# Effect of air movement in building

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ABSTRACT

A number of studies have examined the potential of using natural ventilation as a passive cooling system and comfort under warm conditions. Tanabe and Karma (1994) conducted an experimental work at 50% RH under different level of air speed. They found preferred speed at 28ºC to be 1.0 m/s, at 29.6 ºC, 1.2 m/s and at 31.3ºC, 1.6 m/s.

Although traditional architecture of Iran has a very good background in terms of passive building design strategies for achieving comfort condition, however, they are mostly ignored and people are concerned with the rising costs of electricity and fuel. In their buildings air conditioning is used during hot hours of the days. During the cooler hours, most people are still willing to open their windows and let fresh air in.

The problems with current designs have prompted designers to rethink their designs, particularly because of an increasing awareness of sustainability. To conserve energy and reduce $Co_2$ emissions. It is important to design energy efficient buildings.

This study addresses the effectiveness of air movement on human comfort and the effectiveness of natural ventilation in building design and energy saving.

## 1. INTRODUCTION

Unfortunately, in the third world today borrowing architectural ideas from the western modern style is usual. Developing countries started to receive a major influx of foreign ideas that were very different from their local traditions. One of the more unfortunate aspects of modern global development has been the introduction and widespread acceptance of the use of mechanical means for providing desired comfort levels for human habitation. This caused increasing demand of energy to power the mechanical comfort devices. In fact the proportion of energy used in buildings for providing indoor comfort conditions has significantly increased within recent years.

Fortunately, designers are now actively encouraged to look at energy usage and conservation in many different fields. Studies of indoor thermal comfort will provide an estimate of indoor thermal conditions, which are most suitable for the building’s occupants. It is useful for guiding the design of buildings and enclosed environments, for achieving energy savings and to guide the control of environments which people cannot control for themselves (Raw and Oseland, 1994).

## 2. TWO MAJOR PROBLEMS: WORLD POPULATION AND ENERGY USE BY BUILDINGS

World population has grown nearly seven-fold over the past 200 years. By 2050 there are likely to be nearly 10 billion people using the world’s resources of land, air, water and what lies underground. Of the world’s 6.5 billion people over 5 billion people now live in the poorer countries of our world, nearly 3 billion in rural areas. However, the likelihood remains of further major world population increase, virtually all of it occurring in developing countries. The population in the developed countries is expected to remain about static. The least developed countries are projected to increase their population from 658 million to 1.8 billion between 2000and 2050 whereas the world fertility rate in the period 1995-2000 averaged 2.82, the figure for the more developed countries was 1.57 and that for the least developed countries 5.47. Energy demand for such population is therefore expected to continue to rise.

On the other hand, the earth's energy resources are dwindling and fuels used for heating and cooling buildings constitute a large fraction of total consumption. The vast majority of energy input to buildings is, however, used for space heating and cooling, usually this is in the order of about 68% of the total input. Building energy use therefore has a significant impact on environmental concerns such as global climate change, nuclear waste and acid rain. Recent scientific consensus that this planet has indeed experienced a report, which predicted that in 25 years, energy use will have increased by 88 per cent compared to the 1990 level. In terms of energy sources, almost more than half the electricity is generated from oil, by oil-fired steam turbines or by diesel and at least one third of all commercial energy consumed is used to air-condition and light buildings. At a national or international levels there seems to be a strong case for energy conservation in buildings. Increasing demand for energy has impacted the natural environment and it is so badly condition which all of us are responsible to it. However, the common thread in all these impacts is how we use and abuse our land, water, energy sources and other species.

## 3. THERMAL COMFORT

The thermal comfort of building occupants is related to three groups of factors, namely physiological and psychological parameters match with behavior of occupants, design of the building and the outdoor environment. It may be possible using these principles to establish a set of guidelines for providing thermal comfort conditions in buildings. It cannot be questioned that people have recognized thermal comfort in different ways according to different insights and different expectations of life. These are numerous strategies to achieve thermal comfort. In many climates humans spend most of their time in cleverly constructed shelters and are interested in thermal comfort. One of these strategies is using air movement to achieving human thermal comfort.

For this study a number of routes exist for the investigation of air movement in or out of the buildings. The aim of some studies has been the prediction of air movement through certain standard structural elements or building types, with a view to assessing and minim sing infiltration and ventilation heat losses. A number of studies have examined air movement and comfort under different climatic condition. But the specific aim of present study is to find the potential of using air movement through of the building as a passive strategy and also addresses the effectiveness of it on human comfort. Thus the study has examined air movement and comfort under particular place in Iran.

## 4. AIR MOVEMENT AND HUMAN COMFORT

The effect of air movement on human thermal comfort is different. It depends on environmental temperature and humidity, as well as on the clothing. When air temperature is above the skin temperature, the effect of air movement will be the same as other climatic factors and the increase of air movement will raise the skin temperature (Hoppe, 1988). Air movement is more noticeable when the air is cool and the difference between skin and air temperature is large. Conversely, if the air is only slightly below skin temperature, very large increases in air speed are needed to achieve an increase in convective cooling (McIntyre, 1980). However variation in air velocity is important. ISO 7730, (1994) suggests that both mean air velocity and the standard deviation of the value should be taken. The air movement, in combination with air temperature, will affect the rate at which warm air or vapour (for example) is taken away from the body, thus affecting body temperature (Parsons, 1993). According to Humphreys and Nicol (1998) if the air in a space is still, a person loses heat by natural convection. The rate of heat flow by convection depends on the temperature difference between the surface of the clothed body and its surface area. It therefore depends on a person's posture, being least when the person is lying down and greatest when standing up. Posture also affects the area exposed to convection as this depends for example, on whether the arms are torching the body along their length, or the legs are together or apart. Furnishings such as desks or armchairs also affect his flow of the convection currents. If the convection currents become turbulent the heat transfer is increased. If a person is moving, or the air in the rooms is moving the convection changes because the envelope of rising air around the person is disturbed. The relevant parameter is then the movement of the air relative to the person. In general this increases the heat loss. The heat exchange coefficient at the surface of the clothed body then depends on the speed turbulence of the air impinging on the surface of the body. However, if the room is too warm for the occupant the air movement is perceived as a pleasant breeze, if the room is too cool, an unpleasant draught. This study has found not quite but nearly similar trends in Iran.

## 5. PLACE OF THE STUDY

The study used the subjects who are living in Ilam. This city is located in the west of Iran, and it lies at 1319 meters above sea level on latitude 33° 38′ N and 46° 26′ E longitude. According to Fisher (1968) Ilam is in the Zagros region, which is one of the four major parts of Iran. In this region, in terms of structure and topography, two distinct sub-regions may be recognised as a North-western section and the main Zagros. The general topographical effect on the north-west section is consequently that of a series of irregular tablelands, which lie at an average altitude of 1500 to 2000 m over much of the area, but another part of this region is quite different from the point of altitude. In this city the temperature difference between summer and winter is great, so that is creates an environmental conflict when determining the appropriate form and orientation for both the buildings and the whole settlement. Three months in the winter and four months in the year are periods featuring rather harsh conditions as cold and hot respectively? The most critical months of the year, from the point of view of temperature studies, are the midsummer and midwinter months, during which extremes of temperatures usually occur. In Ilam July is the hottest month and normally January is the cold month.

## 6. METHODOLOGY OF THE STUDY

The field study of thermal comfort is the methodology used for the present study, which is based on observations in the actual environments. The important advantage of the field studies is that it is an in-situ experiment, which means that the results of the method can be directly applied to similar thermal environments. The environmental parameters and personal parameters cannot be closely controlled, so the results are applicable to the normal conditions encountered by the respondents during the season of study. Two basic designs also have been used in the field studies; the longitudinal and the transverse. The longitudinal is to collect the survey data from comparatively few respondents and repeat the surveys over a period of weeks or months. From longitudinal it is possible to investigate the consistency of individual response and to observe the progress of adjustment to changing conditions. Because of the small number of respondents such a study may not provide data, which is representative of the wider population. The transverse is to use a large number of respondents and make only one assessment at a particular time and space. This type of study indicates the extent of variation among individual's responses and gives good estimates for the population (Humphreys, 1976). This field study uses the transverse design survey.

## 7. MEASUREMENT

Air temperature is the most important environmental factor. The study used air temperature as a principle physical variable and measured air velocity as a key parameter. Air temperatures were obtained from Skye Data Hog, data- loggers that gathered and stored results automatically and air velocities were measured frame Air velocity metter-Solomat 550. The data loggers and air velocity meter were carried from subject to subject and measurements of the environmental data taken for the subject making a comfort assessment. The time was accurately written on the questionnaire. The number of data loggers, which were used in each building was equal to number of the subjects except when subjects were in the same place. For individual parameters clothing values were measured. The data on clothing were very important because clothing plays a more important role in thermal comfort. Clo units for clothing insulation are used. The study also asked subjects condition. In terms of sensation two forms of subjective scales with minor variations are about equally common: the Bedford scale and the ASHRAE scale. In this study the ASHRAE seven-point scale was used. The preference vote and air movement votes on three-point also were used.

## 8. DATA

The total sample of responses numbered 1187 drawn from occupants during hot and cool periods. Eight hundred and nine sets of these were obtained in the hot period and 378 sets were in the cool period. From all subjects 628 were men and 559 were women. The age of the subjects ranged from 12 to 75 years with a mean of 36. All subjects were in good and normal health.

The summaries of the climatic data in their means, ranges and standard deviation are tabulated in Table 1.

Temperatures averaging around 30°C for all spaces with 10°C differences between hot and cool seasons (around 20°C in cool season) makes a good opportunity for significant results. Mean square roots of air velocity were 0.3 $(m/s)^{0.5}$ in hot season. This amount was 0.2 $(m/s)^{0.5}$ for indoor condition during cool season. A minimum of zero in the air velocity showed all opening were kept from any air movement, as was seen by the researcher.

Table 2 presented summary of clothing information during two experimental works.

The distribution of sensation votes for both seasons is shown in Table 3. The first and important point is that over 90% of subject votes during both seasons in indoor conditions indicated one of three central categories, between slightly cool and slightly warm. There were no responses on both extreme sides. It is surprising according to the range of air temperature during both seasons that this is enough for the range of comfortable condition. It is also shown that people can be comfortable in many environmental conditions. However the distribution of votes is different for both seasons.

Responses to the preference scale were 23% preferring "no change", 76% for cooler and 1% for warmer during the hot season while these amounts in the cool seasons for warmer and cooler was vice versa and "no change" was equal with hot season. From both experimental work 23% preferring "no change" 52% preferring "cooler" and 25% preferring "warmer". The distributions of thermal preference votes in

Table 1: Mean and standard deviation of environmental data.

| | All.H | All.C | All |
|---|---|---|---|
| Mean Ta | 30.6 | 20.0 | 27.2 |
| SD | 2.51 | 1.73 | 5.43 |
| Min. | 25.4 | 15.4 | 15.4 |
| Max. | 44.4 | 23.0 | 44.4 |
| Mean $\sqrt{V}$ | 0.37 | 0.17 | 0.30 |
| SD | 0.10 | 0.06 | 0.13 |
| Min. | 0.17 | 0 | 0 |
| Max. | 0.73 | 0.31 | 0.73 |

Table 2: Mean and standard divination of clothing value.

| | All.H | All.C | All |
|---|---|---|---|
| Mean clo. | 0.60 | 1.49 | 0.88 |
| SD | 0.19 | 0.34 | 0.48 |
| Min. | 0.37 | 0.90 | 0.37 |
| Max. | 1.92 | 2.19 | 2.19 |

Table 3: Mean and standard deviation of sensation votes.

| | All.H | All.C | All |
|---|---|---|---|
| Mean S | 0.59 | -0.2 | 0.34 |
| SD | 0.74 | 0.59 | 0.78 |
| Min. | -1 | -2 | -2 |
| Max. | 3 | 3 | 3 |

the hot and cool seasons are shown in Table 4.

Subjects indicated their feeling in terms of air movement on a three-category scale. This study used the three-point scale because of low air speed. More than three categories become difficult to recognize. From Table 5 it seems most people were in "just right" condition in terms of airflow during hot season, which is about 70%. The subjective assessment of the air movement by subjects was still (about 73%) during cool season.

## 9. ACCEPTABLE CONDITIONS

As an accepted method for predict boundaries of comfort conditions and according to ISO 7730-1994, the range of PMV (predict mean votes) between [-1 to +1] (of sensation votes on ASHRAE seven point scale) would result in 75% of subjects feeling satisfaction with their thermal environment. For satisfaction of 90% of subjects the range of PMV would be between [-0.5 to +0.5]. In line with this acceptable method the neutral temperature and boundaries of acceptable conditions in both seasons are presented in Table 6.

The results of this study show that in the range of air temperature of 23.0– 30.0 °C around 70% of subjects were in a neutral condition (sensation vote = 0) and all subjects were in comfortable condition [-1 to +1] during hot season. Ninety-six percents of subjects at the range of 17– 24°C also were in a comfortable condition during cool season. These results show that the proportion of subjects feeling comfortable within the range of [-1 to +1] are higher than those predicted by the PMV model in ISO – 7730 (1994). ASHRAE standard 55 defines an acceptable thermal environment as one that satisfies at least 80% of the occupants. In this study 80% of subjects were comfortable during hot season, when the upper limit of the comfort zone was 31.8°C.

## 10. EFFECT OF AIR MOVEMENT ON THERMAL SENSATION

As said ASHRAE standard 55 sets an upper limit of around 0.2 m/s (assuming typical turbulence around 40%) for air velocities within the basic comfort zone to reduce the risk of discomfort from drafts. Higher air speeds are acceptable in an extended zone up to 0.8 m/s if the person has individual control of the local air speed and "to increase temperature to 3°C above the comfort zone" (ASHRAE, 1992). Nicol (1972) in his analysis on Webb's data in Iraq and India noted that air movement reduced discomfort from heat at temperatures above 31°C; below this temperature there were few votes in-

Table 4: Tabulation of thermal preference votes.

| Preference scale | | All.H | All.C | All |
|---|---|---|---|---|
| Cooler | Number | 612 | 6 | 617 |
| ( -1 ) | Percent | 75.5% | 1.5% | 52.0% |
| No change | Number | 190 | 100 | 273 |
| ( 0 ) | Percent | 23.5% | 26.5% | 23.0% |
| Warmer | Number | 7 | 272 | 297 |
| ( 1 ) | Percent | 1.0% | 72% | 25.0% |

Table 5: Tabulation of air movement votes.

| Scale | | All. H | All. C | All |
|---|---|---|---|---|
| Still | Number | 9 | 275 | 284 |
| ( -1 ) | Percent | 1% | 72.8% | 23.9% |
| Just right | Number | 561 | 78 | 639 |
| ( 0 ) | Percent | 69.3% | 20.6% | 53.8% |
| Breezy | Number | 239 | 25 | 264 |
| ( 1 ) | Percent | 29.5% | 6.6% | 22.3% |
| Mean | | 0.28 | -0.66 | -0.02 |

Table 6: Neutral temperature and comfort zone during both seasons.

| | Neutral temperature | $R^2$ | Acceptable condition (75%) | Acceptable condition (90%) |
|---|---|---|---|---|
| Hot season | 28.1°C | 0.64 | 23.8 – 32.3°C | 25.9 -- 30.2°C |
| Cool season | 20.8°C | 0.57 | 16.8– 24.7°C | 18.8 -- 22.7°C |

Table 7: Effect of air velocity on thermal sensation at different temperature and air velocity ranges.

| Range of air temperature | | 25-27 | 28-30 | 31-33 | 34-36 | 37-39 | 40-42 |
|---|---|---|---|---|---|---|---|
| Mean of | V(m/s)> .25 | -0.5 | 0.14 | 0.91 | 1.5 | 2.5 | 3 |
| Sensation votes | V(m/s)< .25 | -0.25 | 0.16 | 1 | 2.08 | 2.11 | 2.25 |

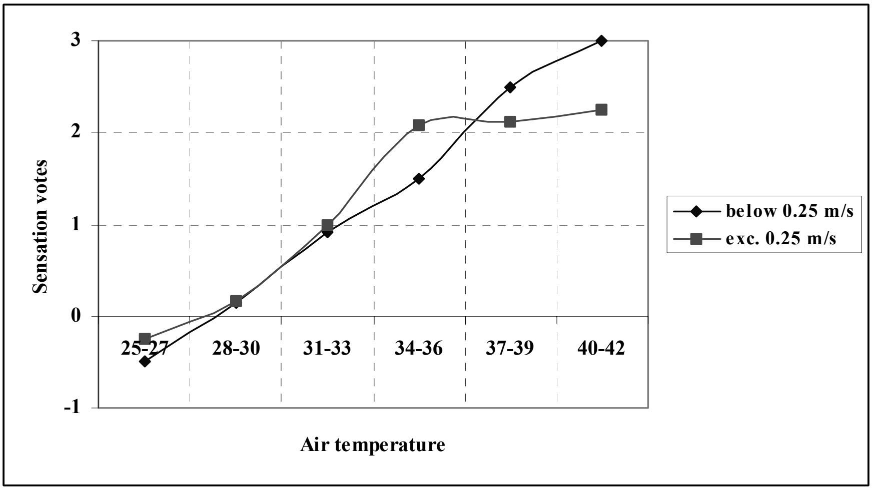


Figure 1: Sensation votes in the different categories of air temperature and air movement.

dicating heat discomfort. At temperatures exceeding 40°C discomfort from heat was experienced whatever the air velocity. Similarly, and according to Givoni (1998), at temperatures below 33°C, increasing air velocity reduces the heat sensation. At temperatures between 33°C and 37°C, air velocity does not affect significantly the thermal sensation. At temperatures above about 37°C increased air velocity actually increases the thermal sensation of heat. Table 7 and Figure 1 show the effect of air movement on sensation votes at different ranges of air temperatures in the present study. These results agree with results of Nicol’s (1972) work. Air movement reduced discomfort from heat at temperatures above 31°C, although it seems that in the range of 31.0-33°C the difference between sensation votes in the two categories is little, but it is noticeable that clothing of subjects in low air velocity category (V(m/s)< 0.25) was 0.53 clo while in another category it was 0.72 clo. About 0.2 clo difference between clothing values implies more difference between sensation votes. At temperatures exceeding 37°C, increased air velocity increases the thermal sensation of heat and this is in agreement with Givoni’s idea. Mallick (1996), in a thermal comfort study in Bangladesh, noted that the comfort temperatures of subjects increase with air movement of 0.3 m/s. There is a rise in the lower and upper limits of comfort range by 2.4°C and 2.2°C respectively. It is possible that within the range of the comfort zone air velocity does not have an effect on the thermal sensation, but at temperatures beyond the upper limit of the comfort zone air velocity has a positive effect on the thermal sensation (but for air temperatures less than 40°C). The difference between mean indoor air velocity during hot and cool seasons is interesting. The mean value of air velocity in the hot season is 0.14 m/s and in winter 0.03 m/s. This is equivalent to a change of at least 1.0°C in neutral temperature. As mentioned, there was a good relationship between temperature and air velocity within the hot and cool seasons.

## 11. CONCLUSION

1. The pattern of sensation votes showed that more than 90 percent of voters indicated one of three central categories on the seven point ASHRAE scale. There were no indoor responses at both extremes side.
2. This study showed a high relationship (but negative) between clothing insulation and air

temperature during the cool season. As an important point the present study well shows that lower temperatures are related to higher clothing insulation

3. The mean sensation votes were 0.59 in the hot season and –0.20 in the cool season. The neutral temperature was 28.1°C with acceptability limits of 24.0°C to 31.8°C (80% satisfy) and a regression slope of 0.24 for hot period and it was 20.8°C with acceptability limits of 17.2°C to 24.2°C (80% satisfy) and a regression slope of 0.25 during cool period
4. The seasonal changes in neutral temperature could be attributed to change in mean air velocity
5. The effect of air movement on thermal sensation showed that at temperatures below 33°C, increasing air velocity reduces the heat sensation and at temperatures between 33°C and 37°C, air velocity does not affect significantly the thermal sensation. At temperatures above about 37°C increased air velocity actually increases the thermal sensation of heat.
6. Finally this study explored the possibility for natural ventilation in building design. The study shows that air movement could be effective on human comfort and human comfort is a main point in building design

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