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Hygrothermic Behaviour and Durability of Vertical External Walls

Comportement hygrothermique et durabilité des parois des bâtiments

Hygrothermisches Verhalten und Dauerhaftigkeit vertikaler Aussenmauern

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SUMMARY

The reliability requirement and the technological requirement of hygrothermic behaviour will fully answer the demands of durability of vertical external walls, if the intervention is carried out only during use but also during the design program, by means of a data input which approaches as nearly as possible the conditions of use which shall actually take place. This study aims at determining, on the basis of several hypothesized models of users behaviour, the maximum quantity of vapour produced one hour in the case of families with the same number of components, but with different characteristics and in the case of families with a variable number of components. The research results are shown in a diagram providing simple use for designers.

RÉSUMÉ

Pour que la fiabilité et la qualité technologique du comportement hygrothermique répondent parfaitement à l'exigence de durabilité des parois, il faut intervenir dans la phase de projet avec des données aussi proches que possible des conditions d'utilisation. Cette contribution essaye de déterminer, sur la base de différentes hypothèses des modèles de comportement des usagers, la quantité maximale de vapeur produite durant une heure dans des familles avec un même nombre de personnes, mais de caractéristiques différentes ainsi que dans des familles avec un nombre variable de personnes. Les résultats de la recherche sont représentés dans un diagramme aisé à consulter par l'ingénieur.

ZUSAMMENFASSUNG

Solange die Vertrauenswürdigkeit und die Technologie des hygrothermischen Verhaltens für die Dauerhaftigkeit massgebend sind, müssen diese nicht nur beim Gebrauch, sondern auch bei der Planung möglichst realistisch berücksichtigt werden. Hier hat man, aufgrund verschiedener Verhaltensmodelle der hypothesierten Bewohner, die maximale Menge des in einer Stunde erzeugten Dampfes, für Familien derselben Grösse, jedoch mit verschiedenen Charakteristiken und für Familien verschiedener Grösse, festzulegen versucht. Die Ergebnisse sind in einer Tabelle und einem Diagram enthalten, welche beim Projektieren verwendet werden können.

1. PRELIMINARY REMARKS

The reliability requirement (see UNI specification 7959) intended as the ability or attitude of external vertical walls, their single parts and their components, to keep quality constant in time, according to clearly defined conditions of use and by control , prevention and maintenance operations, seem to answer fully to the requirement of durability; but with a view to satisfying the durability requirement the intervention is not requested only during the use but also during the design program with a data input approaching as nearly as possible the conditions of use, that shall take place.

2. INTRODUCTION

It is well-known that the production and migration of water vapour is determinant in the shaping of the behaviour model of external walls. In the study of the technological requirements of the hygrothermic behaviour, in order to avoid the interstitial and/ or superficial condensing, it was found necessary to introduce into the construction design program, among the other measures to be taken, the study of the production of water vapour in such buildings as: halls (theatres, cinemas, etc.), hospitals, industrial premises, civil buildings, etc., in relation to the great number of people and to the particular activities that are carried out in them and wherever a severe check of hygrometric conditions could be required.
With a view to examplifying the proposed method, a study has been introduced, which regards the production of water vapour in flats; this method analyzes the causes determining such a production, the behaviour of the users, in relation to their activities carried out in flats and to any other parameter useful for the calculation of the water vapour quantity that is produced in a fixed time's unit.
Therefore the research has set up a methodology of study and investigation useful for the definition of behaviour models of users with a number of hypotheses on the activities of users, on their presence even in relation to their external activities, so that to become a useful support in design stage, supplying an analytical description, whose necessity of further investigation was not felt in the past, in order to prevent condensing that is one of the most frequent pathologies of vertical external walls.
Such a methodology of study and investigation is to become a useful element in the second stage of this research in order to determine an operational metodology intended to extrapolate notions of general use, starting from experimental measurements taken on significant representatives. The choice of exemplification fell on civil buildings because of the availability of data relative to them, in the hypothesis of the consideration that it could be always possible to extend such a methodology of investigation also to other buildings of interest for the research.

3. THE PRODUCTION OF WATER VAPOUR IN FLATS

3.1 Causes

The production of water vapour inside flats is essentially due to:
- the presence of users (breathing, sweating);
- the type of activity carried out (cooking, drying, etc.).

The production is discontinuous both for the intermittent presence of users varying the number of the components and the hours, per day, of their presence, and also for their type of activity.
Consequently it is not right to make an average of water vapour production resulting from a cycle of the occupation of rooms during the whole day because the high productions of vapour are temporary and only inside a few rooms.
It is therefore important to determine the quantity of vapour produced in a short period (an hour).
The parameters determinant of the vapour quantity depend on several factors than can be collected as follows:
- characteristics and composition of the family unit, i.e. if the components are mostly adult, elderly, or children; it is in general interesting to know the composition as to age ranges of users;
- economic and social level of the family unit;
- labour activity of the components of the unit outside and inside the flat and for how many hours;

- free time, hobbies and time devoted to sleep;
- habits at home: daily use of shower, bath, etc.;
- presence o absence of household appliances, such as dishwashers, washing-machine, drying-machine,etc..

The above listed factors that influence the vapour production in each single flat depend, as is easy to understand, on the life habits of each single component so that it appears impossible, in view of the extreme variability of the reference parametres, to determine a model of behaviour to which to refer in the design stage.

As ti is clearly impossible to theorize a sole behaviour model of reference, the research aims at the defining of a set of behaviour models from which to deduce, with simple calculation, useful indications in the design stage for an input of data closer to the actual situation.

3.1.1 Presence of users

The quantity of vapour depending on the kind of activity is expressed in table 1.

USERS	KIND OF ACTIVITY			
	Rest	Light activity	Light working	Heavy working, play and phisical training
ADULT	50 gm/h	100 gm/h	200 gm/h	400 gm/h
CHILDREN	25 gm/h	50 gm/h	100 gm/h	200 gm/h

Table 1 The quantity of vapour produced on the basis of activity (gm/h).

The values shown in the table No 1 and the following are expressed in gm/h, instead of Kg/s as required by the S.I., thus being more significant.

3.1.2 Activities

Consider that the following activities are carried out:

1) Cooking and washing, altogether:

breakfast	700	gm	from	7 to 8	a.m.;
lunch	700	gm	from	12 to 13	p.m.;
snack	350	gm	from	17 to 18	p.m.;
supper	1000	gm	from	19 to 20	p.m..

2) Clothes-washing and drying:

the washing machine but not the drying machine is there; the drying takes place (in winter time) in the toilet and are foreseen:

- No 2 weekly washings (5 kilos each);
- No 2 hand-washings (1kilo each);

time of drying: 12 hours in a room where t=20°C and H.R. = 40%.

Production of water vapour: 200 gm/h.

3) Toilet and bath:

- hot bath 400 gm/h;
- hot shower 2000 gm/h;
- other 200 gm/h.

Consider that each component has at least 2 showers and 1 bath a week, on average.

4) Other works:

- floor washing: 1500 gm in 1/2 hour 2 times a week;
- watering of plants: 400 gm 2 times a week.

Besides consider that fish basins and water vessels, etc. are absent and natural ventilation (opening of windows, draughts, etc.) is not taken into account. It was not considered the hygrothermic role played by hygroscopic materials (furniture,tiling and coating, etc.) that absorb the molecules of water vapour in case of an increase of the air H.R. (Relative Humidity) and give back to the air in the opposite case. The quantity of water vapour absorbed could even not be negligible.

3.2 Exemplification

The author wants to assess for a flat of 190 cubic meters (70 net square meters) the vapour quantity produced by a family unit composed of four people; six different types of family units are hypothesized with the following characteristics:

Ex. No 1: father (8 working hrs. outside);
mother (8 working hrs. outside);
1 child (attending a full time school);
1 child (attending a school 5 hrs.);

Ex. No 2: father (8 working hrs. outside);
mother housewife;
1 adult son (8 working hrs. outside);
1 child (attending a school 5 hrs.);

Ex. No 3: father (8 working hrs. outside);
mother housewife;
2 children from 0- 3 years of age;

Ex. No 4: retired father;
mother housewife;
2 adult sons (each working 8 hrs. outside);

Ex. No 5: father (continous working, 6 hrs.);
mother (part-time working, 4 hrs.);
1 child (attending a school 5 hrs.);
1 child (from 0-3 years of age);

Ex. No 6: 1 elderly;
2 adults (8 working hrs.);
1 child (attending a school 5 hrs.).

For each component of the unit it is summed up in a table, on the basis of both presence and of the kind of activity carried out, the quantity of water vapour expressed in gm/h which has been produced, in the different hours of the day and in a week's time.

Table No 2 is compiled for each component of the family unit. From the summation of all the values tabulated is obtained the vapour production for each day of the week for the whole family unit.

FATHER																								
Day	Hour 0-1	Hour 1-2	Hour 2-3	Hour 3-4	Hour 4-5	Hour 5-6	Hour 6-7	Hour 7-8	Hour 8-9	Hour 9-10	Hour 10-11	Hour 11-12	Hour 12-13	Hour 13-14	Hour 14-15	Hour 15-16	Hour 16-17	Hour 17-18	Hour 18-19	Hour 19-20	Hour 20-21	Hour 21-22	Hour 22-23	Hour 23-24
Mo	50	50	50	50	50	50	50	100						100	50				700	100	100	100	100	50
Tu	50	50	50	50	50	50	50	100						100	50				700	100	100	100	100	50
We	50	50	50	50	50	50	50	100						100	50				700	100	100	100	100	50
Th	50	50	50	50	50	50	50	100						100	50				700	100	100	100	100	50
Fr	50	50	50	50	50	50	50	100						100	50				700	100	100	100	100	50
Sa	50	50	50	50	50	50	50	50	100	100	100		100	100	50				200	100	100			50
Su	50	50	50	50	50	50	50	50	100	100	100		100	100	50				200	100	100	100	100	50
MOTHER																								
Day	Hour 0-1	Hour 1-2	Hour 2-3	Hour 3-4	Hour 4-5	Hour 5-6	Hour 6-7	Hour 7-8	Hour 8-9	Hour 9-10	Hour 10-11	Hour 11-12	Hour 12-13	Hour 13-14	Hour 14-15	Hour 15-16	Hour 16-17	Hour 17-18	Hour 18-19	Hour 19-20	Hour 20-21	Hour 21-22	Hour 22-23	Hour 23-24
Mo	50	50	50	50	50	50	50	100						100	100				100	100	100	100	100	50
Tu	50	50	50	50	50	50	50	500						100	100				100	100	100	100	100	50
We	50	50	50	50	50	50	50	100						100	100				100	100	100	100	100	50
Th	50	50	50	50	50	50	50	500						100	100				100	100	100	100	100	50
Fr	50	50	50	50	50	50	50	100						100	100				100	100	100	100	100	50
Sa	50	50	50	50	50	50	50	100	600	200	200	400	100	100	100				100	100	100	100	100	50
Su	50	50	50	50	50	50	50	50	100	100	100	200	100	100	100	100	100	100	100	100	100	100	100	50
CHILD																								
Day	Hour 0-1	Hour 1-2	Hour 2-3	Hour 3-4	Hour 4-5	Hour 5-6	Hour 6-7	Hour 7-8	Hour 8-9	Hour 9-10	Hour 10-11	Hour 11-12	Hour 12-13	Hour 13-14	Hour 14-15	Hour 15-16	Hour 16-17	Hour 17-18	Hour 18-19	Hour 19-20	Hour 20-21	Hour 21-22	Hour 22-23	Hour 23-24
Mo	25	25	25	25	25	25	25	50										200	200	50	25	25	25	25
Tu	25	25	25	25	25	25	25	50										200	200	50	25	25	25	25
We	25	25	25	25	25	25	25	50										200	200	50	25	25	25	25
Th	25	25	25	25	25	25	25	50										200	200	50	25	25	25	25
Fr	25	25	25	25	25	25	25	50										200	200	50	25	25	25	25
Sa	25	25	25	25	25	25	25	50					50	50				200	200	50	25	25	25	25
Su	25	25	25	25	25	25	25	25	25	100	100	100	50	50	50			200	200	50	25	25	25	25
CHILD																								
Day	Hour 0-1	Hour 1-2	Hour 2-3	Hour 3-4	Hour 4-5	Hour 5-6	Hour 6-7	Hour 7-8	Hour 8-9	Hour 9-10	Hour 10-11	Hour 11-12	Hour 12-13	Hour 13-14	Hour 14-15	Hour 15-16	Hour 16-17	Hour 17-18	Hour 18-19	Hour 19-20	Hour 20-21	Hour 21-22	Hour 22-23	Hour 23-24
Mo	25	25	25	25	25	25	25	50						50	50	50	50	50	50	50	25	25	25	25
Tu	25	25	25	25	25	25	25	50						50	50	50	50	50	50	50	25	25	25	25
We	25	25	25	25	25	25	25	50						50		50	50	50	50	50	25	25	25	25
Th	25	25	25	25	25	25	25	50						50	50	50	50	50	50	50	25	25	25	25
Fr	25	25	25	25	25	25	25	50						50	50	50	50	50	50	50	25	25	25	25
Sa	25	25	25	25	25	25	25	50						50				200	200	50	25	25	25	25
Su	25	25	25	25	25	25	25	25	25	100	100	50	50	50	50	50	50	200	200	50	25	25	25	25
HOME ACT.																								
Day	Hour 0-1	Hour 1-2	Hour 2-3	Hour 3-4	Hour 4-5	Hour 5-6	Hour 6-7	Hour 7-8	Hour 8-9	Hour 9-10	Hour 10-11	Hour 11-12	Hour 12-13	Hour 13-14	Hour 14-15	Hour 15-16	Hour 16-17	Hour 17-18	Hour 18-19	Hour 19-20	Hour 20-21	Hour 21-22	Hour 22-23	Hour 23-24
Mo								700						1500				300	40	1040	40	40	40	
Tu								700						1500				300		1000				
We								700						1500				300	1900	1200	200	200	200	200
Th	200	200	200	200	200	200	200	700						1500				300		1000				
Fr								700						1500				300	40	1040	40	40	40	
Sa								700				1900	200	1900	200	200	200	500	200	1200	200	200	200	
Su									700					1700				300		1000				
Sum. Ex 1																								
Day	Hour 0-1	Hour 1-2	Hour 2-3	Hour 3-4	Hour 4-5	Hour 5-6	Hour 6-7	Hour 7-8	Hour 8-9	Hour 9-10	Hour 10-11	Hour 11-12	Hour 12-13	Hour 13-14	Hour 14-15	Hour 15-16	Hour 16-17	Hour 17-18	Hour 18-19	Hour 19-20	Hour 20-21	Hour 21-22	Hour 22-23	Hour 23-24
Mo	150	150	150	150	150	150	150	1000						1750	200	50	50	550	1190	1340	290	310	310	150
Tu	150	150	150	150	150	150	150	1400						1750	200	50	50	550	1150	1300	250	250	250	150
We	150	150	150	150	150	150	150	1000						1750	150	50	50	550	3050	1600	450	350	350	150
Th	350	350	350	350	350	350	350	1400						1750	200	50	50	550	1150	1300	250	250	250	150
Fr	150	150	150	150	150	150	150	1000						1750	200	50	50	550	1190	1340	290	290	290	150
Sa	150	150	150	150	150	150	150	1000	700	300	300	300	450	2100	750			900	1000	1500	450	450	450	150
Su	150	150	150	150	150	150	150	150	250	500	500	500	300	2000	250	150	150	800	800	1300	250	250	250	150

Table 2 Quantity of vapour produced by a family unit

In the histogram shown in Fig.1 are emphasized the maximum values of water production in the case of example No1.

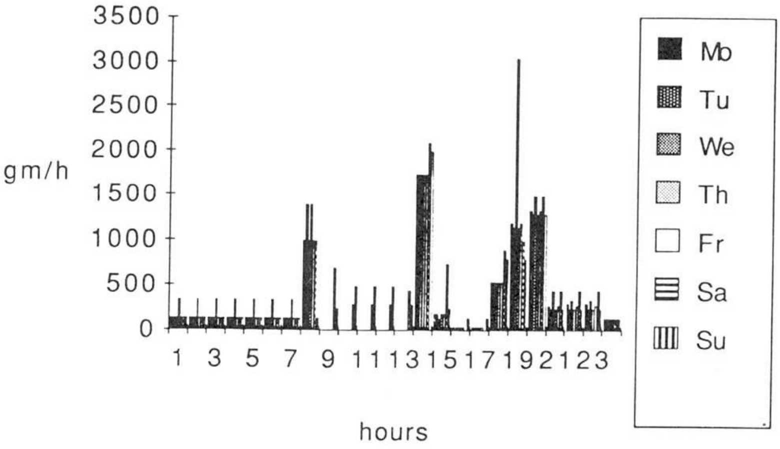

Fig. 1 Histogram of a week's days

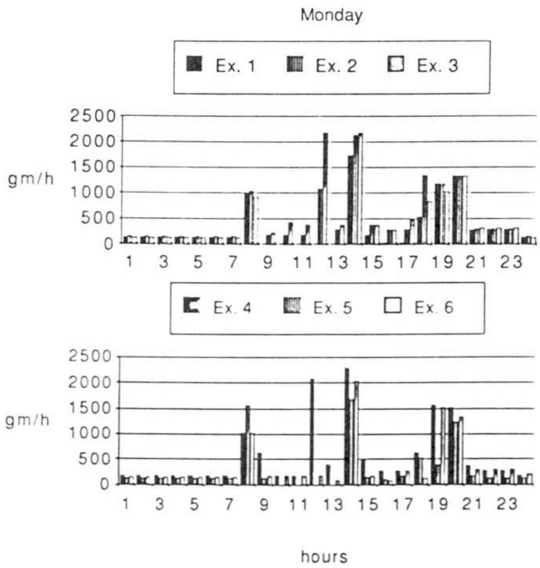

Fig.2 Histograms of three family units in a week's day

Re-processing the same calculation also for the other five hypotheses of composition of the family unit are obtained by comparison indications as to what behaviour model brings in vapour productions most concentrated.

The behaviour model that in the end is the one that gives the highest vapour production in an hour's time is No 4.

Till now it was considered the family unit as composed always by four users in the same flat of 190 cubic meters; let us now consider how vapour production varies for a number of people from 2 to 6 users in the selfsame flat before taken into consideration.

Now are examined the five different situation as follows:

Ex. A: 2 adults (1 working outside, 1 housewife);

Ex. B: 2 adults + 1 child (1 working outside, 1 housewife, 1 child from 0-3 years of age);

Ex. C: 2 adults + 2 children (see Example No 3);

Ex. D: 2 adults + 3 children (Ex. C + 1 child from 0-3 years of age);

Ex. E: 2 adults + 3 children + 1 elederly person.

From the comparison between the different situation analyzed the following diagram, shown in Fig. 2, is obtained that gives useful indications to the designer, in case of over-crowding in the considered flat, on the range of variation of the reference values for an adequate design of vapour suction devices.

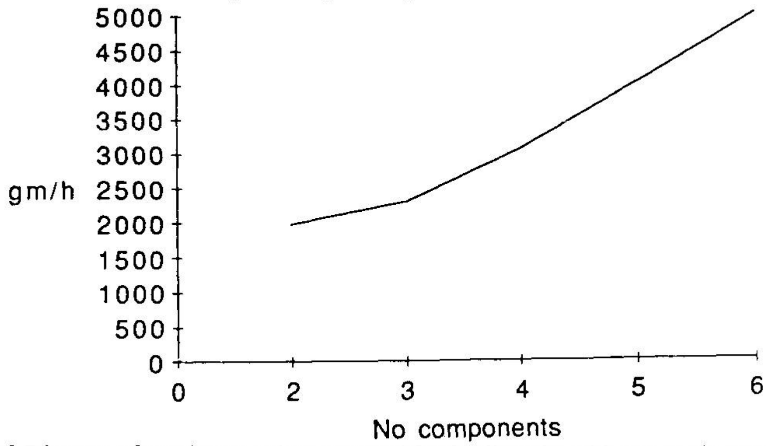

Fig.3 Diagram of maximum values assessed for family units with one to six components

4. FINAL REMARKS

Theanks to an adequate design, in the final use there shall be fewer maintenance interventions in order to ensure standard quality; or better, quality is surely maintained through a certain established period and so it is actually achieved the correspondence of the reliability requirements (ability to maintain constant in time standard quality under predetermined use conditions) and of technological requirements of hygrothermic behaviour to the exigency of durability, as for instance in the reviewed case of vertical external walls.

The presence of such a pathology as condensing causes unforseen damages and faults that require interventions of repair not easily forseen or programmed in advance as in the interventions of a real maintenance course.

To prevent pathologies means even to have global costs better defined and forseen in advance.

The global cost is the summation of the cost of settlement, building costruction, maintenance and operation for the lasting life of the buildings, and besides demolition and reuse at the end of their life (either positive or negative values).

The results of the research are also useful during a recostruction course, when for instance faulty conditions due to condensing depend directly on overcrowded flats or on the peculiar habits of users. In fact this research methodology can be used also for the acquisition of input data so that to give precise indications for the interventions that must be carried out.

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