Thermal effect of orientation differentiations in a university building in Izmir, Turkey

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ABSTRACT

This paper evaluates current situation of the university building which is considered oriented in the wrong direction, in the campus area of Izmir Institute of Technology in Izmir, Turkey. The building, which houses the Faculty offices, is used by the Faculty of Architecture. Experience has indicated that cooling loads of the building are quite high, as it is oriented with the main design decision of facing the sea panorama along the long axis, lying in north-southerly direction, 11° from north to east. The thermal effect of orientation differentiations should have been considered in the design phase. Yet the building is currently occupied, therefore this study only helps to emphasize the necessity to evaluate the thermal performance of buildings before the construction phase for future designs. It underlines that case-specific climatic factors should be considered in design decisions. For the analysis of the building, the thermal performance interface of Ecotect v5.2 software has been used. First, the existing situation of the building is modeled with the weather data file of Ecotect on Izmir. Then, the model is re-evaluated by three different orientations proposed by the authors. The outcomes of four assessments including the existing situation are examined and compared with regard to internal air temperatures and energy loads for cooling in the hottest months of year, July and August. In the conclusion, the most potent orientation for such building in the existing topography and location is proposed.

1. INTRODUCTION

Existing buildings in the campus of Izmir Institute of Technology, Izmir, Turkey are mostly oriented considering the scenery input of the land, i.e. attractive sea vista. The climatic conditions were not much concerned in the development phase of the campus master plan. It is argued that if buildings are tested before construction phase by computer simulation programs, the thermal performance will be an influential criterion for decisions of location and orientation in a more sustainable way. This paper conveys a test base for this proposition through the existing building. Hence, it assesses the current situation of the selected university building, and investigates the most potent orientation in the two hottest months of the year, July and August.

2. GENERAL DATA

2.1 Location

Izmir is a harbor city located in the middle parts of the western coast of Turkey. The campus of Izmir Institute of Technology is situated in the western development axis of Izmir, 55 km from the city-center. It lies on the eastern slopes of a hilly area, facing to the Gülbahçe Village, a rural Aegean town, and the Gülbahçe Gulf of Izmir Bay.

2.2 Climatic Data

Izmir has temperate weather conditions, classified as *Mediterranean climate* (Şensoy, n.d), with hot summers and cool and rainy winters. In the costal zones, snowy weather and frosts are rarely seen.
The average annual mean temperature of Izmir is 16.7°C. Monthly average mean temperatures range from 8.4°C to 25.8°C. It is the lowest in February and highest in July. The second hottest month is August, with 25.4°C. The average annual relative humidity is 65%. The driest months are respectively July, June and August, with 49, 55 and 58%. The average annual rainfall is 726 mm and the rainfall mainly occurs in the winter period. The ratio of summer months' rainfall in annual average is 5.7%, so the summers are quite arid (Şensoy, n.d.). Monthly average global radiation is highest in June with 316 Wh/m^2, then July and August. The average wind speed in Izmir is high at 4.4 m/sec. There are two predominant wind directions: north and southeast. The average wind speed per hour ranges from 3.7 to 5.8 m/sec. It is the lowest in June 03:00 and 06:00, with 2.1 m/sec, and highest in August 17:00, with 8.1 m/sec (Weather Data of Turkey, 2007).
In terms of the degree-day (dd) pattern of Izmir, it is clear that the energy demand for heating is higher than cooling (Fig 1). For example, 998.4 heating degree-days are recorded, while it drops to 612.5 dd for cooling (Ecotect, 2007). Yet, between May and September, especially in June, July and August, there is considerable need for cooling in Izmir.

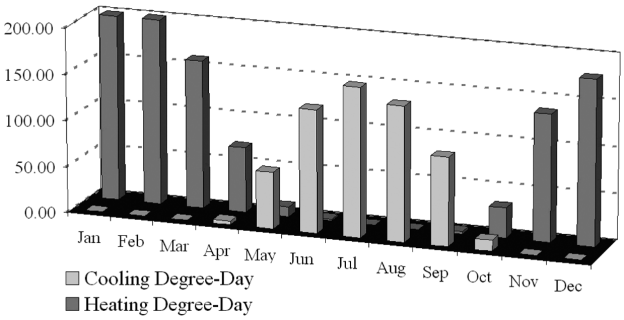

Figure 1. Monthly degree-days (dd) for heating and cooling in Izmir, analyzed with Ecotect v5.2

2.3 Description of the Campus Organization and Selected Building

Buildings in the campus area of Izmir Institute of Technology are scattered inside and around a ring in organic shape defined by the topographic conditions of landscape. The master plan, structured on this ring, directs a base orientation such as; facing east and north dominated by the scenery input of Gulbahce Gulf at northeast and the slight sloped hills rising to the west. Thus, the main façades of almost all existing buildings are oriented to either north or east.

The selected university building is located at the highest level of campus, longitude 26º63'02" E, latitude 38º32'52" N, and the altitude 76 m. It lies in north-southerly direction, 11° from north to east, facing the sea panorama along the long axis (Fig 2).

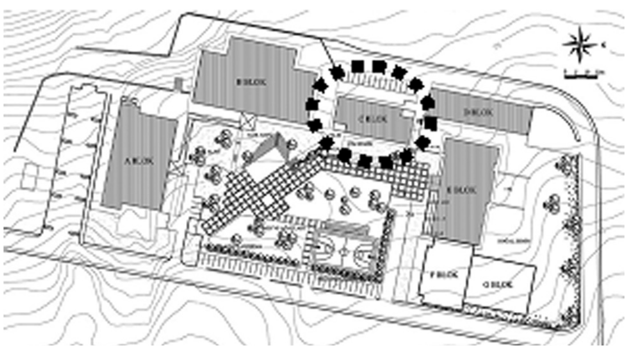

Figure 2. Site plan of Faculty of Architecture, Izmir Institute of Technology, Izmir, Turkey and selected building: C Block (indicated in circle)

This building, named C Block and built in 2003, is one of five blocks, occupying the smallest area in the U-shaped complex of the Faculty of Architecture. It is a two-storey building, which has an atrium joining two floors visually and providing natural lighting with a skylight along the long-axis of the building. The Faculty offices, 24 rooms in total, are organized around the atrium; 10 of them are facing east, while 14 of them are facing west. The total area of building is around 700 m^2 (Fig 3). The C Block is a reinforced concrete building with a flat roof covered with rough gravel. The structural parts are exposed concrete, and walls are double exposed full-brick. Thus, the thermal feature is characterized by the high thermal mass capacity of materials. In terms of openings, the skylight is constructed by the aluminum frame with fixed single-glazing; only two opposite sides have ventilation grills.

Figure 3. East (long) and south (short) façades of C Block

Windows are made of the PVC frame with double-glazing. The building is actively conditioned by the all-water central heating and cooling system, consuming around 18 tons of fuel per year.

2.4 Definition of Problem in C Block

The cooling load of C Block is quite high in the summer period. The offices facing east and west and the atrium are overheated. Poor thermal comfort conditions affect the work performance of the faculty negatively.

There are particular factors affecting the overheating. The major factor is the orientation decision in the design phase, i.e. looking at the attractive sea vista along the axis, by disregarding excessive heat gains from east and west. Thermal features of building components, uncontrolled solar gains by the skylight, insufficient natural ventilation and problems in operation process are also critical factors of overheating.

3. METHOD

This study does not undertake the mission of developing a more sustainable or energy-efficient building model for the already constructed building. It simply tries to underline the importance of using a computer simulation tool for making simple design decisions, e.g. orientation. The artificial platform of the simulation program brings out a safe environment for the comparison of similar data. It comprises the easiest way to see the effect of different orientations on the thermal performance of a predefined building.

For a healthy comparison of differentiations, the modeling should be performed in the same simulation platform. Gordon et al. (cited in Donn, 2001,

675) underpin this by claiming that "as performance simulation can never model all operational parameters, simulationists argue that two building models must be compared using the same performance calculation tool. They can then attribute differences in performance to differences in the two designs." Therefore, this study prefers to evaluate the thermal performance values of both original orientation and other alternative options by the use of same simulation tool. In this respect, the Ecotect software is selected for the analysis of thermal performance of C Block because of its simple, accurate, and most importantly, visually responsive features (Ecotect, 2006).

3.1 Modeling

The modeling of C Block was performed with Ecotect v5.2 software (Fig 4).

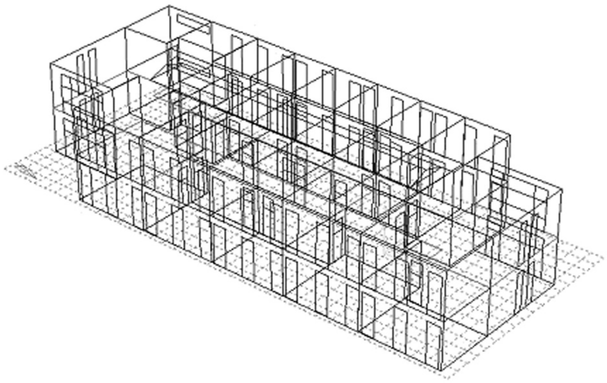

Figure 4. 3D model constructed with Ecotect v5.2

First, the model of the existing situation was constructed with the weather data file of Ecotect on Izmir. Afterwards, six basic surface configurations were created and used appropriately:

- Roof: concrete and gravel (210 mm)
- Suspended Floor: suspended concrete ceiling with ceramic tiles (200 mm)
- Ground Floor: thick concrete slab on ground (100 mm) with ceramic tiles
- Wall: double full-brick (220 mm)
- Skylight: aluminum frame with single-glazing
- Window: PVC frame with double-glazing

3.2 Zones in Computer Modeling

The C Block was divided into four zones where each one may thermally perform differently, because of its location, orientation and function (Fig 5-6):

Zone 1: rooms facing west

Zone 2: wet spaces

Zone 3: atrium

Zone 4: rooms facing east

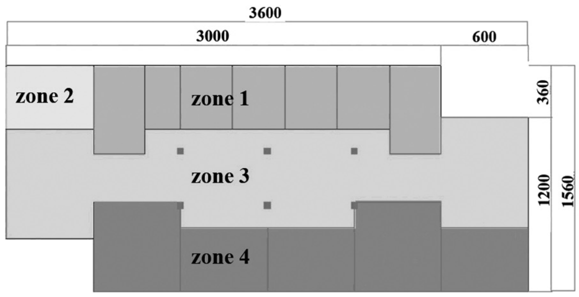

Figure 5. Distribution of zones on Ground Floor Plan of C Block

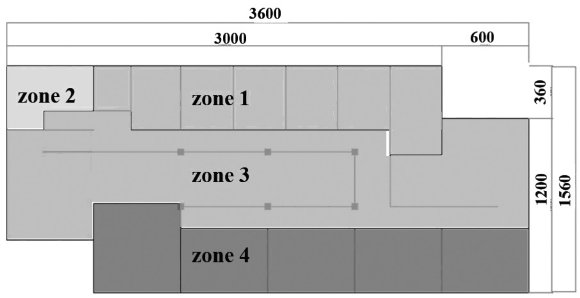

Figure 6. Distribution of zones on First Floor Plan of C Block

3.3 Analysis of Thermal Performance

From the assumption that orientation affects the cooling loads, the building was rotated respectively 19°, 34° and 79° clockwise to obtain the angles of 30°, 45° and 90° with the north and to compare the outcomes of three different orientations with the existing situation (ES), 11° to the north (Fig 7).

The calculations of four directions including the existing situation were conducted with the thermal performance interface of Ecotect. The simulation process was developed based on the outcomes from three series of thermal parameters in Ecotect v5.2: internal air temperature (°C), heat gain (Wh) and heat loss (Wh). Correspondingly, two outcomes, internal air temperature and energy load for cooling, were determined as the comparable variables for study of the most potent orientation in the existing topography and location.

For the systematic comparison, July and August, the two hottest months of year, were chosen as the representative summer months. In this paper, only the calculations for the days of July 1st and August 1st will be presented. These days were selected randomly as the illustrative day of each month.

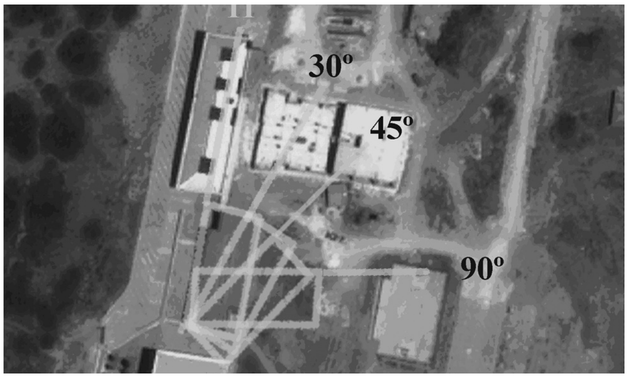

Figure 7. Four different orientations applied in the analysis of thermal performance of C Block

4. ANALYSIS OF THE RESULTS

4.1 Internal Air Temperatures

During the days of July 1st and August 1st, the ambient mean air temperatures in Izmir are high. The minimum temperatures range from 17.5°C to 18.5°C at 05:00 o'clock, while the maximum temperatures reach 37.2°C at 13:00 to 35°C at 14:00 (Fig 8) (Weather Data of Turkey, 2007). In Zone 1, the average daily internal air temperature is 28.5°C on July 1st and 25.2°C on August 1st for four different orientations (Figs 9-10).

On July 1st, the highest temperature is 30.9°C at 16:00 with the existing situation. This case is similar for August 1st: the internal air temperature is the highest in the existing situation with 27.3°C at both 15:00 and 16:00. This indicates that the four orientations do not meet the comfort conditions in the Zone 1, yet the worst case is the existing situation, i.e. nearly 5 degrees over the thermal comfort requirements.

If we compare the lowest temperatures, the most potent orientation is not clear. Almost all four directions give the minimum temperatures at 05:00, yet temperature variations are around 0.1°C, which is too small to be considered.

In Zone 4, the average daily internal air temperature is around 28.8°C at July 1st and 25.4°C at August 1st for four different orientations (Figs 11-12).

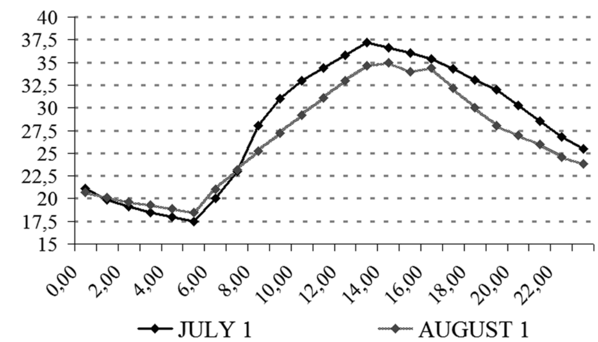

Figure 8. Ambient mean air temperatures in July 1st and August 1st, based on TRY data

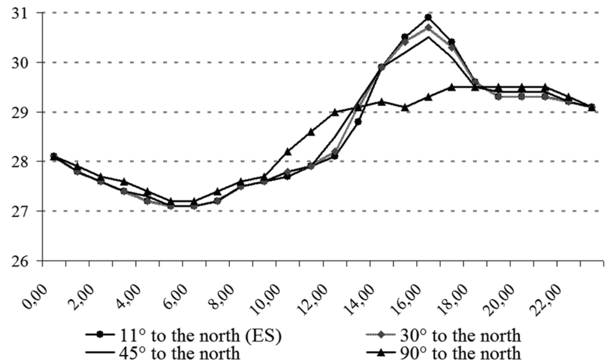

Figure 9. Internal air temperatures in July 1st for Zone 1

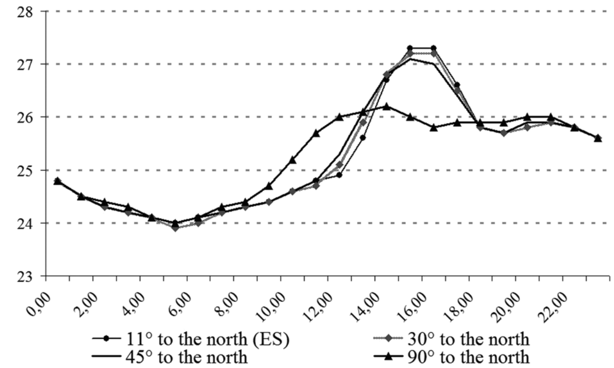

Figure 10. Internal air temperatures in August 1st for Zone 1

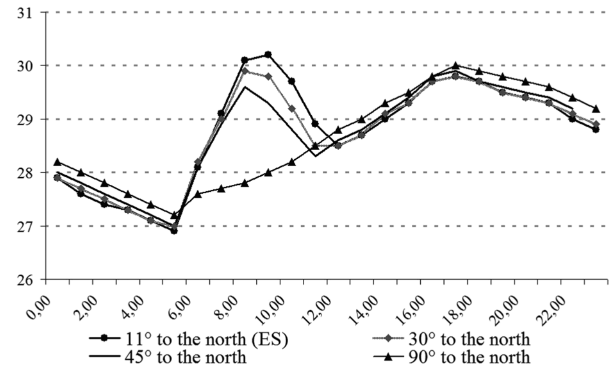

Figure 11. Internal air temperatures in July 1st for Zone 4

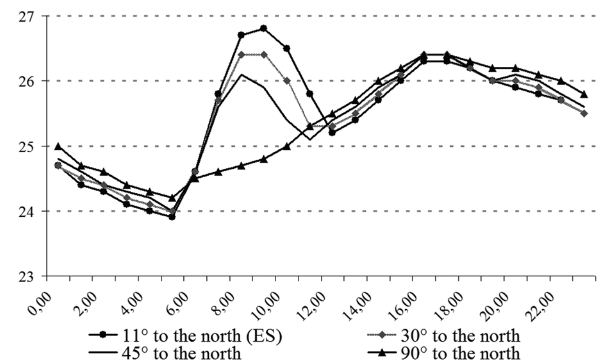

Figure 12. Internal air temperatures in August 1st for Zone 4

On July 1st, the highest temperature is 30.2°C at 09:00 with the existing situation. This case is similar for August 1st: the internal air temperature is the highest in the existing situation with 26.8°C at 09:00.
In both graphs of Zone 4 (Figs 11-12), it is clear that for three orientations, i.e. 11°, 30° and 45° to the north, the air temperatures fluctuate during the day. The spaces heat up twice a day around at 09:00 in the morning and 17:00 in the afternoon. The building rotated 90° to the north is the only case in which the spaces heat up once a day, and logically requires the lowest cooling load. Therefore, it is the most potent orientation in terms of cooling demand for Zone 4.
In terms of diurnal ranges, there are similarities between Zone 1 and Zone 4. First of all, the diurnal range of internal air temperatures is quite low, around 2 and 3 degrees. For both July and August 1st, it is the minimum at the case rotated 90° to the north, and the maximum at the existing situation. The gentle rise and drop of internal air temperatures indicate that due to high thermal inertia of surfaces, the spaces heat up during the day and radiate heat in the evening, even though the diurnal range outside is 19.7°C at June 1st and 16.5°C at August 1st.

4.2 Energy Load for Cooling
The analysis of total energy load for cooling was performed again with Ecotect v5.2 software. The outcome was derived from the simple sum of total heat gains and heat losses of C Block in July and August, which differ according to four orientations. Here, the heat losses are constant, while the heat gains vary (Fig 13).

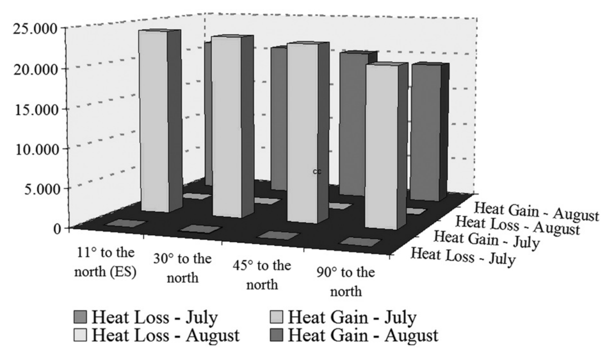

Figure 13. Heat gains and losses according to four orientations in July and August, analyzed with Ecotect v5.2

Figure 13 proves that the existing situation is the worst case with the highest level of heat gains both in July and August. The change in orientation 90° to the north minimizes the heat gains, and thus the energy demand for cooling in the summer period. It brings about 14.6% fall in cooling loads in July and 10.5% in August.

5. CONCLUSIONS

This study revealed three equally significant issues.
Firstly, in terms of internal air temperatures, the worst orientation is the existing situation for both Zone 1 and 4. Yet, it is hard to propose a concrete assumption for the most potent orientation.
Secondly, in terms of diurnal range for both Zone 1 and 4, the internal air temperatures of rooms do not follow the outside air temperature variations closely due to high thermal mass capacity of surfaces.
Thirdly, in terms of energy load for cooling, the most potent orientation is the case rotated 90° to the north because of the lowest heat gain range in both July and August.
In the light of these three issues, it is likely to propose that in terms of cooling demand, the most potent orientation for C Block is the east-westerly direction, 90° from north to east.

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