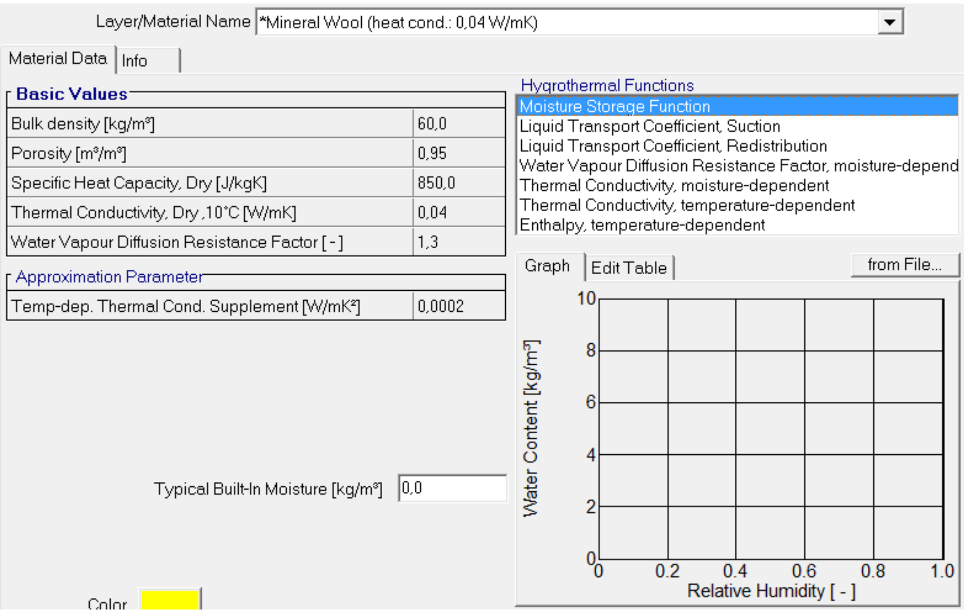


Figure 19 – Properties of mineral wool from the WUFI database

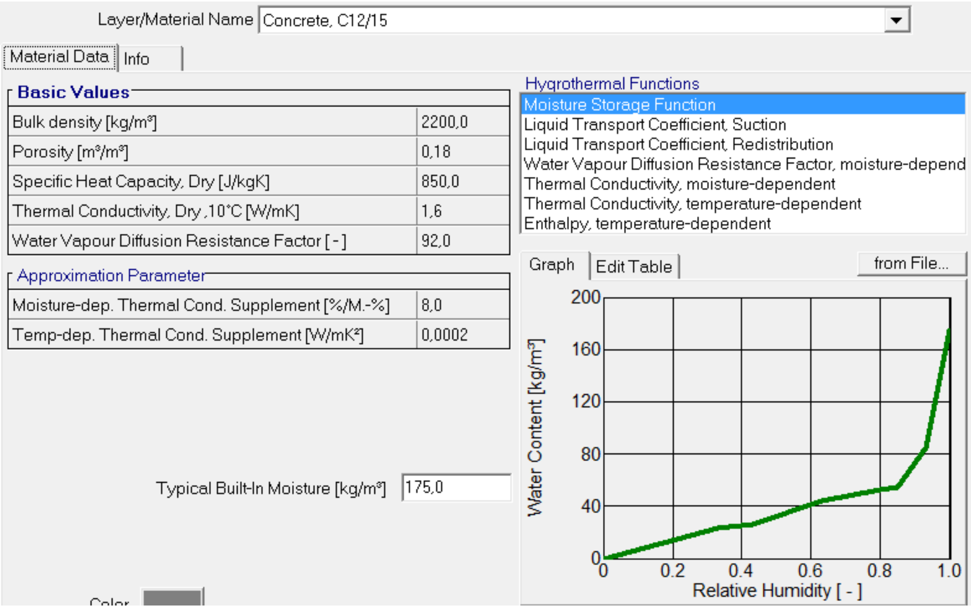


Figure 20 – Properties of Concrete from the WUFI database.

The starting moisture contents of the materials was assumed to be either 'dry' i.e. in equilibrium with 60% relative humidity or 'wet' in equilibrium with 99% relative humidity. This gives the moisture contents shown in Table 7

Table 7 – Starting moisture content of the materials at 60% and 99%RH

Material	Moisture content at 60%RH kg/m^3	Moisture content at 99%RH kg/m^3
Mineral wool	0.7	22.7
Brick	7.2	137
Concrete	41.3	162
Plasterboard	4.7	113

The moisture content of mineral wool at 99% RH is not as high as observed in the tank, however higher values caused WUFI to become unstable and crash.

7.2 Results

7.2.1 Effect of rain

Figure 21 shows the moisture content of the insulation over five years, when rain impact is included in the model, with the insulation starting dry (Run 7) or wet (Run 8). In both cases, the moisture content rises to a high level and then fluctuates annually, with a peak in the winter. No drying of the insulation is observed. It is questionable how realistic this is, perhaps the rain in the in the Glasgow climate used is unrealistically severe. It is possible to introduce sheltering, i.e. multiplying the rain by a factor between 0 and 1.

In some cases the model was run for up to five years; this showed no further long term trends after two years.

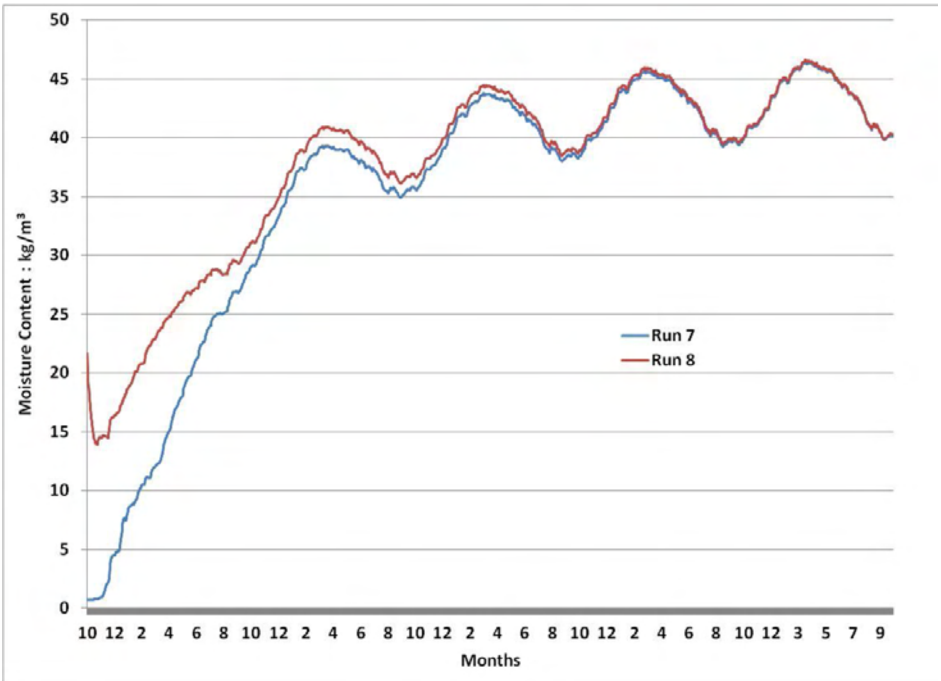


Figure 21 – Base insulation moisture content, with rain turned on, for wall starting dry (Run 7) or starting wet (Run 8)

The further runs were carried out with the less severe climate of Ostend, which is similar to that of SE England, and with structure sheltered from driving rain.

7.2.2 Effect of wet masonry

Water from a flood will permeate mineral wool immediately, but take some time to penetrate brickwork. Therefore in a very short term flood lasting for an hour or less, it is possible that the insulation would become wet while the masonry remained essentially dry. Figure 22 shows the effect of this on the short term mineral wool moisture content. Where the masonry is initially dry, the mineral wool dries rapidly, reaching equilibrium in about 15 days. However, where the masonry is also wet at the start, the long term moisture content in Figure 23 shows that the mineral wool is still drying after 2 years.

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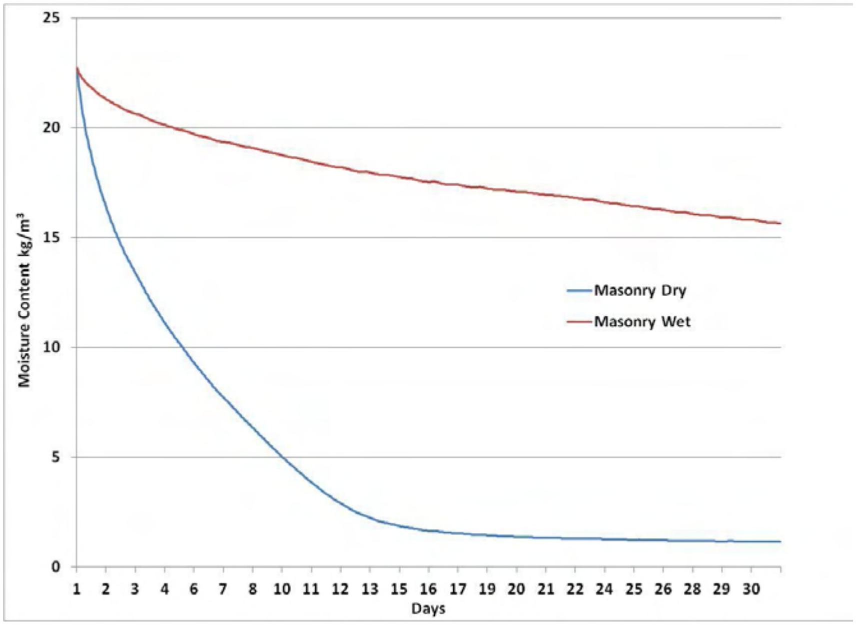

Figure 22 – Mineral wool moisture content over 31 days after flooding, with the masonry initially dry or wet.

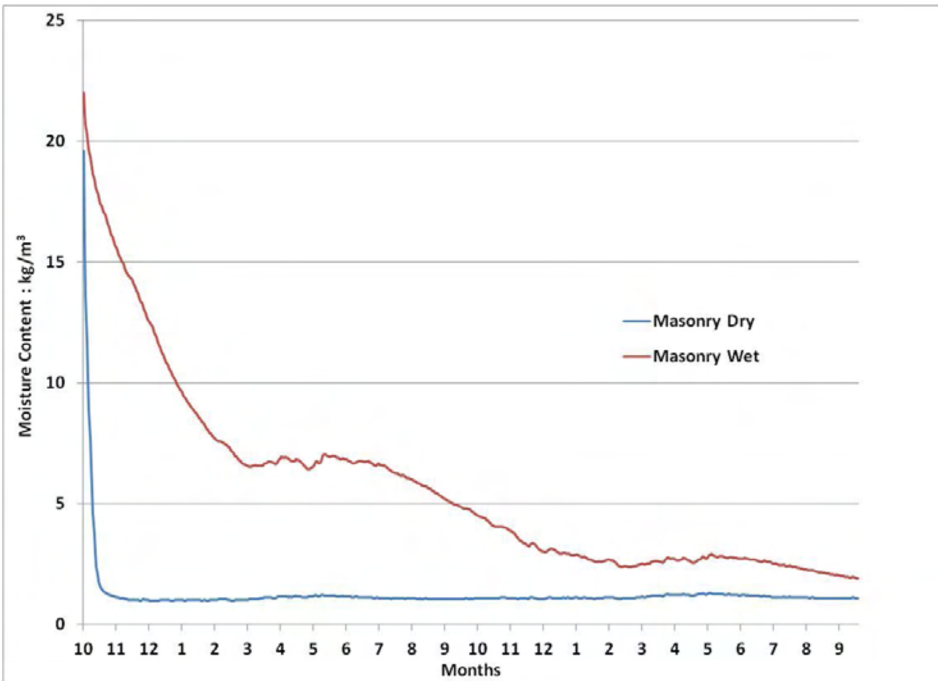

Figure 23 - Mineral wool moisture content over 2 years after flooding, with the masonry initially dry or wet.

7.2.3 Effect of Dehumidification

Figure 24 shows the effect of normal (class 3) occupancy and two dehumification regimes on the moisture content of the inner leaf of brickwork, which has started wet. Not surprisingly the dehumidification regimes are drying the wall much faster than normal occupancy. Going to the 'extreme' regime of 30°C and 10% RH is not giving very much more improvement.

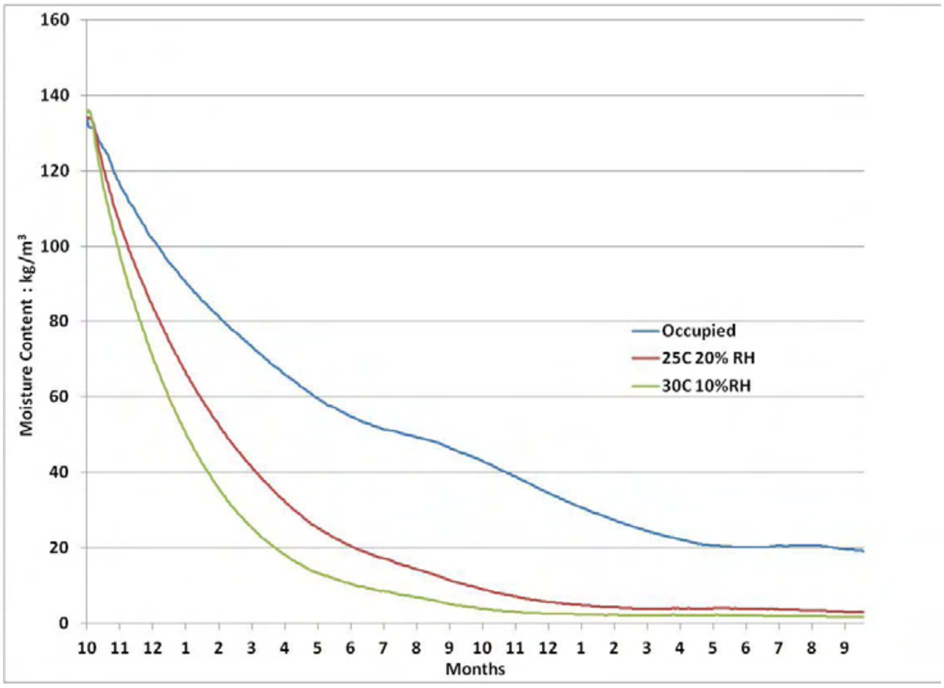

Figure 24 – Inner leaf moisture content with house occupied and with two dehumidification regimes

Figure 25 shows the corresponding effect on the mineral wool moisture content. Dehumidification is bringing it to a low level below 5 kg/m^3, within about 4 months, compared to over 12 months for normal occupancy.

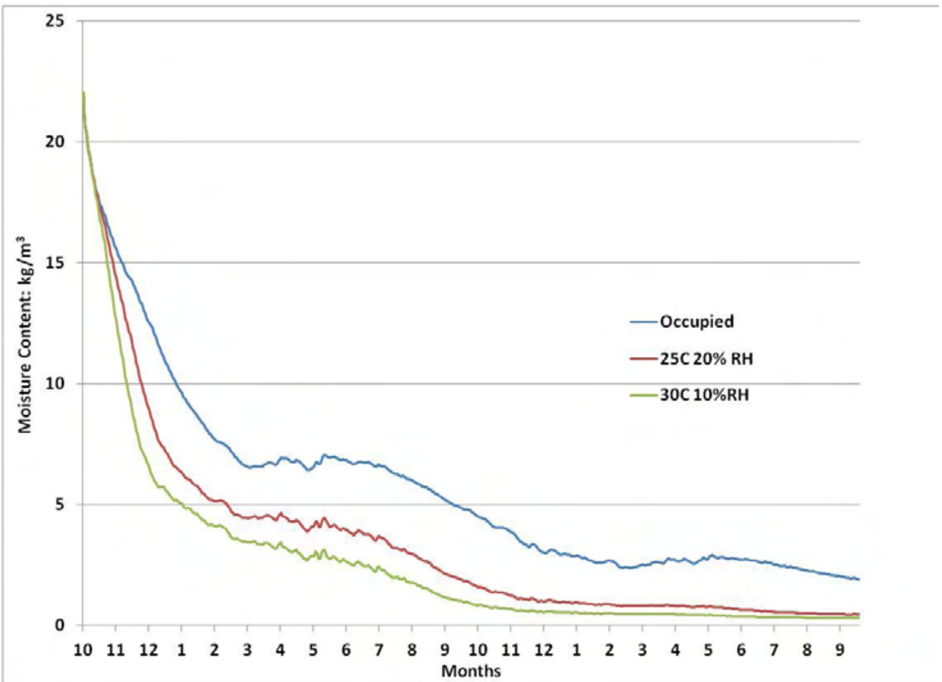

Figure 25 – Insulation moisture content with house occupied and with two dehumidification regimes

7.3 Conclusions from the WUFI modelling

The WUFI modelling done here has shown:

1) Mineral wool in dry masonry will dry rapidly, reaching equilibrium in about 15 days.

2) In the more likely situation where the masonry is also saturated, the insulation will take about a year to dry under normal occupancy.

3) If the dehumidification at 25°C and 20%RH is employed inside, the drying time will be reduced to about 4 months.

8. Discussion

The tests carried out here differ from the reality of insulation in a masonry wall in an important respect. The sides of the batts are in contact with the perspex sides of the tank, which are completely impermeable to water. In a masonry wall there would be exchange of water between the insulation and masonry; whether this would lead to more rapid drying of the insulation as water moved into the relatively dry masonry, or slower drying as water moved out of wet masonry, will depend on a number of factors including the immersion time and the type of masonry.

Nevertheless the tests have shown a number of important features.

- All the batts tested retained their structural integrity after flooding for up to five days; it is unlikely that flooding for longer periods would change this.
- The top and middle batts drain to a fairly low moisture content that will presumably fall slowly over a long period as the whole wall dries.
- Most of the bottom batt dries to a similar level, however there is always a layer about 10 cm deep that remains very wet for long periods, and only releases its water when the batt is turned on end. It is not clear to me why this should occur only in the bottom batt. The same thing occurs when only one batt is installed in the tank, and flooded either only to the top of the one batt, or to the full depth of the tank.

Including a 100mm strip of wet insulation in a wall/ground floor junction will increase the ψ-value of the junction. However this will increase the heat loss from a typical house by less than 1% and will have a negligible effect on the SAP rating. The surface temperatures at the junction will fall slightly, but still be well away from any risk of condensation or mould.

WUFI modelling has shown that the small area of insulation that remains wet after the rest has drained, which is within dry masonry, which might occur after a very short duration flood, will dry within about 15 days. If the masonry is also saturated, which is more likely after a flood lasting several hours or days, the insulation will take up to two years to dry. If heating and dehumidification is applied internally, this time will be reduced, but may still be several months.