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The State of Thermal Situations of Apartment Buildings' Occupants and their Share in Energy Consumption

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ABSTRACT

Regarding the fact that thermal conditions of occupants in high apartments are different from the ordinary ones, it is indispensable to analyze such buildings regarding ease procurement and reduction of energy consumption. The purpose of this article is to study three groups of high apartment buildings' occupants to be able to determine their thermal ease limits. These groups include: northern, southern, and western occupants. The methods used here are field study and library study. For the field studies, we have utilized heat-recording devices such as thermometers and psychrometers. The results show that based on ANSI/ASHRAE Standard 55, from the three groups of the study, the southern part's occupants have the most degree of thermal ease at the peak of summer's heat; and the eastern part's occupants have the least amount of thermal ease. Therefore, the amount of energy consumption is higher in eastern and western sides. As a result, correcting the buildings' typology in cities and using the appropriate direction especially in high apartments is effective in the reduction of energy consumption.

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INTRODUCTION

After the 1973's raise in oil prices, the advanced industrial countries were forced to deal more seriously with energy. In different countries depending on the degree of industrial activities, between 30 to 35 percent of the total energy is consumed in buildings. From this amount, about 50 to 60 percent is consumed for making a building warmer or cooler in different seasons of the year. From the one hand, we should have it in mind that a vast amount of studies conducted in the recent century, have been on the issue of thermal ease, in order to design and maintain comfortable thermal environments with international standards (de Dear 2004). In this period, two approaches to studies in thermal ease have been existed: 1. The method based on laboratory such as Fanger's model of PMV-PPD, 1970. 2. The method dependent on field study, such as compatible standard of ease. Both methods have been covered in the latest edition of ANSI/ASHRAE Standard 55 and ASHRAE 2004.

Studies on compatible thermal ease's models show that these models determine more extensive spectra of temperature in which the buildings' occupants may still gain thermal ease.

In order to prove the founding of this study, the researchers believe that it is important to conduct the studies in a subjective manner to be able to consider the real thermal feelings of the occupants. However, because of some limitations such as different age and gender groups in apartments, it was so difficult to conduct subjective studies especially in the form of questionnaire.

The conditions of thermal ease were studied by a combination of monitoring the parameters effective on thermal ease of the occupants and observations of the environment and occupants. Monitoring founding was compared to the international standards like ASHRAE, ISO, and CIBSE.

From the utilized standards, CIBSE 1999 and Iranian standard MPO 2004 define spectra of the inside's temperature and relative humidity for achieving thermal ease. The international standards ISO 7730 (ISO 2005) define a spectrum for predicting the average of occupants' dissatisfaction (PPD) to achieve thermal ease based on six defining factors PPV or PPD. Table 1 shows the thermal ease based on different standards.

1. Geographical conditions of Iran:

Iran is located in southwest of Asia and has a lot of mountains and deserts. Iran is located in a warm and dry area (Kasmaiee 1993). Kermanshah which has been chosen for field study is in on latitude 34°18′ N and longitude 47°4′ E and has an elevation of 1420 meters above the sea level.

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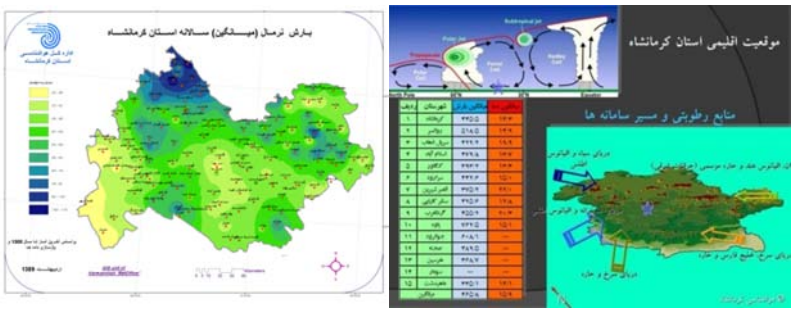
Table 1: Recommended conditions for providing thermal comfort in different standards.

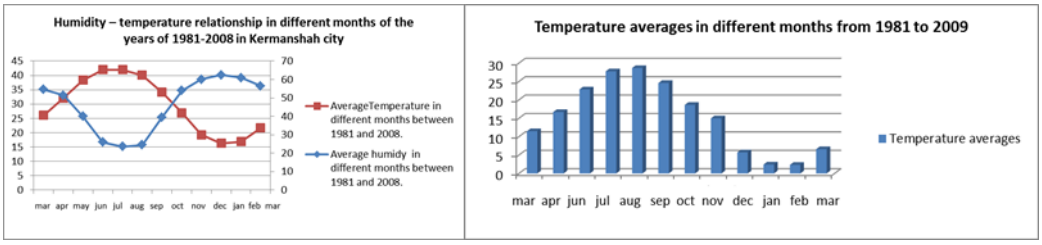
Standard	Recommended thermal condition to achieve thermal comfort
ASHRAE	-0.5<PMV<+0.5, PPD<10% and 0<humidity ratio<0.012
ISO 7730	-0.5<PMV<+0.5, PPD<10% and 30%<RH<60
CIBSE	22 ºC <Temp<24 ºC and 30%<Rh<60
Iranian Regulation	20 ºC <Temp<23 ºC (winter) , 24 ºC <Temp<28 ºC (summer) and 30%<Rh<60



(1) (2)

2.The research method in measuring thermal ease:

All the referral standards for evaluating thermal ease need to measure relative humidity and temperature of the air. In assessments of ISO 7730 and ASHRAE Standard 55 and the observations of the extent of clothes and activities, we must assess temperature and air flow speed. The monitoring of the apartment and the analysis of the occupants were used to collect data.



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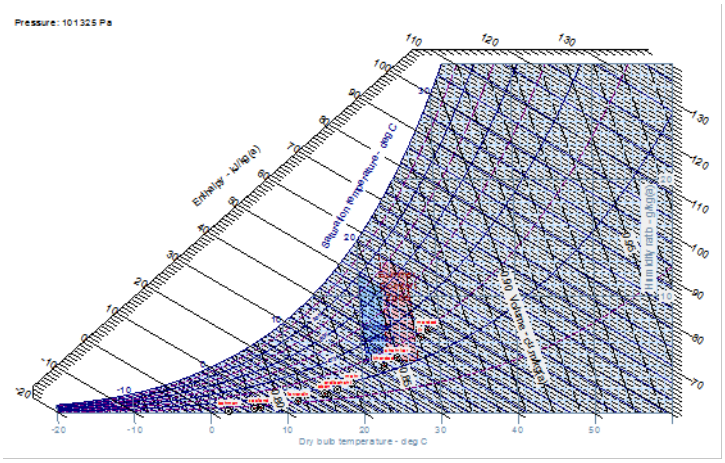

(5)

2.1 Description of the case study:

The monitoring of physical parameters has been performed in summer from 1389/4/5 to 1389/5/11 and three living-rooms with the expense of 30-32 m2 in 3 apartment buildings with northern, southern, and eastern directions were chosen as case studies. Te reason for selecting the living-room is that it is important because family spend most of their time there, ad their routine activities is done there, too. In our studies, we attempted to choose rooms that are similar regarding their total expense, living-room's expense, the extent of openings, the

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room's height, their year of construction, etc. and they are dissimilar regarding their direction and the number of floors. Al the studied apartment buildings had water coolers for summers and heater and fireplace for winters. Moreover, the occupants had the permission to open and close the windows for air-conditioning.

2.2Collecting data:

Thermal data and those of relative humidity have been calibrated by logger devices and recorded each 15 minutes for a week in summer case studies. Three kids of thermal probes with names of "tinytag ultra", "tinytag plus", and "tinytalk" have been utilized for recording thermal data and relative humidity for short-term measuring. All the probes have been calibrated before usage to be assured of their correct performance.

The temperature was recorded with spherical thermometers, too to be able to calculate the monitoring has been performed both about measuring the inner space's thermal conditions and outer space's thermal conditions. All the measuring devices have been contrived in the inner space and near the resting places of the occupants to be reflective of the situations and circumstances of the occupants. These devices have been put in places out of reach of children to reduce measuring mistakes, and we have put them away from direct influence of energy sources such as exit openings of cooling system, sunshine, equipments, etc. Figure 2 shows the devices used in monitoring.

We considered the occupants' clothes and activities in our visits to apartment buildings. After random measuring of air speed in the monitored rooms, we didn't face any considerable amount of air flow. Therefore, we assumed a value of 0/1 m/s for this variable to cover air speed in all monitored rooms.

During the study and the whole summer, we didn't notice variant levels in the occupants' dressings and activities, but they used special clothes based on the weather conditions. They were allowed to wear arbitrary clothes. Cultural, career, and gender elements were involved and effective in their amount of clothes to be worn.

For determining heat covering insulation levels of each group, Clothes, air flow speed, and occupants' activities were taken into account in assessments. Regarding the variant gender types of people under study, including children and adults, it is not such an easy task to determine levels of clothing's insulation that is applicable to all the occupants. Therefore, regarding three main groups of such places, we defined three models and averages for women, children, and men. This study assumed that the combination of different kinds of clothes for men is an average of heat insulation equal to 0/34 clo, for women 1/2, and for children 0/88 clo. The study also defines a range of 0/5 clo to 1/2 clo for women.

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Moreover, noticing different amounts of occupants' activities, determining their amount of activities is not possible. The occupants have different amounts of activities and metabolism while reposing, sleeping, walking, etc.; and their extent of metabolism is also dependant on their special features and also their amount of stress during the day. The women's feeling of hotter temperatures before and after menstruation is also normal. Considering these elements, the study assumes an average of occupants' activities during the day (from 8 a.m. to 9 p.m.) for women it is 2/5 met, for men 1/1 met, and for children 0/7 met while they are asleep.

2.3 Analysis and results:

This study has provided the real thermal conditions based on measurement and monitoring**.**

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2.4. Thermal conditions required in apartments in Iran (theoretical considerations):

Based on table 1, CIBSE 1999 has only defined air temperature and humidity to gain thermal ease. Although we know that different groups of occupants in apartments (women, men, children, and the elderly) need different extents of relative humidity and temperature. These dissimilarities are because of the difference in the amount of clothes they wear and the extent of their physical activities. The assessment, theoretically, show that the change in the extent of thermal ease conditions for occupants in Iranian apartments in between the range of 19 to 26 centigrade. This table provides the ranges of practical weather temperatures that are needed for different groups of occupants to achieve thermal ease. Therefore, it can be noticed that there is not an easily achievable range of temperatures that answers to both men's and women's demands, while the speed of air flow is fluctuating between 0/1 m/s to 5 m/s in a relative humidity of 40 per cent.

This study, as expected, shows that high speed of air flow in rooms extends the limitations of the range of acceptance of temperature in apartments in which building's occupants are comfortable. Although, it seems that there isn't an appropriate combination of air temperature and air speed in which both genders feel comfortable.

2.5. The results of empirical studies:

Table 2 briefly shows the foundings of the percentage of three northern, southern, and eastern blocs as prescribed in standards. Table 2 shows that in all the monitored southern living-rooms 10 per cent of the time they were in accord with the prescribed relative humidity and temperature of Iranian standard, which for northern and eastern blocs equals 5 and 1 per cent retroactively. The recorded records for humidity and temperature clearly show the incompatibility of the specific climate and inappropriate application of cooling systems in an unsuitable place, an issue that regarding the high price and lack of fossil fuels demands overwhelming attention.

	First Floor East	Northward 4th Floor	South ward 4th Floor
1.Unit area	100	97	98
2.Unit height from the ground surface	4	16	12
3.Whether windows are shaded vertically?	No	No	No
4.Whether windows are shaded horizontally?	No	No	No
5. Is connected to controlled space of underneath floor?	No	Yes	Yes
6.Internal temperature mean for 1 week	29.75 ◦c	27.78◦c	28.89◦c
7.Internal humidity mean for 1 week	30.31 % RH	42.56% RH	39.00% RH
8.Residents' self-reported thermal comfort(too cold, cold, neutral warm, hot)	Very Hot	Hot	Hot
8.Standard-based residents' comfort percentages (temp: 23 -26 C; RH: 30%-60%	0%	5%	10%

Figures 3-1 to 3-3 graphically shows the distribution of thermal conditions in all apartment buildings. This picture shows that most of the measured data are not in limitations of Iranian standard and CIBSE. But as the picture shows, when the data are out of limitations, the rooms general conditions became dry and warm and all northern, southern, and eastern occupants were at unsuitable thermal conditions in summer and the only thing they could do was to use cooling systems which need a lot of electrical and water energy.

The above tables and charts show that while southern bloc's occupants have better thermal ease conditions, those in eastern blocs experience unpleasant thermal ease conditions. These conditions are true when most occupants wear warm-weather clothes. Most occupants are young and have one or two children.

Figures 3. Distribution of thermal conditions in the city of Kermanshah and internal spaces of 3 buildings studied.

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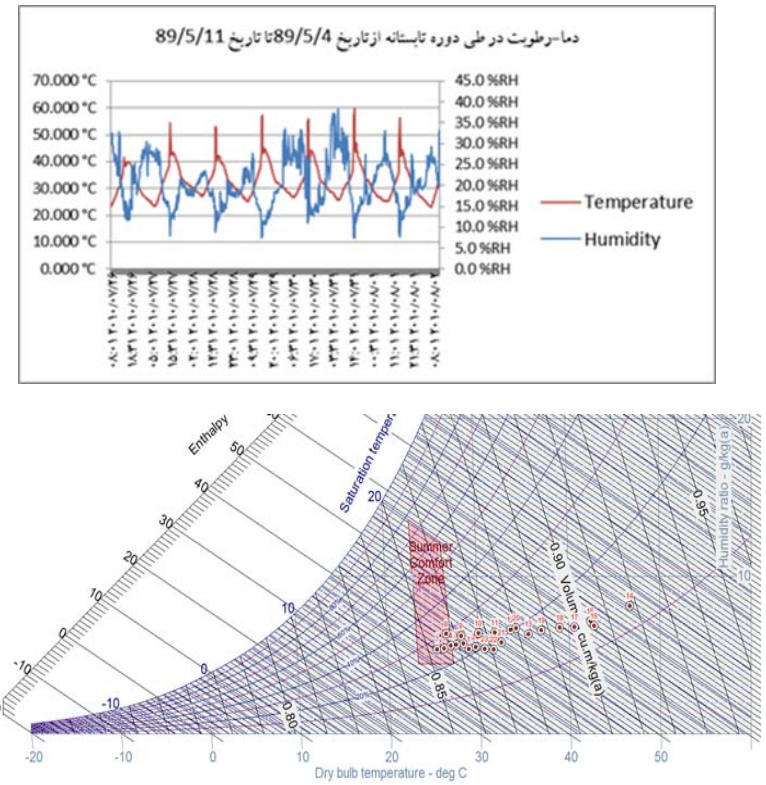

Fig. 3-1: Kermanshah city external temperature state and thermal comfort level.

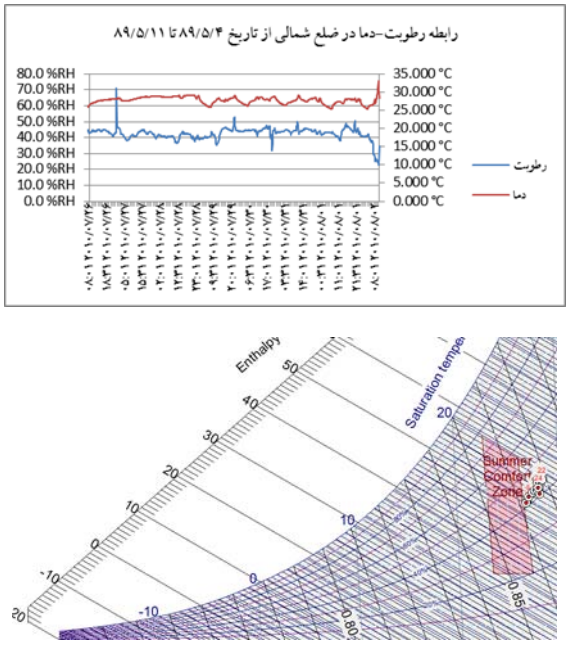

Fig. 3-2: Status of 4th floor northward unit and its residents' thermal comfort levels.

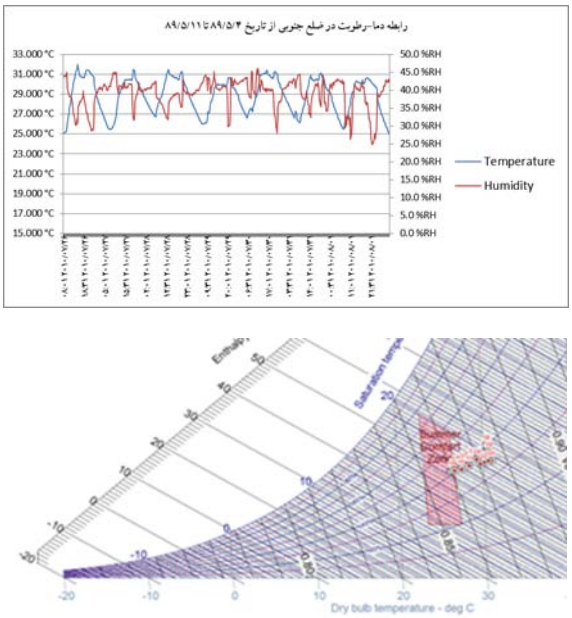

Fig. 3-3: Status of 4th floor southward unit and its residents' thermal comfort levels.

3.Conclusion:

Based on our results, it became obvious that northern, southern, and eastern bloc occupants are out of thermal ease limitations, and the eastern bloc occupants share a bigger amount of dissatisfaction. Therefore, it is more logical to build constructions in the eastern-western direction, in a way that the building's direction is northern-southern that reduces energy consumption and increases thermal ease of the occupants. The most important fact that we get from the charts is the influence of low extent of humidity in reducing thermal ease of the building. It can be also inferred from the psychometric table that in none of the samples the cooling systems has the needed ability to cool the place and positioning the water coolers on the roof causes the inefficiency of these devices that leads to an increase in the consumption of electricity thereof it is not possible to depend on such devices to achieve thermal ease in these apartments, and it demands the application of more modern systems that reduce energy consumption and add up to the air humidity.

What we get from the study of models and comparing them to the standards, has been gathered from different groups (women, children, and men) whose simultaneous preparation is so difficult. Meanwhile, the monitored thermal conditions of the apartments in Iran didn't confirm to the range of rules of national housing standard, article 19, and were out of limitations defined by international standards of ISO, ASHRAE, and CIBSE.

Finally, it shows numerous shortcomings in architecture, city construction in high apartment buildings. All the studied models have a humidity and a temperature that is out of thermal ease limitations, and is representative of the lack of concern of constructors for climatic issues that had led to the problem that high apartments are as intrusive constructions in the context of the cities that cause thermal islands around themselves.

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