424: Passive & Low Energy Architecture of Hammams in the Mediterranean

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Abstract

Initiated in September 2005, the EU H.A.M.M.A.M. project have entered its 3rd and last year; a sufficent number of hammam buildings have been experienced in six cities around the Mediterranean, so as to have an overview from the bio-climatic point of view,
All the hammam buildings are organised following two main parts: the reception area, and the bath itself.
The first one is a passive space where the comfort conditions are obtained thanks to architecture specifically to the local climate ; one can speak about energy zero spaces .
The second one is heated by active means, but energy savings are obtained also by design devices in the volumes combinations and use of materials.
Thermo-hygrometry measures help to appreciate the quality of the environment and its progress profile, then to formulate diagnostics with recommendations for improvement.
The most outstanding point which must be stressed is the specificity of the hammams in each city, even from different historic periods. : the standard belongs to place more than to time.
Two main problems are now rising for hammams : the water supply and energy consumption. The management of these two fundamental components became mandatory if one hope to save institution and monuments.

Keywords : hammam, water, energy, passive, active

1. Introduction

The case of hammams in the Mediterranean is a complex question: even if the trend of institution is slowly falling in disaffection and dilapidation, its remains an important component of the urban fabric of the Islamic city and its identity. The functional dimension is sustained by the cultural and religious ones.
The question of the use of these buildings is very different from a city to the others : very much frequented in Fez-Morocco, they are, in renewal for local and tourism in Damascus , modernization in Ankara, survival in Constantine, disappearing in Cairo.
The present reality of environment and resources problem come to add to the loads which weigh on the future of these important buildings in the urban fabric and cultural heritage of ancient cities around the Mediterranean.

2. Climates

The project have been leaded around the Mediterranean from Tripoli in Lebanon (workshop PLEA 2005 november), then Cairo in March, Ankara July, Fez November 2006, Damascus February and Constantine May 2007.

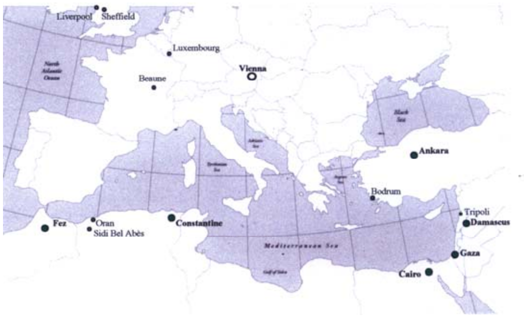

Fig 1. Mediterranean cities in hammam project.

A main interest in the hammam project exists in the comparison of a same function through the different climates and to observe the distorsions of the passive solutions within the hammam buildings
One can distinguish four kinds if climates:

- A littoral climate in Tripoli-Lebanon where the sea influence and no-altitude limits the year range with a regular medium humidity ;
- An alluvial plain climate in Cairo-Egypt where the daily range crosses all the year from normal humidity to dryness through two seasons moderately contrasted ;

- Semi-humid southern plateaux climates in Fez-Morocco and Constantine-Algeria without strong dryness during summer neither real colds in winter;
- Dry plateaux climates in Damascus-Syria and Ankara-Turkey with long dry summer and winters which can be cold with northern wind influence

3. Microclimatic sequences

The bioclimatic surveys have been implemented inside the hammams during different moments in the year as mentioned on head of § 2 (March, July, November, February, May), so, a priori, the results cannot be compared together.

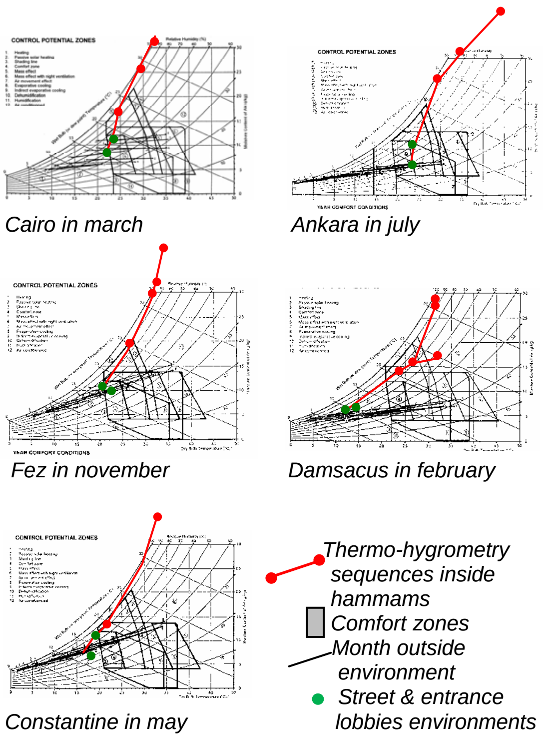

Fig 2. Inner & outer hammams environments

Meanwhile one can observe that the results of measures concerning the street outside and inside the entrance lobbies, which are managed from passive ways, are gathered inside the comfort zone of the chart in Cairo (March), Ankara (July), Fez (November).

It is not the case for Damascus (February) and Constantine (November) (fig 2.).

Indeed, compared to Fez, November is cooler in Constantine with 3°C less in the minimum and maximum.

During February the temperatures fall down in Damascus and the entrance lobbies in the hammams know at worse 13°C (El Omari) and 19°C in the best of cases without heating (El Silsile). But no doubt that the lobbies remain in the comfort zone during summer which remains the longest season in the year, the passive systems in the lobbies have mostly designed in the scope of this major season.

On the other hand the results of measures concerning the hammams themselves (frigidarium, tepidarium, calidarium) can be compared together as the environments are heated and humidified from active ways during the year round, even if the building inertia, the burying on the ground and the volumes of the rooms act from passive ways ; so these results can be compared together.

Another important aspect to observe is the relative positions of the different measures inside the active zone of the hammams ; in the best of the cases these positions reveal good progression sequences, in the worse they reveal lacks which can be caused by design but more often by maintenance or wrong modifying.

Except detail lacks like doors missing in Cairo and Constantine, calidarium transformed into sauna and partitions in the tepidarium in Ankara, inversion between calidarium and tepidarium in Fez, the sequences between the passive area (entrance lobby & rest areas) and the active area (frigidarium, tepidarium, calidarium) are clearly identified with the thermo-hygrometry environment.

Now, what is the part of architectural design?

4. Bioclimatic behaviour and devices in the passive areas

Inside this first part of the hammam the aim of architecture consists in creating a comfortable thermo-hygrometry environment by passive means.

From this basis, these conditions may remain inside the comfort zone all the year round.

We have observed that it was the case in Cairo in march, in Ankara in july, in Fez in november, but if it was not the case in Damascus in february (mainly for maintenance reasons: doors open, neglected buffer-space) it was close to be the case in Constantine.

4.1. Dome structures

Having a look to figures 3 & 5, the verticality and the dome structure of the entrance lobby is the dominant design element , except for Cairo with its flat ceiling and lantern as well in Bab el Bahr (Fig 4.) as in Tambali and the most of Cairo hammams.

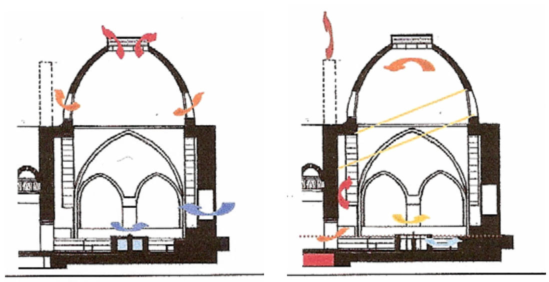

Fig 3. Entrance lobby hammam Ammouneh Damascus in summer and winter

In the most of cases the dome works in summer as hot polarity where hot air is trapped, in phase with the fountain as cool polarity thanks to evaporative cooling: during the day the lighter hot

air can be exhausted through the oculus and lantern windows while the heavier cool air supplied on the bottom of the lobby during the night can remain during the most of daytime, like inside a patio.
During winter, all the openings shut and without water in fountain, the warmth can store inside the heavy structures and participate to convection air movements inside the volume.
The vertical proportions of entrance lobbies say that the summer conditions are the most important to manage (Fig. 3).

4.2. Mineral walls

All the hammams have stone walls, more rarely brick ones, for several reasons: support the roofing structures and ground pressures when buried, and give a strong inertia to the building.

4.3. Burying

In Cairo (Fig 4), Damascus (Fig 3) and Tripoli, burying the building helps to increase the inertia of the building and its capacity to store energy, and take advantage of the ground insulation.
All the year round, the warmth of daytime can be kept inside the structures: during summer it is exhausted during the night and replaced by coolness, during winter it is preserved.

4.4. Pit system

Consequently to burying, the pit allows to concentrate the cool air on the bottom of the lobby and to stay up in the upper air layers sat on the upper benches around, like in hammams of Cairo (Fig 4), Damascus (Fig 3) and Tripoli.

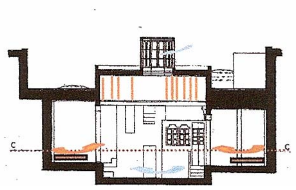

Fig 4. Hammam Bab el Bahr in Cairo

4.5. 2nd Floor

The same idea to stay upper is maximized in Ankara (Fig 5) and Constantine so as to offer warmer rest spaces during winter where the year temperatures means are the lowest (11.7 & 12.6°C)
Attics like Cairo (Fig 4) and 2nd floor galleries help also to dry towels taking advantage of the natural air stratification and convection air movements.

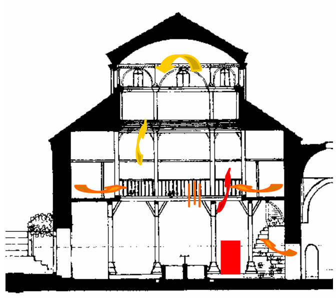

Fig 5. Hammam Sengül in Ankarawith gallery in winter

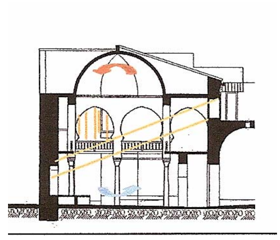

Fig 6. Entrance lobby of hammam Suq el Ghezel in Constantine, with gallery in winter

4.6. Entrance buffer spaces

All the hammams lobbies are provided with entrance buffers paces which insulate them from outside air, summer as winter, in the condition to close the doors.

4.7. Heating

The heat losses from the active area benefit to all the entrance lobbies.
In colder climate seasons, stoves can be seen in Ankara and Constantine, and the smoke chimneys from active areas can be used to heat the lobbies during winter (Damascus).

5. Thermo-dynamic systems & behaviour in active areas

The sections on table 3 illustrate the main sequences inside the hammams, from the grey arrow (entrance lobby) to the last room.
Usually the sequence includes three main rooms: frigidarium, tepidarium, calidarium, from the antique roman thermal baths.

One can observe the two main traditions in the plans of hammams around Mediterranean:

- the directly roman influenced in Fez and Constantine with linear sequences, barrel vaults and bucket system for water
- the ottoman system with tepidarium centred plan, domes and fixed individual basins system for water in Ankara and Cairo

Then the particular and mixed cases with :

- linear-centred in Damascus combining the two
- linear-multi centred in Tripoli

In all these cases, except in Amouneh-Damascus, the tepidarium is the largest room inside the hammam, where the air and floor temperatures allow to stay a long period and then gathering the most of the users of the hammam.

5.1. Heating-steaming systems

The systems are usually specific to all the hammams in the same city :

- hot water pool in Cairo
- hot water tank with steam window and massage hot bench in Ankara and Tripoli
- hot water basin inside calidarium and hypocaust in Fez
- hot water tank with steam window and hypocaust tunnel in Damascus
- hot water basin inside calidarium and massage hot bench in Constantine

But it is possible to gather these techniques following the geographic situation:

- the systems with hot water in pool (Cairo) or basin (Fez, Constantine) inside the calidarium with manual water distribution is typical of North Africa ; climatic or (and) cultural or (and) historic ? Everywhere all these are mixed together. Meanwhile the case of Cairo where you can sit inside the hot pool (in all hammams) is very particular but incongruous with Islamic principle requiring bathing flowing water. Certainly climatically well-adapted to the local daily dryness and dust (all year round).
- the systems with hot water tank, steam window, fixed individual basins and hot massage bench (Ankara, Tripoli, Damascus) in Near East, even if the steam rooms have been transformed into sauna hot dry room with hypocaust and cool pools in the hammams in Ankara

5.2. Volumes sequences

All the visited hammams active areas are covered by vault systems:

- barrel vaults system in Fez and Constantine
- domes in Cairo, Damascus, Ankara and Tripoli

In the two cases, differently to a flat ceiling, a curved one helps to a good air convection circulation from bottom to top (anabatic) and top to bottom (katabatic). The flat roof replacing the collapsed dome above the tepidarium of Bab-el-Bahr hammam in Cairo is not a good solution which causes humidity niches in upper angles.

The organization of the volumes sequences is :

- in Cairo : after a low large dome in the frigidarium, the high domed (anciently) tepidarium is supplied from higher hot pool calidarium : the air stratification and the siphon effect of the last room organize the heat and steam distribution inside the tepidarium;

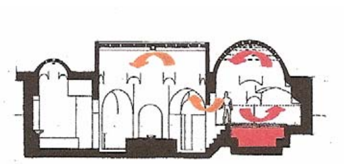

Fig 6. Tepidarium & calidarium in hammam Bab el Bahr Cairo

- In Fez-Saffarin, the high progression of the barrel vaults helps to concentrate the heat and steam inside the last high-narrow calidarium without doors between the rooms, the water sprayed on the floor above hypocaust adding to the steaming of the hot water basin ; the normal progression from the lobby have been perturbed entering tepidarium before frigidarium by inversion of accesses, which is to be rehabilitated. In Fez – Moulay-Idriss, the progression from a high-large-square entrance lobby continues lower and lower towards a low-narrow-long calidarium where the steam and heat can concentrate;

Fig 7. Sequence in hammam Safarin in Fez

Fig 8. Sequence in hammam Moulay Idriss in Fez

- In Tripoli, the domed volumes succeed one another higher and larger from the frigidarium to the calidarium, the steam and heat being as well trapped and kept as the volume is high and large, and the thermo-hygrometry environment increasing naturally towards the last room.
- In Constantine the barrel vaults have the same height in the different rooms and the progression is solved by buffer space between lobby and frigidarium (missing doors actually) and a second buffer space (it is not a real tepidarium) between frigidarium and calidarium ;
- In Ankara, the calidarium was situated between the centre tepidarium and the hot water tank supplying it the heat and steam from a window; the high proportions of this room and the low access door allows to keep the ambiance inside this last room, the heat and steam from the hot massage bench maintaining the balanced environment of the large tepidarium surrounded by three liwans. Hypocaust air ducts with chimneys achieve a complex underground system keeping temperatures inside the thermal mass ;

Fig 9. Sequence in hammam Sengül in Ankara

- In Damascus the successive volumes are composed with standard size domes units which form the tepidarium (2 units, with 1 lateral small unit), and a larger calidarium (3 units with 2 lateral units). The different areas are controlled thanks to doors between them ;

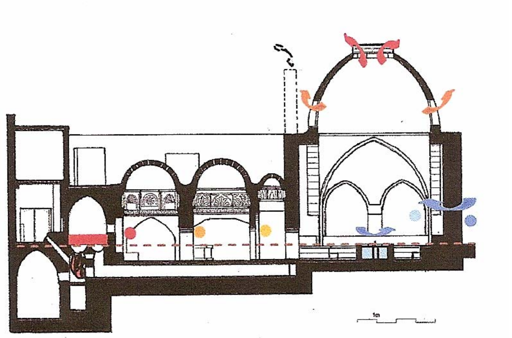

Fig 10. Sequence in hammam Amouneh in Damascus

6. General statements about the climatic impact on hammam design

As shown in § 4, the first part of all the hammams works only by respect to the local climate with the help of the passive features which compose the architectural design of entrance lobbies, reception and rest areas. We call this first part *passive area* by respect to energy coming from outside
As shown in § 5, the second part works thanks to a production of energy from burning a fuel so as to heat water and generate steam. We call it *active area* by respect to energy coming from inside.
Even if this second area has to see more with technology than with passive architecture, it has yet to see with the climate concerning the energy conservation during the cold season and with architecture to create balanced and efficient thermo-dynamic complexes, as seen upwards.
From a global point of view, the hammam design is different from a city to the other, even if some identities can appear in certain fields.
On the other hand, inside the same city, the hammam design is based upon the same principles to produce comparable buildings, even from different historic periods.
These observations sustain the local dimension of hammam buildings which can be developed towards climatic and cultural fields.
In these two fields, through people's habits, the climatic at first influences the cultural and finally creating a local identification through forms which remain native and rooted inside the people's life in the place.
This is a reason why the comparison between different answers to the same programme, except the opportunity to stress the specificities of each one, presents a limited interest in itself.
On the other hand, the answer to the question "Why this form for this hammam building differently to this other one?" is much more interesting.

Global design summer/winter

Another question in these passive areas is the compatibility between the extreme season requirements, summer and winter, inside the same structure.
Even if many similarities can justify climatic families, each climate remains specific to his geographic situation; amongst the five climates in this study, only two, Fez and Constantine, can be considered in a same family (Fig 2.), but yet with nuances due to cooler conditions in the second case: upper gallery, dome with lower proportions and without air ventilations.

Indeed the design challenge is as much difficult as the limit seasons are far the one to the other, like in Damascus. In that case we observe that the design has privileged two main devices useful during the two extreme seasons: on the one hand the inertia of the structure, maximized by burying into the ground, able to store energy and to restore it when the temperature falls, on the other hand a simple and large volume able to promote different air movements according to the opening or the closing of the upper oculus and windows.

It is real that Damascus and Ankara have climatic similarities with a long hot-dry season (Fig 2.), even if the second one is colder in winter (11.7°C year mean) and the first one hotter in summer (17°C), but the profiles on the charts are similar and from the previous analysis, the design is the most aware of summer conditions, the winter design having to adapt to the summer one : upper gallery in Ankara, pit in Damascus.

As Cairo climate has a very specific profile with daytime high dryness during all seasons (Fig 2.), the entrance lobby has also a very specific design inside all the hammams of the city : no dome, soil flat roof with wooden lantern, wooden structure, centre pit, attic for towels drying, cross ventilation system, rest areas on upper lateral galleries.
The most typical element is the soil flat roof on wooden structure with attic and wooden lantern, all together able to prevent heat radiation during summer: if the roof is too hot, it radiate inside the attic volume but this new hot air is immediately taken towards outside through the centre lantern which is open.
One could also understand this ventilated attic as a cooling device working with the help of evaporative effect of drying towels, the cool air being heavier would fall down inside the lobby during summer. During winter the towels dryer could work only thanks to the warm air stratification.

In Fez and Constantine the climate profiles are also very close (Fig 2), but hotter in the first one (17.9°C year mean), colder in the second (12.6°C).
As observed upwards the lobbies have small sizes, like Cairo, with a centre dome staying on poles creating peripheral galleries ; in Constantine, like in Ankara, upper galleries complete the design probably to offer warmer conditions during winter colder than in Fez where the volume remains in a single piece.
Why a so clear difference of size from a climatic point of view ? Why internal galleries ?
One can think that the internal gallery system present several advantages : sustain the structure with smaller elements, vertically partition the space and create a centre air column where the vertical

anabatic (towards top) and katabatic (towards bottom) air movements will work easier respectively during summer and winter.
In Constantine Suq el Ghezel the dome is mostly designed for winter-time to help katabatic air movements, but it is not useful during summer because it has no exits. This explaination is confirmed by the upper gallery which can be used during winter to enjoy the warm air which naturally stratifies up.

7. Conclusions

The observation, analysis and comparaison between these different answers to the same hammam programme help to rise the specificities of each city in matter of passive architecture and to stress the basic climatic dimension of these buildings.
In our times of environment, energy and water supply problems, the most under arid and semi-arid climates, these buildings put also the problems of resources in the near future if innovant solutions are not implemented.
If energy resources can be found in reuse of wooden materials or agricultural waste, eventually and in certain conditions in local solar potentials, the water resources can put unsolvable problems under dry climates like Damascus (218 mm) and Ankara (345 mm)

8. Acknoledgements

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