Bioclimatic design for cooling in mediterranean buildings. The effectiveness of mass increase
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1. INTRODUCTION

This presentation projects the potential of mass interwoven with other aspects of Bioclimatic Design, with the objective of energy conservation and utilization of renewable energy resources for indoor comfort. The variable of mass and its effect on other variables and parameters in building simulations are outlined and discussed. The results are computer calculations of building simulations carried out by computer program SERIRES (Ref 1 – 3.2.2.4 “The Simulation models”). The effect of the most important parameters of the variable of mass, on the thermal response of the building is assessed during both heating and cooling modes. The performance of the parameters analysed, their efficiency is compared with each other and their effectiveness is expressed in the constructional aspects for buildings. Furthermore the adoption of the effectiveness of mass increase is presented in application of the bioclimatic designs for the Student Housing of New University of Cyprus, for which the presenter is the bioclimatic design consultant. The presentation is extensively illustrated with slides.

2. SIGNIFICANCE OF MASS

The thermal capacity of the building elements determines the heat that can be stored in the envelope of the building. This is an important property of the building envelope for energy conservation, since excess heat is stored in it and dissipated at a later stage when needed. In this way, the indoor temperature fluctuations are regulated and overheating is avoided. These temperature fluctuations could be due to:

- Diurnal fluctuations of outdoor Temperatures
- Internal Gains
- Incident Solar Radiation especially in rooms with large South glazing surfaces

The aspects relating to mass are of particular significance for countries with large diurnal fluctuations and the potential possessed by mass for large solar contribution in winter and cooling in summer by retaining the solar radiation during winter days and the night coolth in summer. This implies that heat admitted during the day in winter could be stored for use during the evening hours and in the summer could be dissipated in the cool night.

3. PARAMETERS

In this research the thermal response of the building and the effectiveness of mass increase are examined internally and externally. The concept of addition of mass is presented as an acceptable modification of the walls construction in the Cyprus marketplace. The addition of internal mass is introduced as the replacement of the 100mm typical internal brick walls, by 100mm concrete walls. The addition of external mass is introduced by the replacement of the 200mm external brick walls by 200mm concrete.
walls. (Fig. 3.1. Ref.1.3 “Variables, Varied Parameters – Using Data- Sets”). The studies of addition of mass result at the following percentages regarding energy consumption:

(i) The addition of internal mass yields to 5% reduction of cooling as well as heating load.
(ii) The addition of external mass increases energy consumption by 40%.

A further 30% of internal mass, expressed in the design as additional internal wall, leaves the energy consumption of the house unaffected. This could be attributed to the orientation of the additional mass. A south orientation allows greater insulation in winter and the mass absorbs, stores and dissipates more heat. Another possible reason could be the quantity of the mass. From the studies it appears that the extent of mass increase seems to be critical concerning its effect on the energy loading. Extensive increase of internal mass could act adversely in as far as time needed to cool it in the summer nights or indeed heat it in the winter.

3.1 Mass and shape
The planning, the design, and the appropriate choice of materials, especially the mass distribution and the location, for these walls, the floors and the other indoor building elements contribute enormously in this. The geometry of the rooms, the building materials and the finishing of the internal surfaces aspecting south, have a bearing on the distribution of the incoming radiation among the room surfaces and affect the attainment, storage and redistribution of solar radiation in the form of heat. From the building simulation studies it is derived that more complex configurations result to additional factors which intervene in the thermal behaviour of the building. Such additional factors are:

• The more composite internal layout encompassing more spaces and surfaces facing south.
• Larger internal thermal mass whose position, size and distribution reduce temperature fluctuations by retaining heat within it.
• When insulated, enhanced thermal protection on external envelope as a result of the morphology of the two more complex shapes.
• More useful exchanges through openings and surrounding walls.

Furthermore the study has shown that addition of internal mass incurs energy conservation of varied extent according to the thermal behaviour of each shape. On the contrary addition of external mass leads to higher energy consumption in all shapes. Whereas masonry provides good heat storage medium within a space, it readily passes this heat to the outside when added on exterior walls. More analytically, the studies of shape and mass presented the following observations.

(a) Addition of Mass Internally: The addition of internal mass combined with the maximization of south glazing, increases energy conservation in heating for all shapes. The rectangular shape presents the highest amounts of savings. This difference is attributed to the greater extent of south glazing increase on this shape, the positive effect of which was not apparent prior to the mass addition; it seems that the position, the size and distribution of the mass acted positively on energy conservation in heating load when combined with the south glazing increase. The addition of thermal mass also decreased the cooling load in all shapes. The energy reduction is due to the potential of the mass to retain the coolness of the night. When summing up energy consumption in both heating and cooling, it is observed that the square shape retains its lead in being the most economical house. The compactness of the shape seems to overshadow the other test variables.

(b) Shape and Addition of Mass Externally: The addition of external mass affects adversely the conservation of energy in all four shapes. The replacement of the 20cm external brick wall with 20cm concrete although has greater degree of density, however its thermal conductivity is also greater. During the summer the heat penetrates faster the collective surface and the potential for positive results decreases; consequently the cooling load increases. Based on the same transfer heat principle, in winter the increase of thermal losses results to higher heating demands.

3.2. Mass – improved design
The mass variable was also examined on a thermally improved building and the energy savings compared with those incurring from an unimproved structure. The figures of decrease and increase of energy consumption shrunk correspondingly for both the addition of internal and external mass.

Specifically savings from energy conservation increase when insulation is applied on the external surface of the envelope, for both cooling and heating. The interception of the sun at the very external side of the buildings’ skin in the summer results to the efficiency of external insulation for cooling energy conservation. In the winter with the positioning of the insulation on the external side, the mass of the opaque elements of the structure is utilized by storing the trapped solar energy contributing to the efficient bioclimatic operation of the building. The insulation on the exterior of envelope prevents heat stored in the thermal mass to be conducted rapidly to the outside.

4. CONCLUSIONS
In order to determine the full extent of the effect of mass
on the thermal behaviour of the building further analysis is necessary concerning parameters such as:
(a) Collective and storage characteristics of the materials of the surface finishing.
(b) Location, quantity, distribution and surface colour of mass.
(c) Orientation of internal surfaces.
(d) Diurnal and spatial temperature swings.
(e) Combination of window sizing and extent of thermal mass.
However the mass parameters tested on the current studies were sufficiently indicative as to determine their effect. The addition of internal mass was positive and thus employed as energy conservation measure to reach the zero energy house.

5. APPLICATION IN THE BIOCLIMATIC DESIGN FOR THE STUDENT HOUSING OF NEW UNIVERSITY OF CYPRUS

In this section effective and beneficial aspects of applications of mass in the buildings as well as in open space elements for the designs of the Student Housing of the New University of Cyprus are presented. The bioclimatic design is consciously integrated into the whole planning, siting and architecture of the scheme. The siting of the buildings and treatment of open spaces utilises the natural topography and environmental features.

5.1 Mass and the buildings
In all buildings, the shape, the mass, the orientation, the layout and the openings have been designed to meet the conditions of bioclimatic architecture. The buildings are oriented on East-West axis, to provide for favorable winter solar gain, summer shading, year-round day lighting and natural ventilation. All blocks of buildings feature fixed external passive shading devices. In addition, four of the blocks are beneath a fixed canopy shade, with slats spaced and angled to allow for winter sun exposure and summer sun protection, complementing the passive solar design of the structures. The designs also promote natural summer cooling ventilation, utilizing the prevailing summer wind direction as well as enhancing stack-effect ventilation. These are assisted by rock-bed pre-cooling in the buildings, and rock and screen evaporative cooling structures upwind from the buildings. The buildings on the West Side of the plots, due to the natural contours, are raised at a higher level. The space between the ground and the underside of the buildings

Fig. 5.1. Section views showing, in winter, the sun penetration in the center of the day through the properly angled canopy slats. In summer, direct sun penetration is prevented by the slat angle and spacing. The narrow shape and placement of openings promote natural ventilation. Evaporative cooling from the underfloor wetted rubble stones provides additional summer comfort.
Fig. 5.2 Courtyard defined by circular wall with wetted rubble stone columns for summer evaporative cooling and enhancement of western breezes. In winter the courtyard becomes a pleasant sunny place, warmed by sun and mass.

is filled with loose rubble stones, encased in metal wire. In the summer it is wetted with water, enhancing the cooling effect of the westerly summer breezes (Fig. 4). Openings in the ground floor insulated and waterproofed slab, channel coolness into the rooms. The free flow of air towards all directions and through the gaps between the stones, under the floor slabs, dissipates coolness in the surrounding areas. It also avoids dampness and
creation of mold. The water, which is used for the wetting of the stones, is collected in waterproofed metal trays and is recycled with the aid of a pump, for water conservation. The pumps are activated by an array of photovoltaic panels for solar energy utilization.

The construction of the buildings is of reinforced concrete frame structures with infill panels of concrete blocks, which are locally manufactured. This type of massive construction, in addition to the concrete floor and roof slabs, offers time lag as well as thermal storage. This is of particular significance for the Cyprus climatic conditions, due to the characteristic of large diurnal fluctuations (5 to 25 degrees Celsius) and the potential inherent in mass for large solar contribution in winter and cooling in the night. The walls are insulated externally with rigid extruded polystyrene and rendered with plaster on plastic mesh painted white for sun reflection. The concrete floor slabs are finished with screed and mosaic tiles, enhancing their thermal capacity. The concrete roof slabs are topped with lightweight concrete screed forming slopes for water collection, waterproofing membrane and insulation to intercept the summer solar radiation. A protection layer of white chipping acts as a reflecting surface, necessary for the reflection of the almost vertical summer sunrays.

5.2 Mass in the open spaces
The main open space is formed centrally, connected with the building of common spaces and the semi-open route of circulation and parking. It is paved and acts like a large courtyard, sunny in winter and cool in summer. The uncovered paved surfaces offer pleasant sitting areas to enjoy the warmth of the winter sun. In the summer, open to the clear cold nocturnal sky, they cool by long wave radiation and moderate the heat of the hot days, around them. Within it the open space, which is defined by a circular wall, is pleasant for both summer and winter. It is partly solid toward the northern side for wind protection and the remaining wall and columns are built out of loose rubble stones encased in metal mesh. This is shown in plan view in Fig. 5.2.

In the summer, recycled water trickles through the stones, providing coolness to the adjacent areas. The stone wall and columns are facing the western cool summer breezes to they enhance effectively the cooling of the open and semi-open sitting space. In the winter the stonework is not wetted so that it acts as a wall and columns for solar collection, storage and warmth of the space, which becomes a pleasant sunny courtyard.

REFERENCES