Parameter	Maximum Internal Temperature
Basic regime (Table 1)	35.9°C
Begin analysis at 6pm	36.2
10% absorbtion of internal longwave radiation	24.1
10% absorbtion of internal shortwave radiation	34.3
10W/m2 power supplied to the canopy	36.6
10W/m2 power supplied to the ground	36.2
500m3/hr infiltration of outside air	36.2
Peak solar input increased to 900..1000..900W/m2	36.7
Soil conductivity doubled	35.7
Soil thermal capacity doubled	31.9
Soil longwave absorbtivity/emissivity increased to 90%	36.2
Soil shortwave reflectivity increased to 45%	34.8
All soil layer thicknesses doubled to 0.1m	32.4
Soil lower 5 layers only doubled to 0.1m	36.2
Ground convection increased by 25%	36.3
Canopy convection increased by 25%	35.7
Outside air highest temperature increased to 40°C	38.5
Minimum RH reduced to 5%	33.0
Minimum outside air temperature increased to 23°C and Maximum RH increased to 47% (July/August weather)	37.0

Table 5. Summary of Sensitivity Runs.

Briefly, the conclusion of this paper is that it is possible to design and construct LCMEs that maintain within themselves climates that are significantly cooler than outside. These LCMEs function by passive means alone: that is to say, they need no airconditioning or other power-consuming devices. Their potential uses are extensive: agriculture and horticulture are obvious choices. Computer studies have shown that a louvred roof canopy that provides the necessary thermal control still admits sufficient daylight for vigourous plant growth. Other uses include shopping centres, office parks and manufacturing facilities. In all these cases, the LCME would provide a volume of space in which other more conventional buildings would be constructed. These conventional buildings would then require far less insulation and airconditioning than they would if they were outside the LCME.

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TEST CELL RESULTS ON HEAVY VENTILATED WALLS IN MEDITERRANEAN CLIMATE

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1. Introduction

The research and development activity on the ventilated heavy walls carried out by CONPHOEBUS, was finalized to introduce new prefabrication techniques, able to improve the thermal behaviour of buildings, into the local building firms. Such improvements are mainly directed to control the effects of solar radiation during summer, since the constructive typologies developed for continental climates do not match the peculiar characteristics of the Mediterranean climates.

The specific climatic conditions of the Mediterranean area, besides playing an important role for the design of façade components, emphasize the need of a new test methodology which allows to take into account suitably not only the outside temperature, but also the effect due to the solar radiation which reaches the façade. In fact the combined action of the wide temperature fluctuation between night and day-time (typical of the climate of Catania as well as of many other mediterranean towns) and the high intensity of solar radiation, leads a rapid transient thermal behaviour of the walls. Therefore those test methodologies based on steady or quasi-steady state conditions, are insufficient. Bearing that in mind, the need to utilize test methodologies similar to those adopted for passive components, is a matter of course. For such reason three test cells, which simulate an intermediate ambient of a multistories building, were utilized. By means of these cells the following wall typologies were tested:

a) heavy wall with an outward curtain thermal insulation
b) wall like item a) but with a light ventilating overwall
c) wall like item a) but with a semi-heavy ventilating overwall.

The last two typologies were designed and build in cooperation with two local building firms specialized in prefabricated walls.

Winter and summer tests were performed; their results are in good agreement with the values obtained by means of a simulation computer model recently developed.

2. Choice of the walls to be tested

2.1 Selection of the most suitable existing typology

The choice of the walls to be tested was the final result of a detailed analysis which, starting from a market-research, led us to define and design some component prototypes.
The steps through which the analysis was carried out were:

- Market-research and knowledge of the constructive techniques of the local prefabrication firms
- Analysis of the existing wall typologies and evaluation of their thermal behaviour in the local climate
- Choice of the best wall typology among the existing ones
- Setting of two prototype designs which improve the energy performance of the chosen wall typology.

The first step pointed out the largest market acceptance for the heavy wall, specially in medium/large buildings both public and private. Such trend is matched by the diffusion of firms which are equipped with plants for heavy wall prefabrication. From the energy point of view, the heavy multilayer wall allows to place suitably the thermal insulation respect to the thermal inertia, according to the occupation time of the building and to the exposure of the façade. In fact the position and the wideness of the inertial mass allow to affect the delay-time and the attenuation of the thermal wave.

Nevertheless the constructive techniques locally utilized deliver a product which is burdened by a handicap: the thermal bridges. In fact, according to the different constructive techniques, full stiffening ribs (having wideness up to 20% of the frontal area) or metallic joints (between inward and outward faces) are normally present. Those thermal bridges, besides improving the thermal conductance, cause many troubles like water steam condensation, mould development, etc.

Therefore, the curtain thermal insulation remains the only existing typology which is able to avoid the afore mentioned troubles. Such curtain may be placed inward or outward; the former is more effective where the occupation time is continuous (i.e. residential buildings)(1,2). Nevertheless the outward thermal insulation may be subject to premature ageing and to worsening of performance, due mainly to:

- rapid temperature increase when the wall is reached by solar radiation
- thermal cycles between day and night-time with amplitude as large as 20°C
- water moisture absorption during winter.

2.2 The "Ventilated Wall"

In order to avoid these troubles, the best solution is "the ventilated wall". It consists of an overwall placed outside the insulation in such a position as to obtain an air gap. Two slits, up and down, connect the air gap to outside and allow that, when the heat transmitted through the overwall warms the air in the gap, a natural circulation starts for stack effect. So, both the rapid thermal increase of the insulation surface and the wide temperature fluctuation between day and night-time, may be avoided. Furthermore, the natural circulation of warm air over the insulation surface removes the moisture excess, keeping high insulation performance. On the contrary if the slits are kept closed during winter, the global thermal resistance of the wall may be suitably increased.

So, the three test cells were equipped on South façade with three different wall typologies: one reproduces the best existing typology for residential building (outward curtain insulated wall), the other two are similar to the first, but with an overwall made of:

- Glass Reinforce Concrete (GRC), 1 cm thick
- Steel Reinforced Concrete, 5 cm thick (the minimum allowed by the standard and codes).

The thickness of air gap was defined taking into account two opposite requirements: to facilitate the air circulation in summer and to oppose the natural convection heatflow in winter. Therefore it was fixed equal to 6 cm. The three afore described solutions have the same thermal mass; a 12 cm thick concrete panel which is placed inward and acts as bearing element.
In figure 1 the three wall typologies, which the test cells were equipped with, are shown.

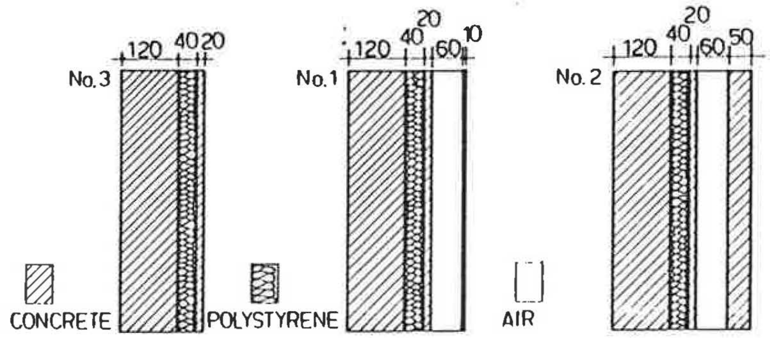

Figure 1: Tested components

3. Experimental set-up

The test cell evaluates the performance of a façade component simulating realistic working conditions. The CONPHOEBUS test cells (see figure 2) simulate an ambient with the following characteristics:
- internal size: 3.2 x 6 x 3.2 H (m)
- reduced heat exchange through Est and West wall, floor, and ceiling, in order to simulate a central module of a building
- North wall with variable transmittance (by means of additional insulation) in order to simulate a "North-South tube" of this building
- the internal air may be conditioned both in winter and summer, and the electric or thermal consumptions of auxiliary devices are measured.

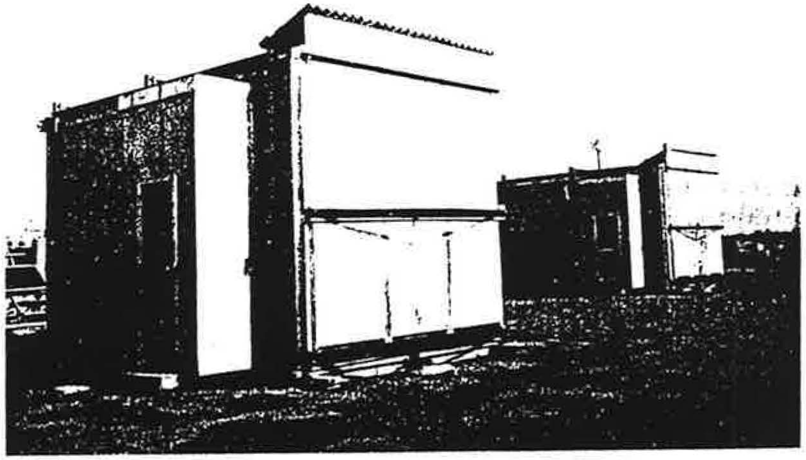

Figure 2: Test cells.

4. Method of approach

Two different types of measurement have been performed for the evaluation of the components (3, 4, 5):

a. Direct measurement of heat fluxes. This measurement was relatively simple because the component surface is opaque to solar radiation and quite homogeneous. Both flux meters and surface temperature sensors were used.

b. Comparative measurements. They were performed when the relative advantage of each selected solution respect to the others was required. Auxiliary heating consumption in winter and internal air temperatures

and temperature difference in summer are the measured parameters.

5. Results

5.1 Comparison of test cell losses

The three test cells, equipped with an identical South wall (12 cm thick concrete slab) were kept at the same temperature and the auxiliary heating consumptions compared.
The differences among cells were within 2%.

5.2 Heating season performance

The thermal performance of the three components may be presented in a graphical form, where the ratio of the daily integrated South wall flux through the component (Qu) to the solar daily irradiation (H) is reported in the y-axis, and the amount of "degree-hours" of the day (DTD) divided by the daily solar irradiation (H) is reported in the x-axis.
Figure 3 shows the curve obtained for cell number 1.

The best linear fits to the experimental data are:

Cell 1 : Qu/H = 0.0014 - 0.55 (DTD /H)
Cell 2 : Qu/H = 0.0020 - 0.56 (DTD /H)
Cell 3 : Qu/H = 0.0030 - 0.49 (DTD /H)

- The y-axis intercept, representing the equivalent "solar factor" is very small, because the walls are opaque and well insulated.
- The U_L values, represented by the slope of the curves, are approximately the same for the three walls.

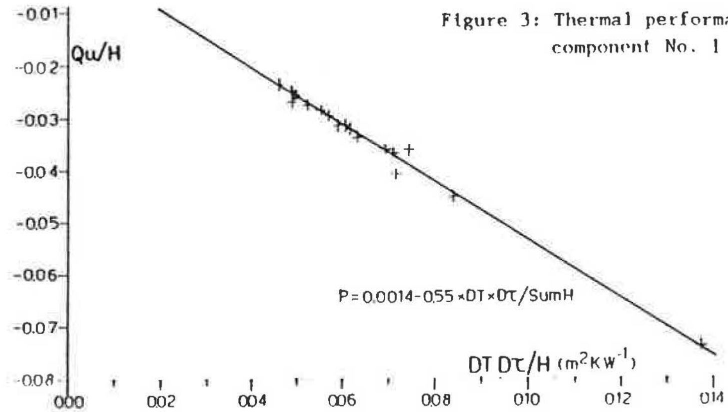

Figure 3: Thermal performance of component No. 1

The heat flux through the ventilated walls has been measured in two different conditions, with the air gap slits open, or with the air gap slits closed. The values when the air gap slits were closed showed an average reduction of the heat losses of about 13%.

Figure 4 shows the time evolution of the internal-external air temperature difference and of the heat flux through the North and South walls, in a sequence of clear days.

The temperature of the test cell was kept at 25°C in order to obtain a sufficiently high winter temperature difference between internal and external air.
The curves exhibit the following features:
a) the strong daily variation of the temperature difference between internal and external air (from 1 to 16°C)
b) the prevalence of the North heat flux (not insulated wall: only concrete 120 mm thick) over the South one
c) the delay time between the peaks of the South heat flux and those of the internal-external temperature difference (about 4 hours); for the North wall this delay is less than 1 hour.

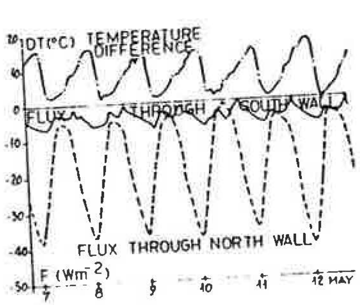

Figure 4: Heat flux and air temperature differences in winter

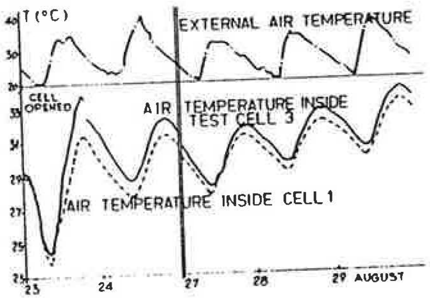

Figure 5: Air temperatures in summer

5.3 Summer performance

The tests have been run without air conditioning, with the internal temperature fluctuating freely.
The following measurements have been performed:

- the surface temperatures of the South walls both on the air gap inner and outer sides (for test cells number 1 and 2)
- the temperature of the sunlit South wall of cell number 3

- the temperature of the air inside the test cells.

The following results have been obtained on the basis of several test days from end June to August:

- The surface temperature of the internal side of the air-gap (test cell number 1 and 2) is lower than the external surface temperature of the South wall in the cell number 3: the mean daytime increase of the wall surface temperature above the air temperature, caused by the solar radiation, is reduced by 50% because of the shading by the ventilating wall.
  No significant differences have been noticed between the two ventilated walls.
- The total daytime heat flux through the South wall is reduced by about 25% in the test cells with ventilated wall, compared with the flux in the cell number 3.
- The reduction of the daytime air temperature inside the test cells number 1 and 2 respect to the cell number 3 is very moderate. The variation is small also with the North wall well insulated. Figure 5 shows the external air temperature and the air temperature inside test cells number 1 and 3; the temperature difference between the test cells is always less than 1°C.

The following considerations may explain the small temperature difference between the test cells:
1) In the three test cells, the South thermal flux is strongly attenuated because of the relatively large thickness of the insulation.
2) The contribution of the other walls to the heat exchanges is not negligible.

6. Conclusions

The comparison among the three façade components has pointed out:

- a moderate improvement of the winter thermal performance of the ventilated walls, if the ventilation slits are kept closed;
- a reduction of the daytime heat flux through the ventilated walls in summer;
- a noticeable reduction of the temperature peaks on the insulating surface due to the ventilating walls;
- a substantial equivalence of the thermal performance of the two ventilated walls.

The solution having the G.R.C. ventilating wall has greater costs than the concrete ventilating wall, not justified by better performances.Moreover, a further saving can derive from the utilization of cheaper insulating materials with ventilated walls, since the exposure conditions in this case are less severe than those experienced by a conventional external curtain insulation.

Although the relative weight of the cooling load due to opaque walls is small compared to the other cooling loads of a building, the advantages of the ventilated wall are remarkable, namely for the reduction of the peak loads, which effect the sizing of the cooling units. It is also interesting the possible application of the concrete ventilating walls for the retrofit of existing buildings.

7. Acknowledgements

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