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Energy Saving from Water Repellents

Several studies have shown that the thermal conductivity of masonry is significantly increased by the presence of moisture (1) (2) and hence, by keeping masonry dry, it should be possible to minimise heat loss.

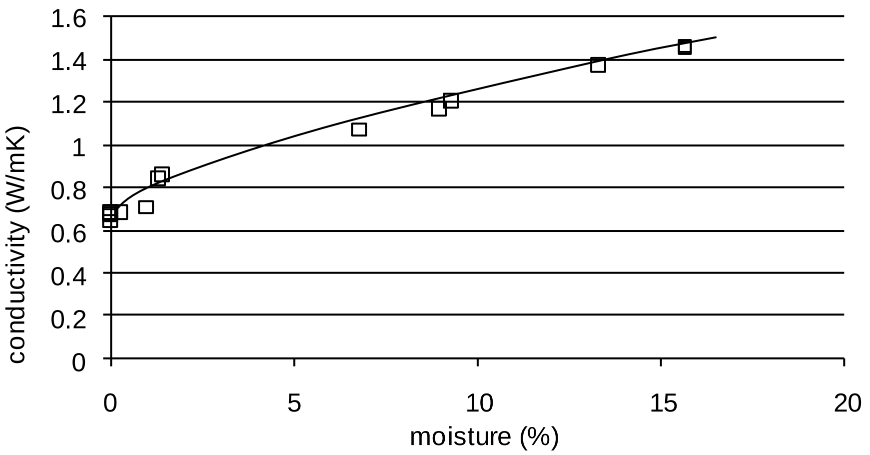
The application of water repellents is one method of keeping masonry dry. There are a range of products on the market from the older products such as stearates and waxes to silicones and silanes. This later area has advanced in recent years from the first introduction of silicone resins in 1966 to water based silane/siloxane mixtures which appeared around 2000 and now having with enhanced properties. Recently new water based creams have been introduced with significantly improved penetration properties. These changes have been summarised by Roos et al (3)

In this paper we report on the measurement of the moisture dependency of thermal conductivity and how water repellent creams can decrease the moisture content of masonry. The significance of these changes is then estimated using the SAP (Standard Assessment Procedure) energy model. Experimental work on a small scale "house" is then described.

1. Thermal conductivity and moisture

The thermal conductivity of London Brick Fletton bricks was measured using a quick thermal conductivity meter QTM-500 from Kyoto Electronics Manufacturing Company Ltd. The brick specimens were condition to different equilibrium moisture contents before testing.

Figure 1: Variation in Thermal Conductivity of Fletton Brick with Moisture Content



It can be seen from Figure 1 that the thermal conductivity increases by more than a factor of two as moisture content of the brick increases. At 0% moisture the conductivity is approximately 0.6 W/mK and at 20% moisture this is raised to 1.6 W/mK. This type of relationship will of course differ depending on the brick or type. In general, the thermal conductivity of a fluid-saturated porous material depends on the mineral and fluid conductivities, the porosity, and the pore structure (4)

The influence of a water repellent cream (Stormdry) on the water uptake of a range of substrates was measured.

The water absorption was measured according to EN ISO 15148:2002 (E). Specimens of approximate size 100 x 100 x 25 mm were prepared by cutting blocks of material. The sides of each specimen were sealed with water and vapour tight sealant (Blackfriars Interior Sealdamp) and allowed to dry. The test coating was then applied to one of the 100 x 100 mm faces on each specimen. This was applied by brush and the amount applied was calculated at the coverage of 200 g/m^2. The specimens were then left for 28 days at 20 °C and 50% RH to allow the treatment to cure.

A metal grid was then placed in a water tight tray. This grid gave a small gap of 3 mm between the specimen and the bottom of the tray which allowed free access of water.

After the conditioning phase was complete, to start the test the specimens were weighed and placed in the water tray. Water was kept to a depth of 5 mm. The weight was then recorded at intervals up to 7 days. The test method is normally run for 24 hours but this was extended to gain data that could be relevant to flood resilience.

Table 1 : Substrates used in the test

Type	Details	Composition	pH
Brick	Fired clay standard LBC Fletton – Most common type	Silicate	8.1
Brick	Fired clay West Hoathly Stock Brick	Silicate	6.4
Brick	Sand-lime type	Silicate	12.0
Mortar	New mortar made with soft sand:cement 5:1	Silicate	11.8
Mortar	“Old” mortar made to Safeguard laboratory recipe	Silicate	9.1
Sandstone	Blaxter sandstone	Silicate	7.7
Sandstone	York sandstone	Silicate	7.9
Sandstone	Sheffield sandstone. Sample from local merchant	Silicate	7.1
Limestone	Portland	Carbonate	8.4
Concrete	Paving slab (Builder Centre)	Silicate	12.9
Granite	Off-cut from a kitchen work top. Italian origin	Silicate	No data

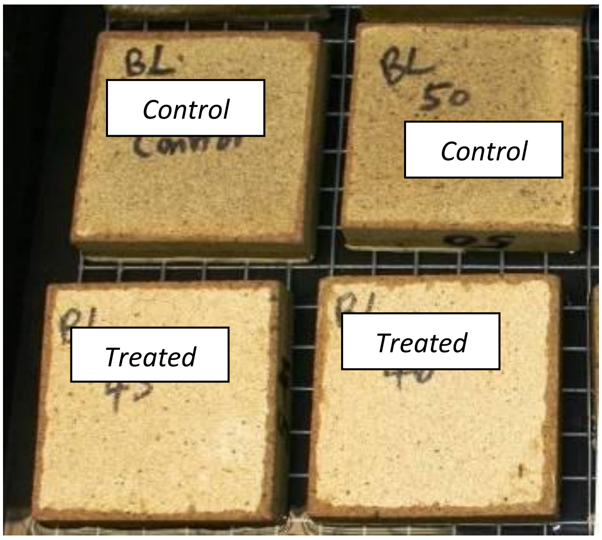
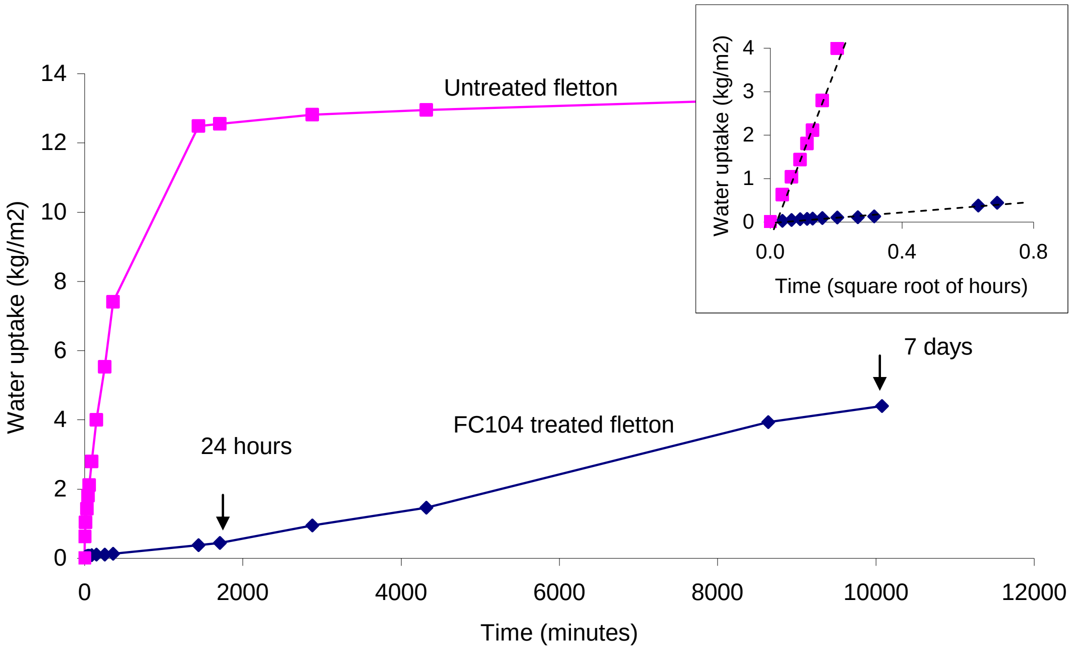


Figure 2 : Appearance of the Blaxter sandstone blocks during the water absorption test.

The darker colour of the control samples has resulted from water reaching the upper surface. The darker colour on the sample edges is the sealant.

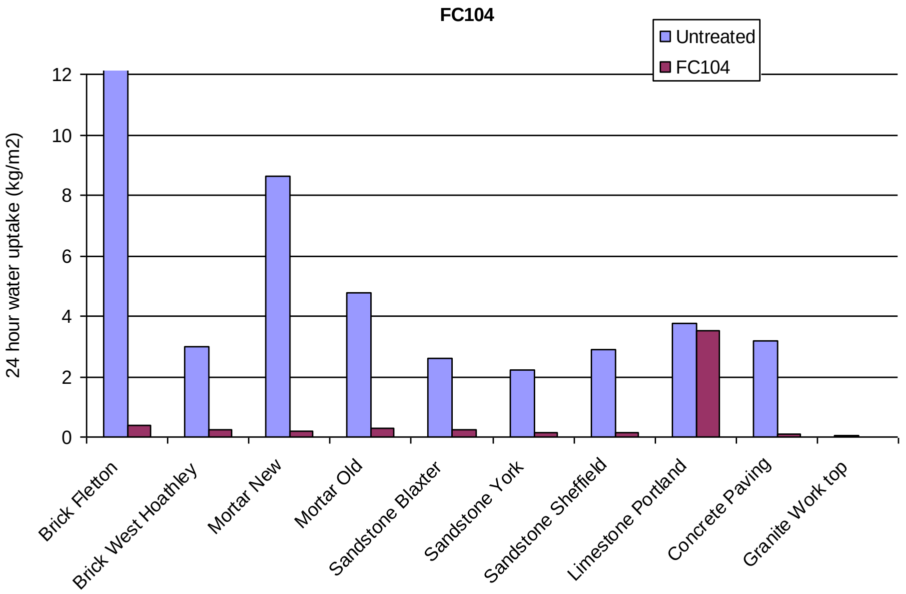
A graph showing typical water absorption is shown below. For the untreated brick most water absorption occurs in the first 24 hours. The treatment has the effect of reducing the rate on water absorption and the final amount.

Figure 3 : Water uptake graphs of treated and untreated Fletton brick



The test method also gives a description of how to calculate the Water Absorption Coefficient (W_w). This is the gradient of the water uptake in kg/m2 against square root of time graph in hours. The inset in the figure shows the data over the first 24 hours plotted against the square root of time. The gradient was measured to be 19.0 $kg/m^2\ hr^{0.5}$ for the untreated brick and 0.59 $kg/m^2\ hr^{0.5}$ for the treated one.

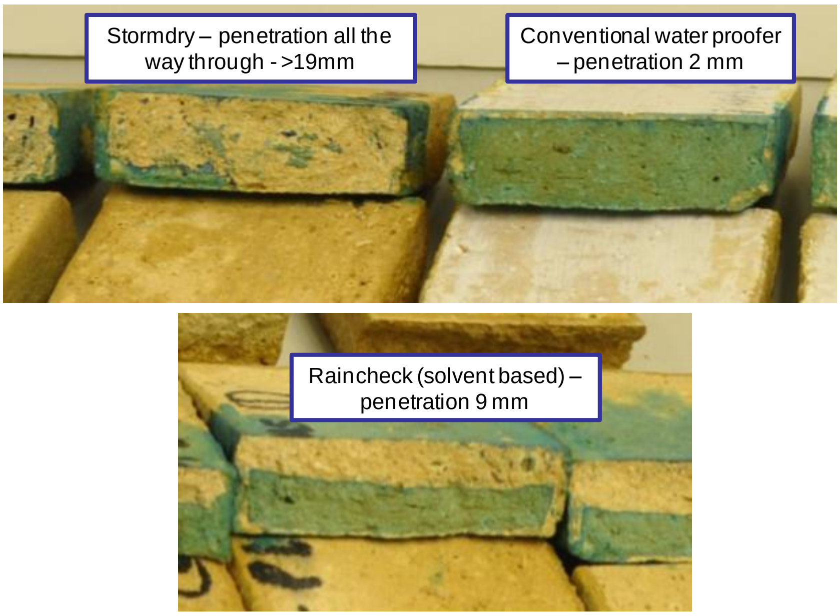
Figure 4 Water Absorption of a range on Treated and Untreated substrates



The test results on a wider range of substrates are shown in Figure 4. It can be seen that the moisture absorption of the untreated materials differ significantly from one another. This can be understood in terms of the sorptivity and available porosity of the substrates. It is notable that the water repellent has minimal effect on limestone.

A photograph showing the extent of penetration of water repellent is shown below. This type of test is done by immersing the broken section of substrate into a solution of soluble dye in water. Blue dye is visible where the substrate is not waterproofed.

Figure 5: Penetration depth comparison

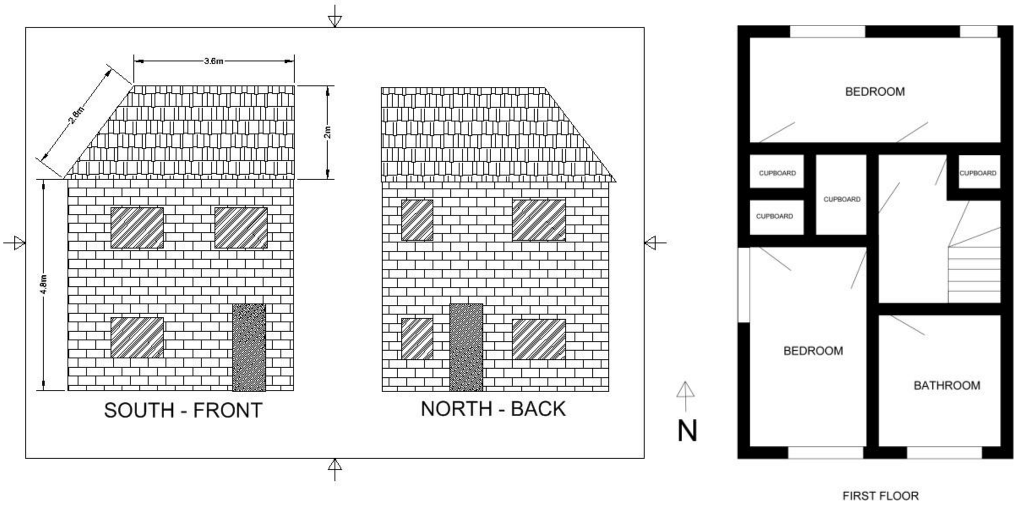


SAP Modelling

Using figures of moisture content, it is possible to calculate U-value differences between dry and damp walls and input data into a SAP (Standard Assessment Procedure) Energy Model.

This exercise was done using the house construction shown in Figure 6.

Figure 6: Solid Walled House used for SAP Model



House: 225 mm solid wall (non-cavity), floor area 73.6 m2, wall area 108 m2, fitted with standard measure of loft insulation and double glazing

The SAP model was run with different U-value of the wall corresponding to different degrees of moisture in the wall. Although it is a 225 mm thick solid wall, Case C below represents the situation where the outer half of the wall is damp and the inner part dry.

Estimates of moisture in walls can be found in the literature and vary widely. Kunzel (5) reports a mean annual moisture content of 10% volume West-facing and 1% East-facing. Averaging this we arrive at a conductivity of 1.1 W/mK for our exposed Fletton brick. The CIBSE guide has a 1% moisture content for protected fire clay and 5% for exposed which (with a 15% increase for each 1% m.c.) gives a conductivity of the exposed wall of 1.0 W/mK.

Additionally, on the basis of an annual surface rainfall of 200/m2/annum and a latent heat of vaporisation of water of 2.3 KJ/m2, then the evaporative cooling effect is 13,000 KWh/a for a 100 m2 wall house (assuming all water is evaporated). For the SAP modelled house, using a dry wall with conductivity of 0.6 W/mK, (U-value 1.91), the space heating requirement is 18,600 KWh/a. So the potential contribution from evaporative cooling is significant.

Realistically, it is difficult to model accurately but some estimates are given in Table 2.

Table 2: SAP Input and Output

Case	Situation	U value	Space Heating Demand	Whole House Energy	Fuel cost	Difference
			kWh/a	kWh/m2/a	£/a (2008)	£/a (2008)
A	Fully dry wall (0.6 W/mK)	1.91	18,600	368	304	0
B	Mostly dry - inner 0.6W/mK outer 1.2W/mk	2.19	20,200	392	328	25
C	Mostly dry - inner 0.6W/mK outer 1.6W/mk	2.30	20,800	402	339	35
D	Mostly dry - inner 1.2W/mK outer 1.2W/mk	2.79	23,200	439	378	74
E	Fully wet wall (1.6 W/mK)	3.16	25,600	476	417	113

(Fuel price 2008)

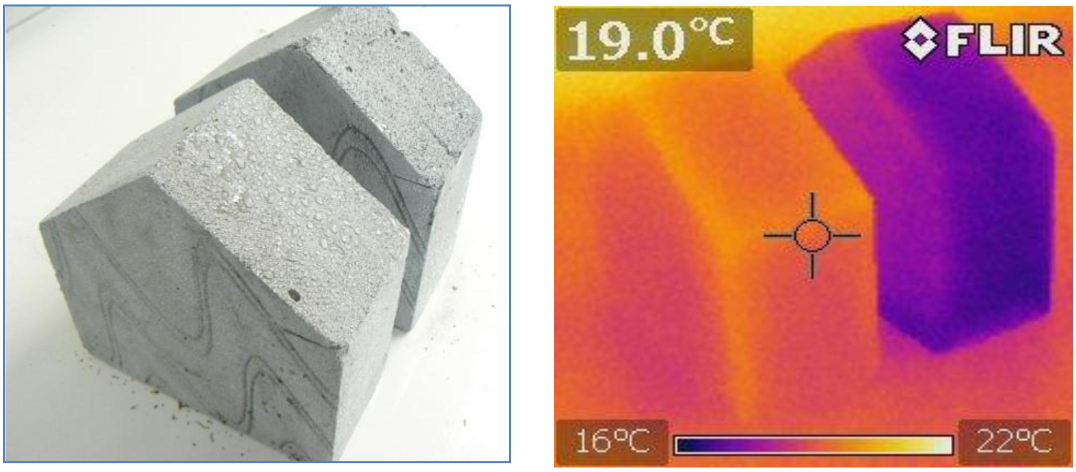
The fuel cost data is shown in the table. Based on conductive heat losses, a fully wet wall situation would result in a fuel cost of £417 and a fully dry one £304 though, realistically Cases B or D might be more representative of conductive heat losses. The influence of evaporative cooling is not considered.

2. Small Scale House

It is possible to show visual evidence of the effect using thermal imaging as shown in Figure 7. A Thermalite block was cut and half and one side treated with Stormdry and left to cure for 28 days. After this time, the block was placed outside the laboratory over night (minimum 6 C, damp/foggy conditions) and then brought back into the laboratory (22 C) in the morning. A thermal imaging camera was used to record the temperature differences.

A temperature difference of approximately 2 C is observed, mostly driven by the evaporative cooling effect of the untreated block.

Figure 7: Visible Temperature differences between Treated and Untreated Blocks



In order to investigate the approach further, a small scale test “house” was built by the University of Portsmouth. (6)

A model house was constructed using two courses of four bricks for an experimental assessment of the heating energy consumption saving. The lid and base of the model house was made from high density Styrofoam for insulation so other variables such as floor and roof thermal leakage could be eliminated. The mortar used for building the model house was similar to typical mortar used for modern buildings.

A printed circuit board (PCB) containing a relay for a 40W light bulb was used to heat the internal environment of the model house. The bulb was powered by mains electricity and interrupted by the PCB relay. A power meter was used to monitor the energy consumption and electrical source characteristics of the bulb. Both the PCB relay and the bulb were powdered from separate sources giving a better representation of the energy used by the system. The bulb was positioned in the middle of the model house.

Figure 8: External and Internal View of Model House

The model house was placed in the environmental chamber where it was tested for 22 hours with a 2 hour equilibrium conditioning period. The 2 hour conditioning scenario for the wet test was at 25°C with 85% humidity, whereas the 2 hour conditioning scenario for the dry test was at 25°C with 0% humidity. Different testing scenarios carried out are shown in Tables 3. For the wet condition a bush was used to apply 32.5g of distilled water to each side of the model house to simulate rain condition before testing.

Table 3: Testing methodology of treated and untreated model house

Untreated Surface				Wetted Surface			
Test No.	External Temperature (C)	External Humidity (%RH)	Internal Temperature (C)	Test No.	External Temperature (C)	External Humidity (%RH)	Internal Temperature (C)
1	-5	10	20	1	-5	10	20
2	0	10	20	2	5	10	20
3	5	10	20				
4	10	10	20				
5	30	10	20				
6	5	10	10				
7	5	10	15				
8	30	90	20				

Table 4 shows the heating energy consumption differences during the wet and dry conditions between the control and treated model house.

It can be seen that the energy saving achieved in wet condition is substantially greater than that of the dry. The greater heat capacity and substantially higher thermal conductivity of water compared to air is considered to be the driving force for this effect. Table 4 shows an energy reduction of 36% compared to the untreated case for the treated model house with a maintained internal temperature at 20°C in wet a scenario with the outside surrounding temperature at -5°C; this was used to simulate extremely cold and wet weather. Similarly, 33% energy saving was achieved from the treated model house under the testing condition of an internal temperature maintained at 20°C whilst the outside surrounding temperature was kept at 5°C; this condition simulated a very wet winter period in which household heating was needed.

Table 4 also shows the energy saving compared with the control as the benchmark in the dry testing scenario. In all testing conditions, the model house was left in the environmental chamber in which its exterior walls were exposed to a series of temperatures from -5, 0, 5, 10 to 30°C but internal ambient temperature was maintained at 20°C. In the case of the external temperature being 30°C, there was no energy saving at all since the external temperature was higher than the internal temperature; therefore no energy is being consumed for heating the model house.

The interesting feature of the results is that there is an energy saving from using a water-proofing cream even in the absence of applied free water on the brick surface (rainfall). This could be attributed to internal humidity/water in the brick interior.

Table 1: Energy saving of model house in dry and wet conditions

	Untreated Surface								Wetted Surface			
	External Temperature C								External Temperature C			
	-5		0		5		10		-5		5	
Test No.	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Heating Duration (s)	7320	7200	6480	6000	4680	4440	2520	2400	7320	4800	4680	3120
Energy Consumed (J)	308904	301680	273456	250800	197496	187368	105336	99840	311100	199680	196092	131664
Energy Reduction (%)	2.3		8.3		5.1		5.2		35.8		32.9	

Energy can be saved by using the cream treatment on walls both in dry and wet weather conditions. Approximately 2-8 % energy can be saved in dry condition whereas as much as 36 % can be saved in wet conditions.

This work is limited to being an experiment on a small scale test house in the laboratory. Further work on full size properties is recommended

3. Discussion

The work has demonstrated that energy reductions are possible from the application of external water repellents. The SAP model analysis and model house experiments suggest that energy savings are significant. The next step is clearly to monitor treated large scale properties to see if the indicated savings are achieved

Overall the level of energy saving is small compared to alternative methods but there are advantages of this approach of

a) easy application with minimal impact on the householder
b) the original appearance of the house is retained
c) potential compatibility with other insulation methods such as internal insulation
d) low cost

Looking at cost effectiveness (in terms of both money and carbon), the table below shows this to be cost effective compared to other measures.

Table 5: Cost effectiveness comparison

Measure	Annual fuel saving from measure (£/a)	Measure Life (yrs)	Capital Cost (£)	Fuel cost savings over 60-yr life (£)	Capital Cost over 60-yr life (£)	Net cost of measure (£)	CO2 saved from measure over 60-yr (t)	£/tonne CO2 saved
Loft Insulation	34	60	750	2040	750	-1290	24	-54
Stormdry withU-value reduction of 2.3 down to 1.9	35	30	500	2100	1000	-1100	25	-44
External Wall Insulation	99	60	19000	5940	19000	13060	71	184
Double Glazing	15	30	6500	900	13000	12100	11	1100
Solar Panel	11	10	2500	660	15000	14340	10	1434
Condensing Combi	99	10	3400	5940	20400	14460	69	210
Low Energy Lighting and Appliances	39	8	1900	2340	14250	11910	10	1191

Note: The base data for the alternative measures is taken from the Retrofit-for-the-future Technology Strategy Board website

Regarding the embodied energy of Stormdry, a carbon footprint calculation has also been made by Giraffe and the Manufacturing Advisory Service. (7) This concludes that the carbon footprint of a Stormdry application is 0.73 kg CO_2e/m^2. This compares with 1.05 kg CO_2e/m^2 for Rockwool insulation (100 mm thickness), 11.2 kg CO_2e/m^2 of EPS slab, 13.7 kg CO2e/m2 of PU foam and 1.3 kg CO2e per 800g loaf of bread – or is the same as driving a small petrol car 2.4 miles.

The average carbon payback for Stormdry treatment due to savings in space heating is one month.

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