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Suitable roof constructions for warm climates—Gazimağusa case

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Abstract

This research aims to find the suitable roof constructions for warm climates. The research has been carried out at Gazimağusa, North Cyprus. With the limited research budget 14 different roof constructions were selected and tested on a test house. These constructions included the types which are widely used in Cyprus and also the new ones. The roof constructions were tested under continuously air-conditioned and non-acclimatised regimes. They were also tested for the risk of condensation.

Most of the research on similar aspects were done in terms of energy loss and gain. This research has been designed to study the roof constructions in terms of thermal comfort of the users. Naturally, the roof constructions which have the highest thermal resistance will result in lowest heat gain and loose. In this study instead of finding the roof constructions which gain the least amount of heat during the hottest days of summer or the ones which loose the least amount of heat during the coldest days of winter, it was aimed to find how much they provide thermal comfort throughout the year.

In this respect, the roofs with thermal insulation showed the best performance. The location of the thermal insulation materials towards the inner surface of the section increased the performance. Inclined timber roof constructions on reinforced concrete ceiling save the buildings from solar bombarding in summer. However, to prevent the humidity accumulated, the attic space should be very well ventilated. On flat roofs, not only the thermal resistance of the roof section, but also the light reflectance of outside surface materials effected the thermal performance. Outside surface materials with very high light reflectance reduced heat gain in summer considerably.

In buildings which are air conditioned in summer, there is condensation risk. The defects due to this condensation can be avoided by the use of thermal insulation materials which are not effected from water. There is also condensation risk for winter. However, it was found that this condensation can dry if the building is ventilated.

Keywords: Warm climates; Flat roofs; Thermal comfort

1. Introduction

In achieving thermal comfort in buildings the behavior of the external building elements is very important. Building elements are designed differently depending on the climatic conditions. Hot-dry, hot-humid, cool and temperate climates need totally different external building elements. There are vast amount of research in literature about the design of building elements in cool climates. However, there isn't enough research on the design of building elements in warm climates. This research aims to study the behavior of the roofs in a climate where the warm period is longer then the cool period.

The experimental study was carried out at the campus of Eastern Mediterranean University, Gazimağusa (35°7′N latitude and 33°57′ longitude). The climate of Gazimağusa is a transition between composite and hot-humid climates, thus it is a good representation of North Cyprus climate.

With the limited research budget 14 different roof constructions were selected and tested on a test house. These constructions included the types which are widely used in Cyprus and also the new ones. The constructions were selected as to test the contrasting features like:

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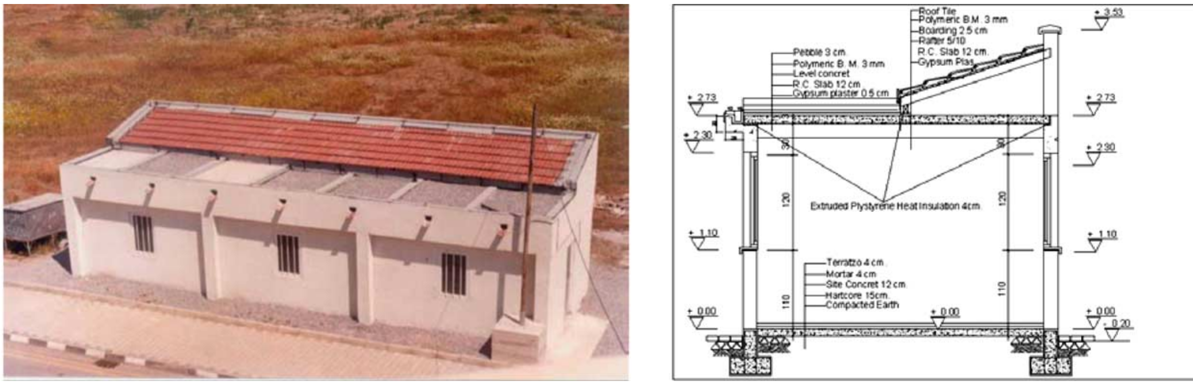

Fig. 1. Picture and the section of the test house.

Reverse flat roof versus conventional flat roof,
Inclined roof versus flat roof,
Ventilated inclined roof versus unventilated flat roof,
Inclined roof with the attic space inhabited versus inclined roof with the attic space uninhabited,
Thermal insulation on the inside of the roof section versus thermal insulation on the outside of the roof section,
Roof with thermal insulation versus roof without thermal insulation,
Accessible flat roof versus inaccessible flat roof.

Most of the researches on similar aspects were done in terms of energy loss and gain. This research has been designed to study the roof constructions in terms of thermal comfort of the users. The predicted mean vote (PMV), which is a thermal comfort index proposed by FANGER and recommended by authoritarian organizations of the subject like American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) and International Standards Organization (ISO) is used to compare the thermal performance of the roof constructions [1–3].

2. The study done

Fourteen roof constructions, approximately 2 m × 2 m in size were selected and constructed on a 12 m × 4 m size single floor test house (Figs. 1 and 2). In order to avoid horizontal heat flow between the roof constructions all of them were separated from each other and from the building structure with thermal insulation materials. The test house is on the university campus with its longitudinal axis on the east–west direction.

The monitoring of the test house was done continuously between July 2001 and 2002.

2.1. Experimental facilities

Inside and outside of the test house various temperature and humidity probes, data loggers to collect and evaluate the measurements and computer programs were used. These are:

1. HOBO data logger and BoxCar Pro Version 3.5 for Windows,
2. ACR data logger and Trend Reader for Windows,
3. CR23X data logger.

HOBO data loggers and their own probes were used to measure the internal surface temperature, air temperature and the relative humidity. Both the internal air temperature and relative humidity were measured at two different points 2.5 m above the floor. For external relative humidity three HOBO data loggers with their own sensors were used 1.5 m above the ground. ACR data loggers with their sensors were used to measure air temperatures at the attic space of Roof 1 and 2.

Twenty three channel Campbell Scientific CR23X micro-logger was used to measure the temperatures of the various roof layers. Cupper constantan thermocouples constructed and tested by the authors were used as temperature probes.

When the test house was not acclimatized in summer all the windows were kept 2 cm open and ventilated. However, in winter all the windows were kept shut. For cooling two window type air conditioning devices with 4000 W capacity each, were used on the narrow side walls, 50 cm above the floor. For heating three electric radiators with 2000 W capacity each, were used. Heating and cooling devices were connected to a thermostat separately. During the acclimatization period, when the internal air temperature fall below 21 °C the heaters, and when it exceeded 25 °C the coolers started to work automatically.

2.2. Thermal comfort

Most of the computer programs for analyzing building energy performance neglect thermal comfort. They mainly aim in finding how much energy can be conserved. They don't handle whether the people in energy conserved buildings are thermally comfortable or not [4].

Thermal comfort is defined as the state in which the body adapts itself to the environment by spending the least amount of energy [5]. It is possible to divide the thermal comfort factors into two groups as objective and subjective. Objective factors are air temperature, relative humidity, air