# PASSIVE RESPONSES FOR COMFORT CONDITIONS IN A CLOSED ATMOSPHERE UNDER HOT DRY CLIMATES

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*ABSTRACT In many countries, besides the hot dry climate, the lack of energy resources is one of the brakes to the development: without air conditioning, it is not yet possible to give good conditions of working inside offices; air movements, dust, pollution are not consistent with cleanliness, controlled atmosphere and calm air.*
*Furthermore, sanitary spaces as hospitals and laboratories, and cultural ones as museums and libraries are interested in passive solutions to cooling in a closed atmosphere, ie: without any air movement, except controlled-filtered ventilation.*
*One solution with two speeds is explored here: the basic one is built up from evaporative cooling, the subsidiary one from air movement; the two work inside the built structures of the building (walls and floors) during the night in hot dry season.*

## 1 Principle of the system

The system is especially designed for a hot dry climate with high temperatures, large diurnal range (20 K and more) and low humidity conditions, where both evaporative cooling and mass effect with night ventilation can be managed.

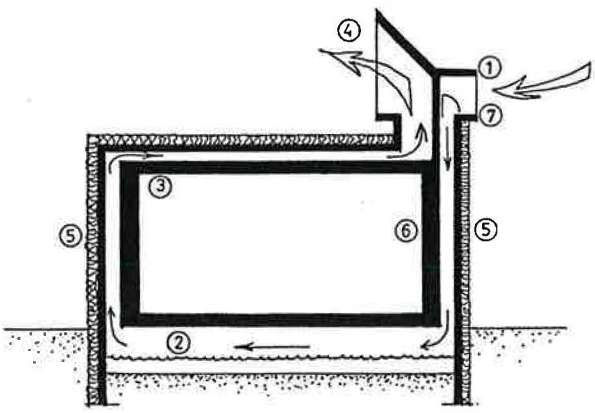


**Fig.1 Section on the system showing the principles**

Take the following the case : DBT between 30 to 36°C and 50 to 10% RH, the building being closed up on outside (doors and windows) with a controlled air renewal system. The basic principle is shown in Fig.1: take air movements (wind) from the top of the building with a wind catcher (1), or badgeer from Persian building tradition, driving it towards the foundation level above a buried pond (2), natural water at water table level or cistern with rain water from cool season, if rainy, cooling the air by evaporative effect and driving it through the structures (3) towards the way out, cooling them by the way.

To be efficient, the system will work the best during the night: the high inertia structures will have taken a maximum of ambient internal warmth during the day and the night air movement, with 15-20K lower in temperature and cooled by water evaporation, will remove the stored heat to the outside and prepare the building for a new comfortable daytime atmosphere.

## 2 Building the system

To be efficient, the system may observe the following basic principles:
- present an insulated outside envelope volume (5);
- have a strong inside building inertia (6);
- present a wind catcher facing prevailing winds (1) during the dry hot season, with shutters for daytime closing (7);
- have a larger air outlet turning awat from the prevailing winds (4);
- dig a pond below the ground floor, either to reach the water table (if there is one) or to manage a cistern for rain-water (2) ;
- build the walls with hollow blocks (concrete or bricks) or with double wall technique (earth or concrete);
- no opening to outside except the door with a flyscreen and air control inlets and outlets.

The demonstration building presents the following elements (Fig.2) :
- the walls are hollow concrete blocks of 20 cm width (8) with 5 cm outside insulation (9) + 2 cm coating (10), and a 16 cm inside concrete wall (11), total width 43 cm;
- the floors and ceilings 15 cm slabs with concrete beams (12) and hollow blocks 12 cm thickness (13) + 3 cm cement topping (14).

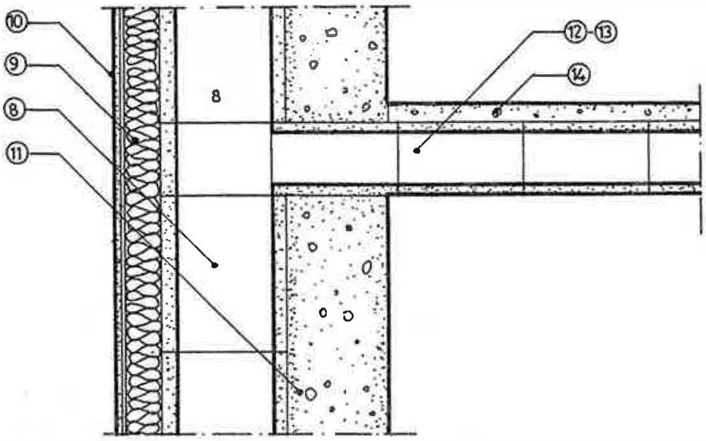


**Fig.2 Details of the system**

## 3 Limits of the system

So as to explore the system efficiency, seven cases have been tested with simulations, with the following climatic working hypothesis:

- in all the cases the outside DB Temperatures are maximum 40°C and minimum 20°C;
- in all the cases, the outside maximum (dawn) RH is 40%;
- two cases of basement : with or without water;
- four wind speeds : no wind, 10 m/s, 5 m/s, 2 m/s.

### 3.1 First case: no wind, S = 0

There is a heat flow towards the outside, the inside DB temperature falls to 30°C during the night.
The mean heat flux: $Q_{total}$ = 0.6 kW (kJ/s)

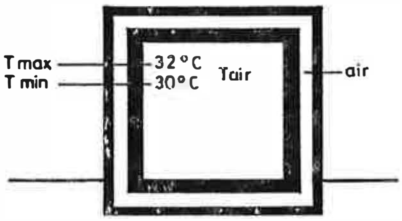


**Fig.3 No wind**

### 3.2 Second case: wind speed S = 10 m/s, with evaporative cooling

The mean flux is by the exhausted air circulated inside the walls: $Q_{total}$ = 16 kW.
The ambient air temperature is practically equal to that of the wall.

After one working hour of the air circulation (DBT 20°C) inside the wall: dTm = 2.5K
*After 4 hours*, one will have lost: 2.5 x 4 = 10K

$T_m = T_{ambient\ air}$ = 20°C

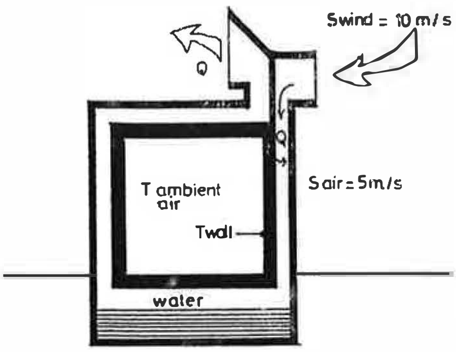


**Fig.4 With evaporative cooling**

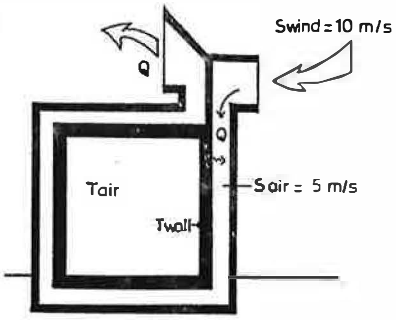


**Fig.5 Without**

### 3.3 Third case: same wind speed S = 10 m/s, without evaporative cooling

$Q_{total}$ = 12 kW.
After one working hour: dTm = 1.8K
*5.5 hours* will be necessary to reach the inside temperature drop of dTm = 10K.

### 3.4 Fourth case : wind speed S = 5 m/s, with evaporative cooling

$Q_{total}$ = 8 kW
After 1 working hour: dT = 1.2K
*After 8 working hours* Tm = $T_{ambient\ air}$ = 20°C

### 3.5 Fifth case: wind speed S = 5 m/s, without evaporative cooling

$Q_{total}$ = 6 kW
After 1 working hour: dT = 0.8K
*After 12 ½ working hours,* Tm = $T_{air\ ambient}$ = 20°C

### 3.6 Sixth case: wind speed S = 2 m/s, with evaporative cooling

$Q_{total}$ = 3.6 kW
After 1 working hour, dT = 0.6K
After 15 working hours, Tm = $T_{air\ ambient}$ = 22°C

### 3.7 Seventh case: wind speed S = 2 m/s, without evaporative cooling

$Q_{total}$ = 2.5 kW
After 1 working hour, dT = 0.42K
After 20 working hours, Tm = $T_{air\ ambient}$ = 22 – 23°C

### 3.8 Curve and comment

The water contribution is relatively more efficient when the wind speed is lower.
A 10 m/s (36 km per hour) wind speed is rather typical of open or (and) high altitude sites.
An average wind speed of 3 m/s gives the discounted result after 12 hours with water evaporation and 17 hours without; thus after 12 hours (without water), one would reach a DB temperature of 23°C.

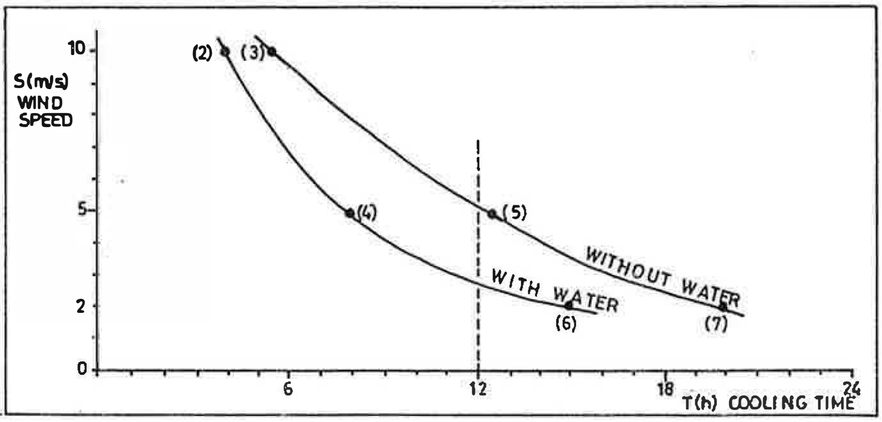


**Fig.6 Cooling time variations with wind speed , with and without evaporative cooling**

## 4 Case study: a family house in Bamako – Mali

This house is proposed in the periphery of Bamako for a 6 persons family.

The climate of Bamako presents two very typical seasons:
- a 5 months hot dry season, with 17K daily range and 36-41% minimum RH.
- a 6 months rain season.

The system can be quite effective for the 5 months dry season, from November to April: rain water is collected during the rainy season inside a cistern buried under the building; useful for cooling, this cistern supplies also water for domestic needs other than drinking.
The system can also be useful during the 6 months of rainy season, working inversely with night prevailing winds from south-west, for cooling the walls without evaporative cooling effect, the air being already saturated with humidity (Figs.7-8)

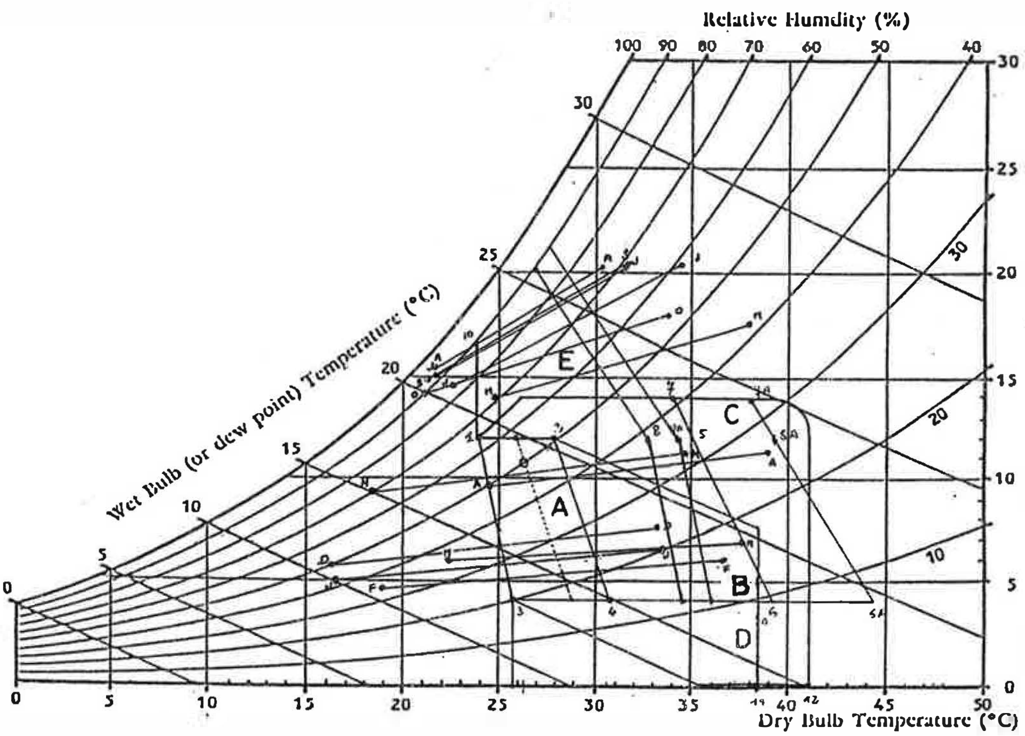


**Fig. 7 Control potential zones for Bamako – Mali**

- **A.** comfort zone,
- **B.** mass effect,
- **C.** mass effect with night ventilation,
- **D.** evaporative cooling.
- **E.** air movement effect

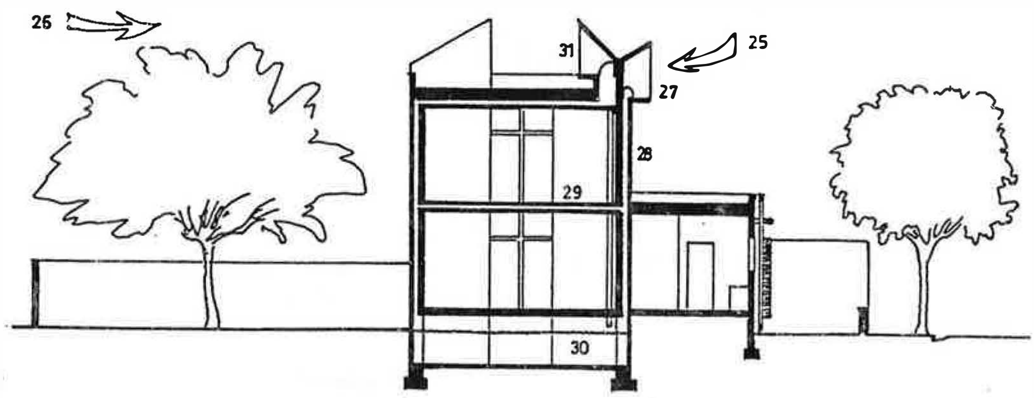


**Fig.8 Typical section on the house of Bamako**

**25.** prevailing wind in dry season
**26.** prevailing wind in rain season
**27.** wind catcher
**28.** hollow wall
**29.** hollow floor
**30.** cistern
**31.** ventilation outlet

## 5 Geography of the system

The study proves that the system can work over two categories of situations:

- arid climates: with high temperatures, a DBT diurnal range of 20K and a minimum (dawn) RH equal or less than 40%; the drier and hotter the climate, the better the system will work;
- semi-arid climates: with high temperatures, a similar DBT diurnal range, but a minimum RH higher than 40%

The first ones are within the hot-arid climate zone, such as the Sahara, Namibia, Soudanian and Syrian deserts, during most of the year, and the Sahelian climate zone, more populated, during a long dry season.

The second ones are typical of the fringes of the Sahelian climates, facing hot humid climates or mediterranean type climates. In Africa: Morocco, Mauritania, Senegal, Mali, Niger, Burkina Fasso, Nigeria, Chad, Algeria, Sudan, Ethiopia, Erythry, Egypt, Libya, Tunisia, Somalia, Kenya, Tanzania, Mozambico, Zambia, Angola, Zimbabwe, Malawi, Swaziland, Namibia, South Africa, Djibouti, Madagascar.

In Asia: Yemen, Syria, Lebanon, Israël, Iraq, Jordan, Saudi Arabia, Oman, Emirates, Afghanistan, Iran, Turkey, Pakistan, India, Burma.

In America: United States, Mexico, Venezuela, Equador, Peru, Argentina, Paraguay, Colombia, Brasil.

as well as in Australia.

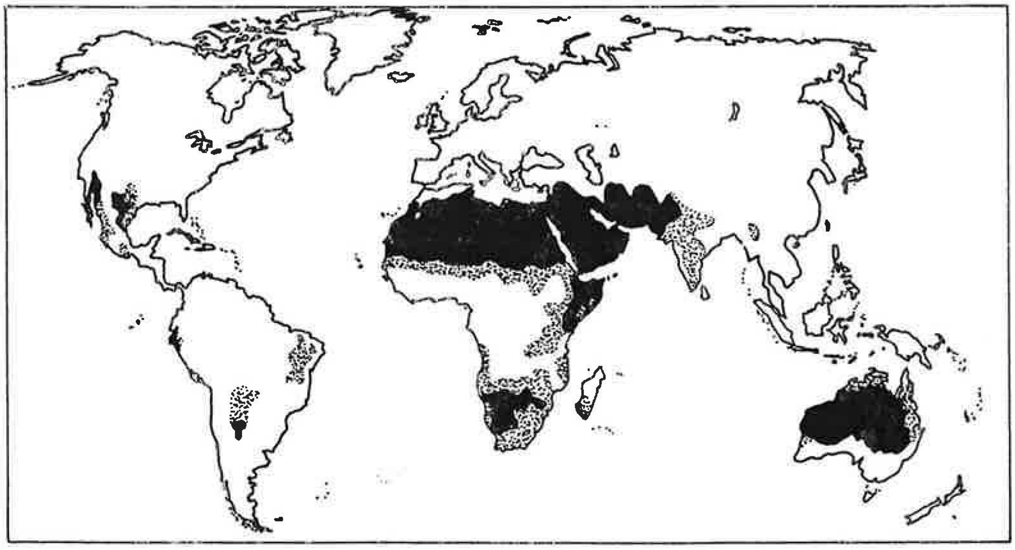

**Fig.8 Map of the areas of the systems' suitability**
**A. arid climates**
**B. semi arid climates**

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