The Skylight in the Roman Baths: The Construction

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ABSTRACT: People from every social level used to take Thermal Baths very often during the Roman Empire. Therefore, Roman Baths are a very important building within the Roman life and culture. The building presents many difficulties due to the necessities that these constructions have to face. Roman builders are able to overcome those difficulties by making buildings that meet the demands. The usual roof of a Thermal Bath is the vault because rooms must be clear and wide spaces due to the big quantity of users; the best way for an optimal acclimatisation is a circular space because it makes hot air to move easily. The roofs need to have holes to give light and air to the rooms because:

- Walls are very thick due to the weight and pressure that they have to bear.
- Bath ritual needs concatenated spaces
- Users should not be seen from the outside.

INTRODUCTION

Thermal baths as we currently know them have their origins in the Greco-Roman culture. We can find ruins of old constructions related to the bath ritual in the first semi-permanent settlements in Centre-Europe and in the civilizations of fertile valleys –Egypt, Mesopotamia-, but they were very primitive and we cannot consider them as a good example of a specific bath ritual that requires an special construction. They are just rooms where steam can be produced or where we can find containers and bath tubs to make ablutions. At that old time we cannot say that there is an specific construction for the public or private bath. We can start to make this statement in the Antique Greece, period where the building of this kind of constructions starts its development at the same time as the complex installations that they need. Even the first Greek baths cannot be defined as such, because they are related with the rest of the athletes after their physical exercise. They were constructions added to the *palestra*. The *palestras* usually had a close construction as an annex without any roof, with a row of bath tubs, full of cold water where the athlete can bathe. These tubs did not have any hot water, it was at the time when the athlete came into the tub when an assistant provided the warm water directly to the body of the athlete. It means that these baths did not have any water supply or sanitary or warming system. They did not need a special floor, roof or lighting structure. These places started very slowly to develop, and it is in the IV century b.C. when the Greek culture started having its first constructions for public or private baths. These places had a first room covered with a roof called *loutron* with small pools with running water, *pediluvium* and cold water showers. They also had a second room where we could find communal bath areas for many people, called *mactras* and *asaminthos* as well as small pools for the immersion –*puelos*-. The last room that made part of the Greek baths was the steam room. As we can see from that description, they were small and simple buildings, without any architectural complexity and where the needs were not yet well defined. Floor distribution is not complex at all because they are only a few rooms to be connected and the distances to be covered are not significant. These simple places started to develop very slowly, at the same time as the urban network of water supply and draining did. New structures related to the carrying and warming of water, and to the steam production appeared and therefore the bath process could develop. At the same time, these more complex baths will demand more complex buildings and therefore new construction solutions.

It is at the Roman period, in Rome and in the rest of the Empire, when these constructions will reach their maximum splendour. From the Second Century b.C. they were very complex buildings where a lot of spaces must be connected with an established order. The number of people to attend to the baths is huge and the distances to be covered are essential. Thermal baths were not only the social development of a culture, they also represent, from the point of view of the architecture, the construction solution for many problems that Roman construction was able to solve. Public baths have many necessities to solve –supplying, carrying and warming water, making steam, etc- and therefore they become a test area for many construction solutions that will be used in many different buildings. Therefore, we have a complex building from the point of view of spaces and use. This building deals and solves efficiently many construction problems that the Roman architecture had in the development of other social activities. Public baths solve problems related to: 1: Covering of big spaces, Bath rooms in big cities with wide population must have a huge dimension. Due to its use, spaces must be clear, therefore roof-vaults were needed for the covering. 2: Buttress Systems, the use of roof-vaults still not very developed produced a big pressure on the walls that had to be solved with buttress. A new way is open with the help of these buttress giving solutions that can be considered as an advance of the gothic flying buttress. 3: Lighting of the different spaces, the spaces were connected to follow the ritual bath, the lighting of these spaces was a problem to solve. The development of the volumes and the different highs of the spaces forced a very rich construction. 4: The space order, as already said, the order of the different rooms in a thermal bath was the first conditioning in the floor planning of a bath. These spaces needed also other service rooms to produce heat to warm the water and the atmosphere. And also problems related to: Acclimatisation, in these buildings there is another problem: the conditioning of different rooms at different temperature. Also the required different temperatures of water are a problem that is also solved in a very efficient manner.

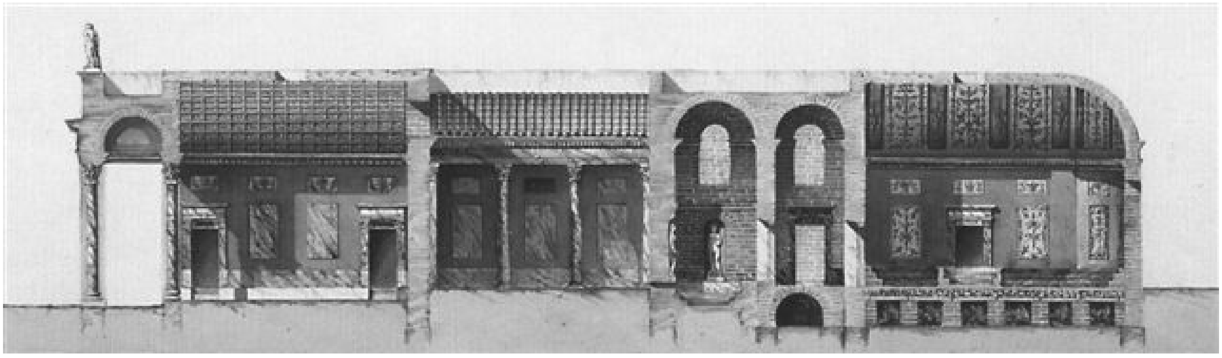

Figure 1: Section of the Termas Menores Trajano's in Itálica (Spain); (de los Ríos 2003)

Rooms of a bath and how they were run

Thermal Baths are one of the most important buildings inside the Roman city. All the social levels attended as a social activity, and they were a social meeting point. In the roman culture the bath ritual had its maximum splendour and it consisted in a complex process with the following phases:
Tepidarium, or warm room where after a half an hour sweating started. This room was a smooth transition to the *caldarium*. This room was warmer than the previous and had, as well as the *tepidarium*, a swimming pool, also warmer. Biggest baths could also have, after that room, the l*aconium*, a room at 100° without any pool. The next step could be the massage room, because after the hot baths skin was ready for oils and massages. The final step was a bath at the f*rigidarium*, o room with a cold water pool.
Heat was created in an oven or stove, the *praefurnium*, and was distributed with the help of the *hipocastium* that gave to the different rooms the heat that they needed, that must be adequate for every phase of the bath ritual. Those were the basic spaces to form part of a thermal bath, but it could have, depending on where the bath was, other rooms to improve the use, the services and the facilities. We can talk, for instance, of an entrance hall or dressing room, the *apodyterium* and different places for the services. Other improved bath places were the *sudatio* or steam room, *palestra* or *gymnasium*, *latrinae* or bathrooms, open air swimming pool and an exedra or resting area. We could also find social areas annexed to the baths such as: libraries, meeting rooms, food or drink stores, etc..
The building of a thermal bath starts with the stove or *praefurnium* that must be placed at the basement of the building in the services areas, near a place where vegetal coal can be store. A big hole in the wall with a front place to store ashes and the chimney were enough to make the *praefurnium* work. The place to feed the stove or boiler must be near the street, never at the main entrance, to be able to supply easily the coal. Heat must expand along the whole place. This basement was called the *hipocaustium*, and it spread along the vertical conducts.
The ceiling of the *hipocaustium* was not solved with vaults but with a flying ceiling or *suspensura*. Ceiling rested on some pillars made of square brick of 20 cm each side, with a distance of their axes of 60 cm to allow the two-feet bricks to rest. Pillars had a high of about 40 to 50 cm usually with a square section. Sometimes curved

bricks were used and their section remained circular except at the last rows that must be square to allow the two-feet bricks to rest comfortably.

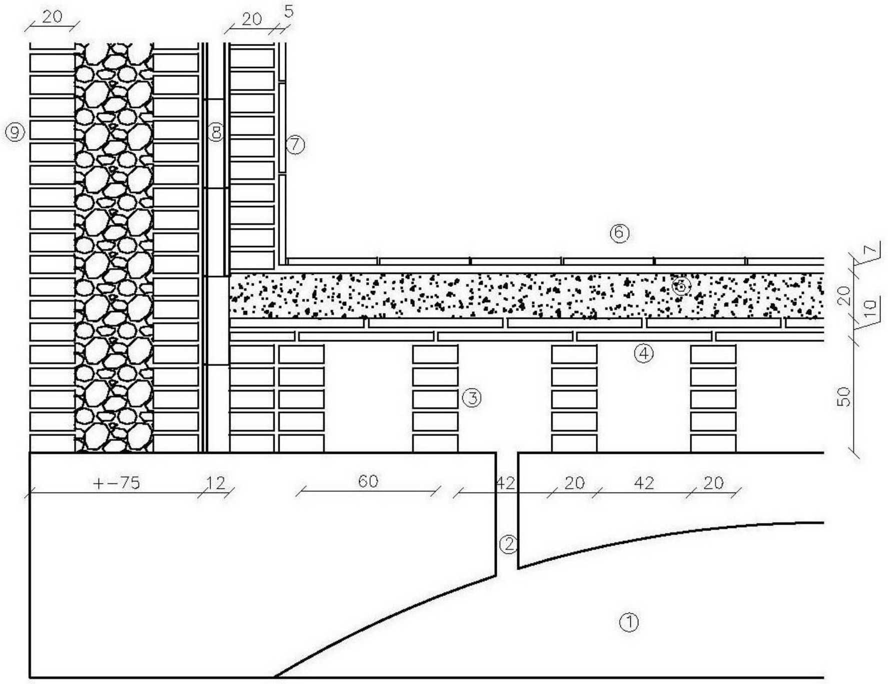

Figure 2: Ideal Building section of the wall and floor of a Roman Thermal Bath. 1-praefurnium or fireplace; 2-chimney; 3-pillars of square-bricks; 4-two-feet-bricks; 5-mortar; 6-floor; 7-interior finish; 8-tubuli; 9-exterior wall

Figure 3: Detail of a wall with tubili (left) and the hipocaustium (right) from the ruins of the Baths of Pompeii in Italy; (Adam 1996)

In some places there were found hollow pillars made of only one piece, manufactured on a specific way to be connected at their ends; I understand that the idea was the standardisation of the building of *hipocaustos* but apparently the idea did not succeed because these pillars were less resistant than the massifs pillars, especially under the swimming pools. On top of the pillars, as we already commented, one or some layers of bricks leaned, working as a kind of ceiling for the pavement to be set. On top of the two-feet bricks, a layer of 15 to 20 cm lightweight-concrete was poured, then a nice layer of smooth mortar was spread to prepare place for the final marble or tile-made floor. The whole floor was about 30 cm thick. This, added to the pillars, made a total ensemble of 80 cm to 1 m. The basins of swimming pools were placed near the oven to receive heat on the most direct way. Logically, more heat intensity was needed to heat the water than to heat the

room air. In these specifics areas –where swimming pools were placed- the isolation was essential, therefore a lead sheet was placed between the two-feet bricks and the first layer of concrete.
The idea was to take as much advance as possible of the fire and even the smoke was used to heat something on its way outside. Therefore, they did not build a hole in the wall to expel directly the smoke outside, they made smoke run along the wall in the space between the supporting area and the walls, until its escape way, passing sometimes even through the buttress. To make more solid the exterior wall, flat square bricks were used provided with four prominent rims, called *tegulae mammatae*. We should stress at this point that this way of setting a wall was used in every wall susceptible of being wet, as a way of avoiding humidity to appear inside the room. It is a kind of air gap as we know it nowadays. This way of evacuating smoke taking advantage of its heat was not very efficient because the hole between the walls was too huge and it did not help the smoke stream towards outside, sometimes smoke came back to the fire, suffocating it. To solve this problem, they conceived these places as chimneys. Around the first century a.D., *tubuli* started to be used. These pottery pieces of a rectangular section and about 8.5x13 cm the smallest and 14x24 the biggest were connected together and were placed inside the camera forming small chimneys where smoke flew easily. A lot of small holes were made in the chimneys to allow smoke to flow horizontally as well as vertically. They were set at the beginning on top of the two-feet bricks and they were fixed to the wall with T-shape metal made staples that took them two by two. A layer of mortar was set on top of the *tubuli* and finally the last finish made of marble or venner plaster. At the end, a hole giving to the outside was open to allow the smoke to run away.

THE COVER AND THE SKYLIGTH

In the Vitrubio treaty we can study the procedures to cover the big rooms of the baths and the different holes that the cover or ceiling needs. Article 46 deals with the structure of the ceiling. It must have the way of a vault or dome, and if this is not possible it is compulsory to build a false ceiling with this structure. For that purpose, the treaty recommends that some iron guides must be set with the necessary distance to allow the ceiling to be closed with pieces named tiles. The unions on the top of these tiles are sealed and behind them are covered with a layer of mortar and finally with the final quality treatment either stucco or veneer plaster.
In article 47 the Treaty recommends the creation of two false vaults to organise an inner space between them to avoid any wet or humidity and a part of the wood structure of the cover. In article 49 the Treaty states the proportions of the rooms, that must sep proportion between the wide and the high until the start of the vault. Sweating rooms must have an *lumbrera*, as a kind of chimney, covered with a piece of bronze able to be opened or closed to regulate the room temperature.
As we can see, the typical and ideal cover of a thermal bath building is the vault or dome. The reasons of this fact are mainly two: one is the use of the building and the other the dimension or size of the rooms. Bath rooms or halls, due to their use, need big and clear spaces, mainly those rooms that have a swimming pool inside and they must be well conditioned. Beside they are building that welcome a wide quantity of public. All the Romans, poor and rich go to the Baths. They are expensive buildings, therefore the proportion of visits must be high, the dimensions and sizes of the spaces must be big. Bearing in mind these conditionings, the most suitable way of doing the building is a circle, both on its plant and on its section. First because of the movement of the hot air, then for the most suitable use of the surface, and finally because they are easier to cover when the size is big. The wood forming wood truss was the material used for huge ceilings or covers and this material doesn't adapt good to a curve shape and to the wet atmosphere of those places. Therefore a new way of building is compulsory, buttress made of mix masonry with mortar or with dry lightweight mortar forming monolithical shells or covers.
The building process starts with the placement of a truss that constitutes the definitive shape of the dome. On the top of this wood structure, the bricks will be set forming a shell. Some half-bricks were set vertically to hold the mortar grout. Above this structure the mortar is poured and then the fillement of masonry to reach the level of the exterior. Once the mortar is dry the truss is retired and the inside of the ceiling is covered in order to allow the application of the final touch and interior layers. Due to the union of the pieces of masonry and to the mortar –increasingly developed- the construction seemed, once without the truss, as a monolith with a big semicircular hole inside. Lateral tensions were produce as on the same way as the brick in an arch, but in this case we also had (as well as the absorption of the pieces of bricks) the paste that put them together. The bricks rings some times did not done and they proceed to pour the mortar directly on the truss as a way of plain concrete. Workers very soon discover that the mortar that forms the dome keeps the shape of the truss and takes exactly its shape. On a first step of this dome the inside stayed directly with the shape of the shuttering, with more or less wide strips stated for the shape of the wood used (see figure 6). Very soon the builders realise that they could give shape to the interior of the domes by making the shape in the shuttering, Therefore the inside part of the dome started to have different geometrical designs –the most famous example is the dome of the Pantheon of Agripa-. The building of the dome develops very quickly and the structures adapt the material used, reinforcing or lighten some points according to the tension that they get. As the results of this development and adaptation the general way of this kind of coverings ended to be nerves at the points with most tension and the use of more light spaces where it is not necessary to reinforce points. As a way of lighten, they use the more and more light material as the vaults advances, they insert hollow pieces in places with less resistance.

Figure 4: Vault with wood shuttering's marks; (Adam 1996)

The mechanism of the vault is similar to that one of the arch but widely improved because it acts or works in three directions. Every meridian works as a funicular arch, it means that it resists tensions without creating pulling tensions, they work on compression. As we are in front of a lot of arches, lateral movement does not work here, they create ring or circular tensions working as a membrane. Inflection is impeached by horizontal rings. On the top they are compressed and as they descend by the rings and they deformed to the outside they start to be driven, therefore hard stirrups are needed to bear those tensions. They are membranes that at the top and high parts need little material and at the beginning need big walls or buttress systems to avoid that open by its own weight. The top part must be very light to avoid weight and pressure to the beginning or lower part.

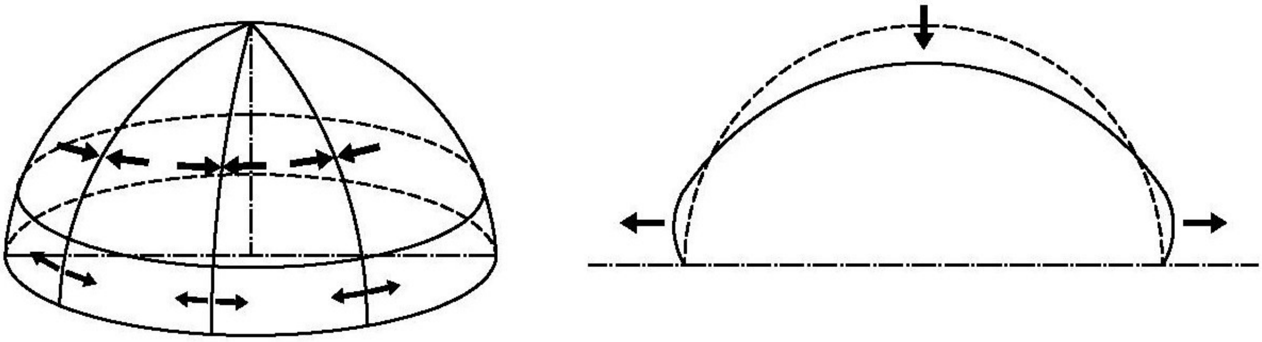

Figure 5: Schedule of tensions on a dome

Once the builders started to know the behaviour of these shells, the next step was to open holes for the lighting and ventilation. The rooms in their major parts were surrounded by small and services areas or other rooms, therefore it was not possible to open holes at the vertical walls (as well for privacy reasons as it is the case of the relaxation room). The bottom of the walls was also too thick to make holes because they had to bear hard tensions. Therefore, the easiest place to introduce light and air were the ceilings and the top of the walls. They were also structures that adapt to a shape, therefore, the easiest way to be "broken" is the ceiling. Builders knew where were places at the dome with the minimum tension where they put filler, therefore they could stay free to give light to the rooms. Also, by heat or steam reasons, rooms needed a central hole able to be open or close. According to the Vitruvio Treaty it is closed with a piece made of bronze with a chain to control its opening from the floor. It is a place that suffered compression tensions so it is easy to substitute by a ring to take all these forces or compressions. The most important example is this is of the already named Pantheon of Agripa similar to that one of the Thermal Baths.

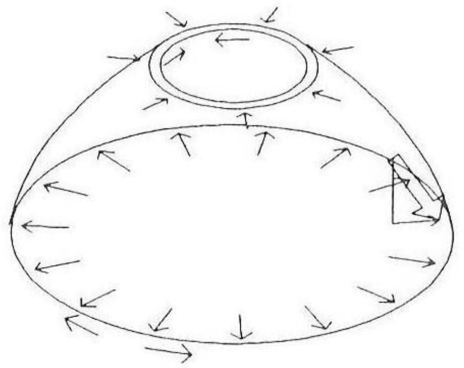

Figure 6: Schedule of tension in the bottom and in the top of a dome; (Quintás 1996, pp. 187)

According to the use of the room, we need more or less light; therefore, more or less skylights were open. Warmer and smaller rooms had only a central hole as an unique source of light. On the contrary, bigger and more popular rooms needed more light. As we already commented, Roman baths were a meeting place where people went to see and been seeing, they didn't need a dark atmosphere with intimacy as it is the case of the Muslims baths, where they went for religious purposes. As they need light and they need to broken the dome, they intended to open the minimum number of holes but as big as the structure of the cover was allow. It is very important to say that when we have ceiling with a semi-cylindrical vaults the way of give light to the room is trough the semicircle that remains in its laterals, known as "thermal window". This semicircle is divided in three parts by means of two pillars. It is the logical place to place the hole because the own construction of the vault generates it, not enlarging a blind wall.

Figure 7: Dome of the Roman baths of Baia in Italy; (Adam 1996*)*

CONCLUSIONS

Thermal Baths were complex buildings that deal and solve important constructive problems impossible to solve before in other kind of buildings. It is compulsory that these complex systems work perfectly because the baths were an important social act in the Ancient Rome. Therefore, builders had to think seriously about the problems and they managed to find very interesting solutions. From the first Thermal Baths until this last explained, we can see an important development in every aspect, floor distribution, acclimatisation, covering of spaces, etc. One of the most significant problems was the covering and lighting of the different rooms that made the bath ritual. Complexity lies in many aspects: they were circular spaces (in plant and in section), it was not suitable the use of pillars in the middle of the room, big distances and spaces must be covered, big spaces that give room to a lot of people, wood -the material previously used- was not the suitable material due to the wet and humidity of those rooms, etc.

Also it is complex the opening of holes: they were connected and joined rooms, the need of intimacy, thick vertical walls because of the tension that they had to bear and to the heating systems. Therefore, the cover was the most suitable place to give light and air to the rooms.
Roman builders found a solution for all those problems in the semi-circle shells of “concrete”, lighten in some parts and poured directly on the shuttering with the suitable shape; we can considered it as a primitive reinforced concrete. These shells works perfectly web from the point of view of the structure because they mainly work by compression as funicular arches. Only the rings in the lower part are driven but these tensions are solved with thick and heavy walls that impeach horizontal movement. The opening of holes in these monolith shells is easy because we only have to keep the space of the vane and not to fulfil with concrete. Being a space of social relationship and meeting the rooms need to have light enough, therefore these holes must be few and big, on the contrary of the Muslims baths where the intention is to create an atmosphere of intimacy and meditation and holes are many and small creating semi-darkness places.

Figure 8: Caldarium from the Pompeia´s Roman baths; (Adam 1996*)*

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