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Moisture Content, Heat flow and paint finish in Brick and mortar walls in the Brazilian Climate

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RESUMO

Este trabalho estuda o conteúdo de umidade e transferencia de calor e massa dentro de paredes de tijolo e argamassa no clima Brasileiro, usando o software Umidus. O razão de fluxo de calor latente ao fluxo de calor total é calculada. Salas condicionadas e não condicionadas são estudadas. O efeito de tinta na superfície interna do parede é investigada. Os resultados mostram que tinta impermeável na superfície interna reduza a carga de resfriamento pelo parede e limite o movimento de umidade de parede para dentro de sala.

A study has been made using the simulation software Umidus of the moisture content and transfer of heat and mass within brick and mortar walls in the Brazilian climate. The contribution of latent heat flow to the total flow of heat through the wall is calculated. Both conditioned and unconditioned rooms are studied. The effect of paint on the internal surface of the wall is investigated. It was found that an impermeable paint on the internal surface reduces the cooling load through the wall as it restricts moisture movement from the wall into the room.

1 Introduction

The calculation of energy consumption in buildings by simulation software normally assumes that heat is transferred through building envelopes by pure conduction. However most building materials are porous, and therefore contain air and water in different phases. Walls are therefore subject to thermal and moisture gradients and the transfer of heat and mass occurs simultaneously and are interdependent. The development and philosophy of Umidus are discussed by Mendes, et al (1999).

The software *Umidus* has been developed to model coupled heat and moisture transfer within porous building elements avoiding limitations such as low moisture content, high computer run time and low accuracy. Both diffusion and capillary regimes are taken into account, that is the transfer of water in the vapour and liquid phases through the material can be analysed for any kind of climate. The model predicts moisture and temperature profiles within multi-layer walls for any time step and calculates heat and mass transfer. Input files containing hourly data provide information on the conditions at the interior and exterior of the wall. A library of material properties is also available. The orientation and tilt of the wall are considered and convection coefficients at the exterior of the wall are calculated hourly from wind velocity and direction data. The software allows the simulation of walls which have paint surfaces.

The aim of this study was to investigate the moisture content and flux of latent heat through brick and mortar walls when subjected to the climatic conditions of 14 Brazilian cities, and to identify a strategy to reduce the cooling load through hygroscopic walls in air conditioned buildings by the use of an impermeable coat of paint on the internal surface of the wall. Both conditioned and unconditioned rooms were considered. The best strategy to deal with the flow of latent heat and moisture from the themo-energetic point of view was studied.

2 Simulations

The following vertical south facing wall element was modelled, Table 1

Tab. 1 Dimensions of the standard Brick and Mortar wall

Layer	Thickness and Material
External layer	1cm mortar
Mid layer	10cm brick
Internal layer	1cm mortar

The wall is south facing, with a vertical inclination of 90^o. The external coefficient of convection was fixed at 12.4 the internal 3.6 W/m2k. The reflectance of the ground in front of the wall was 0, the solar absorbtivity of the external surface of the wall was 0.35.

The permeance of the paint on the external and internal faces are 2.0E-14, 9.0E-14 respectively.

Umidus uses an external weather file to provide data input of the conditions at the exterior surface of the wall. The weather file contains the following variables: Dry Bulb Temperature, Relative Humidity, Direct Normal Radiation, Diffuse Radiation, Solar Altitude, Solar Azimuth, Wind Speed, Wind Direction. Each file contains 8760 hourly data points

Weather files are available for the 14 Brazilian cities given in Table 3. These files were produced from Test References Year weather files for these cities: Belém, Belo Horizonte, Brasília, Curitiba, Florianópolis, Fortaleza, Maceio, Natal, Porto Alegre, Recife, Rio de Janeiro, São Paulo, Salvador, Vitória

The Internal condition file consists of 2 data items, Dry Bulb Temperature, Relative Humidity. Two sets of internal condition files were used

1. Non Conditioned for a free running room
2. Conditioned for room with air conditioning

The non conditioned files were produced using the building simulation programme TRNSYS. The following building was modelled:

1. Each room of the building has an area of 108 m2 and a volume of 324m3. The external wall has a total area of 36 m2 of which 12 m2 is glazed. There is no air conditioning, the air infiltration rate is 0.6.ach-1. The room had zero internal gains

2) The conditioned file were produced using the simulation programme VisualDoe. The identical building was modelled except for the inclusion of an air conditioning unit which functioned during Office Hours.

3 Results

Simulations were performed for the 14 cities, for both the conditioned and unconditioned cases. The moisture contents and flow of latent heat were calculated. Simulations of the conditioned case were then repeated, but the paint on the internal surface of the wall was removed. For the sake of clarity results will be presented here only for the case of Fortaleza.

Tab. 2Simulation 1 : Calculation of Heat Flows, wall humidity and Temperature at centre of wall for an Unconditioned Building with paint on the internal surface (City:Fortaleza)

Month	Qs pos kWh/m2	Qs neg kWh/m2	Ql pos kWh/m2	Ql neg kWh/m2	Moisture Content (%vol)	Temperature ^{o}C.
1	2072.01	-138.51	197.52	-24.48	5.0733	32.9276
2	1764.31	-124.99	131.83	-38.84	5.1424	32.8815
3	1984.77	-103.93	94.46	-58.19	5.3777	31.4765
4	1350.34	-102.00	53.72	-68.25	5.8876	29.9506
5	864.58	-543.08	44.85	-79.69	6.3424	28.6367
6	249.00	-1596.61	52.25	-78.54	6.7845	26.9153
7	280.61	-1378.70	54.55	-60.34	7.0031	26.8877
8	238.14	-1895.87	126.01	-8.77	7.0221	27.2827
9	365.11	-678.02	145.70	-7.89	6.78	29.0501
10	1056.84	-97.74	297.36	-0.87	6.2307	31.2716
11	2009.22	-70.42	295.75	-5.11	5.5555	32.7172
12	1833.65	-156.97	213.01	-19.02	5.2345	33.5983

Qs pos= Flow of sensible heat into building through wall

Qs neg = Flow of Sensible heat out of building through wall

Ql pos = Flow of latent heat into building through wall

Ql neg = Flow of latent heat out of building through wall

Total Cooling Load = 15775.59kWh/m2

Total Heating Load = 7336.83kWh/m2

Peak Cooling Load = 23.80W/m2

Peak Cooling Load = 21.24W/m2

Tab. 3Simulation 2 : Calculation of Heat Flows, wall humidity and Temperature at centre of wall for a Conditioned Building with paint on the internal surface(City:Fortaleza)

Month	Qs pos kWh/m2	Qs neg kWh/m2	Ql pos kWh/m2	Ql neg kWh/m2	Moisture Content (% vol)	Temperature °C.
1	5220.16	0.00	85.42	-9.04	2.3217	32.5094
2	4799.16	0.00	65.25	-11.34	2.3303	32.3209
3	4714.74	0.00	54.47	-17.43	2.4061	31.1971
4	3322.94	-4.49	41.43	-15.85	2.5925	29.9591
5	2407.52	-15.94	32.11	-27.91	2.7654	28.6448
6	1019.19	-422.38	16.67	-46.56	2.9722	27.0193
7	1106.59	-349.26	27.19	-29.99	3.1073	27.0175
8	1075.31	-312.20	32.08	-24.57	3.1434	27.2143
9	2256.31	-39.24	64.36	-2.29	3.0522	28.8502
10	3941.18	-1.49	110.44	-0.31	2.7995	30.9101
11	5449.79	0.00	130.08	-1.02	2.5418	32.0383
12	5687.79	0.00	106.50	-4.26	2.4015	32.7418

Qs pos= Flow of sensible heat into building through wall

Qs neg = Flow of Sensible heat out of building through wall

Ql pos = Flow of latent heat into building through wall

Ql neg = Flow of latent heat out of building through wall

Total Cooling Load =41766.66 kWh/m2

Total Heating Load =1335.57 kWh/m2

Peak Cooling Load =36.21 W/m2

Peak Cooling Load =28.57 W/m2

Tab. 4Simulation 3 : Calculation of Heat Flows, wall humidity and Temperature at centre of wall for a Conditioned Building with no paint on the internal surface (City:Fortaleza)

Month	Qs pos kWh/m2	Qs neg kWh/m2	Ql pos kWh/m2	Ql neg kWh/m2	Moisture Content (% vol)	Temperature °C.
1	5228.49	0.00	697.58	-459.88	1.9864	32.5082
2	4812.38	0.00	473.35	-524.14	2.0107	32.3159
3	4736.13	0.00	438.89	-608.30	2.1271	31.1978
4	3347.20	-4.83	435.17	-482.06	2.3574	29.9558
5	2441.76	-13.47	385.52	-628.38	2.5627	28.6506
6	1037.57	-389.25	260.71	-868.12	2.8267	27.024
7	1121.90	-328.11	384.77	-616.30	2.9579	27.0121
8	1089.39	-283.80	358.96	-633.73	2.9466	27.2109
9	2279.47	-40.63	434.84	-326.79	2.7613	28.8399
10	3949.77	-2.15	720.92	-208.18	2.4135	30.8997
11	5447.75	0.00	955.95	-247.47	2.1497	32.0324
12	5691.51	0.00	764.56	-423.29	2.0266	32.7322

Qs pos= Flow of sensible heat into building through wall

Qs neg = Flow of Sensible heat out of building through wall

Ql pos = Flow of latent heat into building through wall

Ql neg = Flow of latent heat out of building through wall

Total Cooling Load = 47494.52kWh/m2

Total Heating Load = 7088.89kWh/m2

Peak Cooling Load = 44.93W/m2

Peak Cooling Load = 23.14W/m2

Fig. 1 Comparison of Moisture Content at the centre of the wall for the 3 simulated cases

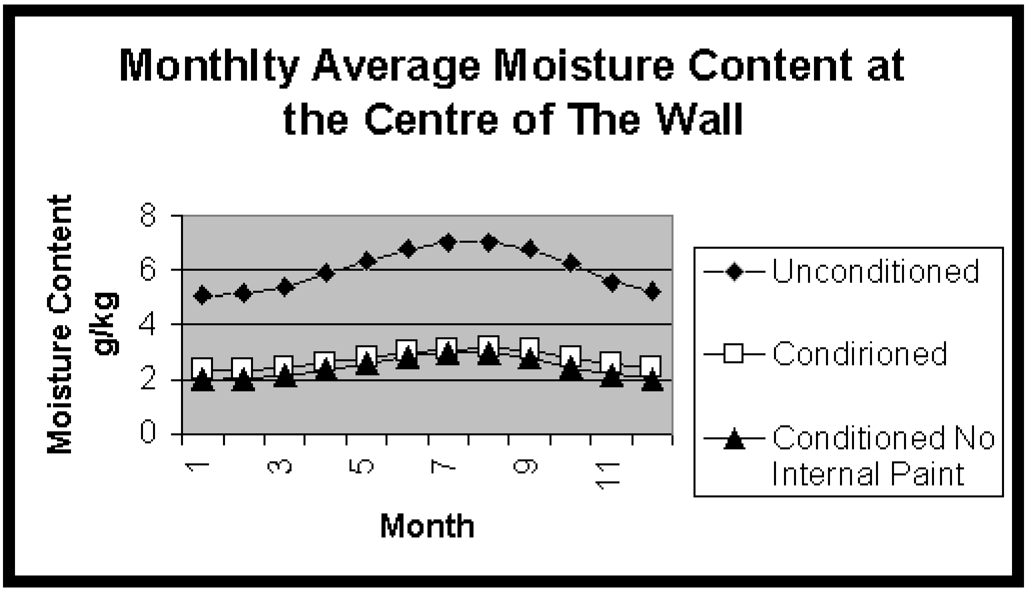


Fig. 2 Comparison of monthly flow of latent heat into the building through the wall for the 3 simulated cases (City Fortelaza)

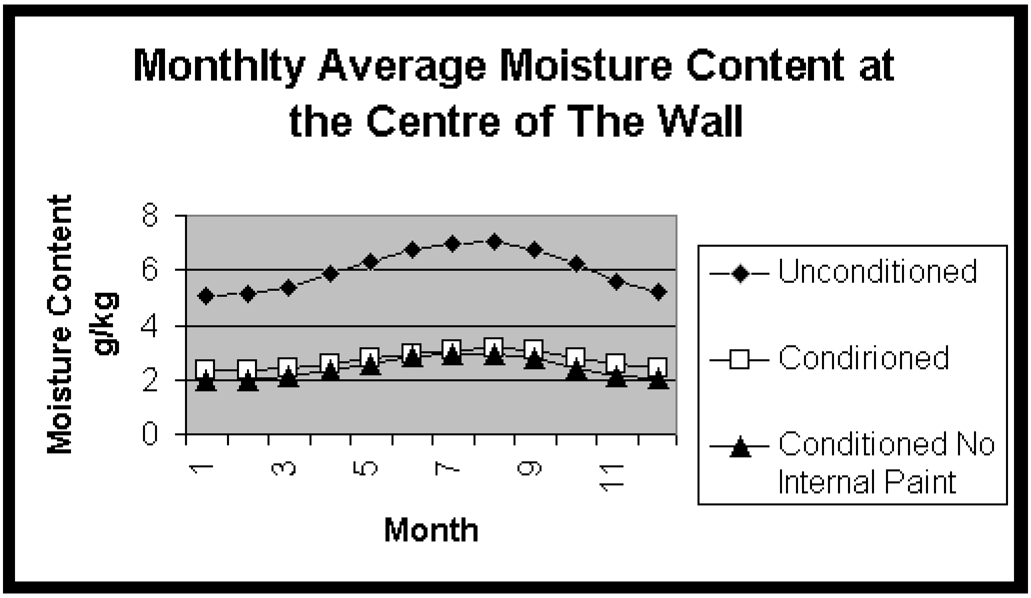
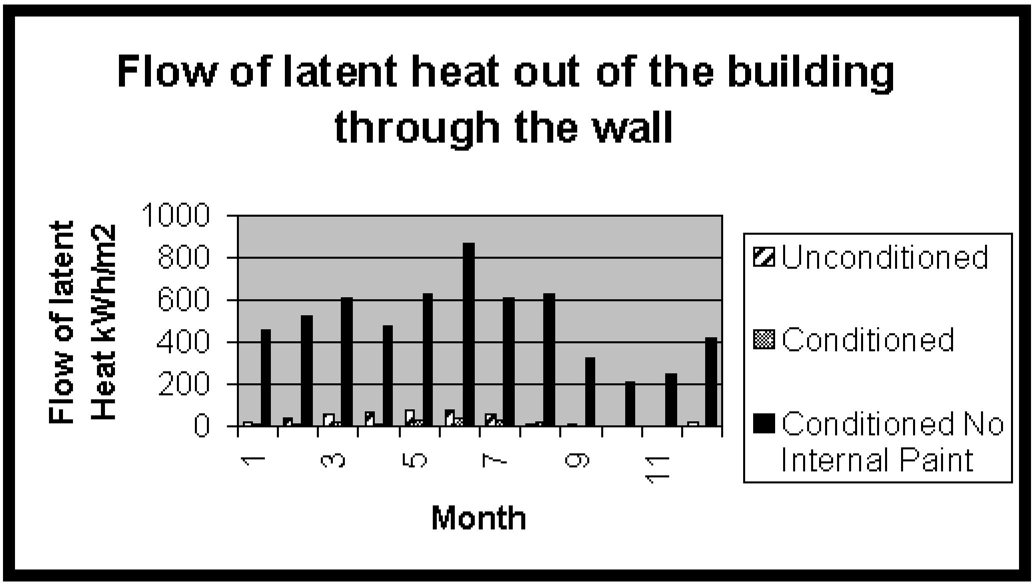


Fig. 3 Comparison of monthly flow of latent heat out of the building through the wall for the 3 simulated cases



4 Conclusions

The moisture content in the conditioned wall is approximately 50% that of the unconditioned wall. The conditioned room has a substantially lower relative humidity and lower summer temperatures. The air conditioner is effectively drying out the wall. The most important result is the heat flow through the wall in the positive direction, that is the cooling load is smaller for the case when the internal surface of the wall is painted. The total annual heat load through the unpainted wall is 13% greater than that of the painted wall. The impermeable paint inhibits the movement of moisture between the room and the wall.

The comparison between a painted wall and an unpainted wall is perhaps not so useful, as in most situations the internal surfaces of the room will be painted. The more useful observation is that reducing the permeability of the internal surface reduces the cooling load. If the permeability of the paint is further reduced, to 0, by the application of a thick latex or silicon sealing agent, the flux of latent heat into the room could be eliminated, thus reducing the total cooling load. In the case of Fortaleza a complete impermeable barrier on the internal surface could reduce the annual cooling load by a further 1.8%.

In Table 4 the reduction in annual cooling loads by eliminating the flux of latent heat into the room by the insertion of an impermeable barrier, for the 13 cities is presented .

Tab. 4Annual Total Cooling Loads, and the contribution of latent heat flow to this loads for the 13 cities in the Simulations

City	Total Cooling Load kWh/m2	Latent Cooling Load kWh/m2	% Latent/Total
Belém	42621.80	837.05	1.96
Belo Horizonte	17460.11	430.93	2.47
Brasília	14779.55	632.05	4.28
Curitiba	7524.32	1369.18	18.20
Florianópolis	15336.91	1125.15	7.34
Fortaleza	41766.66	766.00	1.83
Maceio	38055.70	1063.65	2.79
Natal	46958.50	1052.23	2.24
Porto Alegre	10230.34	869.27	8.50
Recife	39044.54	805.13	2.06
Rio	20008.34	769.93	3.85
Salvador	30142.45	444.08	1.47
Vitória	23181.36	1004.53	4.33

This study demonstrates the important interaction of climate, hygroscopic building materials and paint in the determination of heat flow through a wall in a conditioned environment. The software Umidus is a useful tool for modelling the coupled transfer of heat and mass through hygroscopic materials with painted surfaces.

5 References

Mendes N., Ridley I., Lamberts R., Philppi P.C. and Budag K., Umidus: Umidus: A PC program for the Prediction of Heat and Moisture Transfer in Porous Building, Building Simulation Conference – IBPSA 99, Kyoto, 1999.