Considerations on building skin for energy efficient design

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ABSTRACT

All habitable spaces must provide the visual and thermal comfort, in order to give the inhabitants a living in a pleasant environment (Natural lighting, heating and cooling). This can be achieved through thermal protection during winter and through the use of suitable techniques applied in the exterior shell of the buildings, in order to establish the needed insulation and airproof during summer.

The role of the exterior shell is very important, because it protects the building against unpleasant weather conditions, like strong winds, humidity, and extreme solar radiation. These phenomena cause unfavourable conditions of existence. The shell is also important for the energy output. When considering a two-storey house, the needs are more demanding than those for a one storey house. All floors should have the conditions to offer a pleasant environment, in terms of thermal comfort and of day lighting levels throughout year.

In a project that took place in Patras, in the region of Kastritsi, in a coastal plot, several bioclimatic principles were applied in a two-storey residence, in order to ensure its proper functionality. Due to the fact the building has small openings and therefore the exterior walls are exposed to winds, small temperatures during winter, and high temperatures during summer its total insulation and protection is required (Heat insulation, airproof and sun protection). As it was mentioned before the openings are relatively small. However it is recommended in several occasions their decrease in size mainly on the Eastern and Western façades. This aims in the reduction of heat gains during summer. It is also recommended for the North façade, in order to control the thermal losses during winter. Considering that a residence has increased demands due to its function special attention should be given to the selection of materials.

1. INTRODUCTION

Planning and designing a residence, it is necessary to ensure the right energy operation. Thermal comfort should be achieved, having in mind that a human body maintains its temperature around 37 degrees C. So, it should not be neither cold nor hot.

In the 3rd semester of the School of Architecture at the University of Patras, it was asked to design a residence in a place called Kastritsi on the outskirts of the city Patras. The site is in a coastal area with its nice view towards north. The openings based on the bioclimatic design principles should be bigger on the south façade because that is the best orientation. This creates a difficult situation having the nice view facing north and the best orientation of openings facing south. Therefore the architect is called to make a compromise in order to take advantage of both orientations.

The size and shape of the site has its big axis towards north - south leaving larger facades looking east-west (see topographic plan in Fig. 1). According to the rules of bioclimatic design the rectangular ground plans have a better thermal behavior when their big axis is east – west leaving big sides of the building facing south. Otherwise they behave worse than those of a square plan. This is the reason why a square shape plan was proposed.

In addition a 2-storey building has a better

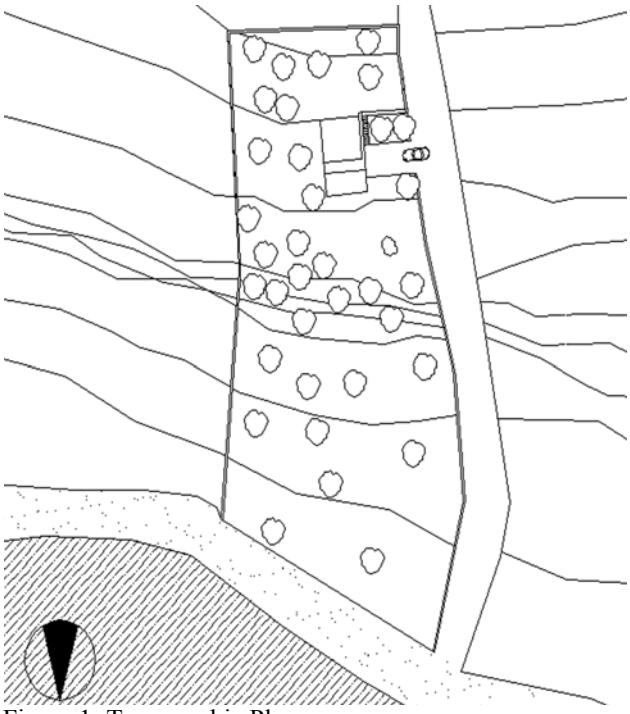

Figure 1: Topographic Plan.

thermal behavior than a one-storey because, even if they have the same volume, the surface of roof is smaller (the losses by the roof are important) and the southern facade is bigger (in surface). Therefore the higher the building the more solar radiation accumulates, which is positive for the winter. In the summer months, shading should be considered to protect the spaces from excessive sunlight.

Moreover, the plan of building is "open", without obstacles. This means that the operation of passive systems (opened windows, thermal mass and solar chimney) is better.

Finally the use of pale colors is suggested in the building, because they have low levels of solar absorption and high levels of reflection so that the heat gain is avoided. Mainly the pale colors are used in hot climates as that of Greece.

2. DESCRIPTION OF THE RESIDENCE

The residence is a two-storey house with a basement. On the ground floor the lounge and the kitchen are placed. On the first floor only the bathroom exists and on the second floor it is the bedroom and on office space. In the basement there exist a storage room and the garage. The house can be used as a single family residence.

After designing this building an effort was given to design the same building having in mind the bioclimatic principles. In this paper the residence is presented before and after applying the rules of bioclimatic design.

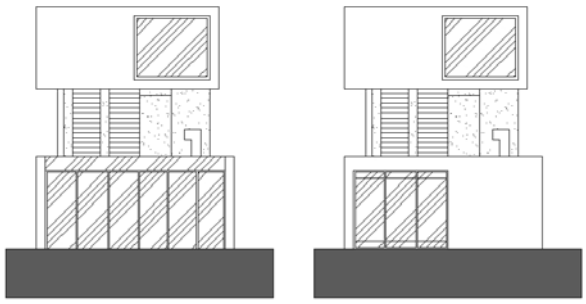

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Figure 2: Northern Façade.

3. STUDY OF THE 2-STOREY RESIDENCE

In order to establish thermal comfort in the habitable space for the tenants, certain changes were necessary that are described below.

Before applying the bioclimatic rules, north façade had more openings (Fig. 2). In order to protect the residence from the winds a decrease on the openings of the ground floor was necessary.

Also on the northern side spaces that need constant light were placed. For this reason, the configuration of the ground floor was changed (Fig. 3). The kitchen is placed on the north while the living room is placed near the entrance towards the south.

On the 2nd floor the orientation of space is functional. The office, that needs constant lighting, is situated in front of the north window. The bedroom is placed south with an opening on the east, in order to exploit the morning light (Fig. 4).

In the southern facade on the second floor an

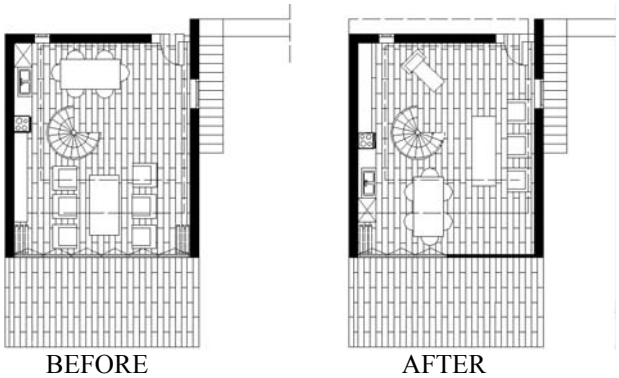

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Figure 3: Ground Floor.

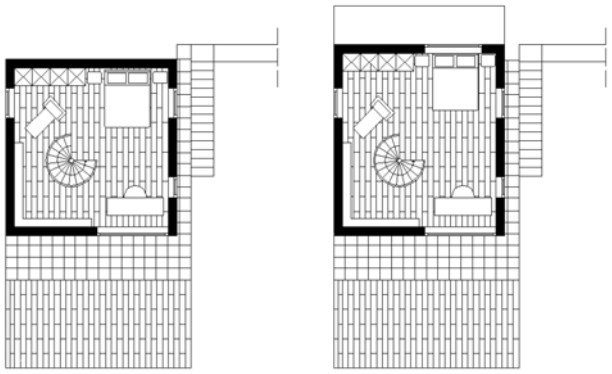

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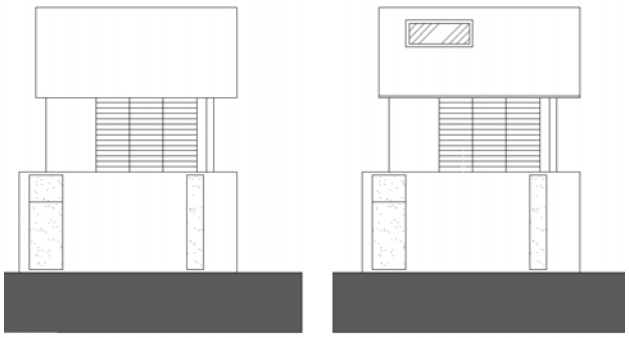
Figure 4: Second Floor.



BEFORE AFTER

Figure 5: Southern Façade.

opening was added so that the sunlight enters into the office space and bedroom during the morning hours (Fig. 5).

During summer, shading is required, due to the fact that the sun is stronger than that during winter. For this reason the sun should not penetrate the building. The size of the shading device is proportional to the length of the window. Thus a shading device is proposed on the southern façade with a growth of the volume of the second floor to the southern side (Fig. 6).

During summer, the sun is higher and is blocked from the shading device (Figs.7, 8). During winter the sun is lower allowing the

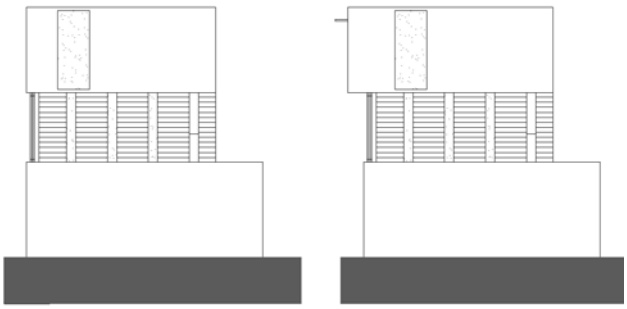


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Figure 6: Eastern Façade.

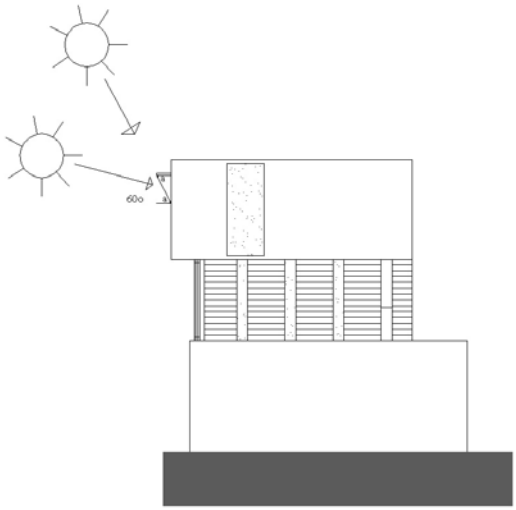
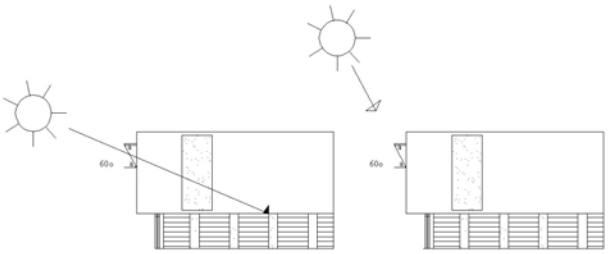


Figure 7: Shading Devices.



WINTER SUMMER

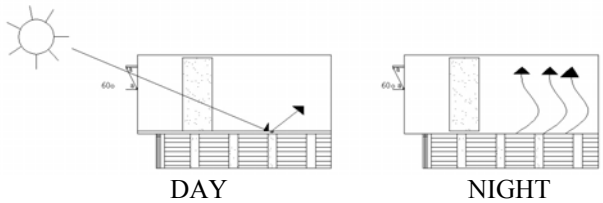
Figure 8: Sun Position.

natural light to enter the interior of the building so that part of the solar radiation is absorbed from the surfaces during the day and released at night.

In winter during the day part of solar radiation is reflected and part is absorbed by the thermal mass. At the night the heat stored during the day is released (Fig. 9).

The Western façade has remained the same. The only change is the addition of a shading device on the southern façade and the elongation of the second floor volume (Fig. 10).

As it appears in the section, in the middle of the building there exists an internal staircase, leading from the ground floor up to the second floor. It is proposed to use this staircase as a solar chimney. In order to achieve this on an opening is created on the roof of the second floor (Fig. 11, section a-a'). The window is operable



DAY NIGHT

Figure 9: Winter.

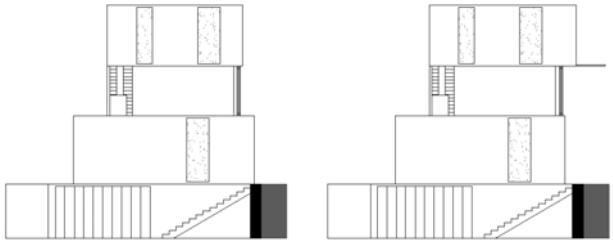


Figure 10:Western Façade.


Figure 11: Section a-a'.

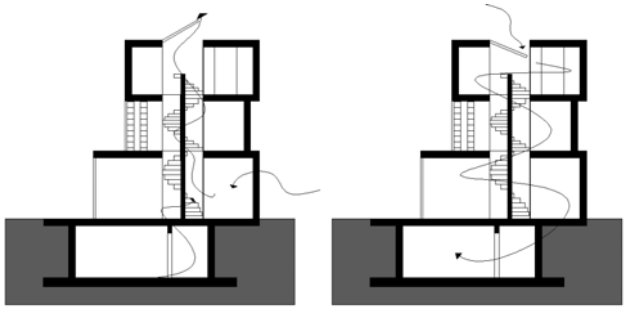


Figure 12: Section B-B'- Function of Roof Opening.

in two directions, in order to allow the air to come into the space, when the window is opened up in order to release the heat so that the space remains cool during summer. It can also open downwards so that the air is allowed to enter inside and the space to achieve natural ventilation, without releasing the heat to the outside (Fig. 12, section b-b').

On the southern façade a Trombe wall could be used (Fig. 13). Building that use Trombe

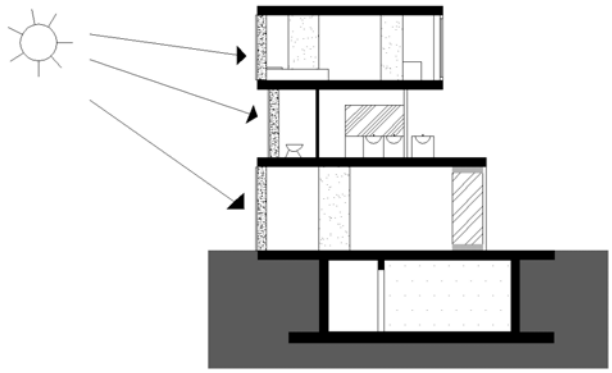


Figure 13: Position of Trombe Wall.

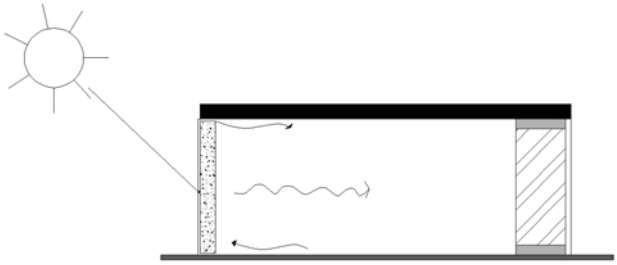


Figure14: Detail of the Trombe Wall.

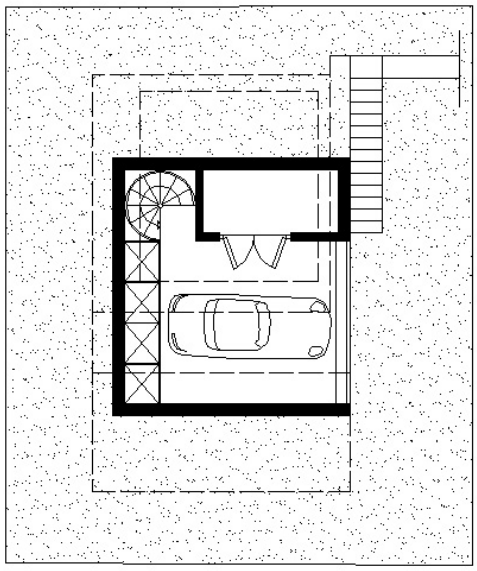


Figure 15: Basement.

walls use them as thermal mass that first absorb solar radiation, then maintain it, and then during night they release it. This wall has apertures for the circulation of air up and down and towards the space (Fig. 14). This wall is covered and air-proofed with a piece of glass. The glass is placed in a distance of 5cm off the surface of the wall. The light strikes on the glass and heats the air in between the glass and the wall. The heat is absorbed by the thermal mass. Then the heat is reflected in the interior of the space. The openings in this wall should remain closed during night. During summer, the undesirable heating of the mass can be avoided with the use of exterior apertures used for ventilation.

The basement that includes the garage and a storage room has not been changed in any way (Fig. 15).

The first floor has not been changed either. There is the bathroom with exterior permanent louvers, which are not only useful for shading, but also restrict the optical contact from the outside (Fig. 16).

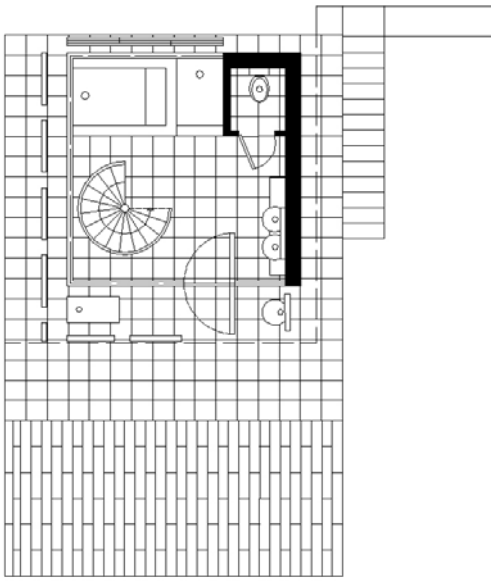


Figure 16: First Floor.

4. CONCLUSIONS

The residence presented in this paper, had been designed according the bioclimatic rules. Thus, there have been certain small changes without altering the overall composition of the residence as it was designed before. The problems due to the site orientation, size and shape were presented and certain solutions were proposed, in order to take advantage of the sun, the air and the view. For this, there have been changes in the interior configuration of certain rooms. Of course there exist also floors that did not undergo any change (underground, first floor). But the most important changes are the following:

- the addition of shading devices in order to avoid extreme solar radiation,
- the transformation of the southern wall in a Trombe wall to absorb heat and to restrict heat losses during winter,
- the creation of new windows for the exploitation of morning light,
- the decrease of the north facing opening of the ground floor, in order to restrict the heat losses, and
- the use of the staircase as a solar chimney.

With these changes, thermal comfort is sought for the inhabitants and better building behaviour is established.

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