A STUDY OF THE FACTORS FOR THERMAL COMFORT IN RESIDENTIAL HIGH-RISE IN DHAKA CITY

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ABSTRACT

A STUDY OF THE FACTORS FOR THERMAL COMFORT IN RESIDENTIAL HIGH-RISE IN DHAKA CITY

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Living in high-rise apartments has been accepted in congested busy cities all over the world and Bangladesh is no exception. A few years' back high-rise apartments were considered to have been so costly as to have been owned by the affluent people only. The recent developments like reduced price, availability of bank loan and government programs to accommodate government personnel in multi-storied buildings have paved the way for the middle income people to live in such apartments. With this change, however, a new responsibility has been placed on the shoulders of the designers of such buildings. While the affluent owners could afford to install and maintain costly gadgets to moderate climatic adversities, the new owners and users, being less affluent can neither afford to install nor maintain costly gadgets. Also, the excessive uses of such gadgets should be discouraged in view of the power crisis in the country, specially in the large cities.

The new responsibility that has been placed upon the designers of high-rise apartments is to design user-friendly, climatically comfortable and energy-efficient apartments. The success of such design lies in the optimum utilization of natural light and ventilation for ensuring thermal comfort. This study project was undertaken to study the existing situations of climates inside high-rise apartments. One objective was to understand the current problems and inadequacies, to conduct studies and investigation to find out causes, such that design guidelines for their improvement can be suggested. The benefit of prevailing wind may be utilized in case of building, where the designer gets scope to maneuver its orientation and configuration. This is seldom possible in case of buildings to be constructed on small-size plots inside congested busy cities. The best way to ensure optimum natural light and ventilation inside is to have suitable-sized windows and other openings at suitable locations. The architects, in general, provide necessary openings and the middle-income people are used to keep their windows open, of course with the use of curtains, for getting in natural light and fresh air, and also for good views. With light and air such openings also bring in the external temperature and humidity. These two important factors of climatic comfort increase further due to presence of human being and their gadgets. One novel way to keep this internal-external variation 'minimum' is to intelligently design the openings by size, locations, fragmentation and passive design elements. Because of their natural settings the rooms at various cardinal locations show difference in temperature and humidity. So, another intelligent way of optimum use of climatic benefit is to accommodate the appropriate type of activities at the proper locations. One objective of this study was to find out the climatic characteristics of rooms at various locations due to their natural settings

This study may be considered as a 'Post Occupancy Occupation Evaluation (POE) of high-rise apartments in climatic aspect', that may acquaint the designers of such apartments to have understanding of various factors responsible and contributing to the creation of 'comfortable' and 'uncomfortable' climatic conditions. It is expected that this understanding would help them to have the knowledge and understanding most essential for designing 'climate-friendly and energy-efficient high-rise apartments for the less-affluent users'.

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PREAMBLE

The principle objective of this work as outlined in the proposal was "to find out factors responsible for the climatic comfort and discomfort in high-rise residential buildings in various locations of Dhaka city. The study is also expected to reveal if there exists any relationship between the inhabitants' feelings of climatic comfort and the locations/orientations of the rooms, architectural design, materials, finishes etc."

For the purpose of investigation and studies of microclimates in various rooms and spaces of high-rise residential buildings 27 living units in 7 buildings located at 5 different locations were selected. The five locations of buildings were (01) Old Dhaka adjacent to Buriganga river to study the effect of the river as additional element, (02) Shantinagar on the north of a busy road and within agglomeration of buildings (03) Elephant road · on the north of the busy commercial road, (04) Farm gate : an area away from busy commercial road and within agglomeretion of high-rise buildings and (05) Dhanmondi residential area : on the east side of a busy road. All these areas have got distinctively different site influences to have reflections on micro-climates. The electronic Hygro-thermometer Clock was used for recording temperature and relative humidity. Also a questionnaire was used to record the comments of the users regarding their feeling of microclimate inside the rooms, such that those could be compared with the measured ones

Chapter One presents a background for this investigation and study and includes in brief, such information like how the habitation of city changed from detached independent rural house to low-rise brick building, to four storied "one-stair-serving-two" type apartments to the present high-rise tower buildings, how the climate changed through years with gradual disappearance of green and open spaces, fields, water bodies etc., how numerous industries and motorized vehicles influenced the city's climate and how all these factors created numerous small regions with independent macro-climates throughout the city.

The Second Chapter deals with the various aspects of climate in general and that of Dhaka city in particular, as a basis for understanding of the problem to be addressed in this work It also mentions brief findings of some works on the climate of the city, conducted in recent years by some researchers

The Third Chapter deals with various aspects of habitation and residential buildings, including the role of architectural design aimed at satisfying user's needs, comfort and aspirations, to suit urban design requirements as also to take care of the profit of the entrepreneurs, who in general consider construction and selling of apartments as a business. It also mentions the Urban Construction regulations and bye-laws, which have relevance with climatic comfort of the users.

Chapter Four describes how the investigation was conducted as per pre-determined methodology. It may be mentioned that as per initial proposal various information regarding the construction materials, internal color, finishes, furniture etc. were collected However, it was later found that those were not much relevant to the investigation, since those were found to have little effect towards the micro-climates inside the rooms.

Chapter Five presents the analysis of the findings that were made in order to find out whether any relation of climatic condition can be established with the vertical position and horizontal location of the room under study, whether or how far the instrumental readings match with users' preferences and so on. It also describes some 'unusual observations' as observed during investigation and also presents probable explanations for those.

In Conclusion, attempts have been made to use up the findings and analysis such that those may be of use by the designers in their endeavor to design climatically better and comfortable apartments within the current bindings and limitations.

Chapter 1

BACKGROUND

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BACKGROUND

1.0 INTRODUCTION:

Dhaka, being the capital of Bangladesh is the most important city of the country. In addition to housing the central administrative and institutional facilities, the city now accommodates nearly 10 million people (Population Census 2001) on an area of 1533 square kilometers (Urban Area Report 1997). These statistics have been presented in more details in respective Chapters. However, the above two figures indicate density of about 6,500 persons per Square Kilometer. A considerable portion of land of the city is now under the control of law-enforcing authorities and that in fact results in higher densities in habitable areas. Pressure of population on limited land has initiated construction of multi-level buildings for habitation in the city. High-rise apartment buildings are now common scenes. According to the Climatologists, the growth of high-rise buildings at close proximity and the use of vehicles have changed the general city climate and have created numerous micro-climates in some areas. It is obvious that such changed micro-climates affect the climates inside the adjacent habitable buildings

The subjects to be discussed in this Chapter include such topics as Objective of study, Background information regarding Bangladesh and Dhaka city, Habitable uses of tall and high-rise buildings with special reference to climatic contexts, Methodology for investigation etc

1.1 OBJECTIVE OF STUDY:

The objective of this study as outlined in the proposal for studies was to find out the climatic conditions inside rooms and spaces of high-rise buildings, to find out if those at higher altitudes vary from that at the lower levels, if there exists any relationship between the inhabitants' feelings of climatic comfort and the location/orientation of the rooms, their architectural design, materials, finishes etc.

1.2 BACKGROUND:

A brief background regarding Bangladesh and Dhaka city, the various contexts and reasons behind the growth of residential buildings in the city, the factors affecting climate and micro-climate inside the city etc. will be discussed hereunder. However, the relevant subjects will be discussed in further details in specific chapters on that subject

1.2.1 BANGLADESH AND DHAKA CITY:

Bangladesh, one time province of erstwhile Pakistan emerged out as an independent state in 1971 Dhaka, being the capital city of this new country witnessed tremendous rate of urbanization during the recent decades. Accommodations were to be constructed for the government offices and the people working there in. People from the rural and fringe areas rushed in to enjoy the benefit of living in the capital city, and the vast number of wage-earners staying in the middle-eastern countries wanted to have accommodation for their families here In such a context, there was a trend to construct houses on all available land. This trend increased the price of land by manifold, in most cases, beyond the limit of the common men Since the city is enclosed by the river Buriganga on the south, Gazipur reserve forest on the north and low lands on the east and west, lateral expansion was both difficult and expensive. Such a context prepared the necessary background for the growth of high-rise buildings in all possible locations.

RAJUK (Rajdhani Unnyan Kartipakkha), the organization responsible for development and control of built-forms in the city prescribes for leaving certain open space on all sides of a building This set-back depends up on a number of factors like plot-size, width of adjacent road, height of building etc and this amounts from 0 to 2 meters[01] After the developers found the construction and sale of apartments as lucrative business, they were after utilizing every square meter of available land, leaving the bare minimum land as specified by RAJUK and at times even encroaching the same. In Bangladesh there is no system of 'Mock-up flats' [02] or Post Occupancy Evaluation (POE) [03] as practiced elsewhere in the world. Thus there is no way of knowing, how far these apartments fulfill the needs of the users. Since most, if not all of the developers are in the habit of constructing apartments leaving more or less the bare minimum open space prescribed by the urban authorities, the intending purchasers of apartments get little scope of comparison and have to accept whatever is available. Once inside the apartment the users have to adjust to the situation that they often do by using electric gadgets like ceiling fan, exhaust fan, light, air-conditioner etc. and suffer from the consequential cost of energy. Their dependence on energy tells upon the present energy-crisis of the country.

1.2.2 GROWTH OF RESIDENTIAL BUILDINGS IN DHAKA:

Situated on 20^0 30' - 26^0 38' North Latitude and 88^0 00' - 92^0 56' East Altitude, with 12,31,51,246 population [04] in an area of 143, 992 sq. kilometers, with a density of 834 persons per Square Kilometer[05] and a GNP per capita $ 350 (1998) [06] Bangladesh is one of the third world countries, endeavoring hard to rise out of her present label and level. The land was part of British-ruled India up to August 14, 1947, after which it became part of Pakistan. After a nine-month long war for liberation that initiated on the night of 25th March 1971, it emerged out from Pakistani as an independent state rule on December 16, 1971.

Situated on 23^0 43' North and 90^0 24' East Dhaka has a population of 99,12,908, in 20,89,336 households with household size 4.7 persons per household [07] in Dhaka Statistical Metropolitan Area, comprising of Dhaka city corporation, Narayangonj, Kadamrasul, Savar and Tongi. The population under Dhaka city Corporation is 53,78,023, in 11,07,474 households with household size of 4.8 persons per household[08]

The 'Urban Area Report' of census gives details regarding areas of urban cities, number and types of structures etc This report of Bangladesh Census 2000 is now under process and is expected to be published in 2005. The urban area report of Bangladesh Census 1991 was published in 1997, according to which the area of Dhaka mega city is 1353 Square Kilometer, with population 64,87,459 and households 11,74,282[09]. About 1 1 million people live in slums and squatter settlements [10] and 3.0 million live below the poverty line[11]. According to reports of the United Nations Population Fund, by the year 2015 Dhaka will be the ninth largest mega-city in the world [12]. The country at present faces acute shortage of housing and the situation is worsening with time. The inter-censal urban population growth of the country has been presented in Table 1-01 below.

Table 1-01.

INTER-CENSAL URBAN POPULATION GROWTH OF BANGLADESH 1901-2001

CENSUS YEAR	URBAN POPULATION	% OF NATIONAL POPULATION
1901	7,02,035	2.43
1911	8,07,024	2 55
1921	8,78,480	2 64
1931	10,73,489	3.66
1941	15,37,244	3 66
1951	18,19,773	4 33
1961	26,40,726	5 19
1974	62,73,602	8.78
1981	1,35,35,963	15 54
1991	2,24,55,174	20 15
2000	2,88,08,477	23 39

Source : BBS. BANGLADESH POPULATION CENSUS 1991, Vol 3 Urban Area Report, 1997 and BBS POPULATION CENSUS 2001. Preliminary Report. August, 2001[13].

The information regarding rate of population growth of the SARC countries in the urban areas is available up to 1991 and has been presented in Table 1-02. In this table, it may be seen that Bangladesh has the third highest urban population growth after Bhutan and Nepal

Table 1- 02

ANNUAL URBAN GROWTH IN SARC COUNTRIES

COUNTRY	YEAR	POPULATION IN MILLION	TOTAL POPULATION GROWTH RATE	URBAN POPULATION GROWTH RATE
Bangladesh	1991	111 5	2.17	5.4
Bhutan	1991	1.5	2 3	5 9
India	1991	853.1	2 1	3 9
Nepal	1991	19 1	2.3	5 5
Sri Lanka	1991	17.2	1.3	4 6
Pakistan	1991	122.6	2.9	2.4
Mal Dives	1991	0.2	–	---

Source: BBS. BANGLADESH POPULATION CENSUS 1991, Vol. 3. Urban Area Report, 1997 and BBS BANGLADESH POPULATION CENSUS 2001 Preliminary Report August 2001[14]

According to one researcher, during the period 1971-96 the urban population of the country increased by 6% [15]

In as early as 1958, for accommodating more people on less land, the firm of Minoprio, Spencerly and Macfarlane suggested for "development of blocks of flats" to replace the congested old city" [16]. No doubt, they made this suggestion in the then context of old Dhaka, where the buildings were mostly two storied and four-story high building were not in vision. By the seventies, however, four storied buildings turned out to be a common scene in the city, especially in the newer northern part. After the government initiated construction of four storied buildings, the common people also accepted the idea as a means of 'accommodating more people on less land, as followed elsewhere It was soon observed that with expanded urbanization and increased pressure on lands, four storied residential buildings became the more common housing type in Dhaka city [17].

Twenty years back Dhaka city dwellers were reluctant to live in flats above four or five stories high[18] possibly because of a change in living pattern due to dis-association from the ground But in the later part of seventies, when the wage earners from the middle eastern countries looked for houses in the urban areas and wished to bye-pass the cumbersome process of acquiring land, getting plan passed and indulge in construction works, a new demand for ready-made apartments was felt The developers came to meet this demand and consequently the construction of 10 to 20 story high apartment buildings was initiated Even though disliked at the initial stage for a number of reasons, the Dhaka city dwellers by now have shown increasing interest in owning and living in apartments. Some experts observe that high-rise buildings are generally constructed to ensure economical use of land in areas where land is scarce and its cost is high [19] This is very true in case of Dhaka In such a context, there had been a new trend of housing developments in a mass scale mainly in the private sector, as a result of which Dhaka has experienced a new type of residential development, broadly termed apartment development. The situation has been expressed by an expert as "A recent trend observed in Dhaka's urban fabric is the rapidly growing number of high-rise apartment blocks, developed by real-estate developers in the formal newer part of the city. These blocks serve to mitigate, to some extent, the severe housing problem which has been caused by the increasing population in this capital city' [20].

The causes of construction of high-rise building, however, vary widely from one country to another and those include factors ranging from creation of corporate image for the affluent firms to means of making money Theoretically, a number of single-storied houses staying side by side on land, when placed one above the other, can form a high-rise housing In practice, however, the process is much more complex and problematic. As soon as such a house soars high up in the sky, apart from engineering complexities of construction and maintenance, there arises problems relating to physical, psychological and climatic environments[21] Of all these aspects of high-rise building climate seems to be most important in case of residential high-rise because such buildings cater for continuous occupancy and multiple activities talking place almost continuously and simultaneously. The climate dependency is greater for this class of buildings, where comfort conditions have to satisfy an extremely wide range of user population, rather than for the single-use and limited time occupancy class of structures [22].

1.2.3 CLIMATE, REGIONAL CLIMATE AND SITE OR MICRO-CLIMATE:

Climate plays crucial and important roles in human habitation. The climate of the external nature in its exactness is not available inside built-forms, because these forms considerably change those. The microclimates inside the built-forms are of utmost importance for living comfort. Various factors like components of climate in general, those affecting regional and micro and site climates, how and to what extent those affect the microclimates in Dhaka city etc will be discussed here

(i) COMPONENTS OF CLIMATE: Climate is the composite effect of a number of factors. Various climatologists have mentioned these factors in different ways, for example,

i). Jeffrey Ellis Aroin[23] in 'CLIMATE AND ARCHITECTURE' mentioned components of climate as:

(1) Sun, (2) Temperature, (3) Wind, (4) Precipitation, (5) Lightning and (7) Humidity.

ii). Koenigsberger[24] in 'MANUAL OF TROPICAL HOUSING AND BUILDING' mentioned components of climate as: (1) Temperature, (2) Humidity, (3) Precipitation. (4) Sky condition, (5) Solar Radiation, (6) Wind and (7) Vegetation.

iii). B. Givoni[25] in 'MAN, CLIMATE AND ARCHITECTURE' mentioned components of climate as: (1). Solar Radiation, (2) Long-wave radiation to the sky, (3) Air Temperature, (4) Humidity (5) Wind and (6) Precipitation.

iv. Markus and Markus[26] in 'BUILDING, CLIMATE AND ENERGY' mentioned components of climate as: (1) Temperature, (2) Humidity and (3) Air movement.

v). B Givoni[27] in 'URBAN DESIGN IN DIFFERENT CLIMATES' mentioned components of climate as: (1) Temperature, (2) Humidity, (3) Wind condition (4) Solar radiation, (5) Long wave nocturnal radiation, (6) Fog and precipitation and (7) Turbulence and chemical composition of air.

(ii) REGIONAL CLIMATES: While global climates composed of the above mentioned factors are extremely variable, the climatologists, depending on a number of similarities or common characteristics, have classified those into a number major regional climates as mentioned hereunder:

i). According to Koenigsberger[28] (MANUAL OF TROPICAL HOUSING AND BUILDING) various regional climates are. (1) Warm Humid Equatorial Climate (2) Warm Humid Island Climate (3) Warm Humid Trade wind Climate (4) Hot Dry Desert Climate (5) Hot Dry Marine Climate (6) Composite Monsoon Climate (7) Tropical Upland Climate.

ii) B. Givoni[29] in 'MAN, CLIMATE AND ARCHITECTURE' mentioned the following as regional climates (1) Hot Dry Climate (2) Warm Wet (a) Equatorial and (b) Tropical Maritime Climate (3) Hot Dry and Warm Tropical Continental Climate (4) Warm Temperate (a) Monsoon (b) Mediterranean (c) Continental (d) Marine and (e) Mountain Climate (5) Eastern Marginal Type Climate (6) Cool Temperate Continental Climate (7) Marine Climate.

iii) According to Martin Evans[30] (METRIC HANDBOOK) the regional climates are (1) Warm Humid Equatorial Climate (2) Tropical Island Climate (3) Hot Dry Tropical Climate (4) Maritime desert Climate (5) Intermediate Composite or Monsoon Climate (6) Equatorial Upland Climate (7) Tropical Upland Climate (8) Mediterranean Climate

(iii) SITE OR MICRO-CLIMATES: Regional climates serve no effective purpose to the designers of built-forms, who need more intense information for designing buildings in any location in any country of the globe MicroClimate is the term usually used to denote the climate of small-sized and specific areas. In place of using the term micro-climate Koenigsberger, however, used the term 'Site Climate' because according to him '(micro-climate) can imply any local deviation from the climate of a larger area, whatever the scale may be. The botanist may consider the microclimate of a single plant leaf, with its temperature and moisture conditions, its population of insects and microorganisms, on the scale of a few centimeters. For the urban geographer the term micro-climate may mean the climate of a whole town"[31].

In case of living comfort in cities, what really matters is not the global climate, and not even the regional climate, but the micro or site climate. In large cities there may exist numerous microclimates due to the local influences of such factors as buildings and structures, roads and pavements, green areas and water bodies, heat and gas generating factories and numerous vehicles According to Markus et al. regional climate on a horizontal scale varies up to 1000 kilometers, top climates extend up to 10 kilometers horizontally and 1 Kilometer depth and micro-climates limit to about 1 kilometer horizontally and 100 meter vertically[32].

While various experts like Leonardo da Vinci[33] recognized 'influence of humidity', John Arbuthnot[34], 'effect of air movement', Thomas Tredgold[35] 'radiant heat' etc. on human comfort, C.P. Yaglou[36] in 1923 published the results of his experiments, in which he presented how the effect of temperature, humidity and air movement on human comfort could be measured. In addition to external climatic factors, human comfort also depends up on subjective variations like age, sex, health condition, clothing, food habit etc. of the subject or person under study. On the basis of their experiments and observations the experts have formulated various scales in combination with Temperature, Humidity and Airflow and those are now used to measure climatic comfort in different climatic situations all over the world Even though the climatic, cultural and physical context prevailing in our country considerably vary from those of the other countries we still have to use those scales, because no such scale was ever developed in our land.

Humphrey[37] in 1935 used a scale, using only Temperature to indicate thermal comfort within a range of 17 ^{0}C to 33 ^{0}C By his consideration since human were accustomed to live within the limit of a maximum and a minimum temperature, they should logically feel comfortable at a temperature near to the average temperature. By experimenting and collecting responses from a number of subjects Humphrey calculated that Neutral Temperature varied from the average temperature as expressed by the equation. $T^n = 2.56 + 0.831\ T^m$ (^{0}C) where T^m stands for average temperature and T^n, for Neutral Temperature His final comment was that normally a band of 4^0 C (2^0 C above and 2^0 C below) centered around T^n comprised the comfort zone. The designers of built-forms, however, were aware that climatic comfort inside the buildings couldn't be expressed through temperature only

Whenever an open country turns into a built-up city, there remains every possibility for temperature inside the city to be higher than the surrounding areas The air flowing through the open country skips the built structures, leaving stagnant air undisturbed in between the built-forms Thus such pocket areas cannot have the benefit of cool air on one hand, and on the other, the heat trapped there cannot escape. Water bodies, green trees, grasses etc reduce heat by the process of evaporation of water. In a congested city, these are gradually replaced by built-forms, roads, pavements, hard courts etc., which first absorb and then emit heat Various machineries and gadgets used in houses and factories, vehicles plying on roads etc. also contribute towards increasing of heat. Some climatologists believe that due to these reasons 'heat island effect' which means an increase of heat from the surrounding open country, has already taken place in Dhaka city. Numerous microclimates, differing in temperature and humidity are now a common experience in Dhaka city and may be easily experienced by one moving from one end of the city say, from the bank of the river Buriganga to congested old Dhaka, through busy markets to the less congested northern part These have been discussed in more details in the Chapter on Climate.

(iv) CLIMATE OF DHAKA: According to some climatologists[38] the climate of Dhaka is tropical. The climate is greatly influenced by the presence of Himalayan mountain range and Tibet plateau in the north and the Bay of Bengal in the south. The climate is characterized by four main meteorological seasons, namely, winter, pre-monsoon monsoon and post monsoon. Period May to March falls under pre-monsoon In this season, maximum day temperature varies between 37^0 and 40^0 C, even though it has been found to rise up to 440 C. From June to September Dhaka city remains under the grip of monsoon Humidity level during this season remains over 80%; the maximum temperature varies between $31^0 - 33^0$ C.

It is found that the range of temperature in the pre-monsoon and monsoon seasons are well over the comfort range of skin temperature, which lies between 31^0 to 34^0 C. In addition, the climatologists have discovered that the urban heat island (in Dhaka city) affects the minimum temperature more than both the mean annual and mean maximum temperatures. Analysis of mean minimum temperature recorded at 14 different mobile places on April 8-9, 1992 and July 6-7 1992 show that the heat island intensity at the time of minimum temperature epoch in Dhaka city in April was 2.5 and that of July, 0.6 [39] The fact that the urban area is always warmer than the surrounding villages has been extensively studied and documented around the world. It is also found that the warmer temperatures are always associated with higher density urban dwellings forming urban heat islands. Mean annual temperature, mean maximum and mean minimum temperature indicate that Dhaka has an urban heat island effect [40]

Since frictional effects become weaker with height above the ground [41] wind velocity, in general, increases with height In the congested areas of Dhaka city the benefit of higher velocity at heights cannot be availed in areas where buildings are closely spaced Again, in some areas the windows cannot be kept open due to excessive velocity of wind and in order to retain privacy. Similarly, radiant and reflected heat in general, decreases with the increase of height from the earth's surface. In high-rise buildings, the materials used as building envelope absorb radiant heat to be transmitted or emitted later The more the height of the building the more is the building mass and so also is the absorption of heat. In extremely congested areas, this radiation may be trapped inside narrow recesses.

1.3 TALL BUILDING AND HIGH-RISE APARTMENTS :

Accommodating more people on less land is the immediate need in most of the important cities and tall and high-rise buildings are accepted solutions. In addition to accommodating working space, those are now extensively used for the purpose of habitation A brief discussion on tall and high-rise buildings, with special reference to their climatic characteristics has been presented hereunder.

1.3.1 TALL BUILDING:

The experts differ in opinions in defining the physical parameters of tall buildings. According to the "The council for Tall Buildings and Urban Habitat" a tall building is not strictly defined by the number of stories or its height. The important criterion is whether or not the design, use or operation of the building is influenced by some aspects of 'tallness'[42]. Some experts attempted to define tall building from structural aspects like, 'From structural design and construction point of view it is simpler to consider a building tall when its structural analyses and design are in some way affected by the lateral loads' [43].

In order to simplify the collection and compilation of data, CTBUH decided to include in its database on tall buildings 'any building nine or more stories in height' [44]. In addition, this made some experts to use the term 'tall building' for any building over nine-stories in height, even though this is contrary to the fact.

1.3.2 HIGH-RISE APARTMENTS:

There is no fixed parameter of height to denote high-rise building and the same depends upon the context in which it stands. In order to denote the height of the majority of the buildings of a city the experts use the term 'urban canopy' All buildings above the urban canopy may be called high-rise or sky-scrapper From a number of considerations like (01) Visual appearance, (02) Structural analysis and design, (03) Walk-up limit (04) Fire escape provisions and (05) Raja's regulation it seems quite logical to opine that, in the present context in Dhaka city buildings above six floors may be considered as high-rise'.

Apartment living is a western concept, but it is gradually finding its way in our society. Even though there were many criticisms of living in high-rise apartments in the past, in view of acute shortage of living accommodations in the large cities, living in such buildings have been socially and culturally accepted. The construction of high-rise apartment buildings at an ever-increasing rate are now changing the cityscape. In such a context, the added moral responsibility that has been placed upon the built-form designers is to ensure user-friendly microclimate in the apartments at minimum cost of energy.

1.3.3 PAST INVESTIGATIONS REGARDING MICRO-CLIMATES IN APARTMENTS:

To the best available information, as of now there has not been any systematic attempt to study and evaluate the climatic situation inside apartment buildings The experts in general observed that (a) High-rise residential buildings were being constructed by private developers along main thoroughfares and at places proximate to central business district without considering various effects [45] and that (b) Apartments have both merits and demerits. They also identified many associated disadvantages with the increase in number of apartments in Dhaka city. Many faults related to planning, architectural design and construction were identified in some apartment buildings, which resulted in lack of proper ventilation and lighting, dampness in walls etc [46]

Even though several projects were undertaken to study the radiant heat and humidity near the earth's surface at various locations of Dhaka city, there has not been adequate studies to investigate microclimates in the high-rise buildings

A study conducted on low-rise residences in 1987 revealed that cross-ventilation was extremely important to feel air-movement under Dhaka's climatic conditions. In this study [47] single-sided ventilated spaces were compared to those with cross ventilation, i.e. having both inlets and outlets on opposite or adjacent walls. In the comparison, it was clear that spaces with single-sided ventilation were extremely inadequate from the view of thermal comfort The study was an indication of the poor condition of ventilation in the residential buildings, which is an outcome of the situations in which the designers design buildings on small sized plots, leaving bare minimum space as prescribed by the urban authorities. These rules were formulated when most of the buildings in Dhaka city were two or four story high. Even after the authorities permitted construction of buildings with much higher heights the inter-building spacing were not increased proportionally Therefore, in order to ensure comfort the users need to depend profusely up on mechanical ventilation through electric fans.

The open spaces inside the city are constantly diminishing to make way for more buildings, roads etc, thus further worsening the situation of airflow. Of all the large cities of the country, Dhaka has the highest consumption of electricity and the higher consumption of electricity in summer rather than in winter is an indication of possible influence of the urban climatic factor on energy need[48].

1.4 METHODOLOGY:

For finding out the climatic condition inside high-rise apartments, a number of high-rise buildings at different locations of the city were selected Arrangements were made to measure the internal temperature and humidity inside each room and in the adjacent external spot. In addition, the enumerators were instructed to record the users' feeling at other times of the year, their own feeling of climatic comfort at the time of survey etc. such that a comparison between the instrumental measurements and users responses could be made The investigation procedure was designed to collect climatic data's and information in the lower and middle floors also, such that a comparison in between the upper, middle and lower floors could be drawn. Details of methodology, investigation, study and analysis have been presented in respective chapter

1.5 CONCLUSION

What has been discussed in this Chapter is a brief introduction of the subjects that might be necessary for the understanding of this project It included, a brief about the objective of study, background information on Bangladesh and Dhaka city, the context regarding growth of residential buildings in Dhaka city etc As a basis for understanding of climate inside high-rise apartments related subjects like climate in general, site or microclimates, microclimates of Dhaka etc. have also been discussed. For a clear understanding of climates in tall and high-rise buildings such topics as tall building and high-rise apartments, past investigations on microclimates in apartments have also been discussed. Finally, a brief discussion on methodology and investigation for this study has also been included in this background chapter

In Bangladesh, there is no system of "Mock flats", Post Occupancy Evaluation (POE) and Generic Participatory Evaluation (GPE) [49] as followed elsewhere Such systems ensure control of the users over the providers of apartments i e designers and builders to meet their needs, including climatic comfort In absence of such measures it is quite likely that climatic comfort did not get due importance in the current design procedure and that the users are being compelled to meet such needs through artificial means at their own and the nation's scarce energy

Residential high-rise buildings have been introduced in Dhaka city not because it was the most appropriate design solution in our context, but because of excessive demand of land for habitation. The construction and sale of apartment is a good business for the developers, where their responsibilities end up with their sales, and the users cannot have any idea of the probable microclimates inside, until of course, they have lived for at least one year. It is evident that setback rules, location and size of openings, orientation etc. have profound influence on microclimates of buildings. In such a context, this study on microclimates may help to find out the state of climatic conditions, which are the outcome of architectural designs and planning. It may be expected that the findings might be of help for the built-form designers in their endeavor to design apartments with user-friendly climate at least cost of money and energy

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Chapter 2

CLIMATE

Chapter 2
CLIMATE

2.0 INTRODUCTION

Climates, defined principally by Temperature, Humidity, Radiant heat and Airflow determine living condition all over the world It is quite evident that, being influenced by numerous factors the global climates widely vary in nature. The climatologists, on the basis of certain criterion have classified the global climates into a number of climates Such climates are seen to prevail in regional basis In case of living comfort in buildings what really matters is not the global climate, but the microclimate, which immensely varies from the regional climates The micro-climate inside the built-form depends upon a number of factors including design parameters, configuration and locations of spaces, environment in the adjacent area, heat and humidity generating or absorbing gadgets used inside rooms, construction materials, finishes and color used etc The feeling of climatic comfort also depends upon acclimatization, clothing and activity and even on the health of the subject in question. Since this investigation deals with the probable climatic discomfort of the inhabitants in built-forms in the hot seasons, the forthcoming discussions on climates has been kept limited to climates relating in tropical regions only.

2.1 TROPICAL CLIMATES

According to Koenigsberger, Tropical Climates are divided into the following major groups (01): (i) Warm Humid Climate: (ii) Warm Humid Island Climate (iii) Hot-dry Desert Climate (iv) Hot-dry maritime desert climate (v) Composite or monsoon climate and (vi) Tropical upland climate. The principle characteristics of these climates are:

(i) **WARM HUMID CLIMATE:** This climate is generally found in the equator extending 150 on both sides There is little seasonal variation throughout the year with occasional appearance of more or less rain gusty winds and electric storm Air Temperature, i.e. Dry Bulb Temperature in shades reaches a mean maximum during the day between 270 C to 320 C, but occasionally rises over the maximum value. At night, the mean minimum varies between 21 and 270 C. Humidity varies between 55% to 100%, annual precipitation, between 2000 mm to 5000 mm, sky remains fairly cloudy throughout the year. Wind velocities generally remain low; with occasional gusts of 30 m/s., Growth of vegetation is quick

(ii) **WARM HUMID ISLAND CLIMATE:** This climate is noticed within the equatorial belt with trade winds. Air Temperature i.e DBT in the shade reach a day-time mean maximum between 290 C and 320 C, and rarely rises above skin temperature Night-time mean minima can be as low as 18 0 C, but it is normally between 180 C and 240 C. Relative Humidity varies from 55% to 100%, Vapor pressure, 1750 to 2500 N/m2, annual precipitation 1250 mm to 1800 mm, sky condition normally clear or filled with white broken clouds, wind velocity between 6 to 7 m/s, vegetation growth is less luxuriant, and there are tropical cyclone or hurricane.

(iii) **HOT-DRY DESERT CLIMATE:** This climate occurs in two belts within latitudes 15^0 and 30^0 on North and South of the equator. Air Temperature i.e. DBT in the shade rises quickly after sunrise to a daytime mean maximum of 43^0 C to 49^0C The ever-recorded maximum temperature of 58 ^{0}C was measured in Libya in 1922. During the cool season the mean maximum temperature ranges from 27 ^{0} C to 32^0 C. Humidity varies from 10% to 55%, and annual precipitation, between 50 mm to 155 mm The sky condition remains normally clear and usually dark blue with a luminance of 1700 to 2500 cd/m^2, winds are only local carrying dust and sand, vegetation is sparse and there are occasional dust and sand storms.

(iv) **HOT-DRY MARITIME DESERT CLIMATE:** This climate occurs in two belts within 15^0 and 30^0 on North and South of the equator Air Temperature i.e DBT in the shades reaches a day-time mean maximum of about 38^0 C, but in the cool season in remains between 21^0 C to 26^0 C The diurnal mean range varies between 9^0 to 12^0 C. Relative humidity varies between 50% to 90%. Precipitation is very low, sky condition normally clear and usually dark blue with a luminance of 1700 to 2500 cd/m^2 Winds are only local, vegetation is sparse and there are occasional dust and sand storms.

(v) **COMPOSITE OR MONSOON CLIMATE:** This climate occurs in large landmasses near Tropics of Cancer and Capricorn Approximately two thirds of the year is Hot- dry and the other third Warm-humid. Also there may be a third season like Cool-dry Air Temperature variations may be as shown in Table 2-01·

Table 2-01:

VARIATION OF AIR TEMPERATURE IN COMPOSITE OR MONSOON CLIMATE			
SEASON	HOT-DRY	WARM-HUMID	COOL-DRY
Day night mean max	32°-43° C	27° – 32° C	Up to 27° C
Nighttime mean min	21°-27° C	24° – 27° C	4° - 10° C
Diurnal mean range	11°-22° C	3° – 6° C	11° - 22° C

Source· MANUAL OF TROPICAL HOUSING AND BUILDING Koenigsberger et al Page 28

Humidity ranges between 20% to 55%, during wet period it rises to 55 to 95% Precipitation remains between 500 to 1300 mm with no rain during the dry season. Sky conditions markedly vary with the seasons. The sky is heavily overcast and dull during the monsoons and clear with a dark blue color in the dry season. Winds are hot and dusty during the dry season Directional changes in the prevailing winds take place at the beginning of the warm humid season and these include rain-clouds and humid air from the sea Monsoon winds are fairly strong and steady. Vegetation is sparse, which is the characteristic of hot-dry region. the ground is mostly brown but it changes rapidly and dramatically with rain Plants grow quickly. In the cooler period vegetation covers the ground, but diminishes as the temperature rises.

(vi) **TROPICAL UPLAND CLIMATE**· This climate occurs in mountainous regions more than 900 to 1200 m above sea level Air Temperature i e the DBT in the shade decreases with altitude. At an altitude of 1800 meters, the daytime mean maxima may range from 24° C to 30° C and the nighttime minimum, around 10 °C to 13 °C At some locations it may fall below 4° C and ground frost is not uncommon. The diurnal range is great The annual range depends up on latitudes Relative Humidity varies between 45% to 99%, annual precipitation is less than 1000 mm, sky condition, normally clear or partly cloudy Vegetation is not very luxuriant during wet season

There may be heavy dew with radiation fog at night and occurrences of thunderstorms and hail with electric discharges

2.2 MICROCLIMATES:

While Global and Regional climates are of general interest for all and especially for the climatologists the designers of built-forms are more concerned with microclimate in small areas where their structures are designed to successfully serve the purpose of human habitation While the microclimate is the term generally used to denote 'the area under consideration Koenigsberger used a different the term 'Site Climate' to denote the area to be considered by the architect According to him "(microclimate) can imply any local deviation from the climate of a larger area, whatever the scale may be. The botanist may consider the microclimate of a single plant leaf, with its temperature and moisture conditions, its population of insects and microorganisms on the scale of a few centimeters For the urban geographer the term micro-climate may mean the climate of a whole town"[02].

For living comfort, the inhabitants are intensely related with site or microclimates Site climate establishes the scale; it implies the climate of the area available and to be used for the given purpose both in horizontal extent and in height[03]. Even though Koenigsberger did not mention physical parameter of site or microclimate, some climatologists have done that. For example, Morris and Markus opined that regional climate on a horizontal scale varies up to 1000 kilometers, top climates extend up to 10 kilometers horizontally and 1 Kilometer depth and micro-climates limit to about 1 kilometer horizontally and 100 meter vertically[04].

Since micro-climates are created by such factors as buildings and structures, roads and pavements, green areas and water bodies, heat-producing factories, vehicles etc it is in fact extremely difficult to fix any physical parameter to denote specific 'micro-climate' or 'site climate' Koenigsberger mentioned the following four factors affecting or deviating the general climate and to form microclimate of an area (a) Topography, i.e slope, orientation exposure, elevation, presence of hills or valleys at or near the site. (b) Ground surface, whether natural or man-made, its reflectance, permeability, soil temperature etc. (c) Three dimensional objects e.g. trees, fences, walls and buildings, which obstruct air movement and cast shadows (d) Anthropogenic activities, i e human activities by means of vehicular emissions and wastes, smoke, dust, fumes, vapor etc. from industries etc.

The site condition alters the air temperature depending upon the heat gain and loss, which considerably depends upon soil condition. The humidity in a site depends upon slope, soil type, vegetation, and heat generation by local factors like factories, vehicles, air-conditioning equipments etc. Both temperature and Humidity of a site depends upon sky conditions, which apart from the general condition of clouds, depend upon smoke, dirt, sand particles etc. suspended in the air. Other than transparency of atmosphere, solar radiation depends also upon slope, orientation, presence of hills or valleys etc Air movement in any site is changed by slope, presence of obstructing objects like buildings and structures etc Table 2-02 below indicates the extent of alteration of wind velocity at different heights due to the presence of various types of obstacles.

Table 2-02

WIND VELOCITY GRADIENTS

	Velocity of	wind in	meters in
Height in Meters	Urban Center	Rough Wooded country	Open country
518	100	--	--
400	90	--	—
396	---	100	--
300	---	95	--
274	—	---	100
200	70	---	96
150	---	92	--
100	52	----	86
50	40	56	78

Source: MANUAL OF TROPICAL HOUSING AND BUILDING Koenigsberger.

Factors like thunderstorms, dust and sand storm, earthquake etc. also modify site or microclimate.

2.3 STUDIES ON MICRO-CLIMATES IN DHAKA CITY:

Before presenting some recent studies on micro-climates of Dhaka city it may be interesting to have a look at a study on the climate of old Dhaka undertaken 173 years ago. Due to lack of authenticity and information regarding specific system of measurements this study may not be considered as standard, but may still be accepted as 'Historical'. A comparison between this one and some recent studies have also been presented.

2.3.1 HISTORICAL STUDY OF CLIMATES OF DHAKA:

James Taylor, who worked as a surgeon and was assigned to prepare a report on the physical and statistical aspects of Dhaka published his findings in a book[05] in which he gave information regarding Mean Monthly Temperature of Dhaka for the period 1826-1836 Another data on Mean Monthly Temperature and Humidity of Dhaka city for the period 1958-1962 is available in Dhaka District Gazetteer [06] In Table 2-03 below the average of Monthly average of 5 hot months, i.e. April to August as found in the historical studies and recent studies have been presented

Table 2-03

CHANGES IN MEAN MONTHLY TEMPERATURE AND HUMIDITY OF DHAKA CITY THROUGH 173 YEARS

Source Period:	APRIL Temp. Hum.	MAY Temp. Hum.	JUNE Temp. Hum.	JULY Temp. Hum.	AUGUST Temp. Hum.
Taylor: 1827-1836 (173 years ago) Average of 10 years	29.7 - ----	30.8 - ----	30.1 - ----	30.1 - ----	29.7 - ----
Dist Gazetteer (42 Years ago) Average of 5 years	29 6 - 72 3	29 2 – 82.0	26 5 – 87.1	28 6 – 88	28 6 - 89 3
Statistical Yearbook (6 years ago) Year 1992	29.0 - 70	29.0 - 79	28.7 - 86	28 6 – 86	28 6 - 86
Statistical Yearbook (3 years ago) Year 1997	26 1 – 74	28.6 - 77	30.2 – 82	29 1 – 86	29 7 - 84

In order to show the changes more vividly, the above information has been shown in graphs below.

Figure 2-01

CHANGE OF TEMPERATURE OF DHAKA CITY IN 173 YEARS

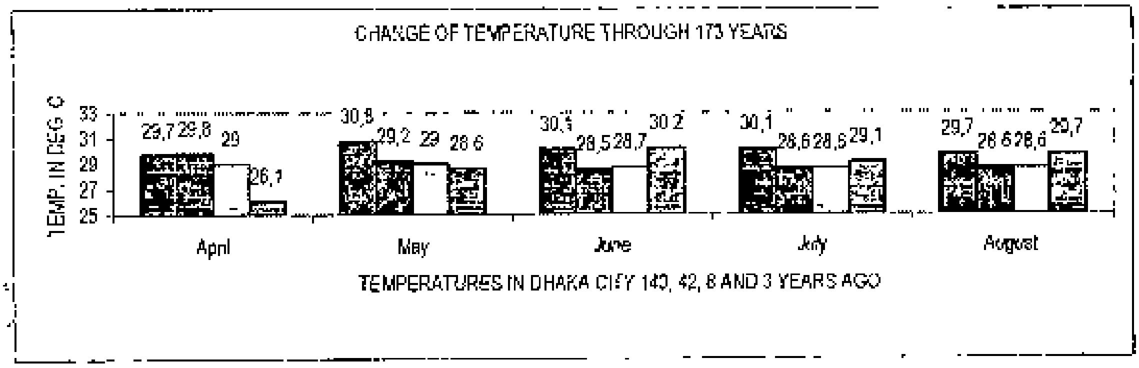
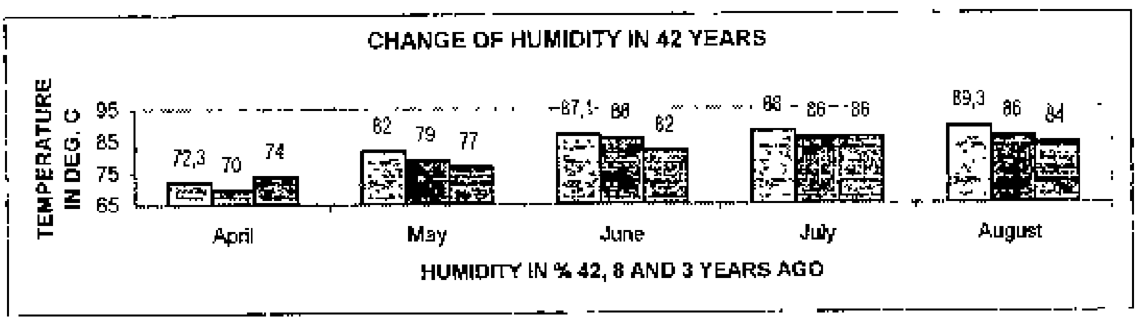


Figure 2-02

CHANGE OF HUMIDITY OF DHAKA CITY IN 42* YEARS



*Since there was no mention of Humidity in Taylor's account, the above comparison of Humidity presents a period of 42 years only.

In the above Table and Figures there is no indication that there was any gradual increase or decrease of temperature or humidity in Dhaka city through a period of 173 or 42 years In case of temperature, gradual decrease may be noticed in the months of April and May, decrease in July and no change in June and August. In case of variation of Humidity through 42 years there are gradual decreases in May, June, July and August and increase in April

From a number of indications like (a) melting of ice at the arctic regions, (b) ever increasing of deposit of CO^2 in the upper boundary layer etc the scientists have arrived at the conclusion that global temperature is on increase. It has also been assumed that the deposit of CO_2 in the upper boundary layer shall nearly double by the year 2030 [37] By those considerations the above table should have indicated some increase in the temperature of Dhaka city through this period, but it did not It is a common experience that with urbanization, trees, green areas and water bodies constantly diminish. The materials used in building, road, pavements etc. absorb heat. Buildings and structures retard air movement creating stagnancy and causing growth of 'heat island' This makes the data shown in Table 2-03 all the more fizzing and points to a possibility that the process or system in which the above measurements were taken might not be inaccurate It may be mentioned that the readings were taken at different locations of the city. The old weather station situated at old Dhaka, then it was shifted to Kurmitola airport and was later handed over to the civil aviation department. New weather station was established at Agargaon. When the Meteorological department supplies climatic data, they maintain continuity, even though the measurements were taken from different locations. This might logically lead one to believe, even though the above data have been collected from authentic sources, they do not reflect the real picture. Nevertheless the data is interesting as it shows that the general populace in this city have been experiencing and becoming habituated to very steady average conditions over large period of time

2.3.2 STUDIES ON MICRO-CLIMATES IN DHAKA CITY:

In the built-up areas with closely spaced tall buildings, there remains every possibility that there would be stagnant air trapped in narrow gaps in between built-masses The air flowing through the open country might skip the built structures. Cool air cannot enter in these areas; in addition, heat trapped in narrow gaps cannot escape. Water bodies, green trees, grasses etc reduce heat by the process of evaporation of water. In congested cities these factors constantly go on decreasing. Various gadgets used in houses, factories and vehicles contribute to increase of heat. Due to such factors, some climatologists believe that 'heat island effect' which means an increase of heat from the surrounding open country has already taken place in Dhaka city. In fact, any person moving from the bank of the river to congested old Dhaka, through busy markets to the less congested northern part might experience numerous microclimates with differing temperature and humidity is now a common experience.

(i) KARMAKAR ET AL'S STUDY ON PRABALISTIC EXTREMETIES IN 1993: On the basis of about 30 years (1960-1990) data regarding variability and probalistic extremities of climates elements in Dhaka [08] one researcher made the following observations:

(a) The mean maximum temperature over Dhaka has its lowest value in January and progresses as the season progresses. It becomes maximum in April with a decreasing tendency up to August The mean temperature increases from January to April, then remains almost constant up to September, and decreases up to January. The mean minimum temperature is the lowest in January, increases up to June and remains fairly constant up to September and decreases after that

(b) The mean prevailing wind speed is minimum in January and maximum in April (No mention of directions).

(c) The mean rainfall increases sharply from January and attains maximum value in June and July, after which it decreases.

(d) The mean relative Humidity has higher values during the southwest monsoon and then decreases sharply up to March.

(e). The probabilistic high values of monthly highest maximum temperature in April are 39.1^0, 40.2^0 end 41.0^0 C in one year out of 4, 10 and 25 years respectively. The probabilistic low values of monthly lowest minimum temperature are 7.4^0, 6.4^0 and 5 6^0 C in the same scale.

(f) The probabilistic high values of maximum wind speed in 1 case out of 25 cases are 108 kph. 123 kph and 100 kph in March, April and May respectively (no mention of directions)

(g) The months of December, January and February are the most comfortable months in Dhaka, where as April through October are uncomfortable months.

(ii). HOSSAIN ET AL.'S STUDY ON DISCOMFORT INDEX IN 1993: For measuring climatic comfort Discomfort Index (D.I) was suggested by Thom's as:

$$D\,I = 0\,4\,(T_d + T_w) + 15,$$

where T_d and T_w stand for Dry bulb and wet bulb temperature respectively in ^{0}F scale In ^{0}C scale it comes to be,

$$D\,I = 0.72\,(T_d + T_w) + 40\,6.$$

The comfort situation in Dhaka city in terms of Discomfort Index (D I) has been expressed as the result of one research [09] in the following way:

(a) MARCH TO MAY: (Regarding time, the original work was done using UTC, which corresponds to GMT and is less than Bangladesh Standard Time BST by six hours. For easy understanding Bangladesh Standard Time BST has been used here)

At 6.00 A M. BST Dhaka (whole Bangladesh) is generally comfortable. Evening Hours 6.00 P.M. BST: Dhaka (and northern half of Bangladesh) is generally comfortable. In April, rest of the country falls under discomfort with D.I value exceeding 75

(b) JUNE TO SEPTEMBER: 6.00 A M BST: Dhaka (whole Bangladesh) is generally under discomfort with D I. Index exceeding 75. The weather is hot and dry.

6 00 P.M. BST Dhaka (whole of Bangladesh) is under discomfort, with D.I. Index exceeding 80.

(c) OCTOBER TO NOVEMBER: 6.00 A.M BST Dhaka (whole Bangladesh) is generally under discomfort with D.I Index exceeding 75

6.00 P M BST: Dhaka (whole of Bangladesh) is under partial discomfort. with high value in D.I. Index.

(d) DECEMBER TO FEBRUARY: 6 00 A.M. BST: In January and February Dhaka is under comfort zone with low D.I Index. 6.00 P M . Dhaka is under comfort zone with low D I Index

The D.I. Index of Dhaka city, calculated by using Thorn's index and using climatic data from the meteorological Department at different months at specified time has been shown in Tables 2-04 and 2-05.

Table 2-04

DISCOMFORT INDEX FOR DHAKA FOR 1991-92 AT 6.00 A.M. BANGLADESH STANDARD TIME

MONTH	TIME	D.I. INDEX	COMMENT
January	6.00 A M BST	60	Within comfort range
February	6.00 A.M. BST	69	Within comfort range
March	6 00 A M. BST	70	Within comfort range
April	6.00 A.M BST	74	Within comfort range
May	6.00 A.M. BST	76	Uncomfortable
June	6 00 A.M BST	79	Uncomfortable
July	6 00 A.M BST	79	Uncomfortable
August	6.00 A M BST	79	Uncomfortable
September	6 00 A.M. BST	78	Uncomfortable
October	6.00 A.M. BST	76	Uncomfortable
November	6.00 A.M. BST	68	Within comfort range
December	6.00 A M. BST	62	Within comfort range

Source Hossain, Akram. Paper HUMAN COMFORT IN THE URBAN AREAS OF BANGLADESH in Technical Conference on Urban Tropical Climates 1993

Table 2-05

DISCOMFORT INDEX FOR DHAKA FOR 1991-92 AT 6.00 P.M. BANGLADESH STANDARD TIME

MONTH	TIME	D.I. INDEX	COMMENT
January	6.00 P.M. BST	60	Within comfort range
February	6 00 P.M BST	72	Within comfort range
March	6.00 P.M. BST	77	Uncomfortable
April	6 00 P M BST	79	Uncomfortable
May	6.00 P.M. BST	81	Uncomfortable
June	6.00 P.M. BST	82	Uncomfortable
July	6 00 P.M BST	81	Uncomfortable
August	6 00 P M BST	81	Uncomfortable
September	6.00 P M BST	80	Uncomfortable
October	6.00 P M. BST	79	Uncomfortable
November	6.00 P.M. BST	74	Within comfort range
December	6.00 P.M. BST	67	Within comfort range

Source : Hossain, Akram. Paper HUMAN COMFORT IN THE URBAN AREAS OF BANGLADESH in Technical Conference on Urban Tropical Climates 1993.

(iii) HOSSAIN, E. ET AL'S STUDY ON GENERAL CLIMATE: On the basis of 40 years (1951-1990) climatic data of Dhaka city one researcher has prepared the following information[10]:

(a) After sunrise, the day temperature increases at attains maximum value at 3.00 P.M. BST. The day temperature in urban area is higher than sub-urban and rural areas. The night temperature in rural areas is lower that that in urban areas.

(b) The relative humidity decreases at daytime and increases at night, the minimum value being at 3.00 P.M BST, when the day temperature is maximum.

(c). Urbanization has profound effect in reducing the wind speed.

(d). The heat island effect is less prominent, the intensity being 2.5 in April and 0.6 in July. The less prominence is due to high humidity and surface wind

(e) Relative humidity is found inversely related to the local intensity of urban heat island in Dhaka.

(f) Total incoming solar radiation in Dhaka city is found about 12% lower than that in the rural areas.

(g) The amount of precipitation is higher in Dhaka city except in August

(IV) KHALEQUE ET AL'S STUDY ON MICRO-CLIMATES OF DHAKA CITY: One group of researchers on the basis of their studies on Temperature and Humidity[11] conducted in 10 points, viz (01) Agargaon, (02) Tejgaon, (03) Motijheel, (04) Dhanmondi, (05) Nawabgonj, (06) Mirpur, (07) Kallyanpur, (08) Gulshan, (09) Bakshi bazaar and (10) Airport, commented:

(a). On January 03, 1992 at 6.00 A.M BST several warm pockets were discovered at Tejgaon Industrial Area, Motijheel Commercial and congested part of old Dhaka.

(b) The cool areas were at Agargaon, Dhanmondi and Zia International Airport

(c) The maximum intensity of heat island or warm pocket was found in the order of 3.6^0 C in Old Dhaka and Motijheel Commercial Area.

(d). During summer months (June 08,1992) heat island intensity was in the order of 0.08^0 C

From the above observations they drew the following deductions:

(a) During winter months maximum intensity of heat island in the order of 3.8^0 C is observed.

(b) Two peaks of heat island intensity are observed one at early morning and another early night, but the early morning heat island is stronger.

(c) The heat island or warm pockets found over the densely populated residential and high-rise building construction area. The cool areas are found over the well ventilated planned residential areas.

(d) During summer months heat island effect is insignificant

(e) Humidity island has an inverse relation to heat island whenever moisture is less, but followed heat island intensity whenever moisture is high.

2.4 CLIMATIC COMFORT

The effects of different climatic variables on human comfort have been slowly recognized by the researchers through ages. The effect of Temperature on human comfort was mentioned by Vitruvius[12] in the first century B C Leonardo da Vinci recognized the influence of Humidity in the fifteenth century. In 1733 John Arbuthnot published "An Essay Concerning the Effect of Air Movement on Human Bodies" Thomas Tredgold in 1824 in his book "Principles of Warming and Ventilating Public Buildings, Dwelling Houses, etc" pointed out that the people could be comfortable from the radiant heat of an open fire even when air temperature was too low for comfort. [13]

The various components of thermal comfort were not assembled into a single criterion until 1923, in which year C P. Yaglou [14] published the results of his experiments at the Pitts burg Research Laboratory of the American Society of Heating and Ventilating Engineers (ASHRAE) A number of men were placed in a room where the temperature, humidity and air movement could be controlled and measured. They were asked to nominate the conditions of temperature, humidity and air movement that gave the same sensation of warmth while they were engaged in light physical activity and wore light clothing The amount of clothing worn in this experiments have been expressed in unit 'clo' and these have presented have in Table 2-06 and 2-07.

Table 2-06

INSULATING EFFECT OF MAN'S CLOTHING

TYPE OF CLOTHING	CLO
Brief swimsuit	0.05
Shorts only	0.1
Shorts and short-sleeved shirt	0.2
Shorts, briefs and short-sleeved shirt, socks and shoes	0.32
Same but long trousers	0 5
Same plus banyan	0 6
Lightweight suit, cotton underwear	1 0
Three piece winter suit, cotton underwear, wool socks	1 5
Same plus overcoat	2 0-2 5
Heavy clothing designed for outdoor use beyond the arctic and Antarctic circles	4 0
Brief swimsuit	0 05
Shorts only	0.1
Shorts and short-sleeved shirt	0 2
Shorts, briefs and short-sleeved shirt, socks and shoes	0.32
Same, but long trousers	0.5
Same plus upper underwear	0.6
Lightweight suit, cotton underwear	1.0
Three piece winter suit, cotton underwear, wool socks	1.5
Same plus overcoat	2.0-2 5
Heavy clothing designed for outdoor use beyond the arctic and Antarctic circles	4.0

Source Yaglou, and Houghton Determination of the Comfort Zone. Trans American Society of healing and Ventilating Engineers

The approximate Metabolic Rates for various activities have been shown in Table 2-06

Table 2-07

APPROXIMATE METABOLIC RATE FOR VARIOUS ACTIVITIES

ACTIVITY	METABOLIC W/m2	RATE Met
Sleeping	41	0 7
Resting, lying down	47	0.8
Sitting and not working	58	1.0
Standing	70	1.2
Typing	80	1 4
Light manual work	120	2 0
Cleaning a house	180	3 0
Heavy work	270	4.5
Walking on level ground at 6 km/h	200	3 5
Walking up a 15^{0} slope at 3 km/h	270	4 5

Source: B Givoni: The Effect Of Climate On Man: Developing Of A New Thermal Index, Proceedings First International Congress of Biometeorology

The combinations of temperature, humidity and air movement that gave equal sensations of comfort were then designated as having the same EFFECTIVE TEMPERATURE (ET), the

Effective Temperature is the dry bulb temperature in that group of equal comfort sensations at which the relative humidity is 100% and air movement is zero [15]

J E. Hill[16] along with other climatologists prepared a comparative study of various thermal indices and calculated their range of application as shown in Table 2-08

Table 2-08

RANGE OF APPLICATION OF PHYSIOLOGICAL INDICES:

INDEX	METABOLIC PRODUCTION	CLOTHING	DBT °C	WBT °C	AIR VELOCITY (m/sec)
ET	Rest only	Summer Clo	1 - 43	1 - 43	0 1 - 3.5
RT	Rest only	Light Clo	18 - 45	18 - 45	0 1 - 3.0
KSU	Rest only	0.6 Clo	15.6 - 36 7	5 6 - 34.4	<0.23
PMV	50kcal/hrm	.25, .6 Clo	-----	---	0 1
HSI	100-500	Unspecified	27 - 60	15 - 35	0.25 -10.0(orig)
HSI	58.2 W/m²	0 6 Clo	---	---	0 1
ITS	100-600 K Cal/hr	Military overall	20 - 55	15 - 35	0 1 - 3 5
ET*	58 2 W/m²	0.6 Clo	---	---	0 1
P4SR	100-350 kcal/hr	Only shorts	27 - 55	15 - 36	0.05 - 2 5

Source: Hill, Kusuda, Liu, Powell. A Proposed Concept for Determining the Need for Air-Conditioning Buildings Based on Building Thermal Response and Human Comfort NBS, Washington.

The experiments determining Effective Temperature (E.T) have been progressively refined The current standards are based on experiments carried out under the auspices of ASHRAE at Kansas University and published in 1973[17]. These experiments were conducted on college students wearing clothing equivalent to 0.6 clo and sitting in the test room without doing any work. The mean radiant temperature (MRT) was equal to the dry bulb temperature and the air velocity was low, less than 0.17 m/s The main variables were Temperature and Humidity The comfort zone as described by the subjects during the experiment was then traced on a Psychometric Chart The recommendation of the ASHRAE comfort standard is limited between relative humilities, 60% and 20% and by the dry bulb temperatures, 22.8^0 C and 25^0 C.

In 1975 at an energy conservation measure higher design temperatures were recommended for summer, and lower ones for winter[18]. At this stage the winter temperature was still considerably higher than that considered appropriate in England before the energy crisis of 1973. The preferred range of temperature for the British House of Commons in 1840 was 11^0 C to 22^0 C Sir Douglas Galton in his article on "Heating" recommended a temperature range for living room as 12^0 C to 20^0 C and a temperature for bed rooms not less than 4^0 C. [19]. Dr Thomas Bedford conducted an inquiry in 1940 and recommended a temperature range on 19 5^0 C to 20^0 C, which was found to be satisfactory. Differences in comfort vote are due to the differences in amount of clothing customarily worn and this varies with time and place; but they also reflect different conceptions of comfort.

On the basis of 40 field studies conducted in a wide range of climatic conditions Humphrey's[20] commented that neutral temperatures T^n for adults range from 17^0 C to 35^0 C, depending on the mean temperature experienced by the population, suggesting that acclimatization indeed affects the temperature required for thermal neutrality. Normally a band of 4^0 C ($^-_+$ 2^0 C) centered around T^n comprises the comfort zone. If T^m is the mean temperature, then Tn may be predicted from the equation:

$$T^n = 2.56 + 0\,831\ T^m\ (^0C)$$

The standard error of prediction considered was 1.1^0 C It is possible to predict T^n for each month of the year by examining the average temperatures T^m for the climate in question The Neutral Temperature T^n and Comfort Zone in Dhaka city for the hot months (April, May, June, July, August, September, October) for twenty year average readings based on Humphrey's equation was calculated by one researcher [21] in 1987 This has been presented in Table 2-09 below.

Table 2-09

HUMPHREYS MONTHLY NEUTRAL TEMPERATURE AND COMFORT ZONE IN DHAKA IN 1987

MONTH	AVERAGE TEMPERATURE Tm ^{0}C	HUMPHREYS NEUTRAL TEMP Tn ^{0}C	COMFORT ZONE ^{0}C	- ^{0}C
April	29.0	26 6	24 6	28.6
May	28 9	26.6	24.6	28 6
June	28 5	26 3	24.3	28.3
July	28 6	26 3	24 3	28 3
August	28 6	26 3	24.3	28.3
September	28 7	26 4	24 4	28 4
October	27.2	25.1	23.1	27.1

Source: Ahmed, Z N 1987, unpublished M Phil. Thesis on The Effects of Climate on the Design and Location of Windows for Buildings in Bangladesh.

It may be relevant to summarize the findings of experiments regarding comfort temperature in various periods and regions and to compare those against the temperature and humidity of Dhaka city of contemporary period in the hot months. The comparison has been presented in Table 2-10 below.

Table 2-10

COMPARISON OF INDOOR COMFORT TEMPERATURES

REFERENCE	COMFORT TEMPERATURE	OTHER FACTORS UNDER CONSIDERATION
01. British House of Commons Recommendations 1840	$11^0 - 22^0$ C	Not mentioned
02. Encyclopedia Britannica 1880	$12^0 - 20^0$ C	Not mentioned
03. ASHRAE comfort Standard of 1974	$22.8^0 - 25^0$ C	Rel. Humidity 60% - 20%
04. Dr. Thomas Bedford 1940	$19.5^0 - 20^0$ C	Not mentioned
05. ASHRAE experiment in Singapore 1952	27^0 C	At R.Humidity 80%, air velocity 0.4 m/s
06. Humphrey's neutral Temp Tn $17^0 - 35^0$C ((based on 40 field studies)	$15^0 - 37^0$	Requires acclimatization and variation of clothing and takes into account human behavioral adaptations
07 Neutral Temp for Dhaka calculated by Ahmed on Humphrey's Equation (Average of April-October Months) Tn 26.46 ^{0}	23.1- 28.6	Same

2.4.1 MAHONEY'S CHART:

Numerous research workers and theoreticians have attempted to construct a schema or model of the design process on climatic considerations. C. Mahoney[22] devised a number of tables to record the essential climatic data for use by the designers of built-forms. In his Table he proposed to record such information as (1) Location (2) Longitude (3) Latitude and (4) Altitude of the site in consideration. Also the Air temperatures like (i) Monthly mean maximum, (ii) Monthly mean minimum and (iii) Monthly mean range, (iv) Ever highest temperature, (v) Ever lowest temperatures, (vi) Highest Annual Mean Temperature and (vii) Lowest Annual Mean Temperatures for each of the 12 months of the year were to be recorded in a chart. The Humidity data was to be maintained in a similar manner. Other Climatic components like Wind and Rain were to be recorded such that the designers may find out comfort ranges

2.4.2 ACTIVITY CHART:

The activity chart[23] is a chart is a chart having two parts, where the upper part shows in graph the outdoor and indoor temperature changes with comfort zone super-imposed and the lower part gives a record of activities in various spaces of the building. The chart indicates the suitability of various rooms at various locations for various activities, where the rooms may be specified depending upon the duration and time of use.

2.5 GLOBAL WARMING AND BANGLADESH:

On the assumption of the experts that deposit of CO^2 in the upper boundary layer shall double by the year 2030[24] the International Panel on Climate Change (IPCC) Group I working in Bangladesh reported the following on the climate of Bangladesh and the surrounding area,

(i) There will be a general rise in surface air temperature, which is likely to be greater in percentage terms in winter than in summer.

(ii) Precipitation forecast for winter seem to have wider range from a reduction to an increase while during summer there may be up to 15% rise in rainfall.

(iii) Soil moisture forecasts seem to be quite uncertain but are likely to increase up to 10% during summer.

It may be opined that due to Global Warming, the summers are likely to be warmer, more humid due to higher rainfall and the soil may be moister. Winters are likely to be warmer, possibly drier and with possibly less soil moisture The IPCC working Group 1 predicted that the changes might take place at the upper and lower ends of the range, keeping the mean value roughly the same as before.

According to Masatoshi Yoshino[25] "(the changes in climate) may result in intensification of heat island, air pollution, pollution dome over cities at night, sea-level rise and other urban climatological phenomenon through the broadening of built-up area, developing transportation system and other related industrial activities". Regarding sea-level rise he opines, "it is said that 72 millions suffer and 70 cities sink in China by I meter sea level rise and 8 million suffers in Egypt There are many similar results of assessment in Nigeria, Brazil, Malaysia etc". In Bangladesh, the low-lying areas especially those at the coastal belt will be affected due to rise of sea level as an after affect of global warming Thus even though this may not be directly related with the aim and objective of this study, the designers of built-forms may attach importance to this phenomenon in their designs, specially in the low lying areas. The city of Dhaka may also be considered as low-lying, since the area goes under floodwater in the years of extreme flush floods. The construction of a dam around the city, however, has stopped this propensity in the recent years

2.6 CONCLUSION:

This Chapter on Climate in general discusses various aspects of climate including factors of climate, regional climates, micro- or site climates, climates in Dhaka city, various factors responsible for climatic comfort etc Most of the studies have been carried out by the climatologists, who are mostly concerned with climate of a large area The designers, however, are in need of climatic information of smaller area, may be of a particular city or part of a city and such information may not be available with the meteorological department, the organization responsible for recording and preserving climatic data. Some of the studies by the climatologists reveal that numerous microclimates have already been generated in Dhaka city and that the climates in these pocket-areas widely vary from the rest or adjoining areas. The success of a building in point of climate, i e. the one utilizing climatic benefits depends considerably upon detail and dependable climatic data of the site. The current system in which the Meteorological Department collects climatic data cannot satisfy these conditions. If detail and dependable climatic data of a site is available, the designers of built-form may make the use of various spaces depending on their relative importance, time of use (through Mahony's activity chart), type of use etc. It is however, a great problem that in urban areas and especially in the congested busy cities microclimates vary quite rapidly. The construction of each building in a congested area brings about new changes in microclimates due to its presence and associated activities. In case a building is not designed with due considerations of probable changes and developments in the surrounding areas, there remains every possibility that the building may not ensure the expected benefit of nature's climate

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Chapter 3

RESIDENTIAL HIGH-RISE IN DHAKA CITY

Chapter 3

RESIDENTIAL HIGH RISE IN DHAKA CITY

3.0 INTRODUCTION:

The residential buildings that one may now see in Dhaka city are the product of recent decades. Initially residences appeared in this land as traditional rural huts Through numerous changes and transformations in configuration, material, construction technique etc. those have attained the present forms. A brief discussion regarding transformations of houses through ages in the site of present Dhaka city has been presented in this chapter such that one may have an understanding of the influence of climate on their design and planning Also there are two topics, one on 'shelter' that includes men's idealistic requirements in shelter, as suggested by various experts and the other on 'shelter policies' taken by the government of Bangladesh. The state of residential accommodation in Dhaka city, the present situation of residential buildings, various measures taken by the Government to meet the demand for accommodation etc. have also been discussed. It is now quite well known that in Dhaka, as elsewhere in the globe high-rise and tall buildings have been accepted as effective solution to human accommodation on less land There is also a topic on some aspects of the design of high-rise and tall buildings.

The context behind the growth of high-rise buildings in the city has been discussed under topic high-rise residences in Dhaka. Because of their relevance to the climatic context various controlling & regulatory measures enforced by the Government from time to time to control the growth of built-forms have also been discussed The topic on climate in high-rise building discusses observations and recommendations by experts regarding environmental impacts of and environmental conditions in high-rise buildings. The above-mentioned topics have been discussed in this Chapter under the following sub-headlines

Transformations of houses through ages
Shelter
Shelter policy of the government of Bangladesh
Residential accommodation in Dhaka city
Situation of residential accommodation in Dhaka city
Government measures to meet demand for accommodation
High-rise and tall buildings

High-rise buildings
Tall buildings
High-rise residences in Dhaka
Context of growth of high-rise residences
Reasons behind the growth of high-rise residences
Controlling & regulatory measures in growth of built-forms in Dhaka
Climate in high rise building
Climate in High-rise tower building
Environmental impacts of high-rise buildings
Environmental conditions in the high-rise buildings
Conclusion

3.1 TRANSFORMATIONS OF HOUSES THROUGH AGES:

In Dhaka, as elsewhere in the world houses have suffered from changes due to new needs, changes in people's attitudes towards living, introduction of new materials and technology, changes in climatic conditions, changes in the attitudes and policies of the government etc The city of Dhaka, that at present stands as a mega polish and capital of independent state, Bangladesh initiated as abode of some businessmen, with some traditional residential and business houses. The houses were constructed with timber posts having sloping thatched roofs above and thatched or mud walls around. As days went on those were gradually replaced by brick walled, burnt-tile roofed, corrugated iron (c.i.) sheet walled and roofed and finally reinforced concrete (r.c.c.) framed and r.c.c. roofed structures. Changes happened also in planning and organizations Earlier, there was no dearth of land and various structures for accommodation were placed far apart for ensuring privacy and having climatic privileges The use of sloping roofs, translucent walls, probable fire hazard etc. also necessitated distant placement. The introduction of c.i. sheet and brick wall made closer placing or even combining several spaces under the same roof possible. The introduction of better-quality toilets and pipe-borne rendered it possible to place toilet and bath room very near or even within the main house The replacement of sloped roofs by flat r.c.c. roofs made the concept of multiple level living The scarcity of land and the question of security initiated the use of boundary walls. The commercial viability of land adjacent to main thoroughfares allured the owners to use those for commercial purposes. With the introduction of multi-level living concept, there was a tendency to use the lower levels for commercial purpose and the upper levels, for residential accommodation. The colonial British rulers introduced bungalow type large house with lavish use of spaces inside and open spaces around, where security was maintained by distance, water-bodies, walls and security guards. Following them the local landlords introduced their own types in which they introduced introvert type of planning, with rooms arranged around closed courtyards. This design basically differed from the traditional type in the point that in the traditional type the inner court was semi-enclosed. The introduction of agitation of air, first by using manual device and consequently by electric fans worked as substitute for ventilation and this one, along with introduction of electric lights that acted as substitute for natural light paved way to closer placing of structures

In case of multilevel brick buildings 'one stair serving two' and 'having a south face type' became very popular because of economic and climatic suitability. In such a design passage to all the livable spaces from the staircase was a dire necessity. The smaller plots of land available in the city, however, made it difficult to avail the climatic privileges In such a context more openings in the internal walls and larger open space inside was a necessity. As a design solution the living room and dining room were combined into one, the internal passage was replaced by a large room to be used as dining space or family space High-windows or fanlights were introduced to retain privacy and maintain ventilation.

As soon as the buildings went up above walk-up limits, elevators found their use for vertical transportation. The urban authorities made it obligatory to provide garbage chute for buildings above six floors. For easy installation, maintenance and changes of service lines of water, gas, electricity etc 'service ducts' found their uses in the multi-level buildings In their endeavor to arrange the rooms of a house in limited space, the designers often found it hard to provide the exterior windows, which were considered essential for toilets and kitchens As a solution they introduced toilet and kitchen ducts Another potentiality of duct for the purpose of ensuring natural light from above not come out successful in high-rise structures because of non-availability of adequate space.

3.2 SHELTER:

Shelter is considered as one of the three basic human needs. By some other considerations shelter may be considered the highest and finest product of civilization. Undoubtedly every human being requires shelter, a roof over his head, and for most of the individuals, it means a home, a permanent 'base' where a greater part of one's life is spent. That indicates, shelter is one of the most important phenomenon in people's lives Various experts and organizations endeavored to stress the importance and scope of shelter in various ways Some of their comments, thoughts and recommendations shall be discussed here.

(i) Marzoric Branin Keizer: Marzoric Branin Keizer considers shelter as a great force in molding the mind, character, attitude and behavior of men. In its essence the physical character of dwellings affects the myriad daily activities necessary for normal personal care and family life Undeniably, in poor housing there is a high incidence of illness and adult delinquency. Housing plays an important role in the life of each individual Its physical condition may facilitate or restrict every day activities and may affect physical and mental health [(01)]

(ii) Swart: Swart retains a slightly different view from the above. He opined, the traditional definition of housing as "shelter", "a commodity" or "product" is not adequate because housing means more than just shelter[(02)] Housing is more appropriately defined as a process involving the interaction between an organism and its environment The organism may be single individual, a family or a communal group The environment refers to natural surrounding along with political, economical, social and cultural environments surrounding the organism. The logic behind this definition seems to be based on the principle that for most organisms environment is a well-defined place in which they grow and reproduce. The longer the organism lives in these surroundings the more perfectly they are attuned to them Thus, human being like other organisms evolve their shelter by adapting to environment

(iii) Rapoport: According to Rapoport, 'It is a truism that various dwelling forms result from a complex phenomenon which defies any single explanation'. [03]

(iv) Samuel Aroni: Samuel Aroni provided a comprehensive definition of human shelter saying, every society, developed or developing, has a basic need for housing For every individual, alone or as a part of a family unit, a house, be it a cave or castle is hopefully more than just physical shelter. It should be a home, a residing place in which to try to fulfill the fundamental purpose of human society, namely, a scheme rewarding happy or at least livable life. In our society, which is still based on family as its fundamental unit, a house and home also represent an extended womb for the young during the formative years, during their physical, psychological, educational and emotional development, so vital both to the person and to the community Through its nature, physical locations and characteristics a house provides the enabling or constraining influence on a variety of important services These include physical services such as power, water, transportation or sewage; social services such as health, education or recreation, and economic services such as opportunities for work and income For the individual or the family, the house is both shelter and symbol, physical protection and physiological identity of economic value and a foundation for security and self-respect. [04]

(v) World Health Organization The World Health Organization defines housing as "an enclosed environment in which man finds protection and feels safe and secured from hostile forces and can function with increased comfort and satisfaction as regards privacy to the individual and his family. The environment must include all necessity, services facilities, equipments and devices needed for physical and social well being of the family of the individual. [05]

(vi) International Planning Associates: According to International Planning Associates, USA housing represents the most basic human needs and has a profound impact on health, welfare and productivity of individuals Housing is more than merely the dwelling unit. It is a complex product made up of a combination of services. indoor living spaces, land, utilities, contextual situations (with respect to work and community services), outdoor living space and relationship to neighbors, family members and friends[06]. The basic inputs of housing are: (a) Land, (b) Materials and (c) Finance Housing starts from one room and the combination of rooms creates a house. The science of arrangement of these houses with the provisions of all necessary infrastructures is 'Housing". [07]

(vii) Vancouver Conference on Human Settlements: In 1976 the Vancouver Conference on Human Settlements, Habitat I formulated 64 recommendations for implementation by the national governments, UN system, donors and international techno-financial organizations. Out of those the following three recommendations relating to human accommodation may be mentioned here (a) Human Settlement Policies and Strategies to make the habitat as the place of residence and economic and social development within the territorial limit of all countries for all, to prepare and pursue national housing policy; and to the issues of human settlements transparent for all citizens. (b) Settlement Planning is to be consistent with self-sustainability, civic facilities and housing for all linking it with the urban and rural areas and so on (c) Shelter, Infrastructure and Services through integrated approach, affordability, standard, local technology, industrial and commercial developments linked to households in communities like cooperatives. (d) Land is to be used optimally for all purposes through acquisition, as appropriate, preparation of land records and ensuring security of tenure. (e) Public participation in all developments in human settlements and shelter and (f) Environmental protection[08].

(viii) United Nations: In November 1988, the United Nations in their "Global strategy for shelter to the year 2000" adopted and called upon different governments to take steps for the formulation of a National Housing Policy in the light of 'the enabling approach to achieve the goals of the strategy. The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992 urged upon the governments to formulate national settlement strategies to implement the recommendations of the UNCED in the field of promoting sustainable human settlements [09].

3.2.1 SHELTER POLICY OF THE GOVERNMENT OF BANGLADESH:

The Government of Bangladesh has attached importance in providing residential accommodation for the citizens. Some of the steps taken by the government to this effect are given hereunder.

The **constitution of the People's Republic of Bangladesh** advocates that the people are the utmost concern for the state (the Constitution 1972, Articles 15 to 20) "They (the people) are entitled to enjoy the benefits of human settlements for a healthy and productive life in harmony with nature and in harmony with shared spiritual and moral values and ethnical considerations Inadequate income, poor shelter and homelessness threaten health and security of life, particularly of the helpless children, women and men." [10]

In **Fifth Five-Year Plan 1997-2002** of Bangladesh housing for people has been given due importance mentioning "Housing is one of the most important basic needs of life". [11]

In the **Draft National Housing Policy 1993** housing has been described as "one of the three basic primary needs and is equally important as food and clothing It provides shelter, safety and a sense of belonging to the owner. It also provides privacy and promotes health and comfort"[12].

3.3 RESIDENTIAL ACCOMMODATION IN DHAKA CITY:

The inhabitants of Dhaka city are having bitter experience regarding the acute shortage of residential accommodation. The situations of residential accommodation along with various government measures to meet the demand have been discussed hereunder.

3.3.1 SITUATION OF RESIDENTIAL ACCOMMODATION IN DHAKA CITY:

The fifth Five Year Plan 1997-2002 cites that, there is an acute shortage of affordable housing both in urban and rural areas of Bangladesh [13]. There is housing crisis in the country both in the rural and urban areas. Housing has been considered by the Government of Bangladesh as an integral part of overall improvement of human settlement and economic development" (14)

In the draft National Housing Policy 1993 the problems regarding Housing has been described as, a serious one because of the large number of homeless households, rapid growth of slums and unauthorized squatter settlements, spiraling price of land and construction materials, rampant speculation and phenomenal increase in house rent, insufficient availability of water, sanitation and basic services to bulk of the population (15).

In 1991, the housing shortage was estimated to be 0.95 million units in urban areas and a total of 3 10 million units(16) in the country. In the same report the total housing shortage in 2000 AD was estimated to exceed 5 million units.(17). The Urban Area Report of 2000 Census is now under preparation and is expected to be published in 2005 The same report on 1991 census has been published in August 1997 As regards to dwelling units (Houses), materials used in wall etc the report presents Table 3-01 below.

Table 3-01

STATE OF DWELLING UNITS (HOUSES) BY MATERIAL OF WALL AND ROOF IN DHAKA CITY

MATERIAL OF WALL	TOTAL NO. OF HOUSEHOLD	MATERIAL OF ROOF STRAW, BAMBOO	TILE/C.I SHEET	CEMENT
Straw, bamboo	3,42,820	1,11,690	2,31,130	
Mud, un-burnt brick	1,25,467	21,871	1,03,596	
C.I. sheet, metal	1,42,319	3,773	1,38,546	
Wood	2,969	248	2 721	
Cement/brick	4,74,803	1,704	1,76,462	2,96,637
TOTAL	10,88,378	1,39,286	6,52,455	2,96,637

Source. BANGLADESH POPULATION CENSUS 1991, Vol 3 Urban Area Report, 1997

3.3.2 GOVERNMENT MEASURES TO MEET DEMAND FOR ACCOMMODATION:

The concern of the government of Bangladesh regarding housing scarcity has been expressed in the draft National Housing Policy 1993 as, "The government is conscious of this problem and the enormity of housing crisis in the country. The government intends to create a favorable and conducive environment in the country to give impetus to this sector. The government will endeavor to provide housing to every citizen of Bangladesh through various measures, incentives, motivation, planning and management. Special housing schemes will be prepared for the low income group, the disadvantaged, the destitute and the shelter less poor."[18] Some of the measures and policies taken up by the government to this effect may be mentioned here.

(i) THE FIFTH FIVE-YEAR PLAN 1997-2002: In the fifth year plan 1997-2002[19], the following objectives have been mentioned for the purpose of people's accommodation:

a. Development of low cost houses/multi-storied buildings for housing / resettlement of slum dwellers, the disadvantaged, the destitute and the shelter less poor and in-situ development of slum and of shelters for squatters.

b. Development of sites and services for residential accommodation of low and middle-income groups of people.

c. Construction of condominiums for low and middle-income groups of people.

d. Construction of multi-storied flats for sale to government employees at different places to ease the accommodation problem.

e. Construction of housing facilities for working women.

f. Construction of low-cost houses in the coastal areas of Bangladesh.

g Involvement of the private sector with necessary incentives for its greater participation in the housing sub-sector.

(ii) **NATIONAL HOUSING POLICY 1993 (Draft):** In order to cater for housing problems the National Housing Policy 1993 was prepared and approved by the government The Aims and objectives, Strategies and Policies mentioned in this policy include the following:

(a) AIMS AND OBJECTIVES:

a. To ensure housing for all strata of society, and to accelerate housing production in urban and rural areas with major emphasis on needs of the low and middle income groups

b. To make suitably located land at affordable price for various target groups, especially for the middle and low-income groups.

c. To mobilize resources for housing through personal savings and other financial inputs.

d To ensure effective implementation of the housing programs, promote use of locally developed materials and construction techniques and increase production of forest based building materials

e. To improve and enhance the character, quality and environment of the existing residential areas in urban areas.

f To promote inter-sectoral coordination within the framework of national, urban and regional plans.

g. To develop new strategies and undertake revision of the policy from time to time to cope with the emerging housing needs and problems in the country.

h. Undertake action oriented research in all aspects of housing problems and to foster minimization of cost and rent.

In order to fulfill the above objectives the following Strategies and Policies were declared in the draft National Housing Policy 1993 [20]:

(b) STRATEGIES:

a. Housing will be given due priority in the national development plans.

b. The role of the government will be primarily be to increase access to land, infra-structure, services and credit and to ensure availability of building materials at a reasonable price, specially to the low and middle income groups and to create and promote housing finance institutions, where as actual construction of housing will generally be left to the private sector developers, the people themselves and the NGO's.

c. Austerity will be maintained in building houses and efforts will be made to economize housing costs, discourage extravagant construction, facilitate incremental house building, ensure wide application of low cost technology and optimum use of resources at the individual and national levels both in public and private sectors.

(c) POLICIES:

a. Tax concession will be given to those who build houses with their own resources.

b Hire purchase system for housing in the private sector will be encouraged.

c. Tenancy Act will be updated for renting houses in the urban areas for mutual benefit of both owners and the tenants.

d. Abandoned houses will be turned into multi-storied buildings by the Housing and Settlement Directorate in phases for solving the housing problem.

e. The size of residential plots will be limited to 3 katha in Dhaka city and 5 katha in other places in housing estates developed by the government and the private sector.

f. Necessary action will be taken to strictly enforce Building Code of 1993.

g Arrangements for soft loans for housing will be máde for the poor; to this end, a special fund will be created by the government.

h. Rural housing will be given emphasis by providing better access to land, finance and cheap affordable and durable building materials and technology following the Grameen Bank Model

i. Houses for working women will be constructed by the relevant city/ town authorities: and

j. Low cost houses in the coastal areas of Bangladesh will be constructed by the local bodies and funded by the government.

(iii) **BANGLADESH NATIONAL BUILDING CODE 1993:** Bangladesh National Building Code 1993 was prepared with an objective 'to establish minimum standards for design, construction, quality of materials, use and occupancy, location and maintenance of all buildings within Bangladesh in order to safeguard within achievable limit, life, limb, health, property and public welfare'. The provision of this code is applicable to all persons of Bangladesh irrespective of class, creed, culture, religion and sex.

According to PREFACE of this book "Buildings, be it for housing, industry and education, healthcare or any other use, constitute the major part of construction for physical infra-structure development of the country. A substantial portion of national resource is invested in building construction both in public and private sectors. In order to ensure optimum return of this investment and to achieve satisfactory performance of the building in terms of serviceability, health, sanitation and general welfare of the people, building construction needs to be controlled and regulated. Legislative measure for such control has been taken in the building construction act of 1952 and other relevant acts, ordinances and regulations"

(iv) **BUILDING CONSTRUCTION ACT 1996:** Ministry of Housing and Public Works, Government of the People's Republic of Bangladesh on July 18, 1996, on the basis of empowerment by Building Construction Act, 1952 [21] Section 18 declared Building Construction Act 1996. It has been made obligatory for all to follow these rules and regulations, at the time of design and construction of buildings and structures in the urban areas of Bangladesh.

(v) **NATIONAL HOUSING AUTHORITY:** In 1993, in view of an estimated housing shortage of 3.10 million units, and 'being conscious of this problem and enormity of the housing crisis in the country' the Government of Bangladesh formulated National Housing Policy. This policy was revised and a law was made for the formation of National Housing Authority (NHA) in 1999. According to this law the Housing and Settlement Directorate (HSD) and the Commissioner (Settlement) were to be abolished and absorbed in the NHA. All the responsibilities, assets, debts, law-suits, offices and employees, contracts or contract of services were to be taken by the NHA. The law was signed by the then president on 11 July 2000 and the date of enactment was fixed to have been 15 July 2001. In a gazette notification the Ministry of Finance informed that the relevant authorities okayed the posts and organogram for the NHA. The Ministry of Establishment, however, pointed out that the organogram and charter of duties for the NHA were not appropriately formulated.

Sri-Lanka formed a co-ordinated organization for the purpose of solving housing crisis in that country in as early as 1979 and attained tremendous success. Even though the policy towards such an organization was initiated in 1993 in Bangladesh, the same could not get a start even after a decade, not to say anything about active ventures to solve housing crises in the country.

3.4 HIGH-RISE AND TALL BUILDINGS:

Even though high-rise and tall buildings were initially constructed to meet corporate image for large corporations, at present these are constructed to accommodate all possible types of uses and a considerable number of those are used for residential purposes These are commonly known as apartment buildings. Before going into the discussion of various aspects of apartment building, a brief discussion on high-rise and tall building shall be presented here

3.4.1 HIGH-RISE BUILDINGS:

The term high-rise is a popular term that people use to identify buildings above the general height of buildings. The experts in urban climates use the term 'urban canopy' to denote this general height. So, in other words, all buildings above the urban canopy may be called high-rise or sky-scrapper. That indicates, the height of such buildings shall vary from place to place and from time to time. And "one should not wonder in it, since the first sky scrapper of the world was a ten-story building [22]. In such a situation endeavor may be made to find out the parameter of high-rise building in Dhaka city from the following considerations:

(a) Visual appearance Up to the sixties most of the buildings in Dhaka were four story high. In the seventies a number of six-storied residential buildings were constructed both in the private and public sectors The trend of the nineties, however, is to go for buildings with 10 to 20 stories or even more. But as of today, any building above six stories presents a 'high-rise appearance' in the city.

(b) Structural analysis and design: In case of structural load calculations of buildings in Dhaka city the lateral loads needs to be taken care of in buildings over six stories.

(c) Walk-up limit: For quite a long time four story height was considered to be the walk-up limit in Bangladesh At present, however, people walk up to six story heights and they are becoming accustomed to this height

(d) RAJUk's regulation: Rajdhani Unnyan Kartipakkha (RAJUK) in their Building Construction Act has made the use of elevator, fire-escape stair and solid-waste chute essential for buildings above six stories.

Thus from the above five considerations viz. (a) Visual appearance, (b) Structural analysis and design, (c) Walk-up limit, (d) RAJUk's regulation it seems quite logical to opine that, in the present context in Dhaka city 'buildings above six floor height may be taken to be high-rise buildings'.

3.4.2 TALL BUILDINGS

As of today there is nothing that defines the physical parameters of high-rise or tall buildings in terms of their heights or number of floors The council for Tall Buildings and Urban Habitat concluded that 'a tall building is not strictly defined by the number of stories or its height'. The important criterion is 'whether or not the design, use or operation of the building is influenced by some aspects of tallness'. In order to simplify the work on collection and compilation of data for such buildings, CTBUH decided to include in its database on tall buildings 'any building nine or more stories in height' in their file[23]. This however, led many experts to present various types of comments like: (i) 'The buildings which are more than 9-storied in height are considered internationally as Tall Buildings' [24] .(ii) 'The definition of Tall Building is controversial. In our country as per provisions of RAJUK, any structure of six or more story is considered as a tall structure. But a more international definition as advocated by council for tall structure is a structure with nine story or more' [25]

Some experts attempted to define tall building from structural aspects like, 'From structural design and construction point of view it is simpler to consider a building tall when its structural analyses and design are in some way affected by the lateral loads' [26]

It is also interesting to note that many experts have considered tall-building and high-rise building synonymous Some of their comments may be cited here. (i) The building with a height of 20 meter or more is normally called as tall (high-rise) building in Bangladesh [27] (ii) 'Recent years, however, have witnessed an ever increasing trend towards construction of buildings which can be classified as "high-rise" (nine stories or more)[28]

The term high-rise has always been used by the common people in a relative or comparative sense. For example, (i) 'The relative term High/Low depending on the height of the adjacent buildings or objects being compared with. has come up to whether the building is more or less six storied in case of Dhaka city' [29] (ii) 'In a single story area a five story building will appear tall. In Europe a 20-story building in a city may be called a high-rise, but the citizen of a small town may point to their skyscrapers of six floors In large cities, such as Chicago or Manhattan which are comprised of a vast number of tall buildings, a structure must pierce the sky about 70 to hundred stories if it is to appear tall in comparison with the immediate neighbors. Tall buildings cannot be defined in specific terms related to height or number of floors' [30].

The most reasonable statement given by CTBUH goes on 'tall building is not defined by the number of stories. heights or the question of structural analysis. But a tall building is the one having "some aspect of tallness in its design, use or operation" Even though CTBUH decided to include all buildings above 9 floor for the purpose of simplicity of collection and compilation in its database on tall buildings, that does not necessarily mean that 'any building above 6 or 9 story height, as commented by some experts, is a tall building'.

3.5 HIGH-RISE RESIDENCES IN DHAKA:

In order to meet the ever-increasing demand for residential accommodation in the limited land of Dhaka city the construction of high-rise residential buildings was a natural and viable solution, of course with natural consequences. The context and reasons behind the growth of high-rise residential buildings have been discussed hereunder.

3.5.1 CONTEXT OF GROWTH OF HIGH-RISE RESIDENCES:

During Pakistan period public sector housing in general denoted accommodation for government employees only. But gradually the horizons of public housing have been extended to include the low to middle income groups, student housing, housing for single working women, relief and rehabilitation housing, worker's housing, housing for squatters and the landless etc [31]

The inadequacies in the then public housing was observed in the draft National Housing Policy 1993 as, "Public housing has, in general, failed to strike a balance between proper housing design, standard and architectural style on the one hand and use of innovative building materials and affordable housing on the other. The public sector has generally followed a land development policy, which largely benefited some higher and upper-middle income groups. This has particularly caused distortions in the land market and often led to sub-optimal development"[32].

Government efforts in providing housing primarily limited to government employees and some of the urban public, could not make any significant development in the urban housing scene. With a huge backlog of housing need mounting in the cities a new generation of real estate entrepreneurs came into the picture. In some cases plots were subdivided and sold out, and in others houses were constructed, some for individual ownership and others for multi-ownership of buildings with flats for individuals [33]

As soon as the policy to accommodate more people on less land was in principle accepted, the inevitable solution was to go for multi-storied residential building. Consequently 'the transformation of public housing from single-family-on-single-lot typology to walk-up flats had been a significant change [34]. Even though apartment living is a western concept and although alien to our culture, it is now gradually finding its way into our society. [35]

In 1993 in a seminar on Tall buildings the planners expressed that, high-rise residential buildings were a new additions in the capital city of Dhaka and that those were being constructed by private developers along main thoroughfares and at places proximate to central business district"[36].

The first residential high-rise building was the 12 story high staff-quarter for Bangladesh Navy at Banani, Dhaka [37] The first developer built housing was at Pallabi, Mirpur in 1964 [38] In this project, the developer made an agreement with the buyers to develop the land and construct complete building just after an initial payment. The rest of the money was borrowed by the company on behalf of the buyers; from a loan giving agency and the company constructed the houses with the borrowed money. So, the buyers had only to invest in the land initially. The project covered 1000 houses of different types ranging from 500 Sq Ft to 1940 Sq Ft on plots of 2 5 to 5.0 Katha[39].

The present scenario of construction and management of apartments, however, is different, because the private apartment developers operate in two different methods In one method they buy land on their own, offer flats to probable buyers through advertisements in newspapers and start construction of flats with installments paid by the buyers and bank loan. In the second method developers come under proportional ownership arrangement They make some down payments to the landowners and share apartments at 60-40 (developer: land owner) arrangement. The quality of construction of apartment buildings is generally better in the second method, since landowners try to ensure the quality of construction [40]

In the urban housing sector, the most noticeable change has been the introduction and the growth of housing colonies and Dhaka now proliferates with multi-storied apartments and flats. The architect's skill now faces a new challenge: the challenge being to keep those marks of Bengali identity in buildings which (for the client) represent a commercial venture and as far as apartment living is concerned the living pattern and needs that it serves, do not have a historical reference within the region but are part of international phenomenon of urban growth How architects respond to this challenge is indeed crucial, as it decides whether our cities will be transformed into faceless concrete jungles, or whether we will be able to stamp our buildings with our history of struggle for identity. The architect/planner has to negotiate between technical / commercial requirements and architectural expression which evokes our history, our culture and traditions [41].

Apartment living is a western concept and although alien to our culture it is gradually finding its way into our society Developer built housing in terms of high-rise apartment living will take some time, before its socio-cultural impact can be properly evaluated

Due to scarcity of land in Bangladesh, where rapid urbanization is taking place the Bengali dream of a personal home ownership with a garden on the ground level, will remain a dream for most of the people Unless there is a revolutionary change in government policy and program on urban housing, developer-built housing will come to be a significant housing supply system for the urban dwellers who can afford it The developer-built housing, particularly the high-rise ones are already changing the cityscape dramatically. Architects and city planning authorities should make a concerted effort so that this newly emerging powerful form can provide a definite and desirable addition to the physical character of our cities. [42]

3.5.2 REASONS BEHIND THE GROWTH OF HIGH-RISE RESIDENCES:

The physical boundary of Dhaka city is growing almost every day. The government, however, has declared a targeted area of 401 Sq. Km. A flood control dam has been constructed enclosing about 260 Sq Km. of land It may be noted that flood has become a headache for Dhaka city in the recent years and it is quite likely that the greater population of the city shall live within the area enclosed by the flood control dam. The Tables 3-02, 3-03, and Figures 3-01, 3-02, 3-03, 3-04 show the Population in Dhaka City Corporation, Area of the city and Population Density in persons per Sq. Km from 1951 to 2001.

Table 3-02

DHAKA CITY: POPULATION, AREA AND POPULATION DENSITY FROM 1951-2001

CENSUS YEAR	POPULATION	AREA IN SQ. KM.	DENSITY IN PERSON / SQ.KM.
1951	335,928	72	4,666
1961	550,143	91	6,046
1974	1,607,495	95	4,981
1981	2,816,805	206	13,452
1991	4,232,034	276	15,333
2001	5,578,023	360	14,939

Source: URBAN AREA REPORT, 1997, Vol. 3 of Bangladesh Population Census 1991 and Preliminary Population Report, 2001 census.

Figure 3-01: INTER-CENSAL INCREASE OF POPULATION IN NUMBER

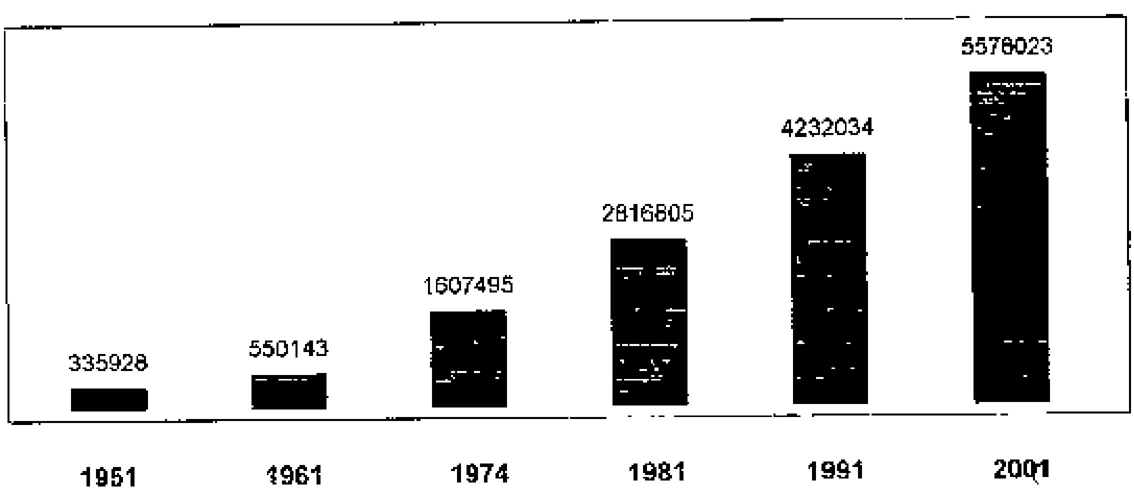


Figure 3-02: INTER-CENSAL INCREASE OF AREA OF DHAKA CITY IN SQ. KM.

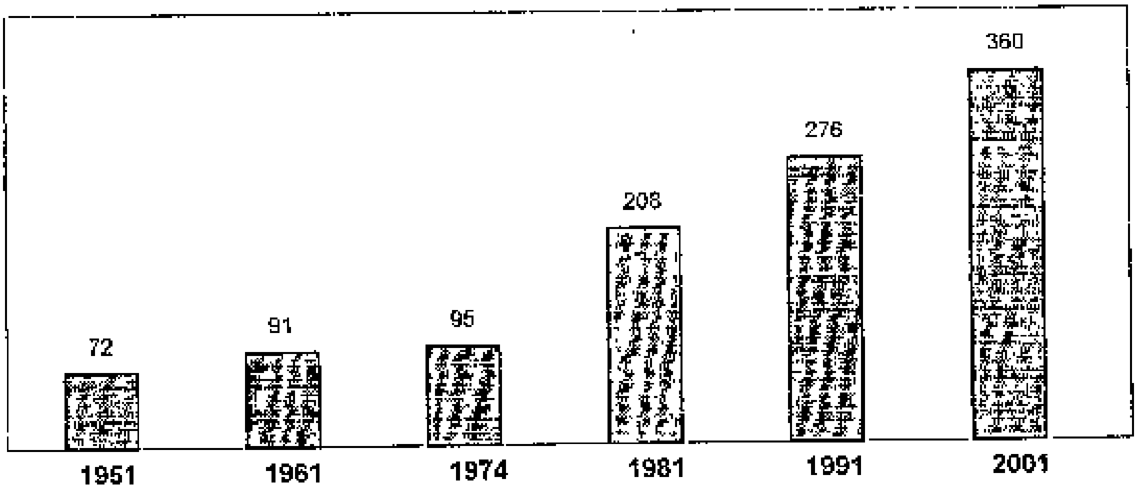
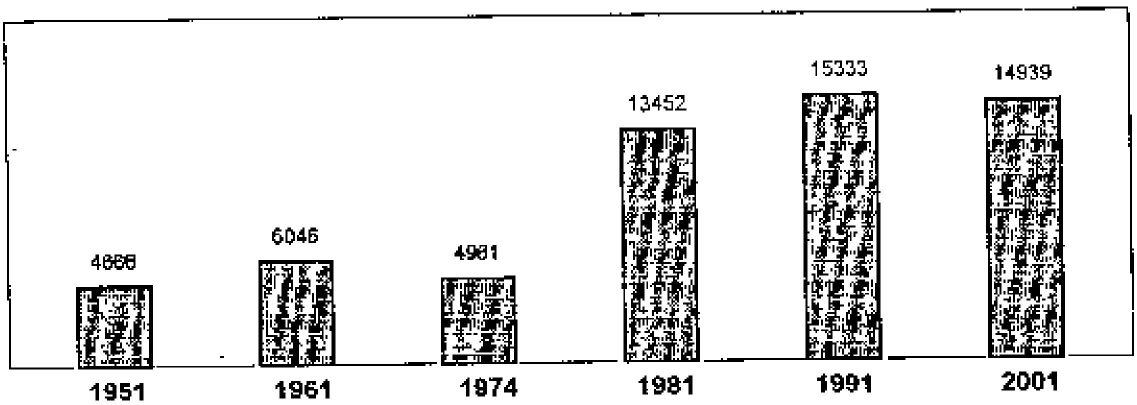


Figure 3-03: INTER-CENSAL INCREASE OF POPULATION DENSITY IN PERSONS PER SQ. KM.



Considering the value of 1951 as 100 and the base, their percentile variations in 1961, 1974, 1981, 1991 and 2001 may be calculated as follows:

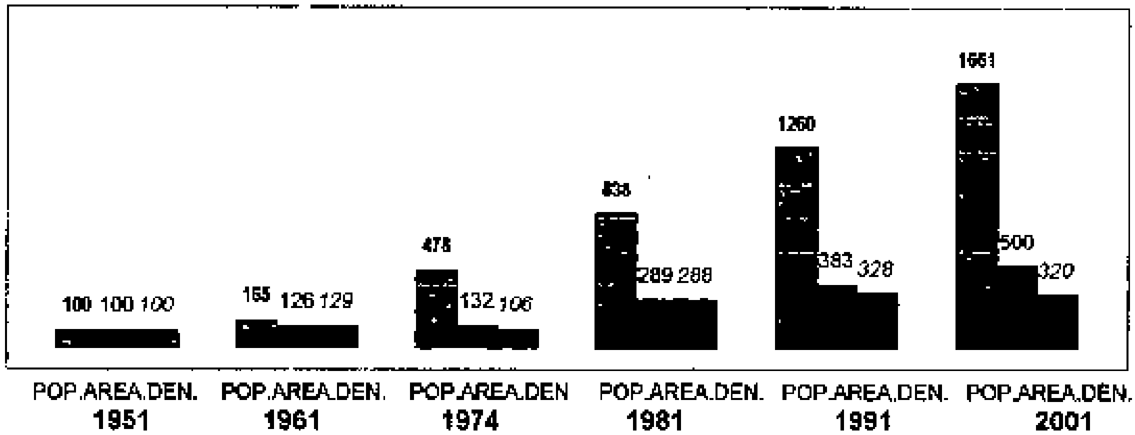
Table 3-03

PERCENTILE VARIATION OF POPULATION, AREA AND DENSITY IN DHAKA CITY THROUGH 1951 - 2001

ITEMS	1951 BASE	1961 VARIATION	1974 VARIATION	1981 VARIATION	1991 VARIATION	2001 VARIATION
(i) Population	100	+65%	+378%	+738%	+1160%	+1561%
(ii) City Area	100	+26%	+32%	+189%	+283%	+400%
(iii) Pop. density	100	+ 29%	+6%	+188%	+228%	+220%

For easy understanding the above Table has been presented in graph in Figure 3-04 below.

Figure 3-04 PERCENTILE VARIATION OF POPULATION, AREA AND DENSITY IN DHAKA CITY THROUGH 1951 - 2001



With the increase of population with lesser increase of area, there was gradual increase in the price of land for habitation The experts observed that, Dhaka experienced an unprecedented increase in land value since the early seventies. In the past decade the city developed mainly towards the north From sixties up to recent times RAJUK has provided nearly seven thousand plots at subsidized rate mainly for the middle and upper income group.

The value of land in Dhaka city, mainly in the central area, has increased at a rate much higher than the rate of any other commodity. While between 1969 and 1979 the cost of living in Dhaka has increased four folds, the price of high-class residential land has increased approximately 25 to 35 times[43].

In a seminar held in Dhaka in 1993 one expert mentioned that the land prices in Central Dhaka soared from Taka 3.00 Sq. Meter in 1950 to Taka 8000 00 per Sq Meter in 1990. The expert also observed that, in the absence of any land value records it was very difficult to compare the land value over the past decades'[44]

The account published by the Center for Urban Studies (CUS), Dhaka University and Sheltech regarding land price in different area in Dhaka city in 1990 has been presented in Table 3-04. While the price up to 1990 was based on information that on 2000 was their speculation This researcher contacted in September 2001 for the latest information regarding land price in Dhaka city. But they replied there was no work in this field.

Organizations like Rehab, (the association of the Real Estate Developers in Bangladesh) was contacted for latest information, but they also could not help In such a situation this researcher contacted the developers. This source informed, they had an understanding among themselves to pay around Taka 12 lac to 14 lac per Katha in areas where there is height restrictions and Taka 12 lac to 18 lac per Katha where there is no such restriction. The land value is Taka has been given in Table 3-04 and in Graph in Figures 3-05 below

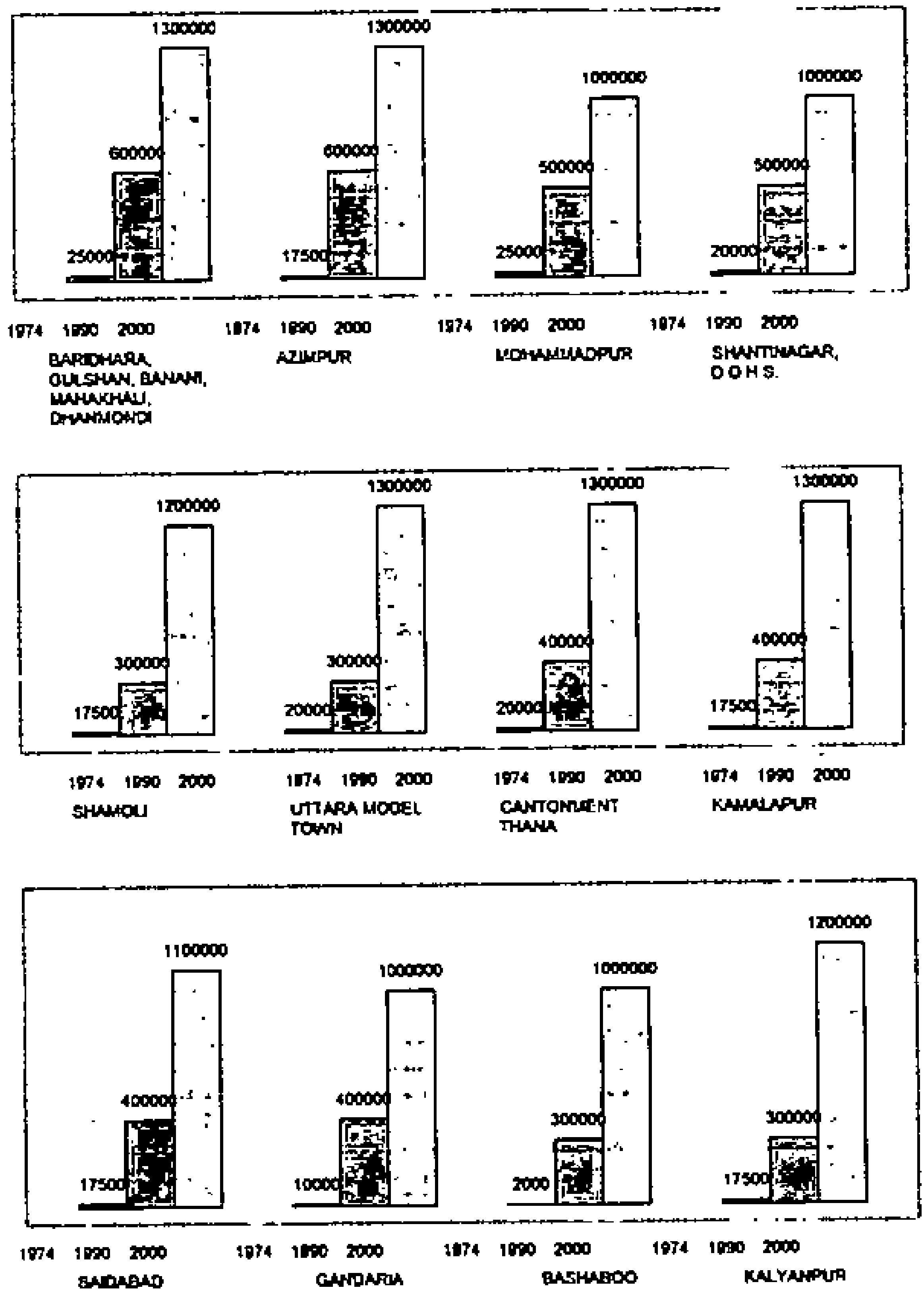
Table 3-04

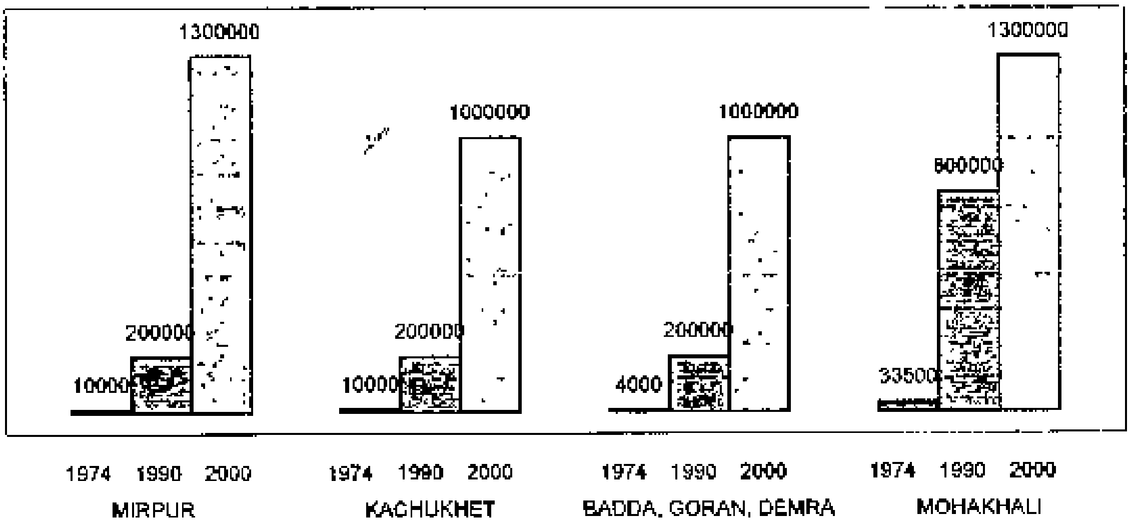
LAND VALUE INCREASE IN DHAKA CITY: 1974-1990-2000

AREA	YEAR 1974 TAKA PER KATHA	YEAR 1990 TAKA PER KATHA	YEAR 2000 TAKA PER KATHA
Baridhara	25,000	600,000	1300,000
Gulshan	25,000	600,000	1300,000
Banani	25,000	600,000	1300,000
Mohakhali	25,000	600,000	1300,000
Dhanmondi	25,000	600,000	1300,000
Azimpur	17,500	600,000	1300,000
Mohammadpur	25,000	500,000	1000,000
Shantinagar	20,000	500,000	1000,000
DOHS	20,000	500,000	1000,000
Shamoli	17,500	300,000	1200,000
Uttara M Town	20,000	300,000	1300,000
Cant Thana	20,000	400,000	1300,000
Kamalapur	17,500	400,000	1300,000
Saidabad	17,500	400,000	1100,000
Gandaria	10,000	400,000	1000,000
Bashaboo	2,000	300,000	1000,000
Kalyanpur	17,500	300,000	1200,000
Mirpur	10,000	200,000	1300,000
Kachukhet	10,000	200,000	1000,000
Badda	4,000	200,000	1000,000
Goran	4,000	200,000	1000,000
Demra	4,000	200,000	1000,000
Motijheel C.A.	50,000	1,200,000	No information
Karwan Bazar	41,500	1,000,000	No information
Mohakhali C.A.	33,500	800,000	1300,000

Source: CUS, Dhaka University 1974, Sheltech – 1990.

Figure 3-05 LAND PRICE IN TAKA PER KATHA IN VARIOUS AREAS OF DHAKA CITY IN BETWEEN 1974 TO 2000.





From Table 3-03 it may be seen that from 1951 to 2001 the area of City Corporation increased by about 400%, where as population has increased by 1561%. This indicates, there is tremendous demand for land for the people who are now living in sub-standard houses or in the fringe areas. The above picture shows only the people who have migrated and are now living in the city. The number of people who now live outside Dhaka and are willing to come to live in the city in the near future has not been considered in this account. The editors of the "Contemporary Architecture Bangladesh" observed, in the seventies the liking of one section of the middle class moved away completely in a different direction. Bangladeshi people working abroad were remitting money to be invested in land with the hope of building a house on it The developers were quick in understanding its potentialities They started producing tempting condominiums on prime land. Bangladeshi abroad saw the chance of owning apartments without the trouble of building houses on their own. Thus a large amount of foreign currency coming in through the wage-earner scheme was being invested in developer-built housing And housing turned to be a booming construction activity in Dhaka [45].

The only way in which the developers could provide more and more number of apartments on limited land was to go for more floors, or in other words, increase height that increased the building height. The trend towards construction of high-rise buildings in Bangladesh is very much connected with the very high price of land in important areas. Since land value is very high in the inner city areas, one may quite logically think of increasing population density through multi-storied construction [46].

Other than the wage earners working in the Gulf countries, there were demands of apartments from another group of consumers. They were, a new group consisting of young urban professionals and young couples, who preferred to break away from the tradition of the joint-family structure and to live independently. For this group the developers were after producing functional, sophisticated apartments with westernized living arrangements, consistent with their lifestyle and taste' [47]. Developer-built housing has in time become a sign of affluence in the city[48]. The change in the clientele has effected internal organization to a large extent As new clients are opting for contemporary ideas, spaces are becoming smaller and manageable and a pattern of simplified living is being developed.

Since these buildings have to compete on the open market, developers are now willing to take into consideration the psychological, aesthetic and environmental needs of the prospective buyers [49]

3.5.3 CONTROLLING & REGULATORY MEASURES IN GROWTH OF BUILT-FORMS IN DHAKA CITY

The physical growth, architectural design and construction of high-rise buildings have always been influenced by various provisions, rules and byelaws imposed by the government Some of these regulatory measures concerning the design of such buildings and related with climatic thermal conditions inside the built-space is discussed here.

(i) **BUILDING CONSTRUCTION ACT – 1996:** It is obligatory for all Architects, Designers and Developers to follow the Building Construction Act of 1996 and hence the design of residential high-rise considerably depends on these rules and regulations. Following are some of the relevant articles that control the growth of residential high-rise buildings in Dhaka city[50] (a). **Setback of building from the road:** (i) There must be a 3 65 Meter wide road leading to the site. In case of the road owned privately, the width may be 3.00 Meter wide. (ii) One Meter by one Meter space must be kept open in case of two roads meeting at a corner. (iii) The building must be placed at a minimum distance of 4 5 Meter from the center of the adjacent road, or it must be at a distance of 1.5 Meter from the site line. The larger one is to be considered.

(b). **Height of building:** The maximum height of the building must not be more than two times of width of the front road plus open space in between the road and the building. Provided,

If this sum is 7.60 Meter, the maximum height of the building will be 9.50 Meter

If this sum is 10.60 –13.59 Meter, the maximum height of the building will be 12 50 Meter.

If this sum is 13.60- 16.59 Meter, the maximum height of the building will be 15.50 Meter.

In case the width of the front road is

between 4 55-7.59 Meter. the maximum height of the building will be 18.50 Meter.

between 7.60-10.66 Meter, the maximum height of the building will be 27.50 Meter.

between 10.67- 15.24 Meter, the maximum height of the building will be 42.50 Meter.

between 15.25- 22.99 Meter, the maximum height of the building will be 60 50 Meter.

(c). **Light and ventilation** (i) There must be provision for light and ventilation in all rooms through door, window, fanlight etc (ii) The kitchen must have an exterior wall.

(d). **Roof overhand, cornice and sunshade** (i) These must be constructed such that there must not be drainage of water to other's properties. (ii). Roof or cornice will be allowed to extend maximum up to 0.50 Meter. (iii) Sunshade over door or window shall extend maximum 0.50 Meter. (iv) In case of seven or more storied residential building, garbage chute must be provided

(e). **Open space for residential building:** Open space to be provided on the rear and two sides as per Table 3-05 below:

Table 3-05

OPEN SPACE TO BE PROVIDED ON THE REAR AND TWO SIDES

AREA OF SITE	REAR OPEN SPACE	OPEN SPACE ON BOTH SIDES
a. Up to 134 Sq. Meter	1.00 Meter	0.80 Meter
b. From 134-200 Sq Meter	1 00 Meter	1 00 Meter
c From 200-268 Sq Meter	1.50 Meter	1 00 Meter
d. Over 268 Sq. Meter	2 00 Meter	1.25 Meter

Source : Building Construction Act of 1996.

(f) Special rules for buildings over seven floors: (i) There must be elevator(s). (ii) There must be an emergency generator. (iii) There must be fire-fighting arrangements. (iv) Buildings over 45 70 Meter tall must have indicator light for aviation (v) For buildings with ten or more floors there must be 2.50 Meter open space on both sides and 3.00 Meter at the rear side. (vi) For buildings with ten or more floors 5% space must be provided as community space

(ii) BANGLADESH NATIONAL BUILDING CODE -1993:

(a) PURPOSE: The purpose of Bangladesh National Building Code or BNBC, as has been mentioned in Chapter 1 Page "is to establish minimum standards for design, construction, quality of materials, use and occupancy, location and maintenance of all buildings within Bangladesh in order to safeguard, within achievable limits, life, limb, health property and public welfare. The installation and use of certain equipment, services and appurtenances related, connected or attached to such buildings are also regulated herein to achieve the same purpose [51]

(b) APPLICATIONS: As for range of application it has been mentioned "The provisions of this Code are applicable to all persons of Bangladesh irrespective of class, creed, culture, religion or sex The Code doers not, in any way create or otherwise establish or designate any particular class or group of persons who will or should be specially protected or benefited by provisions of this Code" [52]

(c) OBJECTIVE: The objective of the Code, as mentioned "is to insure public safety, health and general welfare insofar as they are affected by the construction, alteration, repair, removal, demolition, use or occupancy of buildings, structures or premises, through structural strength, stability, means of egress, safety from other hazards, sanitation, light and ventilation". [53]

(d) SCOPE: The scope for BNBC has been written as "The provisions of this Code shall apply to the design, construction, use or occupancy, alteration, moving, demolition and repair of any building or structure and to any appurtenances installed therein or connected or attached thereto, except such matters as are otherwise provided for in other ordinances and statutes controlling and regulating buildings. [54]

Buildings, be it for housing, industry, education, health care or any other use, constitute the major part of construction. A substantial portion of national resource is invested in building construction both in public and private sectors In order to ensure optimum return of this investment and to achieve satisfactory performance of the building in terms of safety, serviceability health, sanitation and general welfare of the people, building construction needs to be controlled and regulated [55]

Some development and construction agencies of the government have their own rules and established practices. However, these regulations, ordinances, rules and practices are not comprehensive and needs updating, rationalization and unification It is imperative that a uniform standard of practice coving all aspects of planning, design and construction of building, including electrical, mechanical, sanitary and other services, be followed in the country Such a standard can be provided by a comprehensive building code appropriate to the needs of the country. [56]

(e) CLASSIFICATION: In Bangladesh National Building Code 1993, (BNBC) Residential Building has been classed as 'A' by Occupancy Classification.

(f) DESIGNATION OF FLAT: According to BNBC, Flats or apartments have been designated by A-2 and have been defined as, any building or portion thereof or group of buildings in which living quarters are provided for more than one family, living independently of each other, with independent cooking facility for each family. Flats or apartments may be located in walkup buildings, high-rise buildings or in housing complexes.

(g) EXTERNAL OPENING: BNBC has proposed that at least one side of all habitable rooms should be exposed to an exterior or interior open space or to a balcony or verandah Proposal has also been made such that all buildings facing a street and having height not more than 17 Meters or five stories be constructed at a distance of at least 4.5 Meters from the center of the street or at least 1.5 Meters from the road front property line which ever is greater.

(h) **OPEN SPACE:** All buildings facing a street and having height more than 17 Meters or five stories have been proposed to be constructed at a distance of at least 4.5 Meters from the center of the street or at least 2 Meters from the road front property line which ever is greater

The minimum side and rear open space requirement as per BNBC have been shown in Table 3-06 below

Table 3-06

MINIMUM SIDE AND REAR OPEN SPACE REQUIREMENT:

Occupancy :	Plot size	Min. rear open space	Min. side open space
Residential :			
Not higher than 10 stories	Not over 135 m^2	1 25	Nil
(or 33 m)	Over 135 to 200	1 5	1.25
	Over 200 to 265	1.75	1.25
	Over 265 to 330	2.5	1.25
	Over 330 to 660	3 0	1 25
	Over 660	4 0	1.25
Not higher than 10 stories* (or 33 m)	Any	4.0	3.0

*Minimum open space at the front 6.0 m.
Source: BANGLADESH NATIONAL BUILDING CODE (BNBC) - 1993

(i) **INTERNAL COURTYARD** As for interior courtyard, BNBC advocates that if any room depends entirely on an interior open space for its light and ventilation, such interior open space should be in the form of an interior courtyard open to the sky over its entire cross-section The dimension of the courtyard shall depend up on height of the building and shall vary as shown in Table 3-07 below.

Table 3-07

BUILDING HEIGHT AND INTERIOR COURTYARD REQUIREMENT

NO. OF STORIES	HEIGHT IN METERS	MIN. NET AREA OF INTERIOR COURTYARD IN SQ.M.
6	20	36
7	23	49
8	26	64
9	29	81
10	32	100
11	36	121
12-13	42	144
14-15	48	196
16-17	54	256
18-20	63	361

Source BANGLADESH NATIONAL BUILDING CODE (BNBC) - 1993

(j) COMMUNITY SPACE: In case of Community open space and amenities, BNBC advocates that for all residential or residential cum business buildings having ten or more stories, community space at the rate of 5% of the total floor area needs to be provided either within the building or outside within the premises solely for the use of the occupants of the building BNBC suggests that roofs of such buildings should not be considered as community open spaces For residential or residential cum business plots measuring more than 0.1 hectare, 10% of the area of land should be left vacant to be used as children's playground This playground should be continuous and should have a length not exceeding 2.5 times its width. The playground may extend into the mandatory open space of the plot.

BNBC also suggests that for all plots on which more than one residential or residential cum business buildings are constructed. community space at the rate of 5% of the total floor area of all the buildings should be provided either within the building or outside within the premises and that roofs of such buildings should not be considered as community open spaces.

(k) HEIGHT OF ROOMS: As for heights of rooms, BNBC suggests that all habitable rooms in non-air-conditioned residential buildings, apart from kitchen, store room utility room, box room and garage should have a ceiling height not less than 2.75 Meters measured from the finished surface of the floor to the underside of the finished ceiling or false ceiling. A minimum of one third of the floor area of such habitable rooms may, however, have a minimum ceiling height of 2 44 Meters. For air-conditioned rooms in such buildings, the minimum ceiling height should be 2 44 Meters

(l) DIMENSIONS OF ROOMS According to BNBC every dwelling unit in a residential building should have at least one room, which shall have not less than 9.5 Sq Meters of floor area with a minimum width of 2 5 Meters Other habitable rooms in the dwelling unit should have a minimum area of $5m^2$ each with width of 2 Meters.

(m) LOCATION OF BATHS, TOILETS ETC.: Every bathroom, toilet and water closet should be located against an exterior wall or wall on the interior open space, except where they are ventilated through an interior lighting and ventilation shaft with minimum specified dimensions as shown in Table 3-08 below

Table 3-08

BUILDING HEIGHT, MIN. CROSS-SECTIONAL AREA AND MINIMUM WIDTH OF SHAFT

BUILDING HEIGHT No. of Stories	Height(m)	MIN. CROSS-SECTIONAL AREA OF SHAFT m^2	MINIMUM WIDTH OF SHAFT in m
6	Up to 20	5.0	2.0
Over 6	Over 20	6 5	2.5

Source. BANGLADESH NATIONAL BUILDING CODE (BNBC) - 1993

(n) SHAFTS: BNBC suggests that the shafts of buildings exceeding six stories or a height of 20 Meters should be mechanically ventilated and that all shafts must be accessible at the ground floor level for cleaning and servicing purposes

(o) VENTILATION, LIGHTING & SANITATION: BNBC suggests that all rooms and interior spaces designated for human occupancy shall be provided with means of natural or artificial lighting and natural or artificial ventilation. All naturally ventilated and illuminated interior spaces, staircases and other areas of human occupancy in a building should have windows or ventilators opening directly to the exterior or an interior open space or to a verandah. BNBC suggests that ventilation of bathrooms may be ensured through ventilation shafts

(p) AGGREGTE AREA OF OPENING: BNBC suggests that all habitable and non-habitable spaces within a building should have the following minimum aggregate area of openings in the exterior walls, excluding doors Table 3-09 below shows the recommended open space expressed as percentage of the net floor area

Table 3-09

MINIMUM AGGREGATE AREA OF OPENINGS IN THE EXTERIOR WALLS

Habitable rooms like sleeping, living study, dining etc.	15%
Kitchens	18%
Non-habitable spaces like bathroom, store, staircase etc.	10%

Source. BANGLADESH NATIONAL BUILDING CODE (BNBC) - 1993

3.6 CLIMATE IN HIGH RISE BUILDING

The climatic condition in a man-made urban environment may differ appreciably from those in the surrounding environment. Differences may exist in (i) Annual and diurnal patterns of temperature, (ii) Humidity, (iii) Wind conditions, (iv) Solar radiation, (v) Long wave nocturnal radiation, (vi) Fog and precipitation, (vii) Turbidity and chemical composition of air etc. [55] These topics have been discussed in the chapter on Climate. Here discussions will be done on the climatic issues specific to high-rise residential buildings only

(i) DIRECT ACCESS MULTI-STORY APARTMENTS WITH TWO UNITS PER STAIRCASE: Givoni mentioned of climatic problems and advantages of this type of multi-story apartments as, 'a much better design scheme than corridor type buildings, from the climatic view point is to have staircase serving directly two apartments on each floor. With this scheme each apartment has two opposite external walls and the whole building, a block containing several such staircases, can be oriented optimally' [56]

This building type, in conjunction with appropriate urban (neighborhood) design, which provided sufficient exposure of the individual buildings to the sun and the prevailing winds, can ensure the potential for effective cross ventilation and solar heating for all the dwelling units.

In contrast with the single loaded corridor type, such buildings do not compromise the privacy of the inhabitants while the apartments are cross ventilated According to Giovanni "With two apartments to a staircase each one of the external walls can serve as a solar heat source".

COMMENTS ON GIVONI'S ABOVE STATEMENT: Givoni's above statement has been prepared on the basis of conditions prevailing in cold countries. In tropical countries with less of winter solar heating is not essential. Rather minimizing the affect of solar radiation from the western wall presents problem.

(ii) **TOLERANCE OF ORIENTATION**: The 'tolerance' of building orientation, for providing cross-ventilation is about 60 degrees on either side of the prevailing wind direction. Because of the larger tolerance of the solar orientation the prevailing wind direction, especially during the evenings, should be the main factor in choosing the optimal orientation of the building block, especially in hot humid regions.

COMMENTS ON ABOVE GIVONI'S STATEMENT: The statement of tolerance in orientation is idealistically correct and is applicable only in cases where buildings are constructed on vast open land. But this is not possible to apply in designing buildings in small plots in congested built-up cities.

(iii) **MULTI-STORY BUILDINGS WITH MORE THAN TWO UNITS PER STAIRCASE** When three apartments are accessed directly at each floor from a staircase the orientation issue becomes more sensitive. Assuming that the third apartment projects at right angle to the overall building block, it creates a wind "shadow" When the wind is oblique to the building and blowing towards the projecting apartment. While all the apartments can still have reasonable ventilation their conditions are less favorable than in the case of two units to a staircase. When more than three unit per floor are accessed from a staircase (or an elevator) some of the units will always suffer from poor ventilation and solar exposure conditions. Giovanni comments, "Therefore such design schemes are not recommended for low income people which cannot afford air-conditioning[57]".

COMMENTS ON ABOVE GIVONI'S ABOVE STATEMENT: Givoni's above statement is highly applicable in case of high-rise apartments in the context of Dhaka city.

3.6.1 HIGH-RISE TOWER BUILDING:

High-rise narrow tower buildings depend completely on elevators and other sophisticated mechanical systems for their functioning. According to Giovanni, 'they are suitable only for high income people, usually without or with very few children'. Even though Giovanni comments

'Consequently their applicability as residence in developing countries is quite limited', we find such buildings to be aptly used in Dhaka city

3.6.2 ENVIRONMENTAL IMPACTS OF HIGH-RISE BUILDINGS:

High-rise Tower buildings, placed among lower building surrounding them, increase the mixing of air flowing above the urban canopy with air at ground level. As a major source of urban air pollution is vehicular exhaust at the streets, the upper air stream is usually cleaner than the ground level air Increased mixing of the air of these two layers reduces the pollution concentration at the ground level, where its impact on the health of the urban population is at a maximum. In this way high-rise tower building tend to improve the air quality at the street level around them

Another impact of such buildings on the ground level conditions around them is a marked increase in the speed and turbulence of the wind. The wind speed in the streets around high-rise tower buildings may increase up to 300% and in specific locations even higher speeds could be experienced. The desirability of this effect depends, of course, on the 'normal' climatic conditions in the city in question. In cities experiencing insufficient wind this effect will be welcomed. In cities and during times with excessive winds this impact of high-rise building is a negative one [58].

3.6.3 ENVIRONMENTAL CONDITIONS IN THE HIGH-RISE BUILDINGS:

The environmental conditions of the inhabitants of the upper floors of high-rise buildings are, to some extent, different from those of the rest of the urban population. The main difference are in the ventilation potential and solar exposure and exposure to storms and wind-driven rain, as well in the view from the windows. Because of the generally higher wind speeds above the average height of the urban canopy the upper floors of the high-rise buildings enjoy better ventilation conditions during weak winds, but on the other hand, are exposed to more severe winds during storms [59]

Penetration of wind-driven rain through openings and joints is also a more serious problem at these floor levels than for the rest of the urban buildings. Consequently more careful details of windows and joints between wall elements are needed there

Intelligent use of duct may help to reduce maintenance cost by removing hot air. Mick Pearce in his mixed-use building at East Gate, Harare, Zimbabwe made use of 35% less energy than six conventional buildings in Harare combined It saved $ 3 5 million in energy costs using no air conditioner[50].

Philip Longdon observed, in a tropical region where many recent buildings depend on mirror glass to keep out the fierce sun, Pelli (in Petronas Tower, Malaysia) is using a more artful climate control device, horizontal bars, tear-drop shaped in section, which will block 50 to 60% of the solar gain and at the same time give a sense of protection to workers stationed near the windows[51].

One of the major environmental advantages of the inhabitants of the high-rise building is the better view offered from their windows. Giovanni commented, "While the rest of the city inhabitants may feel their visual environment congested, those living in the upper floors of the high-rise building often enjoy a view of distant scenes". However such is not the case in Dhaka city, where most of the high-rise buildings are placed at close proximity, thus blocking distant views.

The environmental noise level at these upper floors is substantially lower than at the typical urban buildings. Both greater distances from the noise sources and reduced reflection contribute to this condition. [52]

Complex interaction and feedback exists between the buildings and their outdoor environment The indoor climate and comfort conditions in any given building depend on the climatic conditions surrounding the building At the same time the building itself modifies the climatic conditions of the air surrounding it The urban geometry and profile, shape height and size of the buildings, orientation of streets and of buildings and nature of the surfaces of the urban open areas, all have impact on urban climates

Thus each urban man-made element viz buildings, roads, parking area, factories, water-bodies etc. create around and above it a modified climate with which it interacts

The color of the building walls affects not only the interior climate conditions, but also the light and glare in the street In this respect there is, in many instances, contradiction between the requirements of indoor climate and those necessary to reduce the blinding glare in the streets. [63]

Leaves of plants, due to eva-transpiration, are cooler than other surfaces of materials in the urban environment They then cool by convection the air flowing past them. The result is that the temperature in areas covered by plants is a great deal cooler than in other areas of the city, i.e areas of exposed asphalt, concrete or sand [64]

In addition to lowering of ground and air temperature, the trees also provide shade to the pedestrians. With deciduous type of trees this effect is seasonal. they provide shade in the summer, when it is needed and allow for heating by solar radiation during winter months when it is most desirable

3.7 CONCLUSION:

Before Dhaka turned to be the capital of Bangladesh the city was congested in the southern part, usually known as old Dhaka and was being expanded towards the north Most of the houses in old Dhaka were constructed at a time when there were no effective rules and byelaws regarding construction of buildings and structures enforced by the urban authorities. As a consequence the owners constructed structures according to their needs and will in a piece meal way. In case of expansion in the new northern part, the urban authorities allocated land according to a Master Plan and rules and regulations enforced by them were to be followed during construction. However, all those were prepared and formulated to suit the need of a provincial capital, and not the capital of an independent state. After the country became independent tremendous pressure was felt on limited land to accommodate the demands of the capital. Since the land all around the city were low-lying, only excepting on north where there was the reserve forest tremendous problem was to be encountered to expand the city The people who constructed their houses in the fringe areas were not willing to surrender their land for planned development and that also acted as a hindrance towards the city's expansion. The government addressed the problem by constructing 'Maitree Sethu' over the river Buriganga and thus bringing the southern bank of the river Buriganga under the city's jurisdiction. Also better roads were constructed to connect fringe and sub-urban areas like Savar, Narayingonj, Gazipur etc. for the purpose of expansion. Endeavors were made to earth-fill low-lying areas also. But the demand of land for housing accommodation was much more than what could have been provided. The result was the congested and unhealthy development of residential accommodation, due to which the city now suffers.

High-rise buildings with all its advantages, disadvantages and risks are a reality in Dhaka city and it will remain so for a long time. There were valid reasons for their growth in the city and those reasons still exist Even if a high-rise building collapses by accident, there is every possibility that the only option that remains before the owners is to construct a similar building, such that none of them are deprived of their interest. In such a situation, such buildings may be considered perennial in this land. Because of the change of density and living condition in high-rise in comparison with the traditional low-rise buildings there has been marked changes in climatic conditions within these buildings. These changes not only affect the thermal conditions and well-being of the occupants, but also have an impact on energy efficiency of the enclosures. In such a situation ensuring better climatic situation inside these buildings may be of enormous benefit to numerous users to retain good health within affordable budget

In the present chapter topics like transformations of houses through ages, men's idealistic requirements in shelter. shelter policy of the government the residential condition of residential accommodation in the city, government measures to meet demand for accommodation etc. have been discussed. Also various positive and negative aspects of high-rise buildings came under discussion. In order to have an understanding of their microclimates the climatic impacts climates of high-rise building has also been discussed. The next chapter will deal with the investigation, which primarily aims at finding out thermal and humidity conditions in high-rise residential buildings in various locations of Dhaka city.

Chapter 4

THE INVESTIGATION

Chapter 4
THE INVESTIGATION

4.0 INTRODUCTION:

This chapter discusses the methodology and investigation procedure for surveying the climatic conditions in various rooms of high-rise apartment buildings in Dhaka city The discussions include how the buildings and living units to be surveyed were selected, how the responses of the users regarding climatic comfort and discomfort in their apartment throughout the year were to be known and recorded, what type of instruments to be used for climatic measurements etc.

For the purpose of climatic investigations a number of buildings were selected from various locations of Dhaka city so as to take care of the micro-climatic variations in different areas. Apartments at various heights and cardinal locations were selected to take care of climatic variations, if any, at different heights and locations. The instrument suitable for measuring temperature and humidity of rooms and spaces were selected. The instruments were to give instant and easily readable readings. Naturally electronic instruments were found to be superior to conventional mercury thermometers. However, in order to find out how far the readings of the digital electronic thermo-hygro meter were acceptable, the readings were to be compared with standard mercury or other thermometers. Since the users of apartments are not usually trained to express the climatic conditions of their living environment the enumerators were asked to record their own feelings of climate at the time of survey, such abnormal responses expressed by the users, if any, may be verified and checked This chapter also deals with the system in which the readings information, comments etc. were to be recorded such that those could be made easily available for analysis and study. The Questionnaire was specially designed to include the queries and their probable answers at appropriate places. All these were considered necessary for measuring and documenting information of the microclimates, such that those could be presented in suitable forms to be usable by the designers of such apartments in the coming days. The above-mentioned topics shall be discussed in this chapter under the following major sub-headlines

Methodology:
Selection of buildings, living units etc
Questionnaire:
Instrument for measurement
Buildings and living units surveyed
Measurement of temperature:
Measurement of humidity:
Recording of users' responses
Recording of enumerators' responses
Other observations:
Conclusion:

4.1 METHODOLOGY:

The methodology followed for the purpose of investigating factors for thermal comfort in high-rise residential buildings in Dhaka city comprised the following steps: (a) A number of high-rise residential buildings situated at various locations of the city were selected for investigation and study (b) A questionnaire was prepared to record information regarding user's responses to climatic comfort in their apartments, (c) Sketches of the rooms surveyed were prepared with details of construction materials, finishes, furniture, openings etc. recorded, (d) Temperature and humidity readings were taken in all the rooms and spaces and (e) The enumerator's own perception of climate inside the room were also recorded.

After the above-mentioned information, data and sketches were available, those were to be analyzed to find out relationship, if any, between the various physical factors constituting the rooms and spaces and the climatic conditions there in, to find out, if possible, the condition that ensure maximum climatic comfort for the users

4.2 SELECTION OF BUILDINGS AND LIVING UNITS:

The buildings for investigation were selected in areas with conceivable variations in micro-climates. These were located at such areas as Old Dhaka, Shantinagar, Elephant Road, Farmgate, Dhanmondi etc. Only those living units where the users lived for nearly one year and not over four years were selected for investigation This was done because the inhabitants need at least one year to experience the annual changes of climates On the other hand, exposure greater than four years may lead to such state of acclimatization that the inhabitants may overlook important changes due to acustomization and feeling of familiarity.

4.2.1 SELECTION OF BUILDINGS BY MICROCLIMATIC VARIATIONS:

The various ways in which elements like buildings, trees, plants, green fields, paved surfaces, water-bodies, vehicles, factories, workshops, ports, water bodies etc. influence the microclimate of Dhaka city are:

Buildings: Build-masses regulate and divert airflow, cast shadows, absorb, transmit and emit heat and moisture. Human activities like cooking, ironing etc inside the building also generate heat. Equipments like air-conditioner, dehumidifier, water-heater, amplifier etc also generate heat

Trees and plants: Trees and plants cast shadow, absorb heat and emit water vapor, divert airflow and reduce reflectivity of ground surface.

Green Fields Grass fields absorb heat, emit water vapor and reduce reflectivity of ground surface.

Paved Surfaces: Hard surfaces reflect, absorb, transmit and emit heat and reduce water absorption after rain.

Water-Bodies: Water bodies absorb heat and emit water vapor to increase humidity These also indicate temperatures different from those of the surrounding areas and cause delay in temperature and radiation effects

Vehicles Various motorized vehicles emit heat, gas and smoke, which influences the state of temperature and humidity and in-coming solar radiation.

Factories Factories and industries generate heat and smoke, which influence temperature, humidity and radiation input

Since there is no homogeneous or even distribution of these elements through out the city considerable variations of microclimate is experienced in different areas In the city buildings, trees, plants etc considerably vary in heights and thus constitute an undulating urban canopy, which profusely interfere with the velocity and direction of air-movements. All these factors contribute to the generation of differing types of microclimates at various locations. In such a context the following criteria were used for the selection of buildings and living units:

(i) The buildings should be located in the city in areas with wide micro-climatic variations

(ii) The units to be surveyed should be located at various levels and cardinal locations.

4.2.2 SELECTION OF LIVING UNITS DEPENDING ON DURATION OF STAY:

Subjective response to climate depends up numerous factors like clothing, acclimatization, age and sex, body shape, subcutaneous fat, state of health, food and drink, skin color etc. [91]. While the period for acclimatization is taken to be 30 days, a man needs at least one year to experience climatic changes through out the year. However, prolonged living in the same unit for longer periods accustom the subject to that situation and his response towards the surrounding climates may not reflect the accurate picture. In order to take this point into consideration, the following criterion was followed in the selection of units.

(iii) Only those living units where the residents have lived for a period of about one year in the lower limit and four years in the upper limit were selected for study and investigation.

4.2.3 BUILDINGS AND LIVING UNITS SELECTED:

By following the above criteria, seven buildings in five different locations of Dhaka city were selected for investigation. Twenty-seven living units at various heights and locations of these buildings were selected for investigation. The locations of buildings selected have been given in site plan enclosed at the Appendix. The list of buildings with location, address, height, height etc has been presented hereunder in Table 4-01.

Table 4-01

BUILDINGS AND LIVING UNITS SELECTED

LOCATION	BUILDING & ADDRESS	HEIGHT	TOTAL NO. UNITS	NO. OF UNITS SURVEYED
01. Old Dhaka .	(01) Wahiduzzaman Bhaban 52, B.K Das Road Shyambazar, Dhaka	07 Stories	24	03
02 Shantinagar	(02) EHL Building -01 88, Shantinager Dhaka	09	16	03
	(03) EHL Building –02 88, Shantinager Dhaka	16	56	06
03. Elephant Road	(04) Razzak Complex 223, New Elephant Road, Dhaka	07	12	3
	(05) Reza Complex 224, New Elephant Road, Dhaka	08	14	3
04 Farm Gate :	(06) MONIHAR (7/1) 154/1, Monipuripara Dhaka-1215	07	12	3
05. Dhanmondi :	(07) Square Tower Mirpur Road, Dhanmondi, Dhaka	14	52	3
5 Locations	7 BUILDINGS	7-16 stories	186	27 Units

4.3 QUESTIONNAIRE:

A Questionnaire was prepared for recording responses and comments of the users, noting the temperature and humidity conditions, recording enumerator's feelings etc. The objective of Questionnaire was to collect the following data and information:

i) Information of the buildings under study: These included location of the building along with layout map, number of floors, details about the owner etc.

ii) Information of the living units: These included floor plans and plan of the respective unit, materials used for construction and finishing, active and passive cooling devices used for climatic control, furniture etc.

iii) Users' responses regarding thermal comfort: These included information like, (a) users' comments and subjective responses to climate (composite effect of temperature, humidity and ventilation), (b) ventilation (effect of stagnant air or low rates of air change), (c) dampness or dryness (d) air quality (e.g. odor from kitchen or bath room) in the rooms and spaces, (e) information regarding cost for energy required to control climatic adversities.

The sample Questionnaire has been enclosed at APPENDIX as **Appendix 4-01**

4.3.1. ABOUT THE QUESTIONNAIRE:

In the questionnaire, the building surveyed was first identified with such information like location of the building (Address: Name if any), Road, House No , Number of floors, Number of units per floor, Date on which surveyed etc. Temperature and Humidity data near the ground were also to be collected in all accessible directions of the building

As for general inquiry, the user/owner was asked about the duration of stay This was aimed to have an idea about their acustomization to the climatic condition prevailing in their apartment. They were asked whether they were the Owner or Rent payer. It is a common psychology that the owners endeavor to remain satisfied with their possession. where as the rent payers, in general complain. There were questions to find out how they felt in their house in the summer and winter, whether there was air-flow in the rooms, which one was the coolest/ most ventilated / hottest room in the house etc These were done in order to verify how far the users' perception varied from the measured ones Due to time constraints the survey was conducted during a specific period in the summer season. So, the only way to know the climatic conditions in other seasons was by asking the users and their comments were recorded in the Questionnaire.

The users were asked about their perception of the hottest month of the current and previous years, whether they ever felt their building wall and roof to radiate heat etc. These were done with the general idea that the top floor and the western wall might allow transmitted or radiated heat. Since the respondent was supposed to express his perception from his own experience, and since clothing was important determinant of climatic comfort the enumerators were asked to keep a record of the clothing of the respondent at the time of interview. A plan of the apartment under study was either procured or prepared and materials, finishes, color of the walls and roofs, along with the thickness of the walls were noted on this plan. Those were done on the presumption that climatic conditions might be considerably influenced by such factors.

There were provisions to note the number of people using the room under investigations and the number of electrical fixtures like fans, lights etc. in use Provisions were also there to note user's responses regarding most comfortable/uncomfortable time of the day, perception of temperature humidity, sweating, ventilation etc. in the hot days at times and months beyond the specific time of survey.

There was an inquiry regarding the condition of natural light at the center and near external window, and whether there was any problem in keeping the windows open. The questionnaire had provisions to record temperature and humidity at the center of each room and space of the living unit. It has been recognized by some experts that most of the users of such apartments in Dhaka are not trained enough to properly express their subjective feeling regarding climatic comfort. In order to take care of this inadequacy and to have trained responses the enumerators themselves were asked to record their own perception of climatic factors like air movement, temperature, dampness etc. in the house in a condition of no fan or air conditioner.

4.3.2 USER'S RESPONSES:

It was recognized that the general users were not trained to respond objectively to their accustomed general environment. However their responses bear some weightage on the conditions felt within and were therefore recorded. Responses like hot, cool, dryness, dampness etc. as felt by the users in different rooms and spaces in various seasons were recorded by the enumerators by placing Tick mark in the specified place or noting comments where only tick could not indicate the situation. Later these information were to be compared with the instrumental findings to determine relationship between users' perceptions and conditions indicated by instrumental measurements.

4.3.3 ENUMERATOR'S COMMENTS:

In addition to the user's responses the enumerators were asked to record their own perception of Temperature, Humidity and Air flow in the space under survey and were instructed to note those along with their comments in specified place. This part of the Questionnaire included the following.

F Enumerators comment (Please perceive the following climatic condition in the room/ at the time of investigation. Please keep off the fan/AC and feel)

AIR MOVEMENT: Perceptible / Imperceptible
TEMPERATURE Hot / Comfortable/ Cool
DAMPNESS : Whether Convenient in indoor conditions or not
ANY STAIN ON WALLS : Yes or No.

COMMENT ON PERCEIVED HUMIDITY IN THE SPACE : ....

4.4 INSTRUMENT FOR MEASUREMENT:

The instrument used for the measurement of Temperature and Humidity was 'Thermo-Hygro clock' with the following specifications:

Instrument: **THERMO-HYGRO CLOCK**. Model No. **J412-CTH**

Specifications : 0 Thermometer/Hygrometer with Alarm Clock

0 Maximum and minimum temperature and humidity records with optional daily reset feature

0 Current time, Indoor temperature and Humidity display simultaneously °C and °F range selectable at any time.

0 Maximum and Minimum temperature and humidity memory function with optional daily reset function.

0 Temperature measuring range : -10°C to 50°C (23°F to 122°F) with 0.1°C (°F) resolution

0 Humidity measuring range 20-99% with 1% resolution.

The detail Specification and Instruction manual of the instrument has been given at the APPENDIX.

4.4.1 SAMPLE TESTS WITH THE INSTRUMENT:

In order to test the validity and performance of the above instrument the following sample tests were carried out:

(a)One-hour intensive observation regarding variation of temperature and humidity with time.

(b) 10-hour and 14½-hour observations to record 'half-hourly' variations of temperature and humidity.

(c) Validation of readings with standard mercury thermometer and Digital Delta thermometer to check quickness of response to changing conditions

(a) ONE HOUR INTENSIVE OBSERVATION: The instrument was placed on the third floor of a four-storied building at Zigatola, Dhaka on June 20, 2000 and every change of Temperature and

Humidity with time was recorded for one hour starting at 09.30 A M. to 10 30 A M. The objective of this test was to study the nature of variations of climates in the specified season and to find out the 'response period' of the instrument. The observed readings of Temperature and Humidity variations have been presented in Table 4-02 and 4-02(a) and as Graphs in Figures 4-01 and 4-02

Table 4-02

ONE HOUR INTENSIVE CHECK WITH THERMO-HYGRO CLOCK TO FIND OUT THE RATE OF CHANGE OF TEMPERATURE WITH TIME

TIME OF MEASUREMENT			ELAPSED TIME			RECORDED TEMPERAT.	TEMPERATURE VARIATION
Hour	Min	Sec	Hour	Min	Sec	in Deg	in Deg.
09	30	15	00	00	00	28.2	---
09	32	23	00	02	08	28.1	-0 1
09	34	55	00	02	32	28 0	-0.1
09	36	31	00	01	36	27.9	-0 1
09	38	05	00	01	34	27.8	-0 1
09	39	37	00	01	32	27 7	-0.1
09	58	36	00	08	59	27 8	+0.1
10	08	12	00	09	36	27.9	+0 1
10	16	52	00	08	40	28 0	+0.1

*Recorded on June 20, 2000, Time: 9.30 A.M. to 10.30 A.M at 7/1, Zigatola, (2nd Floor), Dhaka.

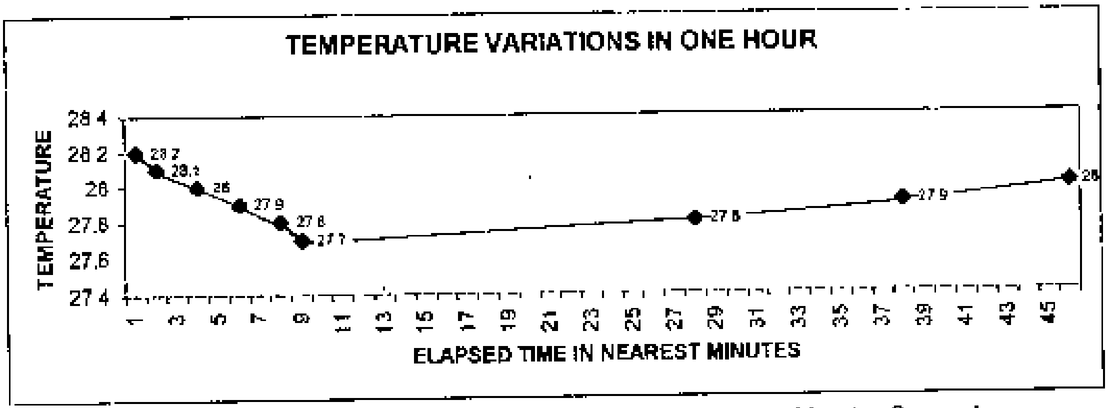
Table 4-02(a)

ONE-HOUR INTENSIVE CHECK WITH THERMO-HYGRO CLOCK TO FIND OUT THE RATE OF CHANGE OF HUMIDITY WITH TIME

TIME OF MEASUREMENT			ELAPSED TIME			RECORDED HUMIDITY	HUMIDITY VARIATION
Hour	Min	Sec	Hour	Min	Sec	in %	in%
09	30	15	00	00	00	92	---
09	32	23	00	02	08	93	+01
09	36	31	00	04	08	95	+02
09	40	25	00	03	54	96	+01
10	15	18	00	34	53	97	+01
10	16	52	00	01	34	96	-01

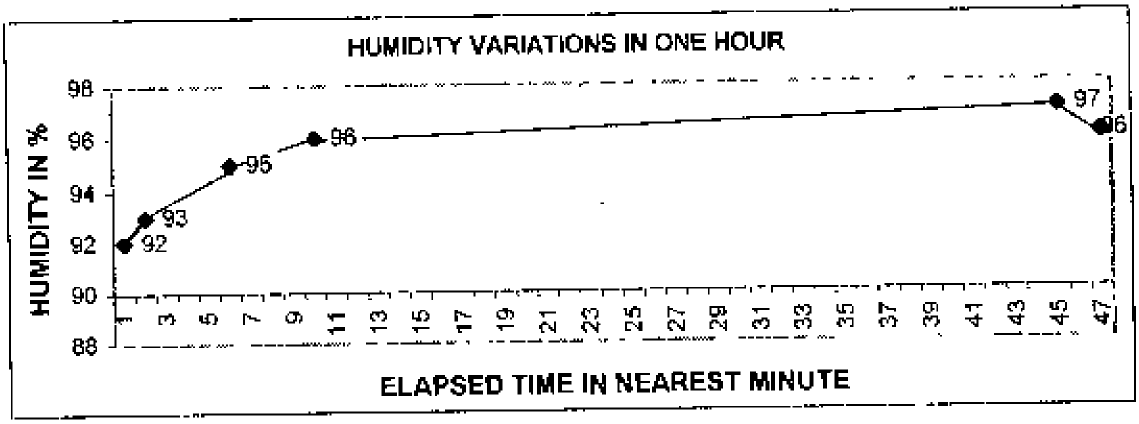
* Recorded on June 20 2000, Time : 9 30 A M to 10,30 A.M. at 7/1, Zigatola, (2nd Floor), Dhaka.

Figure 4-01: TEMPERATURE VARIATIONS IN ONE HOUR SHOWN IN GRAPH



The above changes in Temperature took place at time A M Hour: Minute Second
(From Left to Right): (1) 9.30:15, (2) 9:32.23, (4) 9·34 55, (6) 9.36.31, (8) 9.38·05, (9) 9 39·37, (28) 9·58:36, (38) 10.08·12, (46)10 16.52,

Figure 4-02 HUMIDITY VARIATIONS IN ONE HOUR SHOWN IN GRAPH



The above changes in Humidity took place at time Hour: Minute Second A M.
(From Left to Right): (1) 9:30,15, (2) 9 32·23, (6) 9·36 31, (10) 9 40·25, (45) 10,15 18, (47) 10·16:52

The above Table and Figure indicate the Shortest Duration of (i) Temperature and (ii) Humidity with time follows

SHORTEST DURATION:			
(i). The QUICKEST variation of Temperature was	0.1 Deg. C	in	1 Min 32 Seconds
(ii). The QUICKEST variation of Humidity was	1%	in	1 Min. 34 Seconds

In addition, the longest durations with same value of (i) Temperature and (ii) Humidity were.

LONGEST DURATION OF SAME READING:	
(i). Longest duration of same Temperature.	09 Min. 36 Sec
(ii) Longest duration of same Humidity	34 Min. 53 Sec.

These readings were, however, taken in an enclosed space where relatively unchanged condition reigned, i.e changes were imperceptible to human observers In order to find out how much time the THERMO-HYGRO CLOCK takes to show any change in temperature and/or humidity, the instrument was taken to different places with changed conditions of temperature and humidity and it was found that it takes about 5 to 10 seconds to record such changes

In such a situation in order to avoid any probable error in the reading it was decided that the instrument will be placed in each location for not less than 15 seconds, and this procedure was followed through out the entire survey work.

b. 10-HOUR AND 16 HOUR TEMPERATURE AND HUMIDITY VARIATION CHECK

In order to have an idea of how Temperature and Humidity varies through out the day Half-Hourly variation of Temperature and Humidity were recorded on the following date, time and duration:

DATE	FROM	TO	DURATION IN HOURS
(i) June 21, 2000	11.00 A.M.	9.00 P.M.	10 hours
(ii) June 22, 2000	6.00 A.M	9.00 P.M.	14 ½ hours

The results have been shown in Tables 4-03 and 4-04 and in Graphs in Figure Nos. 4-03, 4-04, 4-05 and 4-06 below

Table 4-03

HALF-HOURLY VARIATION OF TEMPERATURE AND HUMIDITY IN 10 HOURS

	READINGS BY MET OFFICE				READINGS BY THERMO-HYGRO CLOCK		
	TEMPERATURE		HUMIDITY		TIME	TEMPERATURE	HUMIDITY
DATE	MAX.	MIN.	MAX.	MIN.	HOUR: MIN.	IN DEG. C.	IN %
June 21, 2000	30.8°C	23.8°C	92%	75%	11 : 00	30.40	87
					11 : 30	30.40	88
					12 : 00	30.10	85
					12 : 30	29.10	87
					01 : 00	29.00	87
					01 : 30	29.20	88
					02 : 00	29.30	88
					02 : 30	29.10	86
					03 : 00	29.10	85
					03 : 30	29.10	86
					04 : 00	29.30	87
					04 : 30	29.50	88
					05 : 00	28.90	89
					05 : 30	28.80	90
					06 : 00	30.00	92
					06 : 30	30.60	86
					07 : 00	30.10	88
					07 : 30	29.40	88
					08 : 00	29.80	89
					08 : 30	30.00	88
					09 : 00	30.10	89

* Recorded at 30-Minute intervals on June 21, 2000 at 7/1, Zigatola, 2nd Floor, Dhaka

Figure 4-03 HALF-HOURLY VARIATIONS OF TEMPERATURE IN 10 HOURS.

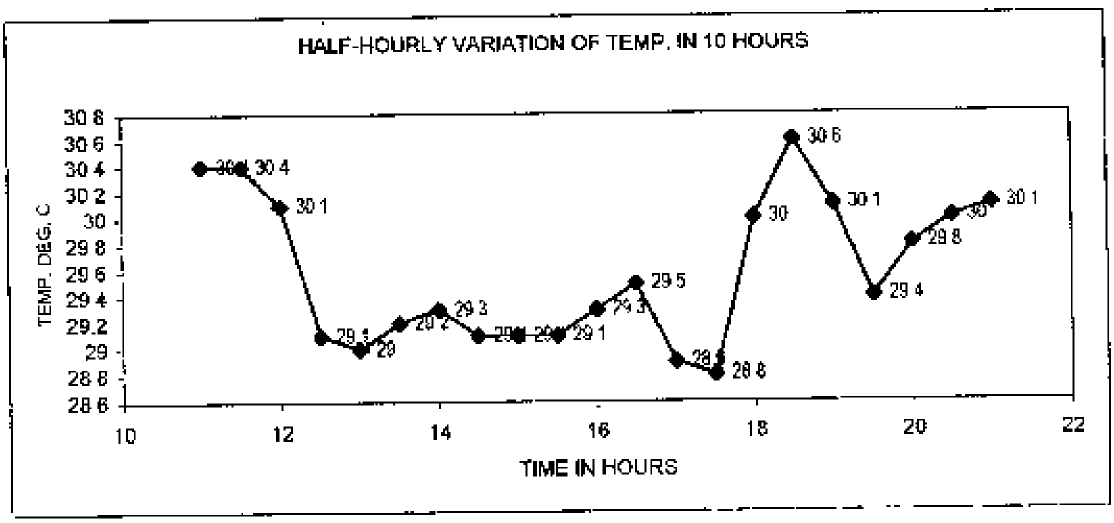
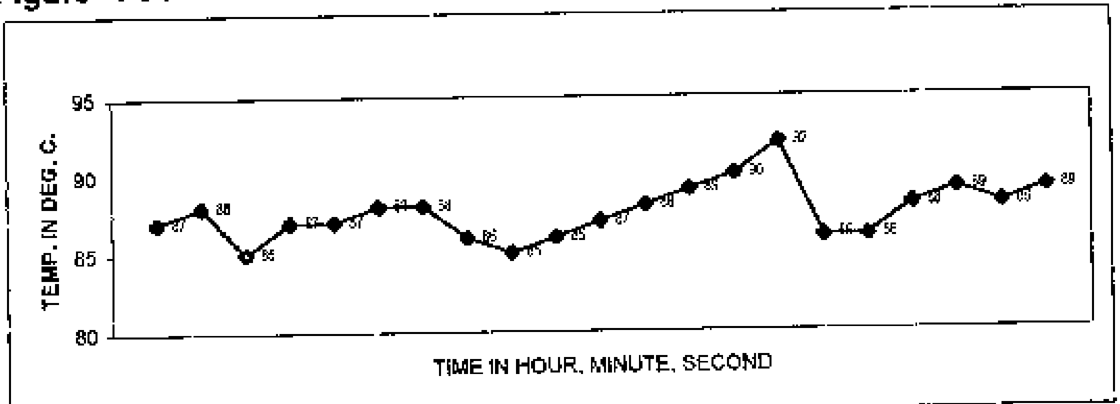


Figure 4-04 HALF-HOURLY VARIATIONS OF HUMIDITY IN TEN HOURS



N B The above readings on Humidity corresponds to Time :
A M. 11:00, 11:30, 12.00, P.M 12:30, 1:00, 1:30, 2:00, 2:30 3:00, 3:30, 4.00, 4:30, 5:00, 5:30, 6.00, 6 30, 7:00, 7:30, 8 00, 8:30, 9.00

Table 4-04

HALF-HOURLY VARIATIONS OF TEMPERATURE AND HUMIDITY IN 14.5 HOURS

	READINGS BY MET OFFICE				READINGS BY THERMO-HYGRO CLOCK		
	TEMPERATURE		HUMIDITY		TIME	TEMPERATURE	HUMIDITY
DATE	MAX.	MIN.	MAX.	MIN.	HOUR: MIN.	IN DEG. C.	IN %
June 22, 2000	32 4°C	23 4°C	89%	83%	06 : 30	28 90	92
					07 : 00	28 90	92
					07 : 30	29 10	90
					08 : 00	29 50	89
					08 : 30	29.80	88
					09 : 00	30.00	87
					09 : 30	30 00	86
					10 : 00	30.10	87
					10 : 30	29.20	90
					11 : 00	29 10	92
					11 : 30	33 40	93
					12 : 00	33 40	93
					12 : 30	33 40	95
					01 : 00	33 40	95
					01 : 30	33 40	95
					02 : 00	33.40	95
					02 : 30	30 30	89
					03 : 00	31.00	86
					03 : 30	31.10	84
					04 : 00	30 40	86
					04 : 30	30 40	86
					05 : 00	30.40	86
					05 : 30	30.40	86
					06 : 00	30 60	86
					06 : 30	30 30	84
					07 : 00	30.30	84
					07 : 30	30 30	84
					08 : 00	30 30	84
					08 : 30	30 30	84
					09 : 00	30.30	84

* Recorded at 30-Minute intervals on June 22,2000 at 7/1, Zigatola, 2nd Floor, Dhaka

Figure 4-05 HALF-HOURLY VARIATIONS OF TEMPERATURE 14.5 HOURS

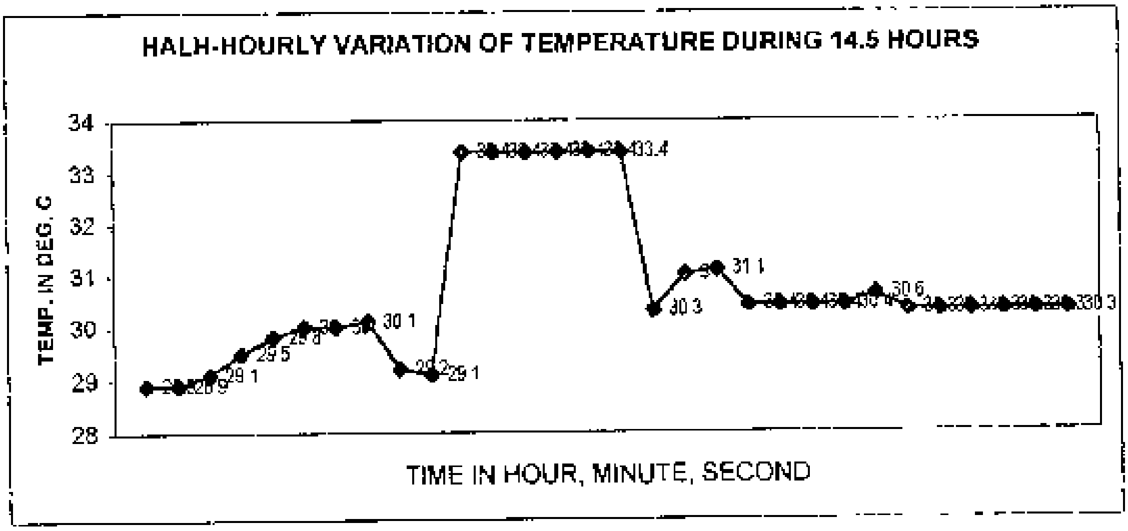
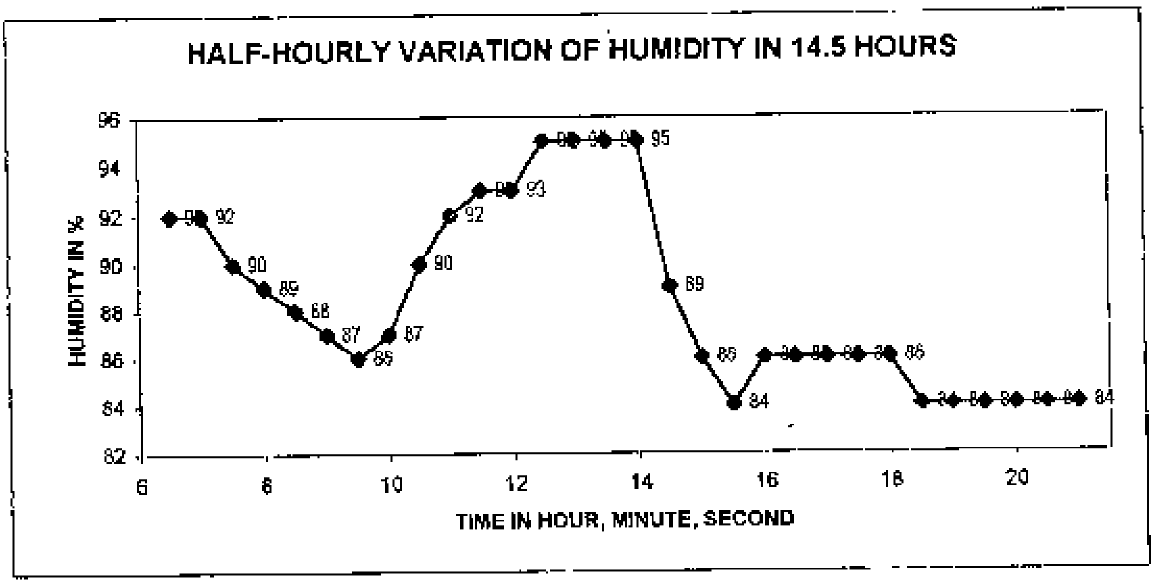


Figure 4-06 HALF-HOURLY VARIATIONS OF HUMIDITY IN 14.5 HOURS



N B. The above readings on TEMPERATURE corresponds to Time .
A.M. 6 00, 6:30, 7:00, 7.30, 8·00, 8:30, 9·00, 9 30, 10:00, 10:30, 11.00, 11:30, 12.00, P M 12 30, 1:00, 1·30, 2:00, 2·30, 3 00, 3:30, 4:00, 4 30, 5·00 5:30, 6:00, 6:30, 7 00, 7 30, 8 00, 8 30, 9 00.

The following deductions regarding Variations of Temperature and Humidity may be had from the above Figures It should however, borne in mind that these deductions stand valid only for the specified season, time and place.

4.4.2 MAXIMUM AND MINIMUM CHANGES OF TEMPERATURE AND HUMIDITY IN HALF HOURLY MEASUREMENT:

From the above Tables and Graphs showing Ten hour and Fifteen and half hour half-hourly variation of temperature and humidity it is possible to find out, at what rate the indoor Temperature and Humidity changed in this season. These are shown hereunder.

(i) Maximum variation (rise) of Temperature in ½ hour	:	4 5 Deg C
(ii) Maximum variation (fall) of Humidity in ½ hour	:	6%

4.4.3 VALIDATION OF READINGS OF THERMO-HYGRO CLOCK WITH STANDARD THERMOMETERS:

In order to compare and validate the (a) Thermo-Hygro Clock, (the instrument used to measure temperature and humidity in this study), its readings in identical conditions were compared with those of the following two thermometers

(b) Digital Thermometer DELTA SK 1250 Thermistor and K sensor

(c) Mercury thermometer ZEAL

The work was carried in the Heat Engine Laboratory, Mechanical Department Bangladesh University of Engineering and Technology, Dhaka In order to find out the quickness of responses the three thermometers were taken to an engine emitting hot exhaust

The comparative readings given by three thermometers in identical conditions are given in Table 4-05 These have also been shown in Graph at the APPENDIX as **Appendix 4-02**

Table 4-05

COMPARISON OF READINGS BY THREE THERMOMETERS.

TIME P.M Hour Min :Sec	THERMO-HYGRO[a] Temp in ^{0}C	DIGITAL DELTA[b] Temp in ^{0}C	MERCURY ZEAL[c] Temp in ^{0}C	COMMENTS
3 · 05	31.4	32	31	Placed on the Table
3 · 08*	31.5*	32*	31.5*	
3 · 10*	31.8*	34+*	30*	Taken near hot engine(*)
3 : 13	32 6	34+	32 7	
3 : 14	32 9	33	32.0	Placed on the table
3 : 15	32 9	33	32.0	
3 16	32.8	33	32 0	
3 · 16 30	32.7	33	32.0	
3 · 17	32 6	33 -	32.0	
3 . 18	32 8	33	32 2	
3 : 19	32.4	33	32.0	Placed on the table
3 : 20	32 4	33	32.2	
3 : 20 15	32 4	33	32 5	
3 . 20 50	32 3	33	32.5	
3 · 21	32 3	33	32.4	
3 . 22	32 3	33	32.6	
3 : 22 40	32.3	33+	32 8	
3 : 23 . 20	32 3	33 -	32.7	
3 25 · 40	32.4	33	32.9	
3 . 27 . 45	32 4	33	32.8	
3 · 28 : 15	32.4	33	32.6	Placed on the table
3 : 29 · 30	32.4	33	32 8	
3 · 30	32.4	33	32.5	
3 : 31 . 55	32 4	33+	32.7	
3 . 34 : 05	32 4	33	32.8	
3 34 ; 43	32.4	33	32.5	
3 : 36 · 10	32.4	33+	32.6	
3 . 37 35	32 5	33	32 7	
3 · 38 : 05	32 4	33	32.7	
3 : 38 : 25	32.5	33	32.8	
3 : 39 : 40	32.4	33	32 6	Placed on the table
3 : 42 . 15	32.4	33	32.6	
3 43	32.4	33 -	32 5	
3 . 45	32.4	33	32 6	
3 · 46 . 05	32.4	33+	32.6	
3 . 47	32 4	33+	32 6	
3 : 48 . 30	32 4	33	32.7	
3 · 48 · 50	32.5	33	32 7	
3 49 20	32.5	33+	32.8	
3 · 50 : 10	32.5	34 -	32 9	
3 : 50 : 40	32.6	34 -	33.0	Placed on the table
3 ; 52 50	32 6	33+	33.0	
3 . 53 35	32 6	33+	32.9	
3 : 49 : 35	32.5	33+	32.8	
3 : 55 : 50	32.6	33+	32 8	
3 : 58 : 35	32.6	34 -	32.9	
3 : 59 : 45	32.6	33+	32 9	
4 : 00 · 55	32.6	33+	32.8	
4 · 02 . 45	32.7	33+	32.8	
4 . 04 25	32 7	33+	32.9	
4 · 05	32 7	33+	32.9	Placed on the table

* The time when all the three Thermometers were taken near an engine emitting hot air and also the temperatures recorded at this time have been shown with (*) asterisk marks

From the above comparative readings of three thermometers it may be opined that:

(a) The Thermo-Hygro Clock gave instant Digital reading up to 1/10th of a degree in case of Temperature and 1% in case of humidity, along with time.

(b) The Digital Delta Sk 1250 Thermometer gave Digital reading with full number. Whenever there was a propensity of variation it showed by blinking the immediate higher or lower number depending on propensity of increase or decrease respectively. In the above Figure the propensity of increase has been shown as + and that of decrease by ⁻ sign after the reading

(c) The Mercury Zeal Thermometer gave analogue readings and the fractions were read by 'eye-estimation' with probable human errors

The digital Delta thermometer was equipped with a sensor and was found to have been more sensitive to radiant temperature, as was seen when all the three was taken to a heated engine. In comparison with the digital one, the Mercury Thermometer was seen to respond to changes in temperature at a slower rate. The readings of the Thermo-Hygro clock was found to correspond with those of the two other thermometers. It was found that the digital thermometers gave quick readings and the mercury thermometer followed with a little delay.

4.5 BUILDINGS AND LIVING UNITS SURVEYED:

For ease of Survey, Identification and analysis the buildings and living units under survey were coded in the following ways

Building Code : The 7 nos of buildings have been Coded by alphabets, e g A, B, C, D, E, F and G.

Living Unit Code: The Living Units under survey have been Coded with (i) a number indicating the Floor and (ii) a letter indicating Cardinal position as shown hereunder:

(i) CODES TO INDICATE FLOORS :

Floor :	Ground floor	First floor	Second floor	....	Fifth floor	... ..	Sixteenth floor
Indicated by .	1	2	3	. . ..	5	.. ..	16

(II) CODES TO INDICATE CARDINAL POSITIONS :

Cardinal positions	EAST	WEST	NORTH	SOUTH	SOUTH-EAST	SOUTH-WEST	NORTH-EAST	NORTH-WEST
Indicated by.	E	W	N	S	SE	SW	NE	NW

Thus a living unit coded as, say, **B 7 SW** indicates that the Unit is located in **Building B**, on the **7th floor** and in **South-West** cardinal position.

The Table 4-06 below shows the locations of the buildings, date and time of survey and Codes of the living units surveyed.

Table 4-06

BUILDINGS AND LIVING UNITS WITH LOCATIONS, DATE AND TIME OF SURVEY AND CODES

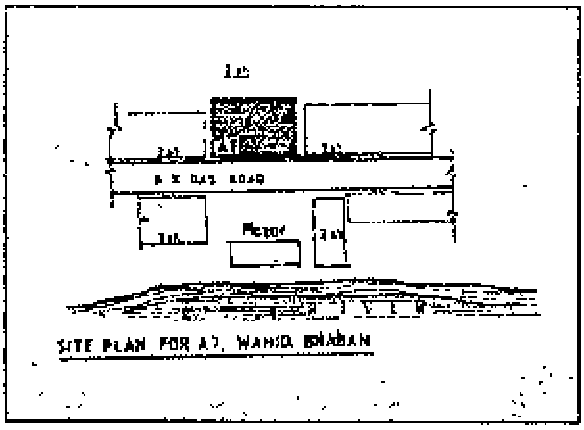
BUILDINGS AND THEIR LOCATIONS	DATE SURVEYED	STARTING TIME OF SURVEY	HEIGHT OF BUILDING IN STORIES	LOCATION OF LIVING UNITS VERTICAL	LOCATION OF LIVING UNITS CARDINAL	CODE
1. WAHIDUZZAMAN BHABAN 52, B.K Das Road Shyambazar, Dhaka	21.6.2000	10:17 A M	7 Floors	4 th floor	North-West	A 4 NW
		10 23 A M.		4	North-East	A 4 NE
		10.55 A M		4	South-East	A 4 SE
		11:20 A.M.		4	South-West	A 4 SW
		11.37 A M		5	South-West	A5 SW
		11 50 A M.		7	South-West	A 7 SW
2 EHL BUILDING-1 88, Shantinagar Dhaka	23.6.2000	1.40 P.M	9 Floors	4	North	B 4 N
		2:15 P M.		7	North	B 7 N
		2 35 P M		9	North	B 9 N
3 EHL BUILDING -2 88, Shantinager Dhaka	23.6.2000	10:05 A.M.	16 Floors	4	South-East	C 4 SE
		10:17 A.M.		4	North-East	C 4 NE
		10:30 A.M.		6	South-East	C 6 SE
		11:57 A.M.		6	North-East	C 6 NE
		12:20 A.M.		16	South-East	C 16SE
				16	North-East	C16NE
4 RAZZAK COMPLEX 223, New Elephant Road, Dhaka	25.6 2000	12.00 P.M	7 Floors	4	South	D 4 S
		12:20 P.M.		5	South	D 5 S
		12 50 P.M		7	South	D 7 S
5. REZA COMPLEX 224, New Elephant Road. Dhaka	25 6.2000	10.30 A.M.	8 Floors	2	East	E 2 E
		11 00 A M		6	East	E 6 E
		11:15 A.M.		8	East	E 8 E
6. MONIHAR (7/1) 54/1, Monipuripara Dhaka -1215	21 6 2000	3.20 P.M.	7 Floors	4	North	F 4 N
		3.42 P M		6	North	F 6 N
		4.05 P M		7	North	F 7 N
7. SQUARE TOWER Mirpur Road Dhanmondi, Dhaka	29 6.2000	11:10 A.M.	14 Floors	2	North-West	G2NW
		11:30 A.M.		5	North-West	G5NW
		12:05 A.M.		14	North-West	G14NW
7 BUILDINGS				27 LIVING UNITS		

4.5.1 LOCATIONS OF BUILDINGS AND SITE PLANS:

The locations of the seven buildings inside Dhaka city has been shown in Site plan enclosed at the APPENDIX as **Appendix 4- 03.**

The site plans along with brief description of the buildings and their surroundings are given hereunder in Figures 4-06, 4-07, 4-08, 4-09,

Figure 4-06. SITE PLAN -01 : APARTMENT "A" (WAHIDUZZAMAN BHABAN) AT 52 B.K. DAS ROAD, DHAKA.

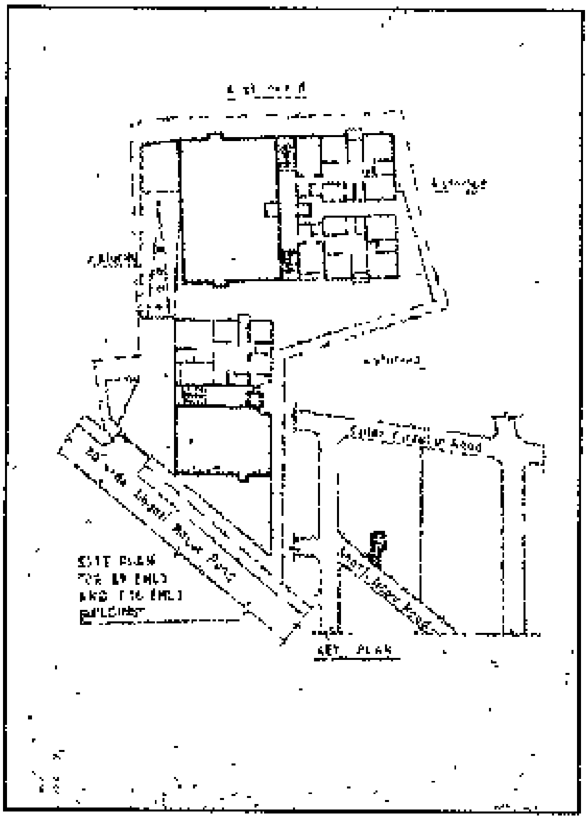


NORTH UP-WARD

APARTMENT BUILDING "A" is a seven storied building at B.K. Das Road, Old Dhaka. The building faces B.K Das road on the south. On the south side of the road is "Bibir Mazar", a single storied structure. On south of this, there lies Buriganga River. Thus the building enjoys direct wind rushes through the open river at south. The ground floor of the building has been used for shops. On the east, there is a two-storied building and on the west, a three storied both used for commercial purposes On the north of the building there are a number of two storied residential buildings

In this building there are four living units in each floor The living units have been designated SW (South-West), SE (South-East), NW (North-West) and NE (North-East) The total number of living units surveyed in this building is six with identities A07SW, A05SW, A04WS, A04SE, A04NE and A04NW.

Figure 4-07 SITE PLAN -02 : APARTMENTS "B" (EHL-1) AND "C"(EHL-2) AT SHANTINAGAR, DHAKA.



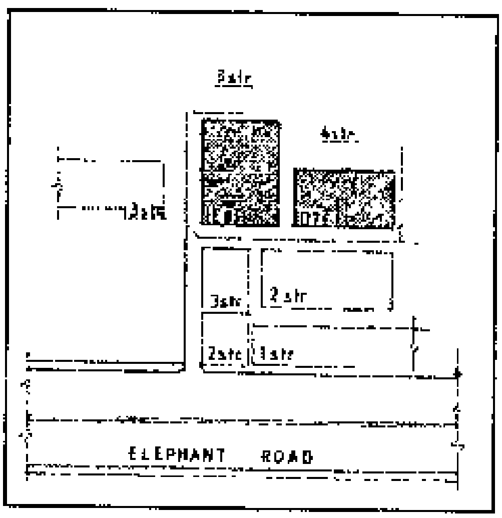
NORTH-UPWARD

There are two apartment buildings, 9-storied Building B and 16-storied Building C in this site Both are approachable from Shantinagar Road, which is on the south There is a three-storied office building on the east and four storied residential building on the east of the complex The ground floors of both the buildings are used as store. A car-ramp runs from the road to the first floor level of the rear 16-storied building. In this building there is car park on the first floor level.

APARTMENT BUILDING B is a nine-storied building, having two living units per floor on both sides of a common staircase and elevator aisle The long side of the building faces west The number of living units surveyed is 3 with identities B09N B07N and B04N,.

APARTMENT BUILDING C is a sixteen-storied building, having four living units in each floor. There are two units on either side of a common 'staircase elevator' aisle. The adjacent living units are separated by a narrow 8-Feet gap. The number of living units surveyed is 6 identified as C16NE, C16SE, C06NE, C06SE, C046NE and C04SE.

Figure 4-08 SITE PLAN - 03 : APARTMENTS "D" AND "E" AT ELEPHANT ROAD, DHAKA.



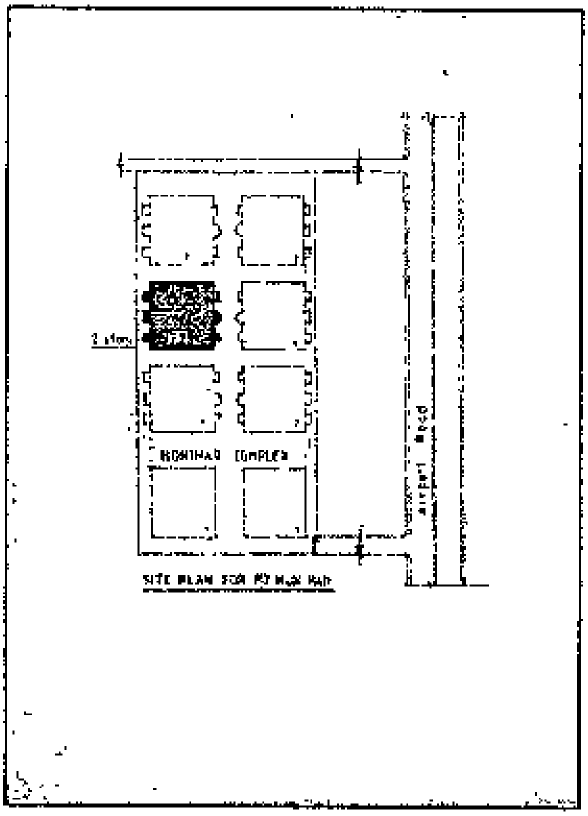
NORTH UP-WARD

There are two apartment buildings, Building D and E in this complex. The buildings stand a little away on the north side of Elephant road There are two and three storied buildings on the south, three storied office building on the west and three and four storied buildings on the north of the complex There is a vacant plot on its southwest corner The ground floors of both the buildings are used as car parking.

APARTMENT BUILDING D is a seven-storied building having two living units per floor on two sides of a staircase elevator shaft. The building faces south The number of living units surveyed is 3 identified as D07S, D05S and D04S.

APARTMENT BUILDING E is an eight seven storied building having two living units per floor on two sides of a staircase and elevator shaft. The building faces west. The number of living units surveyed is 3 identified as E08E, E06E and E02E.

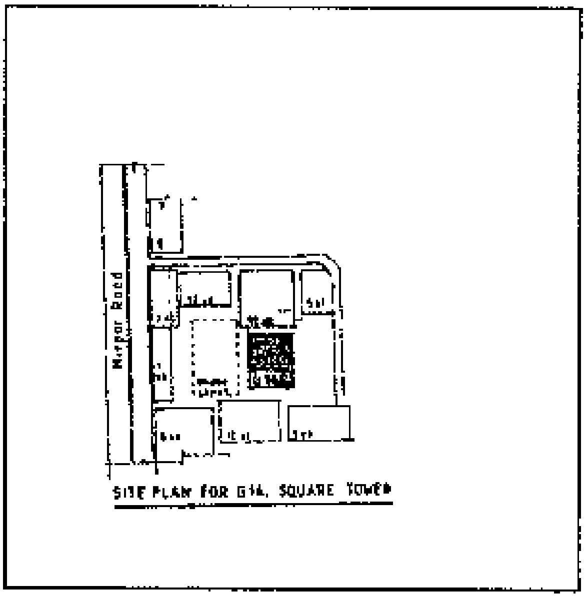
Figure 4-09 SITE PLAN - 04 : APARTMENT "F" (MOHIHAR, SHELTECH) AT FARM GATE, DHAKA.



NORTH UP-WARD

APARTMENT BUILDING F is a seven storied building, situated among an agglomeration of eight apartment buildings of Sheltech-Monihar complex at Farmgate. There are seven to nine storied buildings at close distance on north, south and east side, where as on the west there are low single storied buildings The apartment has got two living units per floor on two sides of a stair elevator case and shaft The building faces East The number of living units surveyed is 3, identified as F07N, F06N and F04N.

Figure 4-10. SITE PLAN - 05 : APARTMENT "G" (SQUARE TOWER) AT MIRPUR ROAD, DHANMONDI, DHAKA



NORTH UP-WARD

APARTMENT BUILDING G is a fourteen-storied building on the East of Mirpur road. There is large vacant plot in between the building and the road and there are single storied buildings on far West. On the East there is large vacant land. On the North and south there are sixteen storied apartment buildings. There are four living units in each floor on four sides of a stair and elevator shaft. The adjacent buildings have common party walls The number of living units surveyed is 3 identified as G15NW, G5NW and G2NW.

4.5.2 DESIGNATING ROOMS OF THE LIVING UNITS :

For the purpose of this study the various rooms of a living unit were classed into six or nine groups as per their cardinal locations as outlined hereunder. The numbers within parenthesis indicate 'types by location'.

i. Six groups	(1) NORTH-WEST (7) SOUTH-WEST	(2) NORTH (8) SOUTH	(3) NORTH-EAST (9) SOUTH-EAST
ii. Nine groups .	(1) NORTH-WEST (4) WEST (7) SOUTH-WEST	(2) NORTH (5) CENTRAL (8) SOUTH	(3) NORTH-EAST (6) EAST (9) SOUTH-EAST

In case of the presence of blank walls due to staircase or any other reason the above groups had a changed classification as shown hereunder:

(1)NORTH-WEST (4) WEST (7) SOUTH-WEST	(2) NORTH (5) CENTRAL (8)SOUTH	Staircase or solid wall	(2) NORTH (5) CENTRAL (8) SOUTH	(3) NORTH-EAST (6) EAST (9) SOUTH-EAST

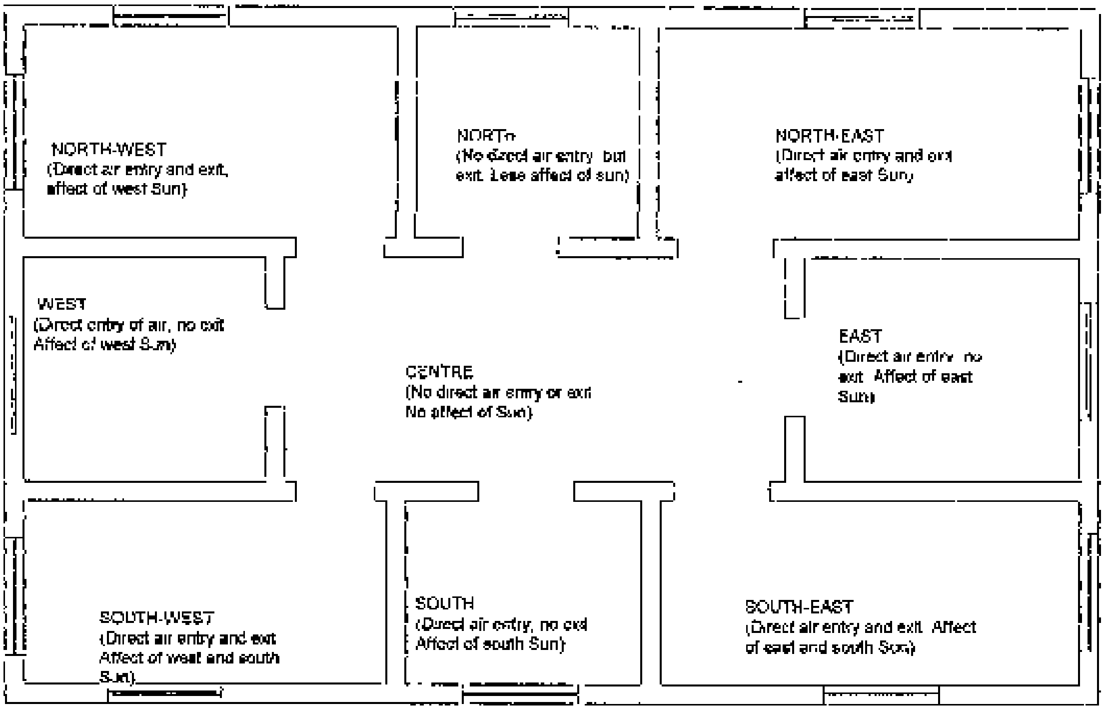
The physical parameters of the above sub-groups in terms of external walls with or without windows and internal walls may be explained as hereunder.

GROUP NO.	NAME OF GROUP	LOCATION OF ROOM OF LIVING UNIT WITH RESPECT TO CARDINAL DIRECTION
01.	North East	Located in the North East corner of the unit with windows on North and East external walls
02	North West :	Located in the North West corner of the unit with windows on North and West external walls.
03	South East :	Located in the South East corner of the unit with windows on South and East external walls
04.	South West .	Located in the South West corner of the unit with windows on South and West external walls.
05.	Central .	Located centrally inside the unit, with no external wall or window
06	North	Located on the North side of the unit, with windows on the North wall only.
07.	South	Located on the South side of the unit. with windows on the South wall only
08	East .	Located on the East side of the unit, with windows on the East wall only.
09.	West :	Located on the West side of the unit, with windows on the West wall only.

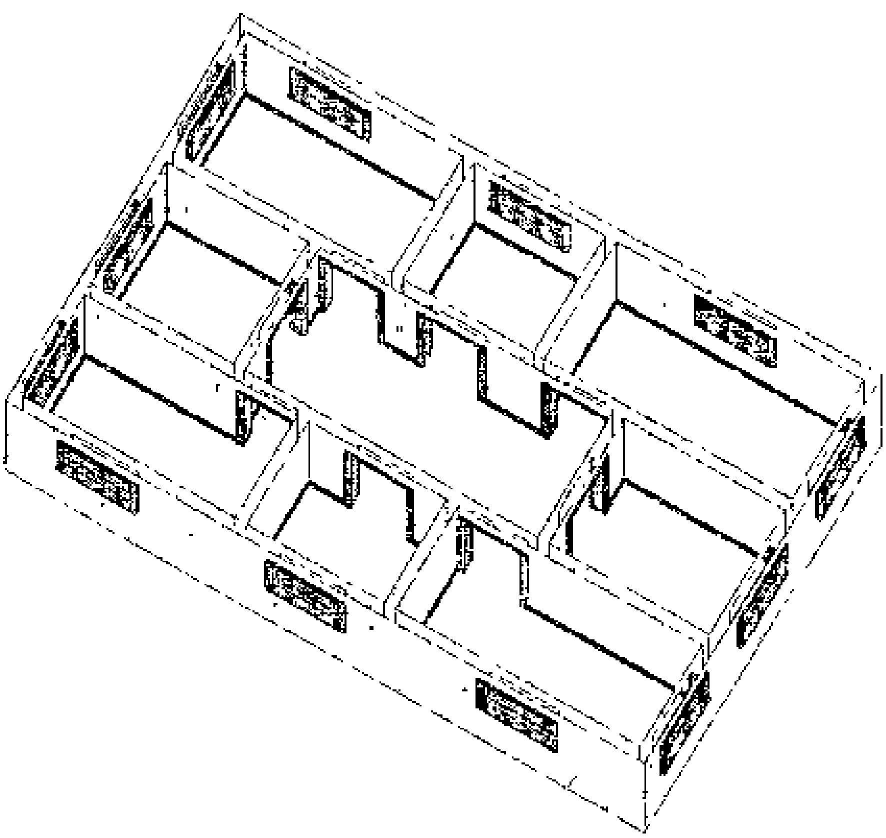
The natural settings and views of rooms of an apartment have been shown in Figure 4-11 below.

Figure 4-11

NATURAL SETTINGS OF ROOMS OF AN APARTMENT (9 GRID)



NORTH ABOVE. NO SCALE



4.6 MEASUREMENT OF TEMPERATURE:

While measuring Temperature in and around any Living Unit the following three types of readings were taken

(a) Outdoor Temperature at the ground in front of the building
(b) Indoor Temperature in all rooms and spaces and
(c) External Temperature at the same level outside the apartment.

(a) OUTDOOR TEMPERATURE AT GROUND LEVEL AROUND THE BUILDING: Temperature at the ground level in the surrounding area of the building was taken. For this purpose readings were taken at the entrance and on all four sides viz. North, South, East and West of the building. However, in case of some buildings it was not possible to take readings on all sides because those were not accessible. In some cases the ground floor was used as service floor, and hence readings were taken on the first floor.

(b) INDOOR TEMPERATURE IN ROOMS AND SPACES: All indoor readings of Temperature were taken by placing the instrument at the center of each room or space In order to avoid excessive changes in outdoor temperature and humidity levels it was essential to take all the measurements of a living unit within minimum time So, the inmates were first informed of the matter and all the rooms/spaces were made ready for access. The enumerator first placed the equipment at the center of the living room, remained waiting for at least 15 seconds and declared the reading, which was written by another enumerator. The first enumerator then quickly carried the equipment to other rooms/spaces and conducted similar operations

(c) EXTERNAL TEMPERATURE: Reading of the external temperature at this level was also taken For this purpose South side was given the first preference In case the unit lacked in south aspect, east or west (which ever available) was utilized. North, however, was avoided. For the purpose of measurement the instrument was held outside the room through the window or verandah grill, avoiding direct sunlight, and the reading was taken. Table 5.5 (ii) a shows the Temperature measured in each room and space of the 27 living units

Table 4-07

TEMPERATURE RECORDED

SL. NO.	LIVING UNIT CODE	EXTERNAL TEMPERATURE	TEMPERATURE RECORDED IN LIVING RM.	MASTER BED	CHILD'S BED	GUEST'S BED	DINING RM/SP.
01.	A 7SW	30.8	30.9	30.8	30.6	-----	30.9
02.	A 5SW	30.6	30.7	30.6	30.6	----	30.7
03	A 4SW	30.4	30.0	29.9	29.9	----	30.0
04	A 4SE	30.5	30.9	30.8	30.6	----	30.9
05	A 4NE	30.1	30.4	30.3	30.4	----	30.4
06	A 4NW	30.5	30.8	30.7	30.7	-----	30.8
07.	B 9N	31.7	31.8	31.7	31.8	31.7	31.9
08	B 7N	32.8	33.2	33.0	33.0	32.8	32.9
09	B 4N	32.7	33.0	32.8	33.0	32.7	33.1
10.	C16NE	31.8	32.6	31.9	31.9	32.0	31.8
11.	C16SE	31.7	31.9	31.8	31.9	31.6	32.1
12	C6NE	31.7	31.8	31.6	31.7	31.6	31.7
13	C6SE	31.7	32.2	31.7	31.8	32.2	32.0
14	C4NE	31.1	31.1	30.9	30.7	30.7	31.0
15.	C4SE	30.7	30.8	30.9	30.8	30.8	30.9
16.	D 7S	30.8	31.1	30.9	30.9	31.2	31.1
17	D 5S	31.9	31.8	31.7	31.6	31.8	31.6
18.	D 4S	33.2	33.4	33.4	33.3	33.2	33.2
19.	E 8E	29.2	29.4	29.3	29.3	29.4	29.4
20.	E 6E	29.0	29.2	29.1	29.2	29.3	29.2
21	E 2E	29.1	29.3	29.2	29.4	29.3	29.3
22.	F 7N	East 31.2 West 31.4	31.3	31.2	31.4	31.6	31.5
23.	F 6N	East: 30.3 West: 30.2	30.2	30.2	30.5	30.6	30.4
24.	F 4N	East: 30.9 West 30.9	30.2	30.4	30.5	30.6	30.7
25.	G14NW	31.3	31.5	31.1	31.2	31.0	31.3
26.	G 5NW	30.3	30.3	30.2	30.2	30.2	30.1
27	G 2NW	30.8	29.8	30.1	30.0	30.2	29.9

In order to have an idea how far the internal temperature varies from one room or space to another, the temperature in each room and space of the living units have been given ar APPENDIX as **Appendix 4-04.**

4.7 MEASUREMENT OF HUMIDITY:

In measuring Humidity in and around the Living Unit the two types of readings taken were

(a) Outdoor Humidity at the ground in front of the building

(a) Indoor Humidity in all rooms and spaces and external Humidity at the same level outside the apartment.

All readings of Humidity were taken along with the readings of temperature mentioned above.

The measured readings of Humidity have been presented in Table 5 10.

Table 4-08

			HUMIDITY RECORDED				
SL. NO.	LIVING UNIT CODE	EXTERNAL HUMIDITY	H U M I D I T Y R E C O R D E D I N LIVING RM.	MASTER BED	CHILD'S BED	GUEST'S BED	DINING RM/SP.
1.	A07SW	88	90	89	89	----	90
2.	A05SW	86	90	89	87	-----	90
3.	A04SW	84	85	86	86	-----	85
4	A04SE	88	90	89	89	---	90
5	A04NE	85	88	86	86	-----	86
6.	A04NW	82	83	83	83	-----	83
7.	B9N	94	94	94	94	93	94
8.	B7N	91	92	91	92	91	91
9	B4N	90	91	90	92	91	91
10	C16NE	91	92	92	91	92	92
11.	C16SE	91	91	92	92	91	92
12	C6NE	91	91	92	92	91	92
13.	C6SE	92	93	92	92	93	93
14.	C4NE	92	93	91	92	92	91
15	C4SE	92	93	94	93	92	93
16.	D07S	92	94	93	92	94	94
17.	D05S	94	94	95	95	94	95
18.	D04S	94	95	95	95	95	94
19.	E08E	84	84	85	85	86	86
20.	E06E	84	85	85	86	86	86
21	E02E	81	85	82	84	84	85
22.	F07N	85	85	84	85	84	85
23.	F06N	84	84	83	85	85	85
24	F04N	85	87	88	88	85	87
25	G14NW	84	84	84	84	85	83
26.	G05NW	86	87	86	87	85	86
27.	G02NW	85	86	86	85	88	86

In order to have an idea how far the internal Humidity varies from one room or space to another, the humidity in each room and space of the living units are shown in APPEXDIX at **Appendix 4-05.**

4.8 RECORDING OF USERSER'S RESPONSES :

At the time of survey, the users' responses in their apartments regarding (a) extent of stay in the apartment, (b) whether the inhabitant was owner or rent-payer, (c) their feeling of climate in the Summer (d) whether there was air-flow in the rooms, (e) their feeling of climate in the Winter etc were collected and recorded in appropriate place in the questionnaire. The important information collected has been presented in Table 4-09 below.

Table : 4-09

USERS' RESPONSES REGARDING THEIR LIVING UNIT

(DURATION OF STAY, OWNER OR RENT-PAYER, FEELING IN SUMMER, AIR-FLOW IN THE APARTMENT, COOLEST ROOM, MOST VENTILATED ROOM, FEELING IN WINTER ETC.)

SL. NO.	LIVING UNIT CODE	(a) EXTENT OF STAY	(b) OWNER RENT-PAYER	(c) FELING IN SUMMER	(d) AIR FLOW	(e) FEELING IN WINTER
01.	A 7SW	1-3	Rent-payer	Warm	Yes	Warm
02 .	A 5SW	2-0	Rent-payer	Cool	Yes	Cool
03	A 4SW	2-0	Rent-payer	Comfort	Yes	Comfort
04	A 4SE	2-0	Rent-payer	Comfort	Yes	Cool
05.	A 4NE	2-0	Rent-payer	Warm	N.S	Comfort
06.	A 4NW	1-4	Rent-payer	Warm	N.S.	Cool
07.	B 9N	1-3	Owner	Hot	N.S	Cool.
08.	B 7N	1-0	Owner	Warm	N.S.	Cool
09	B 4N	1-0	Owner	Hot	N S	Comfort
10	C 16E	1-0	Owner	Hot	N.S	Cool
11.	C 16E	1-0	Owner	Hot	Yes	Cool
12.	C 6NE	1-1	Owner	Warm	Yes	Comfort
13	C 6SE	1-0	Owner	Comfort	Yes	Comfort
14	C 4NE	1-6	Owner	Hot	Yes	Cool
15	C 4SE	1-2	Owner	Warm	Yes	Comfort
16.	D 7S	1-6	Owner	Hot	Yes	Cool
17.	D 5S	1-6	Owner	Comfort	Yes	Cool
18	D 4S	1-7	Owner	Warm	N.S	Cool
19.	E 8E	1-6	Owner	Comfort	Yes	Cool
20	E 6E	2-0	Owner	Warm	Yes	Cool
21.	E 2E	1-9	Owner	Hot	Yes	Cool
22	F 7N	2-0	Owner	Comfort	Yes	Cool
23.	F 6N	2-0	Owner	Comfort	Yes	Comfort
24.	F 4N	0-11	Owner	Warm	N.S.	Warm
25.	G14NW	1-8	Rent-payer	Warm	Yes	Warm
26.	G 5NW	1-3	Rent-payer	Hot	N S	Cool
27.	G 2NW	1-6	Rent-payer	Warm	N S	Cool

4.8.1 USERS' RESPONSES IN ROOMS:

The users' responses like which one, according to the user was the Coolest room, which one, according to the user was the hottest room in the summer, user's vote regarding hottest month in 1999 and in 2000, their feeling of radiation, if any, from wall or roof, number of persons usually occupying or using the room/space, most comfortable and un-comfortable time of the day, feeling of temperature in the hottest days, feeling of humidity, sweating and ventilation etc. condition of natural light at the center and near the external window, whether the user had any problem in keeping the windows open etc were collected and recorded in appropriate place Out of those, the information relevant to this study has been presented in Table 4-10 below.

Table : 4-10

USERS' RESPONSES IN ROOMS

SL. NO	LIVING UNIT CODE	(a) COOLERST ROOM	(b)HOTTEST ROOM IN SUMMER	(c) HOTTEST MONTH IN 1999	(d) HOT. MONTH IN 2000	(e) RADIATN. FROM ROOF	(f) RADIATN. FROM WALL
01.	A 7SW	Child Bed	Livn/Din	June	June	No	Yes
02.	A 5SW	Master Bed	Living	May	May	No	No
03	A 4SW	Master Bed	Living	April	April	No	No
04	A 4SE	Child Bed	Living	May	June	No	No
05.	A 4NE	Child Bed	Living	May	April	No	No
06.	A 4NW	Master Bed	Living	May	April	No	No
07	B 9N	Master Bed	Childbed	June	June	No	Yes
08.	B 7N	Master Bed	Dining	June	April	No	No
09	B 4N	Master Bed	Childbed	July	June	No	No
10.	C 16NE	Child bed	Dining	July	June	No	Yes
11.	C 16SE	Child bed	Dining	July	June	No	Yes
12.	C 6NE	Master Bed	Dining	June	June	No	No
13.	C 6SE	Master Bed	Dining	July	June	No	No
14.	C 4NE	Child bed	Living	May	June	No	No
15.	C 4SE	Child bed	Guest	April	June	No	No
16.	D 7S	Master Bed	Dining	July	June	No	Yes
17	D 5S	Child bed	Dining	May	June	No	No
18	D 4S	Master Bed	Dining	June	June	No	No
19.	E 8E	Guest Bed	Childbed	June	June	No	Yes
20.	E 6E	Master Bed	Childbed	July	June	No	No
21	E 2E	Master Bed	Childbed	May	May	No	No
22.	F 7N	Master Bed	Guestbed	May	May	No	Yes
23	F 6N	Living	Guestbed	July	June	No	No
24.	F 4N	Master Bed	Guestbed	May	June	No	No
25	G14NW	Master Bed	N.S	NS	N.S.	No	No
26	G 5NW	Master Bed	Livn/Din.	July	June	No	No
27	G 2NW	Master Bed	Guestbed	June	June	No	No

4.8.2 SUMMARY OF USERS' RESPONSES :

For the purpose of having a comprehensive idea about the user's climatic responses, the above information may be expressed in a summarized form as presented hereunder in Table 4-11

Table 4-11

SUMMARY OF USER'S RESPONSES

	(a) OWNER	(b) TENT-PAYER		
(01) USERS' STATUS ·	66.7%	33.3 %.		
	(a) YES	(b) CAN'T SAY		
(02) AIRFLOW IN ROOMS :	70%	30%.		
	(a) COOL	(b) COMFORTABLE	(c) WARM	(d) HOT
(03) FEELING IN SUMMER ·	3.7%.	30%	40.8%	30%.
WINTER :	63%	26%	11.2%	0%.
	(a) APRIL	(b) MAY	(c) JUNE	(d)JULY.
(04) HOTTEST MONTH IN 1999.	7%	33%	22%	26%.
2000.	11%	11.2%	67%	—
	(a) YES	(b) NO		
(05) RADIATION FROM WALL ·	0%.	100%.		
ROOF ·	30%	70%.		

4.9 RECORDING OF ENUMERATOR'S RESPONSES

The enumerators responses regarding (a) air movement, (b) temperature, (c) dampness, (d) stain on wall etc. as observed and recorded at the time of survey have been presented in Table 4-12 below.

Table 4-12

ENUMERATORS' RESPONSES					
SL. NO.	LIVING UNIT CODE	(a) AIR MOVEMENT	(b) TEMPERATURE	(c) DAMPNESS	(d) STAIN ON WALL
01.	A 7SW	Perceptible	Hot	No	No
02 .	A 5SW	Not	Hot	No	No
03.	A 4SW	Perceptible	Comfortable	No	No
04	A 4SE	Perceptible	Comfortable	No	Yes
05.	A 4NE	Not	Hot	No	No
06.	A 4NW	Not	Comfortable	No	Yes
07.	B 9N	Not	Hot	No	No
08	B 7N	Not	Hot	No	Yes
09	B 4N	Not	Hot	No	No
10	C 16NE	Perceptible	Hot	No	No
11.	C 16SE	Perceptible	Hot	No	No
12.	C 6NE	Perceptible	Comfortable	No	No
13	C 6SE	Not	Hot	No	No
14	C 4NE	Not	Comfortable	No	No
15.	C 4SE	Not	Hot	No	No
16.	D 7S	Perceptible	Hot	No	No
17.	D 5S	Not	Hot	No	No
18.	D 4S	Not	Hot	No	No
19	E 8E	Perceptible	Hot	No	No
20.	E 6E	Perceptible	Hot	No	No
21.	E 2E	Not	Hot	No	No
22.	F 7N	Not	Hot	No	No
23	F 6N	Perceptible	Hot	No	No
24	F 4N	Not	Hot	No	No
25.	G14NW	Perceptible	Hot	No	No
26	G 5NW	Not	Hot	No	No
27	G 2NW	Not	Hot	No	No

4.9.1 SUMMARY OF ENUMERATOR'S CLIMATIC RESPONSES :

For the purpose of having a comprehensive idea, the above information regarding enumerator's responses may be expressed in a summarized form as presented in Table 4-11 hereunder :

Table 4-13

SUMMARY OF ENUMERATOR'S CLIMATIC RESPONSES		
(01) Air movement :	(a) PERCEIVABLE 40.8%	(b) IMPERMEABLE 59.2%
(02) Temperature	(a) HOT 81.5 %	(b) COMFORTABLE 18.5%
(03) Dampness	(a) YES 00%	(b) NO 100%
(04) Stain in wall :	(a) Yes 11.1%	(b) No 88.9%

4.10 OTHER OBSERVATIONS :

At the time of measuring Temperature and Humidity all the related information that might come to some use were collected and noted Later, however, it was found that some of the information could not be collected. For example, even though there was a program to measure temperature and humidity on all sides of the building some of the sides were inaccessible, and in case of at least one building there was no ground floor, because the entire area was being used as store At the beginning it was planned that readings on temperature and humidity shall be made at the center and near all the four walls of the room. Later, however, it was found that the readings in general, remain the same through out the room, only excepting near the windows, where those are affected to incoming air. Only in one case (F6N), a 0 1^0 C difference at the center and the western extreme of the living room was observed. This room was poorly ventilated with external walls on east, west and north and the kitchen was on the west. At the time of survey, only one fan was working in the east and cooking was going on in the kitchen Those were the probable reasons to cause this minute variation.

Even though user's response were collected with utmost care, in some cases it seemed as if they gave the reply most reluctantly or without enough thought. For example, some opined their western room as most comfortable In spite of few such exceptions, most of the responses and comments were consistent with what could normally be expected. When asked about their general perception in living in high-rise apartments, one respondent on 7th floor in Elephant Road complained that whenever there was strong wind especially at night in the rainy season they suffered from a very bad smell. The residents of the same building in the lower floors did not make such complain

Investigation of such a variable entity like climate is associated with enormous complexities. The little variations in temperature that usually exist in between various rooms and spaces cannot be measured accurately with mercury thermometer The digital thermometer was advantageous because it gave instant and easily readable readings in digits Long habituation with mercury thermometers may raise question about the validity of digital readings. To eradicate any doubt, the digital thermometer was later compared with one standard mercury thermometer and another digital thermometer It was revealed that even though the three did not give exactly the same reading, the variations were negligible. The mercury thermometer responded a bit lately, and its fractions were to be read by eye-estimation, with probable percent of error. The two digital thermometers were prompt in showing variations.

4.11 CONCLUSION:

The topics discussed in this chapter include methodology and investigation procedure followed in this study. There include how the various readings were taken and recorded, how the users' and enumerators' climatic responses were collected and recorded etc The apartment buildings for investigation were selected from areas so as to take care of greater range of micro-climatic variations in the city Apartments or living units were selected at various levels and cardinal locations. The questionnaire was prepared to record the responses and comments of the respondents. The enumerators were trained regarding how to conduct measurements and collect information and record in the Questionnaire. Before finalizing the investigation procedure a number of sample tests, viz. one-hour intensive observation, 10-hour and 14.5-hour temperature and humidity variation check etc were done with the instrument Also the instrument used was validated against one standard mercury thermometer and another electronic digital thermometer. The validation revealed, the readings given by the instruments had conformity with those by the standard thermometers.

Some of the formats in which the collected data and information were recorded in the Questionnaire have been presented in this Chapter The data and information were transformed into tables or graphs or summarized so as to present comprehensive pictures of the findings In addition to those mentioned in methodology and questionnaire the enumerators were asked to observe any other phenomenon, related to climate in and around the building, on the presumption that those may also come to use for this study. Few such observations have also been presented in this chapter. These data's and information shall be analyzed in the following Chapters for a better understanding of the thermal situation in high-rise apartments

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Chapter 5

ANALYSIS OF FINDINGS

Chapter 5
ANALYSIS OF FINDINGS

5.0. INTRODUCTION:

The various findings including instrumental measurement, sketches, user's responses, enumerators comments etc., which were recorded in the previous chapters have been analyzed in this Chapter to find out the state of micro-climate inside the high-rise apartments Various comparisons and analysis were made to find out the relationship between the inside and outside temperature and humidity, between rooms of the living units in different cardinal locations and in the rooms at different levels or stories. Attempts have also been made to find out how far the user's responses match those of the measurements. Most of the analyses were done with the objective such that the expected results might be of use for the future designers of built forms. This chapter shall deal various aspects of analysis and studies under the following major sub-heads :

Climatic analysis of Living units

Climatic analysis of Rooms/spaces

Comparison of Instrumental findings and Users comments

Comparison of Internal and External climates.

The micro-climate of a living unit or of the rooms there in depends upon numerous factors relating to (a) Physical characteristics like cardinal and vertical locations (b) Architectural design like dimension of rooms, size and location of openings etc. (c) Materials used construction and finishes, (d) gadgets and furniture used, (e) Internal heat generation and absorption etc. Some of these factors cannot be quantified and some are extremely variable In such a situation this thesis project was aimed at finding out the climatic characteristics of living unit and of the rooms there in with their physical characteristics only

As for internal climatic comfort, the important factors are (a) Temperature, (b) Humidity and (c) Air-movement Since Air-movement itself is a very large topic and is such erratic in nature that it needs longer time and logistic facilities to study and investigate. By nature Air-movement demands independent study that may not be feasible within limited time For these reasons the remaining two factors, viz Temperature and Humidity have been dealt with in this thesis

After the measurements of Temperature and Humidity is various rooms and spaces in apartments at various cardinal and vertical locations were taken, endeavors shall be made to identify living units or rooms with extreme values i.e. High or Low range of Temperature or Humidity, after which attempt shall be made to relate their climatic characteristics with their physical characteristics.

For easy identification as required for analysis the rooms and spaces will be coded The physical characteristics i.e. Cardinal location, Vertical position etc. of the living units in the building and those of the rooms in the building plan shall be found out and Coded. To ensure a simplified system of comparison, the range of variation of Temperature or Humidity shall be grouped into a number of broad categories and Coded. Similar categories shall be made in case of vertical positions also. Finally endeavor shall be made to relate the climatically extreme livings units or rooms/spaces among the tested samples with their physical characteristics. Endeavor shall also be made to find out 'comfortable rooms' from the readings of Temperature and Humidity and those shall be compared with 'comfortable' commented by the users. A comparison will be drawn between the Temperature given by the Meteorological Department and that obtained by measurement in the site.

5.1 CLIMATIC ANALYSIS OF LIVING UNITS:

It has been mentioned in the Chapter on Investigation that readings of Temperature and Humidity were taken near the ground of each building, all rooms inside and immediately outside the living unit of the selected living units In analysis attempts will be made to relate such physical factors like (a) Cardinal location of the living unit in the total building plan, (b) Vertical position of the living unit in the building, (c) Cardinal location of the rooms in the plan of the unit, (b) Vertical position of rooms etc with their climatic characteristic, i e. levels or extremities as regards to Temperature and Humidity.

5.1.1 ANALYSIS OF INTER-SPACE TEMPERATURE VARIATIONS:

Since the measurements of Temperature and Humidity could not be taken at one single instant on a single day, it is not possible make any direct comparison of one living unit with another The data regarding temperature and Humidity in each living unit, however were taken at 'fairly' one time So, it is possible to compare the readings obtained in various rooms and spaces each unit independently In every unit there was one HIGHEST reading and one LOWEST reading in Temperature and Humidity The difference between the two of any unit gives the "INTER-SPACE TEMPERATURE VARIATION"(ISTV) or "INTER-SPACE HUMIDITY VARIATION"(ISHV) of that unit.

After finding out the ISTV and ISTH of all the 27 units, those were found to vary from one another. While taking measurement it was found that both INTER-SPACE TEMPERATURE AND HUMIDITY varies from one living unit to another The probable reasons for this variations might be, (1) Site or location of the building in the city, (2) Cardinal location of the Living unit in the entire building plan, (3) Vertical position of the living unit in the building etc. The time of taking measurement also may have relevance.

Since it was not possible to take all those factors into consideration in such a time and budget constraint study, only the physical factors like (1) Cardinal location and (2) Vertical positions of the living units or rooms/spaces have been considered for analysis

The findings and analyses regarding Temperature and Humidity variation in living units or rooms/spaces shall be presented following in general the following sub-headlines -

Finding out inter-space Temperature/Humidity variations

Identifying living units/rooms with 'Hot', Average' and 'Cool' ranges of inter-space Temperature and 'Dry' 'Moderate' and 'Wet' range of Humidity variations

Finding out physical characteristics of living units and rooms under 'Hot', 'Cool' 'Dry', and 'Wet' categories

Relating the physical characteristics with probable cause of such Climatic extremities.

Each of the above topics shall be discussed in general under the following minor sub-heads (a) Brief Introduction, (b) Coding of physical characteristics (Cardinal location, Vertical position etc.) of units/rooms, (c) Categorization and coding of Temperature/Humidity variations etc

5.1.2. LEGENDS AND CODES USED FOR IDENTIFICATION :

For the purpose of analysis various apartments, living units, rooms, their Cardinal and Vertical locations etc. have been coded. Also LEGENDS have been used to indicate their Cardinal and Vertical locations. The LEGENDS for CARDINAL LOCATIONS are :

CARDINAL LOCATION	LEGEND	CARDINAL LOCATION	LEGEND	CARDINAL LOCATION	LEGEND	CARDINAL LOCATION	LEGEND
EAST	E	WEST	W	NORTH	N	SOUTH	S
NORTH-EAST	NE	NORTH-WEST	NW	SOUTH-EAST	SE	SOUTH-WEST	SW

The climate similar to that at the ground is mostly felt in the lower floors of the buildings The top floor of any building suffers from differences in climate due to the constant exposure of its roof to the sun at daytime. The floor immediately below it is partially affected by these factors. The other floors in between the lower floor and the top floor enjoy more or less equal type of climate The following LEGENDS have been used to indicate the BROAD CATEGORY OF FLOORS of the building:

FLOOR	LEGEND	FLOOR	LEGEND
Top floor	Top or T	Below top floor	High or H
Middle floors	Mid or M	Lower 2 floors	Low or L

The various buildings and their floors have also been coded. Table 5-01 shows the Codes of buildings and their Vertical category and Horizontal Codes.

Table 5-01 :

CODES OF APARTMENTS OR LIVING UNITS

APARTMENT	CODE	SERIAL NO. OF UNITS	FLOOR	CARDINAL LOCATION OF SURVEYED UNIT	CATEGORY OF VERTICAL LOCATION OF SURVEYED UNIT	CODE
WAHID. SHABAN	A	01	07	SW	Top	A7SW
		02	05	SW	Mid	A5SW
		03	04	SW	Mid	A4SW
		04	04	SE	Mid	A4SE
		05	04	NE	Mid	A4NE
		06	04	NW	Mid	A4NW
EHL BLDG.-1	B	07	09	N	Top	B9N
		08	07	N	Mid	B7N
		09	04	N	Mid	B4N
EHL BLDG -2	C	10	16	NE	Top	C16NE
		11	16	SE	Top	C16SE
		12	06	NE	Mid	C6NE
		13	06	SE	Mid	C6SE
		14	04	NE	Mid	C4NE
		15	04	SE	Mid	C4SE
RAZZAK COMPLEX	D	16	07	S	Top	D7S
		17	05	S	Mid	D5S
		18	04	S	Mid	D4S
REZA COMPLEX 01		19	08	E	Top	E8E
		20	06	E	Mid	E6E
		21	02	E	Low	E2E
MONIHAR	F	22	07	N	Top	F7N
		23	06	N	High	F6N
		24	04	N	Mid	F4N
SQUARE TOWER	G	25	14	NW	Top	G14NW
		26	05	NW	Mid	G5NW
		27	02	NW	Low	G2NW

5.1.3. FINDING OUT INTER-SPACE TEMPERATURE VARIATION :

It has been found that readings of temperature in various rooms of a living unit vary from one another. The (a) Maximum temperature observed in a living unit, (b) Minimum temperature observed in the same unit and (c) their variations have been calculated out and presented in Table 5-02. The inter-space variation of Temperature shown in the last column of this table varies from 0.1 to 0.8 deg. C. For the purpose of comparison and analysis, this range have been classed into three broad categories, viz Considerable, Average and Negligible and the following LEGENDS have been used to indicate those:

TEMPERATURE VARIATION RANGE	BROAD CATEGORY	LEGEND
0.5 - 0.8	Considerable	Con
0 3 - 0.4	Average	Ave
0.1- 0.2	Negligible	Neg

Table 5-02 :

MAXIMUM MINIMUM TEMPERATURES AND INTER-SPACE VARIATIONS IN LIVING UNITS				
LIVING UNIT CODE	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE	TEMPERATURE DIFFERENCE	LEGEND FOR TEMP. VARIATION
A07SW	30.9	30.6	0.3	Ave
A 5SW	30.7	30 6	0.1	Neg
A 4SW	30.0	29.9	0.1	Neg
A 4SE	30 9	30.6	0.3	Neg
A 4NE	30.4	30 3	0.1	Neg
A 4NW	30.8	30.7	0.1	Ave
B 9N	31.9	31 7	0.2	Neg
B 7N	33.2	32.8	0.4	Ave
B 4N	33.1	32 7	0.4	Ave
C16NE	32.6	31.8	0.8	Con
C16SE	32.1	31 6	0.5	Con
C 6NE	31.8	31 6	0.2	Ave
C 6SE	32.2	31 7	0.5	Neg
C 4NE	31.1	30 7	0.4	Ave
C 4SE	30.9	30.8	0.1	Neg
D 7S	31.2	30.9	0.3	Ave
D 5S	31.8	31.6	0 2	Neg
D 4S	33.4	33 2	0 2	Neg
E 8E	29.4	29.3	0 1	Neg
E 6E	29.3	29.1	0.2	Neg
E 2E	29.4	29.2	0.2	Neg
F 7N	31.6	31.2	0.4	Ave
F 6N	30.6	30.5	0 2	Neg
F 4N	30.7	30.4	0.3	Ave
G14NW	31.5	31.0	0.5	Con
G5NW	30 3	30 1	0 2	Neg
G2NW	30.2	29.8	0.4	Ave

5.1.4 IDENTIFYING LIVING UNITS WITH CONSIDERABLE ('CON') CATEGORY OF TEMPERATURE VARIATION :

The living units with CON, AVE and NEG category of inter-space temperature variations have been presented in Table 5-02 above. For the purpose of analysis only the extreme cases shall be considered and the Average (Ave) range shall be avoided. The units under category - CONSIDERABLE TEMPERATURE VARIATION and their Cardinal and Vertical locations have been presented in Table 5-03 below

Table 5-03 :

CARDINAL LOCATION AND VERTICAL POSITION OF LIVING UNITS WITH 'CON' (CONSIDERABLE) RANGE OF VARIATIONS OF TEMPERATURE			
INTER-SPACE TEMP. DIFF.	LIVING UNIT CODE	(a)CARDINAL LOCATION	(b)CATEGORY OF VERTICAL POSITION
Con (.5 - .8)	C16NE	NE	Top
	C16SE	SE	Top
	G14NW	NW	Top

5.1.5 RELATING UNITS UNDER 'CONSIDERABLE' RANGE OF TEMPERATURE VARIATION WITH THEIR (a) CARDINAL LOCATIONS AND (b) VERTICAL POSITIONS.

After identifying the living units under 'CON' temperature variation category from Table 5-02 and having known their physical characteristics from Table 5-03, endeavors shall now be made to relate the cause of this variation with such physical characteristics like (a) Cardinal location and (b) Vertical position.

The following are the OBSERVATIONS regarding relation of HIGHER INTER-SPACE VARIATION OF TEMPERATURE with the physical characteristics of the living units :

(a). CARDINAL LOCATION : There are 8 probable Cardinal locations, viz. East, West, North, South, Northeast, North-West, South-East, South-West for the living units under study. CONSIDERABLE Inter-space Temperature variations were observed in 7 locations viz. E, N, S, NE, NW, SE, SW and none on the West. Out of these 7, 3 came under the CON category and these happened in cardinal locations, Northeast, Southeast and Northwest at the rate of 1 each. The frequency in number and % of occurrences of CONSIDERABLE INTER-SPACE VARIATIONS OF TEMPERATURE are shown in Table 5-04

Table 5-04 :

FREQUENCY OF CONSIDERABLE INTER-SPACE VARIATIONS OF TEMPERATURE IN CARDINAL LOCATIONS

CARDINAL LOCATION	OCCURRENCE IN NUMBER	OCCURRENCE IN %
North East	1 out of 3	33% (equal)
South-East	1 out of 3	33% (equal)
North-West	1 out of 3	33% (equal)

(b). **VERTICAL POSITION** : There are 4 categories of vertical positions, viz. Top, High, Mid and Low All the cases of CON category temperature variations were observed on the Top floor So, the frequency of CONSIDERABLE INTER-SPACE VARIATIONS OF TEMPERATURE are 3. The frequency in number and % of occurrence of considerable inter-space Temperature variations in various vertical categories have been shown in Table 5-05 :

Table 5-05 :

FREQUENCY OF CONSIDERABLE INTER-SPACE VARIATIONS OF TEMPERATURE IN VERTICAL POSITIONS

VERTICAL LOCATION CATEGORY	OCCURRENCE IN NUMBER	OCCURRENCE IN %
Top floor category	3 out of 3	100%.

On the basis of above observations, **INFERENCES** may be drawn that,

01. There is greater possibility of Considerable inter-space temperature variations to occur in living units in cardinal locations, Northeast, Southeast and Northwest.

02. There is greater possibility of Considerable inter-space temperature variations to occur on the Top floors than on other positions

5.1.6 IDENTIFYING LIVING UNITS SHOWING 'NEG' (NEGLIGIBLE) RANGE OF TEMPERATURE VARIATION :

Table 5-06 below shows the living units with NEG category of temperature variation along with (a) Cardinal locations and (b) Vertical positions of the living unit

Table 5-06 :

CARDINAL LOCATION AND VERTICAL POSITION OF LIVING UNITS SHOWING 'NEG' (NEGLIGIBLE) RANGE OF TEMPERATURE VARIATION

INTER-SPACE TEMP. DIFF.	LIVING UNIT CODE	(a)CARDINAL LOCATION	(b) CATEGORY OF VERTICAL POSITION
(b) NEG(.1, 2)	A5SW	SW	Mid
	A4SW	SW	Mid
	A4NE	NE	Top
	A4NW	NW	Top
	B9N	N	Top
	C6NE	NE	Mid
	C4SE	SE	Mid
	D5S	S	Mid
	D4S	S	Mid
	E8E	E	Top
	E6E	E	Mid
	E2E	E	Low
	F6N	N	High
	G5NW	NW	Mid

5.1.7 RELATING UNITS UNDER 'NEG' CATEGORY TEMPERATURE VARIATION WITH THEIR (a) CARDINAL AND (b) VERTICAL POSITIONS

(a). CARDINAL LOCATIONS : A total no of 14 cases were observed in 7 locations, none was observed on the West. The frequency in number and % of occurrence of NEGLIGIBLE INTER-SPACE VARIATIONS OF TEMPERATURE in various vertical categories have been shown in Table 5-07

Table 5-07 :

FREQUENCY OF CONSIDERABLE INTER-SPACE VARIATIONS OF TEMPERATURE IN CARDINAL DIRECTIONS

CARDINAL LOCATION	OCCURRENCE IN NUMBER	OCCURRENCE IN %
(1). East	3 out of 14	22%
(2). North	2 out of 14	14%
South	2 out of 14	14%
North-East	2 out of 14	14%
North-West	2 out of 14	14%
South-West	2 out of 14	14%
(3) South-East	1 out of 14	7%.

(b). VERTICAL POSITION : Total 14 cases were observed. The frequency in number and % of occurrence of NEGLIGIBLE INTER-SPACE VARIATIONS OF TEMPERATURE in various vertical categories viz Top, High, Mid and Low have been shown in Table 5-08.

Table 5-08 :

FREQUENCY OF CONSIDERABLE INTER-SPACE VARIATIONS OF TEMPERATURE IN VERTICAL CATEGORIES

VERTICAL CATEGORIES	OCCURRENCE IN NUMBER	OCCURRENCE IN %
(1). Mid	8 out of 14	57%
(2). Top	4 out of 14	29%
(3) High	1 out of 14	7%.
Low	1 out of 14	7%.

From the above analysis, INFERENCE may be drawn to the following effects,

01. There is greater possibility of Negligible inter-space temperature variations to occur in cardinal locations in the following descending order : (1) East, (2) North, South, Northeast, Northwest and Southwest and (3) South-East.

02 The findings of negligible inter-space temperature variations in different vertical locations were inadequate to establish any relation.

5.1.8. ANALYSIS OF INTER-SPACE HUMIDITY VARIATION :

The inter-space variation of Humidity shown in the last column of Table 5-09 varies from 0% to 3%. For the purpose of comparison this range have been classed into four broad categories, viz. High, Mid, Low and Same and the following LEGENDS have been used to indicate those:

TEMPERATURE VARIATION RANGE	BROAD CATEGORY	LEGEND
3%	Higher variation	High
2%	Middle variation	Mid
1%	Lower variation	Low
0%	No variation	Same

The analysis on Inter-space humidity variation in living units have been done exactly in the same way as was done in case of Temperature. The Codes used are also the same or similar. Table 5-05 below shows the Maximum and Minimum humidity, their variations and Legends in the living units

Table 5-09 :

MAXIMUM, MINIMUM & VARIATIONS OF HUMIDITY IN LIVING UNITS

LIVING UNIT CODE	MAXIMUM HUMIDITY	MINIMUM HUMIDITY	HUMIDITY DIFFERENCE	HUMIDITY VARIATION LEGEND
A7SW	90	89	1	Low
A5SW	90	87	3	High
A4SW	86	85	1	Low
A4SE	90	89	1	Low
A4NE	86	86	0	Same
A4NW	83	83	0	Same
B9N	94	93	1	Low
B7N	92	91	1	Low
B4N	92	90	2	Ave
C16NE	92	91	1	Low
C16SE	92	91	1	Low
C6NE	92	91	1	Low
C6SE	93	92	1	Low
C4NE	93	91	2	Mid
C4SE	94	92	2	Mid
D07S	94	92	2	Mid
D05S	95	94	1	Low
D04S	95	94	1	Low
E08E	86	84	2	Mid
E06E	86	85	1	Low
E02E	85	82	3	High
F07N	85	84	1	Low
F06N	85	83	2	Mid
F04N	88	85	3	High
G14NW	85	83	2	Mid
G05NW	87	85	2	Mid
G02NW	88	85	3	High

5.1.9 IDENTIFYING LIVING UNITS WITH 'HIGH' INTER-SPACE VARIATION OF HUMIDITY :

After knowing the Inter-Space Humidity variations of the apartments in terms of High, Mid, Low and Same categories attempts shall be made to find out if there exists any relation in between these variations with the (a) Cardinal location and (b) Vertical position of the unit. Table 5-06 below shows the living units with HIGH INTER-SPACE VARIATION OF HUMIDITY along with their physical characteristics :

Table 5-10 :

LIVING UNITS WITH 'HIGH' CATEGORY INTER-SPACE VARIATION OF HUMIDITY AND THEIR (a) CARDINAL LOCATION AND (b) VERTICAL POSITION

CATEGORY OF INTER-SPACE HUM. DIFF.	LIVING UNIT CODE	(a)CARDINAL LOCATION	(b)VERTICAL LOCATION
High (3%)	A5SW	SW	Mid
	E02E	E	Low
	F04N	N	Mid
	G02NW	NW	Low

5.1.10 RELATING LIVING UNITS WITH 'HIGH' CATEGORY OF HUMIDITY VARIATION WITH (a) CARDINAL AND (B) VERTICAL LOCATIONS

The occurrences and % of HIGH INTER-SPACE VARIATION OF HUMIDITY as observed in 4 nos. of living units in Tables 5-09 and 5-10 are shown in Table 5-11 bellow

(a). CARDINAL LOCATIONS :

Table 5-11 :

FREQUENCY OF HIGH INTER-SPACE VARIATIONS OF HUMIDITY IN CARDINAL LOCATIONS

CARDINAL LOCATION	OCCURRENCE IN NUMBER	OCCURRENCE IN %
East	1 out of 4	25% (equal).
North	1 out of 4	25% (equal).
South-West	1 out of 4	25% (equal).
North-West	1 out of 4	25% (equal).

(c). VERTICAL POSITION:

Table 5-12 :

FREQUENCY OF HIGH INTER-SPACE VARIATION OF HUMIDITY IN VERTICAL CATEGORIES

VERTICAL CATEGORIES	OCCURRENCE IN NUMBER	OCCURRENCE IN %
Mid category	2 out of 4	50 %
Low Category	2 out of 4	50 %

From the above findings it may be opined that

(1) The HIGH inter-space Humidity variation is independent of cardinal location of the living unit.

(2) The HIGH inter-space Humidity variation is independent of vertical position of the living unit

5.1.11 IDENTIFYING LIVING UNITS SHOWING 'LOW' INTER-SPACE VARIATION OF HUMIDITY :

Table 5-13 presents the living units with LOW INTER-SPACE HUMIDITY VARIATION along with (a) Cardinal location and (b) Vertical position of the living unit

Table 5-13:

LIVING UNITS WITH 'LOW' CATEGORY OF INTER-SPACE VARIATION OF HUMIDITY AND THEIR (a) CARDINAL LOCATIONS AND (b) VERTICAL POSITIONS

CATEGORY OF INTER-SPACE HUM. DIFF.	LIVING UNIT CODE	(a)CARDINAL LOCATION	(b)VERTICAL CATEGORY
LOW (1%)	A7SW	SW	Top
	A4SW	SW	Mid
	A4SE	SE	Mid
	B9N	N	Top
	B7N	N	Mid
	C16NE	NE	Top
	C16SE	SE	Top
	C6NE	NE	Mid
	C6SE	SE	Mid
	D05S	S	Mid
	D04S	S	Mid
	E06E	E	Mid
	F07N	N	Top

5.1.12 RELATING LIVING UNITS SHOWING 'LOW' HUMIDITY VARIATION WITH THEIR CARDINAL AND VERTICAL LOCATIONS

From Table 5-13 showing 13 nos. living units with 'LOW' INTER-SPACE VARIATION OF HUMIDITY in various cardinal locations and heights the pictures shown in Table No. 13 and Table 14 may be drawn :

(a). CARDINAL LOCATIONS :

Table 5-14 :

FREQUENCY OF 'LOW' INTER-SPACE VARIATION OF HUMIDITY IN CARDINAL LOCATIONS

CARDINAL LOCATIONS	OCCURRENCE IN NUMBER	OCCURRENCE IN %
(1). North	3 out of 13	23%
South-East	3 out of 13	23%
(2). North-East	2 out of 13	15%
South-WesT	2 out of 13	15%
South	2 out of 13	15%
(3) East	1 out of 13	8%

(b). VERTICAL POSITION :

Table 5-15 :

FREQUENCY OF 'LOW' INTER-SPACE VARIATION OF HUMIDITY IN VERTICAL LOCATIONS

VERTICAL LOCATIONS	OCCURRENCE IN NUMBER	OCCURRENCE IN %
(1). Mid	8 out of 13	62%
(2). Top	5 out of 14	39%

The following inference may be drawn from the above realities :

01. The LOW inter-space Humidity variation is independent of cardinal location of the living unit

02. There is greater probability that LOW inter-space Humidity variation may take place in Mid, and Top category of vertical heights.

5.1.13. ZERO INTER-SPACE VARIATIONS OF HUMIDITY :

Zero or no inter-space variation of Humidity was observed in two living units at Old Dhaka site on the 4th floor and on cardinal locations North-East and North-West, as shown in Table 5-16.

Table 5-16 :

LIVING UNITS WITH 'LOW' INTER-SPACE VARIATION OF HUMIDITY AND CARDINAL LOCATION AND (b) VERTICAL POSITION

CATEGORY OF INTER-SPACE HUM. DIFF.	LIVING UNIT CODE	(a)CARDINAL LOCATION	(b) VERTICAL LOCATION
Same (0%)	A4NE	NE	Mid
	A4NW	NW	Mid

The data obtained were not sufficient to establish reasons for this zero-variation. It is interesting to note the units located on the south or above these two units indicated variations of humidity. One probable reason for no change in humidity may be, since these two units were located on the north of other units, there was no or very little air-movement inside.

5.2. CLIMATIC ANALYSIS OF ROOMS/SPACES :

5.2.1. CATEGORIZATION AND CODING OF RELATED FACTORS :

In analyzing the measured Temperature and Humidity in the rooms of the following procedure has been followed (1) The Mean Temperature/Humidity of each living unit has been calculated by adding the ever-highest and ever-lowest temperatures/humidifies observed in any unit and dividing this sum by 2. (2) The variation of Temperature/Humidity from the Mean temperature/humidity in each rooms/space has been calculated and presented by + for above and - for below the Mean value. (3) In case of Temperature the Mean has been termed as AVERAGE and that above as HOT and below as COOL. (4) In case of Humidity the mean has been termed as MODERATE, that above as WET and below as DRY. (5) Rooms/spaces under each category have been identified. (5) The Cardinal and Vertical locations of the rooms/spaces with extreme variations (In case of Temperature - HOT and COOL and in case Humidity DRY and WET) have been found out. (6) Endeavors have been made to relate those with Cardinal and Vertical locations of the rooms or spaces.

5. 2.2. 'AVERAGE' TEMPERATURE AND VARIATION OF TEMPERATURE FROM THE AVERAGE :

The inter-space temperature variation in rooms and spaces have been found out by first calculating the AVERAGE temperature in the living unit and then finding out the variations in each room/space above or below the AVERAGE temperature. In every living unit there is one highest and one lowest temperature The summation of these two divided by 2 gave the AVERAGE Temperature of that unit. The variation of temperature from the AVERAGE has been calculated in terms of temperature above (+) or below (-) the AVERAGE temperature. Table 5-17 below shows (a) AVERAGE Temperature in each living unit and (b) Variations of temperatures in each room or space like Living Room, Bed Rooms, Dining Room etc. above (expressed by +) or below (expressed by -) the AVERAGE temperature.

Table 5-17 :

AVERAGE TEMPERATURE & VARIATIONS OF TEMPERATURES IN ROOMS AND SPACES

SL. NO.	LIVING UNIT CODE	(a) MEAN TEMPERATURE	(b) TEMPERATURE VARIATIONS IN ROOMS AND SPACES LIVING RM.	M. BED	CHILD'S BED	G. BED	DINING RM/SP.
01	A 7SW	30.8	+.1	00	-.2	——	+ 1
02 .	A 5SW	30.65	+.05	- 05	-.05	——	+.05
03	A 4SW	29 95	+.05	-.05	-.05	——	+ 05
04	A 4SE	30.8	+.1	00	-.2	——	+ 1
05.	A 4NE	30.35	+.05	- 05	+.05	——	+.05
06.	A 4NW	30 75	+.05	- 05	-.05	——	+ 05
07.	B9N	31.8	00	-.1	00	- 1	+ 1
08	B7N	33.0	+.2	00	00	-.2	-.1
09.	B4N	32.9	+.1	-.1	+.1	-.2	+ 2
10.	C16NE	32.2	+.4	-.3	-.3	-.2	- 4
11.	C16SE	31.9	00	- 1	00	-.3	+ 2
12.	C 6NE	31.7	+ 1	-.1	00	-.1	00
13.	C 6SE	32 0	+.2	-.3	-.2	+.2	00
14.	C 4NE	30.9	+.2	00	-.2	- 2	+.1
15.	C 4SE	30 85	-.05	+.05	- 05	-.05	+.05
16.	D 7S	31.1	00	-.2	-.2	+.1	00
17.	D 5S	31.7	+ 1	00	-.1	+ 1	-.1
18.	D 4S	33 3	+.1	+ 1	00	-.1	-.1
19.	E 8E	29.35	+ 05	-.05	-.05	+.05	+ 05
20.	E 6E	29 2	00	-.1	00	+.1	00
21.	E 2E	29.3	00	-.1	+.1	00	00
22.	F 7N	31.4	- 1	-.2	00	+.2	+.1
23.	F 6N	30 4	-.2	-.2	+ 1	+.2	00
24.	F 4N	30 5	-.3	-.1	00	+.1	+.2
25.	G14NW	31.3	+ 2	-.2	- 1	-.3	00
26.	G 5NW	30 2	+.1	00	00	00	-.1
27.	G 2NW	30.0	- 2	+.1	00	+.2	-.1

5. 2.3 CATEGORIZATION AND CODING OF TEMPERATURE VARIATIONS

It is found that variations from the Average temperature ranges from -.05 to +.05 deg. C. On the basis of their propensity to relative 'Hotness' or 'Coolness' this range has be classified into 3 categories and Coded as shown in Table No. 5-18 :

Table 5-18 :

CATEGORY, RANGE AND CODE OF TEMPERATURE VARIATIONS

CATEGORY	RANGE	CODE
Above Average	+ 05 to +.5	HOT (or H)
Average	-0.05 to +0.05 (within and not inclusive)	AVERAGE (or Ave.)
Below Average	-.05 to -.5	COOL (or C)

5.2.4 'MODERATE' HUMIDITY AND VARIATION OF HUMIDITY FROM MODERATE IN EACH ROOMS :

The Humidity measured in each room and space of the 27 living units of 7 buildings have been presented in Table 4-07 in Chapter IV. In each living unit there is one highest and one lowest Humidity. The summation of these two divided by 2 gives the MODERATE Humidity in that unit

The variation of Humidity in each room from the MODERATE has been calculated in terms of Humidity above or below the Moderate Humidity. Table 5-19 below shows (a) MODERATE Humidity in each living unit and (b) Variations of Humidity in each room or spaces like Living Room, Bed Rooms, Dining Room etc. above, expressed by + or below, (expressed by - the Moderate Humidity

Table 5-19 :

MODERATE HUMIDITY & VARIATIONS OF HUMIDITY IN ROOMS AND SPACES							
SL. NO.	LIVING UNIT CODE	(a) MODERATE HUMIDITY	(b) HUMIDITY VARIATIONS IN ROOMS AND SPACES LIVING RM.	M. BED	CHILD'S BED	G. BED	DINING RM/SP.
01.	A 7SW	89.5	+.5	-5	-.5	----	+.5
02.	A 5SW	88.5	+1 5	+.5	-1.5	----	+.5
03	A 4SW	85.5	-.5	+5	+.5	----	-.5
04	A 4SE	89.5	+.5	-.5	-5	----	+.5
05	A 4NE	86	00	00	00	----	00
06	A 4NW	83	00	00	00	----	00
07.	B9N	93.5	+.5	+.5	+.5	-.5	+.5
08.	B7N	91.5	+.5	-5	-.5	-5	-.5
09.	B4N	91	00	-1	+1	00	00
10.	C16NE	91 5	+.5	+.5	-.5	+.5	+5
11	C16SE	91.5	-5	+.5	+.5	-5	+.5
12.	C 6NE	91.5	+.5	-.5	-.5	+.5	-.5
13.	C 6SE	92.5	+.5	-5	-.5	+.5	+.5
14.	C 4NE	92	+1	-1	00	00	-1
15	C 4SE	93	00	+1	00	-1	00
16	D 7S	93	+1	00	-1	+1	+1
17.	D 5S	94.5	-5	+5	+5	-.5	+.5
18.	D 4S	94 5	+.5	+.5	+.5	+.5	-5
19	E 8E	85	-1	00	00	+1	+1
20.	E 6E	85.5	-5	-.5	+.5	+5	+.5
21.	E 2E	83.5	+1 5	-1 5	+.5	+.5	+1.5
22.	F 7N	84.5	+.5	-.5	+.5	-.5	+.5
23.	F 6N	84	00	-1	+1	+1	+1
24.	F 4N	86.5	+.5	+1.5	+1.5	-1.5	+.5
25.	G14NW	84	00	00	00	+1	-1
26.	G 5NW	86	+1	00	+1	-1	00
27.	G 2NW	86.5	-.5	-.5	-1.5	+1.5	-.5

5.2.5 CATEGORIZATION AND CODING OF HUMIDITY VARIATIONS :

It has been found that that with respect to MODERATE Humidity, humidity in other rooms varies in the range of -1.5 below to +1.5 above the MODERATE. For the purpose of analysis and study this range has been classed into 3 categories, viz 'DRY', 'MODERATE' and 'WET' The Categories, ranges of variation and Codes have been given in Table 5-20:

Table 5-20 :

CATEGORY	RANGE	CODE
Below Moderate	.5 to 1.5	DRY (D)
Moderate	-.5 to +.5 (within and not inclusive)	MODERATE (MOD)
Above Moderate	.5 to 1 5	WET (W)

5.2.6 CODING OF CARDINAL LOCATION :

In determining the cardinal locations of rooms of the living units the eight cardinal codes as used in case of living units were not found sufficient. Some rooms or spaces were found at the central location of the living unit, with no external wall and no direct opening or windows. The cardinal location of such room or space have been specified as "CENTRAL". Thus the Cardinal Locations and LEGENDS of the rooms/spaces under study have been shown in Table 5-21 below .

Table 5-21 :

LEGENDS OF CARDINAL LOCATIONS OF ROOMS/SPACES

CARDINAL LOCATION	LEGEND	CARDINAL LOCATION	LEGEND	CARDINAL LOCATION	LEGEND
(1) East	E	(2) West	W	(3) North	N
(4) South	S	(5) North-East	NE	(6) North-West	NW
(7) South-East	SE	(8) South-West	SW	(9) Central	C

5.2.7 CODING OF VERTICAL POSITION : The procedure for Coding of vertical positions have already been described in connection with Living Units and the same codes as described here under remains valid in case of rooms also.

FLOORS :	CODE.
The topmost floor.	Top
The floor immediately below the top floor.	High
All floors in between the High and Low floors.	Mid
The lower two floors	Low

5.3 IDENTIFICATION OF 'HOT, AVERAGE, COOL' AND 'DRY, MODERATE, WET' ROOMS

Table 5-22 has been prepared to identify the HOT, AVERAGE and COOL (in terms of Temperature) and DRY, MODERATE and WET (in terms of Humidity) category rooms in each living unit. Also the Cardinal location and Vertical category of each room have been shown for easy understanding.

Table 5-22 :

IDENTIFICATION OF 'HOT, AVERAGE, COOL' AND 'DRY, MODERATE, WET' CATEGORY ROOMS.

LIVING UNIT	ROOM OR SPACE	(a) CATEGORY OF TEMPERATURE	(b) CATEGORY OF HUMIDITY	(c) CARDINAL LOCATION	(d) VERTICAL CATEGORY
A07SW	Living Rm	HOT	WET	C	Top
	Master Bed	AVER.	DRY	S	Top
	Child Bed	COOL	DRY	SW	Top
	Dining	HOT	WET	C	Top
A05SW	Living Rm.	HOT	WET	C	Mid
	Master Bed	COOL	WET	S	Mid
	Child Bed	HOT	DRY	SW	Mid
	Dining	HOT	WET	C	Mid
A04SW	Living Rm.	HOT	DRY	C	Mid
	Master Bed	COOL	WET	S	Mid
	Child Bed	COOL	WET	SW	Mid
	Dining	HOT	DRY	C	Mid
A04SE	Living Rm.	HOT	WET	C	Mid
	Master Bed	AVER.	DRY	S	Mid
	Child Bed	COOL	DRY	SE	Mid
	Dining	HOT	WET	C	Mid
A04NE	Living Rm.	HOT	MOD	C	Mid
	Master Bed	COOL	MOD	N	Mid
	Child Bed	HOT	MOD	NE	Mid
	Dining	HOT	MOD	C	Mid
A04NW	Living Rm.	HOT	MOD	C	Mid
	Master Bed	COOL	MOD	N	Mid
	Child Bed	COOL	MOD	NW	Mid
	Dining	HOT	MOD	C	Mid
B09N	Living Rm	AVER.	WET	W	Top
	Master Bed	COOL	WET	NW	Top
	Child Bed	AVER.	WET	N	Top
	Guest Bed	COOL	DRY	NE	Top
	Dining	HOT	WET	C	Top
B07N	Living Rm.	HOT	WET	W	Mid
	Master Bed	AVER.	DRY	NW	Mid
	Child Bed	AVER.	DRY	N	Mid
	Guest Bed	COOL	DRY	NE	Mid
	Dining	COOL	DRY	C	Mid
B04N	Living Rm.	HOT	MOD	W	Mid
	Master Bed	COOL	DRY	NW	Mid
	Child Bed	HOT	WET	N	Mid
	Guest Bed	COOL	MOD	NE	Mid
	Dining	HOT	MOD	C	Mid

Table 5-22 (Contd.)

IDENTIFICATION OF 'HOT, AVERAGE, COOL' AND 'DRY, MODERATE, WET' CATEGORY ROOMS

LIVING UNIT	ROOM OR SPACE	(a) CATEGORY OF TEMPERATURE	(b) CATEGORY OF HUMIDITY	(c) CARDINAL LOCATION	(d) VERTICAL CATEGORY
C16NE	Living Rm	HOT	WET	N	Top
	Master Bed	COOL	WET	NE	Top
	Child Bed	COOL	DRY	SE	Top
	Guest Bed	COOL	WET	N	Top
	Dining	COOL	WET	C	Top
C16SE	Living Rm	AVER	DRY	S	Top
	Master Bed	COOL	WET	SE	Top
	Child Bed	AVER.	WET	NE	Top
	Guest Bed	COOL	DRY	S	Top
	Dining	HOT	WET	C	Top
C06NE	Living Rm.	HOT	WET	N	Mid
	Master Bed	COOL	DRY	NE	Mid
	Child Bed	AVER.	DRY	SE	Mid
	Guest Bed	COOL	WET	N	Mid
	Dining	AVER.	DRY	C	Mid
C06SE	Living Rm	HOT	WET	S	Mid
	Master Bed	COOL	DRY	SE	Mid
	Child Bed	COOL	DRY	NE	Mid
	Guest Bed	HOT	WET	S	Mid
	Dining	AVER.	WET	C	Mid
C04NE	Living Rm	HOT	WET	N	Mid
	Master Bed	AVER.	DRY	NE	Mid
	Child Bed	COOL	MOD	SE	Mid
	Guest Bed	COOL	MOD	N	Mid
	Dining	HOT	DRY	C	Mid
C04SE	Living Rm.	COOL	MOD	S	Mid
	Master Bed	HOT	WET	SE	Mid
	Child Bed	COOL	MOD	NE	Mid
	Guest Bed	COOL	DRY	S	Mid
	Dining	HOT	MOD	C	Mid
D07S	Living Rm.	AVER.	WET	W	Top
	Master Bed	COOL	MOD	SE	Top
	Child Bed	COOL	DRY	E	Top
	Guest Bed	HOT	WET	SW	Top
	Dining	AVER.	WET	C	Top
D05S	Living Rm.	HOT	DRY	W	Mid
	Master Bed	AVER	WET	SE	Mid
	Child Bed	COOL	WET	E	Mid
	Guest Bed	HOT	DRY	SW	Mid
	Dining	COOL	WET	C	Mid
D04S	Living Rm.	HOT	WET	W	Mid
	Master Bed	HOT	WET	SE	Mid
	Child Bed	AVER.	WET	E	Mid
	Guest Bed	COOL	WET	SW	Mid
	Dining	COOL	DRY	C	Mid

Table 5-22 (Contd.)

IDENTIFICATION OF 'HOT, AVERAGE, COOL' AND 'DRY, MODERATE, WET' CATEGORY ROOMS					
LIVING UNIT	ROOM OR SPACE	(a) CATEGORY OF TEMPERATURE	(b) CATEGORY OF HUMIDITY	(c) CARDINAL LOCATION	(d) VERTICAL CATEGORY
E08E	Living Rm.	HOT	DRY	S	Top
	Master Bed	COOL	MOD	NE	Top
	Child Bed	COOL	MOD	N	Top
	Guest Bed	HOT	WET	SE	Top
	Dining	HOT	WET	C	Top
E06E	Living Rm.	AVER.	DRY	S	Mid
	Master Bed	COOL	DRY	NE	Mid
	Child Bed	AVER.	WET	N	Mid
	Guest Bed	HOT	WET	SE	Mid
	Dining	AVER.	WET	C	Mid
E02E	Living Rm.	AVER.	WET	S	Low
	Master Bed	COOL	DRY	NE	Low
	Child Bed	HOT	WET	N	Low
	Guest Bed	AVER	WET	SE	Low
	Dining	AVER.	WET	C	Low
F07N	Living Rm.	COOL	WET	E	Top
	Master Bed	COOL	DRY	NE	Top
	Child Bed	AVER.	WET	NW	Top
	Guest Bed	HOT	DRY	W	Top
	Dining	HOT	WET	C	Top
F06N	Living Rm.	COOL	MOD	E	High
	Master Bed	COOL	DRY	NE	High
	Child Bed	HOT	WET	NW	High
	Guest Bed	HOT	WET	W	High
	Dining	AVER.	WET	C	High
F04N	Living Rm	COOL	WET	E	Mid
	Master Bed	COOL	WET	NE	Mid
	Child Bed	AVER	WET	NW	Mid
	Guest Bed	HOT	DRY	W	Mid
	Dining	HOT	WET	C	Mid
G14NW	Living Rm.	HOT	MOD	W	Top
	Master Bed	COOL	MOD	NW	Top
	Child Bed	COOL	MOD	W	Top
	Guest Bed	COOL	WET	N	Top
	Dining	AVER	DRY	C	Top
G05NW	Living Rm.	HOT	WET	W	Mid
	Master Bed	AVER.	MOD	NW	Mid
	Child Bed	AVER.	WET	W	Mid
	Guest Bed	AVER.	DRY	N	Mid
	Dining	COOL	MOD	C	Mid
G02NW	Living Rm.	COOL	DRY	W	Low
	Master Bed	HOT	DRY	NW	Low
	Child Bed	AVER.	DRY	W	Low
	Guest Bed	HOT	WET	N	Low
	Dining	COOL	DRY	C	Low

5.3.1 SPECIFYING CARDINAL AND VERTICAL LOCATIONS OF ROOMS UNDER 'HOT' RANGE.

There are 48 rooms that fall under 'HOT' range. The Cardinal locations and categories of Vertical location of the se rooms have been shown in Table 5-23 below.

Table 5- 23:

CARDINAL LOCATION AND CATEGORIES OF VERTICAL LOCATION OF ROOMS/SPACES UNDER 'HOT' RANGE

SL. NO.	LIVING UNIT	ROOM OR SPACE	CARDINAL LOCATION	VERTICAL CATEGORY
01.	A07SW	Living Rm.	Central	TOP
02.		Dining	Central	TOP
03.	A05SW	Living Rm.	Central	MID
04.		Child Bed	South-West	MID
05		Dining	Central	MID
06	A04SW	Living Rm.	Central	MID
07.		Dining	Central	MID
08.	A04SE	Living Rm.	Central	MID
09.		Dining	Central	MID
10.	A04NE	Living Rm.	Central	MID
11.		Child Bed	North-East	MID
12		Dining	Central	MID
13.	A04NW	Living Rm	Central	MID
14		Dining	Central	MID
15.	B09N	Dining	Central	TOP
16.	B07N	Living Rm	West	MID
17.	B04N	Living Rm.	West	MID
18		Child Bed	North	MID
19		Dining	Central	MID
20.	C16NE	Living Rm.	North	TOP
21.	C16SE	Dining	Central	TOP
22.	C06NE	Living Rm.	North	MID
23.	C06SE	Living Rm.	South	MID
24.		Guest Bed	South	MID
25.	C04NE	Living Rm.	North	MID
26		Dining	Central	MID
27	C04SE	Master Bed	South-East	MID
28.		Dining	Central	MID
29.	D07S	Guest Bed	South-West	TOP
30.	D05S	Living Rm.	West	MID
31.		Guest Bed	South-West	MID
32.	D04S	Living Rm	West	MID
33		Master Bed	South-East	MID
34.	E08E	Living Rm	South	TOP
35.		Guest Bed	South-East	TOP
36.		Dining	Central	TOP
37.	E06E	Guest Bed	South-East	MID
38.	E02E	Child Bed	North	LOW
39.	F07N	Guest Bed	West	TOP
40.		Dining	Central	TOP
41.	F06N	Child Bed	North-West	HIGH
42.		Guest Bed	West	HIGH
43.	F04N	Guest Bed	West	MID
44.		Dining	Central	MID
45	G14NW	Living Rm	West	TOP
46.	G05NW	Living Rm	West	MID
47.	G02NW	Master Bed	North-West	LOW
48.		Guest Bed	North	LOW

Based on Table 5-23 above, the number and percent of 'HOT' category rooms in various cardinal locations have been found out and presented in Table 5-24 below.

Table 5-24 :

NUMBER AND PERCENT OF 'HOT' CATEGORY ROOMS IN VARIOUS CARDINAL LOCATIONS

	CARDINAL LOCATION									
	EAST	WEST	NORTH	SOUTH	NORTH EAST	NORTH WEST	SOUTH EAST	SOUTH WEST	CENTRAL	TOTAL
Total no. of Rooms/ spaces in specific cardinal locations (From Table 5-22)	6	15	18	12	16	10	13	6	33	129
No. of 'HOT' Rooms/spaces (From Table 5-23)	**0**	**9**	**6**	**3**	**1**	**2**	**4**	**3**	**20**	**48**
Percent of HOT Rooms/spaces	**00**	**60%**	**33%**	**25%**	**6%**	**20%**	**31%**	**50%**	**61%**	37%

The number and percent of 'HOT' category rooms in various Vertical categories have been found out from Table 5-23 and presented in Table 5-25 below.

Table 5-25 :

NUMBER AND PERCENT OF 'HOT' CATEGORY ROOMS IN VARIOUS VERTICAL CATEGORIES

	VERTICAL CATEGORIES				
	TOP	HIGH	MID	LOW	TOTAL
Total no. of rooms or spaces under specific category (From Table 5-22)	39	5	75	10	129
No. of 'HOT' rooms found (From Table 5-23)	**12**	**2**	**30**	**3**	**48**
Percent of rooms/ spaces	**31%**	**40%**	**40%**	**30%**	37%

5.3.2 ESTABLISHING RELATION OF HOTNESS WITH CARDINAL AND VERTICAL POSITION.

From Table 5-23 it has been revealed that 37% of the total rooms/spaces surveyed fall under "HOT" category. After deductions from the above Tables the following relation shown in Table 5-26 is found to exist between the hotness of rooms and their Cardinal locations :

Table 5-26 :

RELATION BETWEEN 'HOT' CATEGORY ROOMS AND CARDINAL LOCATIONS

OCCURRENCES IN %	RELATIVE POSITION	CARDINAL LOCATION
61%	HIGHEST	CENTRAL
60%	2ND HIGHEST	WEST
50%	3RD HIGHEST	SOUTH-WEST
33%	4TH HIGHEST	NORTH
31%	5TH HIGHEST	SOUTH-EAST
25%	6TH HIGHEST	SOUTH
20%	7TH HIGHEST	NORTH-WEST
6%	8TH HIGHEST	NORTH-EAST
00%	LOWEST	EAST

From Table 5-24 and 5-25 the following relation shown in Table 5-27 has been found to exist between the hotness of rooms and Vertical categories :

Table 5-27 :

RELATION BETWEEN 'HOT' CATEGORY ROOMS AND VERTICAL CATEGORIES

OCCURRENCES IN %	RELATIVE POSITION	VERTICAL CATEGORY
41%	HIGHEST	HIGH
41%	HIGHEST	MID
31%	2ND HIGHEST	TOP
30%	LOWEST	LOW

5.3.3 IDENTIFYING 'COOL' CATEGORY ROOMS/SPACES :

From Table 5-23, 52 nos. rooms have been found to have been under 'COOL' category. The Cardinal locations and Vertical categories of these rooms have been shown in Table 5-28 below.

Table 5-28:

CARDINAL LOCATION AND CATEGORIES OF VERTICAL LOCATION OF ROOMS UNDER 'COOL' CATEGORY

SL. NO.	LIVING UNIT	ROOM OR SPACE	CARDINAL LOCATION	VERTICAL CATEGORY
01.	A07SW	Child Bed	South-West	TOP
02	A05SW	Master Bed	South	MID
03.		Child Bed	South-West	MID
04.	A04SW	Master Bed	South	MID
05.		Child Bed	South-West	MID
06.	A04SE	Child Bed	South-East	MID
07.	A04NE	Master Bed	North	MID
08	A04NW	Master Bed	North	MID
09.		Child Bed	North-West	MID
10.	B09N	Master Bed	North-West	TOP
11		Guest Bed	North-East	TOP
12.	B07N	Guest Bed	North-East	MID
13.		Dining	Central	MID
14.	B04N	Master Bed	North-West	MID
15		Guest Bed	North-East	MID
16.	C16NE	Master Bed	North-East	TOP
17.		Child Bed	South-East	TOP
18		Guest Bed	North	TOP
19		Dining	Central	TOP
20.	C16SE	Master Bed	South-East	TOP
21		Guest Bed	South	TOP
22.	C06NE	Master Bed	North-East	TOP
23.		Guest Bed	North	TOP
24.	C06SE	Master Bed	South-East	MID
25.		Child Bed	North-East	MID
26.	C04NE	Child Bed	South-East	MID
27.		Guest Bed	North	MID
28.	C04SE	Living Rm.	South	MID
29		Child Bed	North-East	MID
30.		Guest Bed	North	MID
31.	D07S	Master Bed	South-East	TOP
32.		Child Bed	East	TOP
33	D05S	Child Bed	East	MID
34		Dining	Central	MID
35.	D04S	Guest Bed	South-West	MID
36.		Dining	Central	MID
37.	E08E	Master Bed	North-East	TOP
38.		Child Bed	North	TOP
39.	E06E	Master Bed	North-East	MID
40	E02E	Master Bed	North-East	LOW
41	F07N	Living Rm	East	TOP
42.		Master Bed	North-East	TOP
43.	F06N	Living Rm.	East	HIGH
44.		Master Bed	North-East	HIGH
45.	F04N	Living Rm	East	MID
46.		Master Bed	North-East	MID
47.	G14NW	Master Bed	North-West	TOP
48.		Child Bed	West	TOP
49.		Guest Bed	North	TOP
50.	G05NW	Dining	Central	MID
51.	G02NW	Living Rm.	West	MID
52		Dining	Central	LOW

Based on Table 5-28 above, the number and percent of rooms under 'Cool' range in various cardinal locations have been presented in Table 5-29 and their categories of vertical positions in Table 5-30 below.

Table 5-29 :

NUMBER AND PERCENT OF 'COOL' CATEGORY ROOMS IN VARIOUS CARDINAL LOCATIONS

	CARDINAL LOCATION									
	EAST	WEST	NORTH	SOUTH	NORTH EAST	NORTH WEST	SOUTH EAST	SOUTH WEST	CENTRAL	TOTAL
Total no. of rooms or spaces in this category (From Table 5-22)	6	15	18	12	16	10	13	6	33	129
No. of COOL Rooms/spaces (From Table 5-28)	**5**	**2**	**8**	**4**	**13**	**4**	**6**	**4**	**6**	52
Percent of Cool rooms	**83%**	**13%**	**44%**	**33%**	**81%**	**40%**	**46%**	67%	**18%**	40%

Table 5-30 :

NUMBER AND PERCENT OF 'COOL' CATEGORY ROOMS IN VERTICAL CATEGORIES.

	VERTICAL CATEGORIES				
	TOP	HIGH	MID	LOW	TOTAL
Total no. of rooms or spaces (From Table 5-22)	39	5	75	10	129
No. of COOL rooms (From Table 5-28)	20	2	28	2	52
Percent of COOL rooms	**51%**	**40%**	**37%**	**20%**	40%

5.3.4 ESTABLISHING RELATION OF COOLNESS WITH CARDINAL OR VERTICAL POSITION:.

From Tables 5-29 and 5-30, the relation found to exist between the 'Coolness' of rooms and their Cardinal locations have been presented in Table 5-31:

Table 5-31 :

RELATION BETWEEN 'COOL' CATEGORY ROOMS AND CARDINAL LOCATIONS

OCCURRENCE IN %	RELATIVE POSITION	CARDINAL LOCATION
83%	HIGHEST	EAST
81%	2ND HIGHEST	NORTH-EAST
67%	3RD HIGHEST	SOUTH-WEST
46%	4TH HIGHEST	SOUTH-EAST
44%	5TH HIGHEST	NORTH
40%	6TH HIGHEST	NORTH-WEST
33%	7TH HIGHEST	SOUTH
18%	8TH HIGHEST	CENTRAL
13%	LOWEST	WEST

Also, from Tables 5-29 and 5-30, the relation found to exist between the 'Coolness' of rooms and their categories of Vertical locations have been presented in Table 5-32

Table 5-32 :

RELATION BETWEEN 'COOL' CATEGORY ROOMS AND CATEGORY OF VERTICAL LOCATIONS

OCCURRENCES IN %	RELATIVE POSITION	VERTICAL CATEGORY
51%	HIGHEST	TOP
40%	2ND HIGHEST	HIGH
37%	3RD HIGHEST	MID
20%	LOWEST	LOW

5.4 IDENTIFICATION OF DRY, MODERATE AND WET ROOMS :

For the purpose of identifying rooms/spaces under DRY, MODERATE and WET categories, the various Legends and Codes used in case of TEMPERATURE have been utilized.

5.4.1. IDENTIFICATION OF DRY ROOMS

In Table 5-23, 42 rooms have been found to have been under ranges DRY category. These rooms along with their Cardinal and Vertical location categories have been shown in Table 5-33 below.

Table 5-33 :

CARDINAL AND VERTICAL POSITIONS OF ROOMS/SPACES UNDER 'DRY' CATEGORY

SL. NO.	LIVING UNIT	ROOM OR SPACE	CARDINAL LOCATION	VERTICAL CATEGORY
01.	A07SW	Master Bed	South	TOP
02.		Child Bed	South-West	TOP
03.	A05SW	Child Bed	South-West	MID
04.	A04SW	Living Rm.	Central	MID
05.		Dining	Central	MID
06	A04SE	Master Bed	South	MID
07		Child Bed	South-East	MID
08	B09N	Guest Bed	North-East	TOP
09.	B07N	Master Bed	North-West	MID
10		Child Bed	North	MID
11.		Guest Bed	North-East	MID
12.		Dining	Central	MID
13.	B04N	Master Bed	North-West	MID
14.	C16NE	Child Bed	South-East	TOP
15.	C16SE	Living Rm.	South	TOP
16.		Guest Bed	South	TOP
17.	C06NE	Master Bed	North-East	MID
18.		Child Bed	South-East	MID
19.		Dining	Central	MID
20.	C06SE	Master Bed	South-East	MID
21.		Child Bed	North-East	MID
22	C04NE	Master Bed	North-East	MID
23.		Dining	Central	MID
24.	C04SE	Guest Bed	North	MID
25.	D07S	Child Bed	East	TOP
26.	D05S	Living Rm.	West	MID
27.		Guest Bed	South-West	MID
28.	D04S	Dining	Central	MID
29.	E08E	Living Rm.	South	TOP
30.	E06E	Living Rm.	South	MID
31.		Master Bed	North-East	MID
32.	E02E	Master Bed	North-East	LOW
33.	F07N	Master Bed	North-East	TOP
34.		Guest Bed	West	TOP
35.	F06N	Master Bed	North-East	HIGH
36.	F04N	Guest Bed	West	MID
37.	G14NW	Dining	Central	TOP
38.	G05NW	Guest Bed	North	MID
39	G02NW	Living Rm.	West	LOW
40.		Master Bed	North-West	LOW
41		Child Bed	West	LOW
42		Dining	Central	LOW

On the basis of Table 5-33 above the number and percent of 'DRY' range of rooms in various Cardinal locations have been identified and presented along with their Cardinal locations and category of vertical locations in Table 5-34 and those with Category of Vertical locations in Table No. 5-35.

Table 5-34 :

NUMBER AND PERCENT OF 'DRY' ROOMS IN VARIOUS CARDINAL LOCATIONS.

	CARDINAL LOCATION									
	EAST	WEST	NORTH	SOUTH	NORTH EAST	NORTH WEST	SOUTH EAST	SOUTH WEST	CENTRAL	TOTAL
Total no of Rooms/ spaces cardinal locations (From Table 5-22)	6	15	18	12	16	10	13	6	33	129
No. of 'DRY' Rooms/spaces (From Table 5-33)	**1**	**5**	**3**	**6**	**9**	**3**	**4**	**3**	**8**	42
Percent of DRY Rooms/spaces	**17%**	**33%**	**17%**	**50%**	**56%**	**30%**	**31%**	**50%**	**24%**	33%

Table 5-35 :

NUMBER AND PERCENT OF 'DRY' ROOMS IN VARIOUS VERTICAL CATEGORIES

	VERTICAL CATEGORIES				
	TOP	HIGH	MID	LOW	TOTAL
Total no of rooms or spaces (From Table 5-22)	39	5	75	10	129
No. of 'DRY' rooms /spaces (From Table 5-33)	**11**	**01**	**25**	**05**	42
Percent of 'DRY' rooms/spaces	**28%**	**20%**	**33%**	**50%**	**33%**

5.4.2 RELATING 'DRY' ROOMS WITH THEIR CARDINAL AND VERTICAL POSITIONS :

Out of total 129 rooms, 42 nos. or 33% rooms were found to be 'DRY'. The relation found to exist between DRYNESS and Cardinal location and Vertical positions are presented in Table 5-36 and Table 5-37 respectively

Table 5-36 :

RELATION OF 'DRY' ROOMS WITH CARDINAL LOCATIONS		
OCCURANCE EXPRESSED IN %	RELATIVE POSITION	CARDINAL LOCATION
56%	HIGHEST	NORTH-EAST
50%	2^{ND} HIGHEST	SOUTH & SOUTH-WEST
33%	3^{RD} HIGHEST	WEST
31%	4^{TH} HIGHEST	SOUTH-EAST
30%	5^{TH} HIGHEST	NORTH-WEST
24%	6^{TH} HIGHEST	CENTRAL
17%	LOWEST	EAST and NORTH

Table 5-37 :

RELATION OF 'DRY' ROOMS WITH CARDINAL VERTICAL POSITION		
OCCURRENCES IN %	RELATIVE POSITION	CARDINAL LOCATION
50%	HIGHEST	LOW
30%	2^{ND} HIGHEST	MID
28%	3^{RD} HIGHEST	TOP
20%	LOWEST	HIGH

5.4.3 IDENTIFYING 'WET' ROOMS.

There are 62 rooms under WET category. These rooms with their cardinal locations and vertical positions have been presented in Table 5-38.

Table 5-38:

CARDINAL LOCATIONS AND VERTICAL POSITIONS OF ROOMS/SPACES UNDER 'WET' CATEGORY				
SL. NO.	LIVING UNIT	ROOM OR SPACE	CARDINAL LOCATION	VERTICAL CATEGORY
01	A07SW	Living Rm.	Central	TOP
02.		Dining	Central	TOP
03	A05SW	Living Rm.	Central	MID
04.		Master Bed	South	MID
05		Dining	Central	MID
06.	A04SW	Master Bed	South	MID
07		Child Bed	South-West	MID
08	A04SE	Living Rm.	Central	MID
09.		Dining	Central	MID

Table 5-38 (Contd.) :

CARDINAL LOCATIONS AND VERTICAL POSITIONS OF ROOMS/SPACES UNDER 'WET' CATEGORY				
SL. NO.	LIVING UNIT	ROOM OR SPACE	CARDINAL LOCATION	VERTICAL CATEGORY
10.	B09N	Living Rm.	West	TOP
11		Master Bed	North-West	TOP
12.		Child Bed	North	TOP
13.		Dining	Central	TOP
14.	B07N	Living Rm	West	MID
15.	B04N	Child Bed	North	MID
16	C16NE	Living Rm	North	TOP
17.		Master Bed	North-East	TOP
18.		Guest Bed	North	TOP
19.		Dining	Central	TOP
20.	C16SE	Master Bed	South-East	TOP
21.		Child Bed	North-East	TOP
22		Dining	Central	TOP
23.	C06NE	Living Rm	North	MID
24.		Guest Bed	North	MID
25.	C06SE	Living Rm.	South	MID
26.		Guest Bed	South	MID
27.		Dining	Central	MID
28.	C04NE	Living Rm.	North	MID
29.	C04SE	Master Bed	South-East	MID
30	D07S	Living Rm.	West	TOP
31.		Guest Bed	South-West	TOP
32.		Dining	Central	TOP
33.	D05S	Master Bed	South-East	MID
34.		Child Bed	East	MID
35.		Dining	Central	MID
36.	D04S	Living Rm.	West	MID
37.		Master Bed	South-East	MID
38		Child Bed	East	MID
39		Guest Bed	South-West	MID
40.	E08E	Guest Bed	South-East	TOP
41		Dining	Central	TOP
42.	E06E	Child Bed	North	MID
43.		Guest Bed	South-East	MID
44.		Dining	Central	MID
45	E02E	Living Rm.	South	LOW
46		Child Bed	North	LOW
47.		Guest Bed	South-East	LOW
48		Dining	Central	LOW
49.	F07N	Living Rm	East	TOP
50.		Child Bed	North-West	TOP
51.		Dining	Central	TOP
52.	F06N	Child Bed	North-West	HIGH
53.		Guest Bed	West	HIGH
54.		Dining	Central	HIGH
55.	F04N	Living Rm.	East	MID
56.		Master Bed	North-East	MID
57.		Child Bed	North-West	MID
58.		Dining	Central	MID
59.	G14NW	Guest Bed	North	TOP
60	G05NW	Living Rm	West	MID
61.		Child Bed	West	MID
62.	G02NW	Guest Bed	North	LOW

On the basis of Table 5-38 above the number and percent of 'WET' rooms in various Cardinal and Vertical locations have been found out and presented in Table 5-39 and Table 5-40 respectively.

Table 5-39 :

NUMBER AND PERCENT OF 'WET' ROOMS IN VARIOUS CARDINAL LOCATIONS.

	CARDINAL LOCATION									
	EAST	WEST	NORTH	SOUTH	NORTH EAST	NORTH WEST	SOUTH EAST	SOUTH WEST	CENTRAL	TOTAL
Total no. of WET rooms (From Table 5-22)	6	15	18	12	16	10	13	6	33	129
No. of 'WET' rooms/ spaces (From Table 5-38)	4	7	11	5	3	4	7	3	18	62
Percent of WET rooms	67%	47%	61%	42%	19%	40%	54%	50%	55%	48%

Table 5-40 :

NUMBER AND PERCENT OF 'WET' ROOMS IN VARIOUS VERTICAL CATEGORIES.

	VERTICAL CATEGORIES				
	TOP	HIGH	MID	LOW	TOTAL
Total no. of WET Rooms/ spaces (From Table 5-22)	39	5	75	10	129
No. of WET rooms/ Spaces (From Table 5-38)	22	3	32	5	62
Percent of WET rooms/ Spaces	56%	60%	43%	50%	48%

5.4.4 ESTABLISHING RELATIONS OF WET ROOMS WITH CARDINAL AND VERTICAL POSITIONS

Out of 129 rooms, 62 nos. or 48% were found to have been in the WET range The relation that has been found to exist between WET rooms and their Cardinal locations have been found out and presented in Table 5-41. Also that between WET rooms and their Vertical locations have presented in Table 5-42 below.

Table 5-41 :

RELATION BETWEEN WET ROOMS AND CARDINAL LOCATIONS		
OCCURRENCES IN %	RELATIVE POSITION	CARDINAL LOCATION
67%	HIGHEST	EAST
61%	2ND HIGHEST	NORTH
55%	3RD HIGHEST	CENTRAL
54%	4TH HIGHEST	SOUTH-EAST
50%	5TH HIGHEST	SOUTH-WEST
47%	6TH HIGHEST	WEST
42%	7TH HIGHEST	SOUTH
40%	8TH HIGHEST	NORTH-WEST
19%	LOWEST	NORTH-EAST

Table 5-42 :

RELATION BETWEEN 'WET' ROOMS AND VERTICAL CATEGORY		
OCCURRENCES IN %	RELATIVE POSITION	VERTICAL CATEGORY
60%	HIGHEST	HIGH
56%	2ND HIGHEST	TOP
50%	3RD HIGHEST	LOW
43%	LOWEST	MID

5.5 IDENTIFICATION OF BOTH 'COOL AND DRY' ROOMS/SPACES

Theoretically speaking, COOL and DRY rooms/spaces are climatically the most 'comfortable rooms/spaces' in tropical countries in hot seasons. The rooms/spaces that fall in these two categories have been identified from Tables 5-22 and have been presented below in Table 5-43, along with their cardinal location and vertical categories.

Table 5-43 :

CARDINAL LOCATION AND VERTICAL POSITIONS OF 'COOL AND DRY' ROOMS/SPACES				
SL. NO.	LIVING UNIT	ROOM OR SPACE	(a)CARDINAL LOCATION	(b) VERTICAL POSITION
01	A07SW	Child Bed	SW	Top
02.	B09N	Guest Bed	NE	Top
03.	B07N	Guest Bed	NE	Mid
04.		Dining	C	Mid
05.	B04N	Master Bed	NW	Mid
06	C16NE	Child Bed	SE	Top
07	C16SE	Guest Bed	S	Top
08.	C06NE	Master Bed	NE	Mid
09.	C06SE	Master Bed	SE	Mid
10		Child Bed	NE	Mid
11.	C04SE	Guest Bed	N	Mid

Table 5-43 (Contd.):

CARDINAL LOCATION AND VERTICAL POSITIONS OF 'COOL AND DRY' ROOMS/SPACES				
SL. NO.	LIVING UNIT	ROOM OR SPACE	(a)CARDINAL LOCATION	(b) VERTICAL POSITION
12	D07S	Child Bed	E	Top
13	D04S	Dining	C	Mid
14.	E06E	Master Bed	NE	Mid
15	E02E	Master Bed	NE	Mid
16.	F07N	Master Bed	NE	Top
17.	F06N	Master Bed	NE	High
18.	G02NW	Living Rm	W	Low
19.		Dining	C	Low

On the basis of Table 5-43 above the number and percent of 'COOL and DRY' rooms in various Cardinal locations have been calculated and presented in Table 5-44 below. Also those in various vertical categories have been presented in Table 5-45.

Table 5-44 :

NUMBER AND PERCENT OF COOL AND DRY' CATEGORY ROOMS IN VARIOUS CARDINAL LOCATIONS.

	CARDINAL LOCATION									
	EAST	WEST	NORTH	SOUTH	NORTH EAST	NORTH WEST	SOUTH EAST	SOUTH WEST	CENTR.	TOTAL
Total no. of rooms (From Table 5-22)	6	15	18	12	16	10	13	6	33	129
No. of 'Cool, Dry' rooms/ spaces (From Table 5-43)	1	1	1	1	8	1	2	1	3	19
Percent of Cool, Dry rooms	17%	7%	6%	8%	50%	10%	15%	17%	9%	15%

Table 5-45 :

NUMBER AND PERCENT OF 'WET' CATEGORY ROOMS IN VARIOUS VERTICAL CATEGORIES.

	VERTICAL CATEGORIES				
	TOP	HIGH	MID	LOW	
TOTAL Total no. of Rooms/ spaces (From Table 5-22)	39	5	75	10	129
No. of Cool and Dry rooms/Spaces (From Table 5-43)	6	1	10	2	19
Percent of Cool and Dry rooms/spaces	15%	20%	13%	40%	15%

5.5.1 ESTABLISHING RELATIONS OF 'COOL AND DRY' ROOMS WITH CARDINAL AND VERTICAL POSITIONS :

Out of 129, 19 nos or 15% were found to have been both 'COOL and DRY' The relation that exist between such rooms and their Cardinal locations have been found out and presented in Table 5-46 Also, their relations with vertical positions have been presented in Table 5-47

Table 5-46 :

RELATION OF 'COOL+DRY' ROOMS/SPACES WITH CARDINAL LOCATIONS

OCCURRENCES IN %	RELATIVE POSITION	CARDINAL LOCATION
50%	HIGHEST	NORTH-EAST
17%	2ND HIGHEST	SOUTH-WEST & EAST
15%	3RD HIGHEST	SOUTH-EAST
10%	4TH HIGHEST	NORTH-WEST
9%	5TH HIGHEST	CENTRAL
8%	6TH HIGHEST	SOUTH
7%	7TH HIGHEST	WEST
6%	LOWEST	NORTH

Table 5-47 :

RELATION OF 'COOL+DRY' ROOMS/SPACES WITH VERTICAL POSITIONS

OCCURRENCES IN %	RELATIVE POSITION	VERTICAL POSITION
40%	HIGHEST	LOW
20%	2ND HIGHEST	HIGH
15%	3RD HIGHEST	TOP
13%	LOWEST	MID

5.6 INSTRUMENTAL FINDINGS AND USERS RESPONSES.

Theoretically, a cooler and drier room is comfortable in hot seasons. From the available data regarding temperature and Humidity, it is possible to find out such 'theoretically comfortable' rooms. During survey the users were asked about their own feeling of temperature and Humidity in various rooms and spaces of their units Also the enumerators documented their own feeling in the living rooms. It is evident that beyond temperature and humidity air movement plays significant role in human comfort, and this movement or agitation is available either by air flow or electric fans . It may be interesting to have a look a comparison between 'comfortable rooms by instrumental findings' and 'comfortable rooms preferred by the users'.

The 'comfortable rooms as per instrumental measurement' and those by users' responses have been presented in Table No. 5-48 below. Also there is a column indicating 'yes' or 'no' revealing whether the users' preferences coincided with that by the instrument.

Table 5-48 :

COMPARISON BETWEEN ROOMS FAVORED BY INSTRUMENT AND BY THE USERS

SL. NO.	LIVING UNIT	ROOM OR SPACE	FINDINGS BY INSTRUMENTAL MEASUREMENT	FINDINGS BY USERS' COMMENTS	WHETHER COINCIDED
01.	A07SW	Child Bed	COOL + DRY	COOL	Yes
02.	A04SE	Child Bed	COOL + DRY	COOL	Yes
03.	B04N	Master Bed	COOL + DRY	COOL	Yes
04.	C16NE	Child Bed	COOL + DRY	COOL	Yes
05.	C06NE	Master Bed	COOL + DRY	COOL	Yes
06.	C06SE	Master Bed	COOL + DRY	COOL	Yes
07.	E02E	Master Bed	COOL + DRY	COOL	Yes
08.	F07N	Master Bed	COOL + DRY	COOL	Yes
09.	G02NW	Living Rm.	COOL + DRY	COOL	Yes

5.6.1 SUMMARY OF COMPARISON OF 'FAVORABLE ROOMS' :

Data's regarding Temperature and Humidity were obtained in cases of 129 rooms/spaces in 27 living units. Since the users gave selection of rooms as 'the best' in their living unit the number of such cases were to be 27 By comparing the comments of the users with the measured result it may be seen that, out of 27 cases users preferences, there were coincidence in 9 cases. The case of coincidence expressed in per cent (%) of total cases have been presented in Table 5-49

Table 5-49 :

COINCIDENCE BETWEEN USERS' PREFERENCE AND INSTRUMENTAL MEASUREMENTS

TOTAL NO. OF CASES FOR COMPARISON	NUMBER OF CASES COINCIDED	PERCENT OF CASES COINCIDED
27	09	33%

5.6.2 CARDINAL LOCATIONS OF 'FAVORABLE' ROOMS BY INSTRUMENTAL MEASUREMENT AND THOSE BY USER'S CHOICE :

It has been found that the preferences given by the users did not in all cases coincide with that obtained by instrumental measurement. Table 5-50 shows such rooms preferred by either of the ways, along with their cardinal locations.

Table 5-50 :

CARDINAL LOCATIONS OF ROOMS FAVORED BY INSTRUMENT AND BY USER'S CHOICE

LIVING UNIT	ROOM OR SPACE	PREFERENCE-1	PREFERENCE-2	CARDINAL LOCATION
A07SW	Child Bed	BY INSTRUMENT	BY USERS	South West
A05SW	Master Bed	——	BY USERS	South
A04SW	Master Bed	——	BY USERS	South
A04SE	Child Bed	BY INSTRUMENT	BY USERS	South East
A04NE	Child Bed	——	BY USERS	North East
A04NW	Master Bed	——	BY USERS	North
B09N	Master Bed	——	BY USERS	North West
	Guest Bed	BY INSTRUMENT	——	North East
B07N	Master Bed	——	BY USERS	North East
	Guest Bed	BY INSTRUMENT	——	North East
	Dining	BY INSTRUMENT	——	Central
B04N	Master Bed	BY INSTRUMENT	BY USERS	North West
C16NE	Child Bed	BY INSTRUMENT	BY USERS	South East
C16SE	Child Bed	——	BY USERS	North East
	Guest Bed	BY INSTRUMENT	——	South
C06NE	Master Bed	BY INSTRUMENT	BY USERS	North East
C06SE	Master Bed	BY INSTRUMENT	BY USERS	South East
	Child Bed	BY INSTRUMENT	——	North East
C04NE	Child Bed	——	BY USERS	South East
C04SE	Child Bed	——	BY USERS	North East
	Guest Bed	BY INSTRUMENT	——	North
D07S	Master Bed	——	BY USERS	South East
	Child Bed	BY INSTRUMENT	——	East
D05S	Child Bed	——	BY USERS	East
D04S	Master Bed	——	BY USERS	South East
	Dining	BY INSTRUMENT	——	Central
E08E	Guest Bed	——	BY USERS	South East
E06E	Living Rm.	——	BY USERS	South
	Master Bed	BY INSTRUMENT	——	North East
E02E	Master Bed	BY INSTRUMENT	BY USERS	North East
F07N	Master Bed	BY INSTRUMENT	BY USERS	North East
F06N	Living Rm.	——	BY USERS	East
	Master Bed	BY INSTRUMENT	——	North East
F04N	Master Bed	——	BY USERS	North East
G14NW	Guest Bed	——	BY USERS	North
G05NW	Guest Bed	——	BY USERS	North
G02NW	Living Rm.	BY INSTRUMENT	BY USERS	West
	Dining	BY INSTRUMENT	——	Central

On the basis of Table 5-50 above the number and percent of 'Preferable category rooms' in various Cardinal locations have been calculated and presented in Table 5-51 below

Table 5-51 :

PERCENT OF TOTAL AND NUMBER OF PREFERABLE CATEGORY ROOMS IN VARIOUS CARDINAL LOCATIONS

	C A R D I N A L L O C A T I O N									
						NORTH	NORTH	SOUTH	SOUTH	
	EAST	WEST	NORTH	SOUTH	EAST	WEST	EAST	WEST	CENTRAL	TOTAL
	%(No)	%(No)	%(No)	%(No)	%(No)	%(No)	%(No)	%(No)	%(No)	%(No)
Rooms found favorable by Instrumental measurement (From Table 5-50)	5(1)	6(1)	5(1)	6(1)	40(8)	5(1)	15(3)	5(1)	15(3)	100%(20)
Rooms preferred By the users (From Table 5-50)	7(2)	4(1)	11(3)	11(3)	30(8)	7(2)	26(7)	4(1)	0(0)	100%(27)

5.6.3. RELATING 'PREFERABLE ROOMS' WITH THEIR CARDINAL LOCATIONS:

Some of the important revelations regarding relation of 'preferable rooms' with their physical characteristics and the characteristics of users' preferences are the following:

(a)..The instrumental measurement indicated **15%** climatic suitability for **CENTRAL** location, where as the users expressed **00%** preference for this location.

(b) The instrumental measurement indicated **North East** as the most preferable cardinal location, the users also preferred **North East** as the most preferable.

(c) By instrumental measurement the least preferable cardinal locations are : : West, South West, North, East, South, North West,. The same by users' preference are: West, South West and Central.

5.7 INTERNAL AND EXTERNAL CLIMATES :

While taking measurement of temperature and Humidity in the apartment buildings external temperature and humidity near the ground were also measured. Such measurements were taken at the ground level or on the first floor level where ground floor was not accessible. External temperature and humidity in each of the living unit were taken either in the adjacent veranda or by holding the instrument outside the window in the accessible directions. Such verandas or external windows were available on limited cardinal directions only.

5.7.1. INTERNAL AND EXTERNAL TEMPERATURE VARIATION :

Information like date and time of Survey work, Temperature near the ground, Time of Surveying the living units, External Temperature immediately outside the living units, internal temperature nearest to this spot etc. have been presented in the Chapter on Investigation. Some of these information, like Date and time of survey, Maximum and minimum temperature of Dhaka city on that date, External temperature measured in living units, Cardinal direction(s) in which the measurements were taken, Internal temperature next to the spot of taking external measurements etc. have been presented in Table 5-52 below. The readings of temperature have been noted under the major cardinal directions, i.e East, West, North and South and under sub-head "Exter", meaning external and "Inter", indicating measurement taken inside and nearest to the external spot.

Table 5-52 :

EXTERNAL AND INTERNAL TEMPERATURE

Sl. No.	Date Bldg. Living Unit	Temp. from Met Office Max.	Min.	Temp. at Ground	Survey Time	TEMP. IN AND OUT OF ROOMS ON DIRECTIONS: EAST Exter.	EAST Inter.	WEST Exter.	WEST Inter.	NORTH Exter.	NORTH Inter.	SOUTH Exter.	SOUTH Inter.
A : WAHID BHABAN													
Date 20.06.2000 : 31.7–25.0 · 32.1 C : 11:20													
01.	A07SW				11:50	—	—	—	—	—	—	30.8	30.6
02.	A05SW				11:37	—	—	—	—	—	—	30.7	30.7
03.	A04SW				11:20	—	—	—	—	—	—	30.4	29.9
04.	A04SE				10:55	—	—	—	—	—	—	30.5	30.6
05.	A04NE				10:23	—	—	—	—	30.1	30.4	—	—
06.	A04NW				10:17	—	—	—	—	30.5	30 7	—	—
B : EHL BLDG-2													
Date · 23 06.2000 : 31.8–25 5 :32.1 C :12:00													
07.	B9N				12:50	—	—	—	—	31.7	31 7	—	—
08	B7N				12:05	—	—	—	—	32 8	33.0	—	—
09	B4N				11:35	—	—	—	—	32 7	32.8	—	—

Table 5-52 (Contd.):

EXTERNAL AND INTERNAL TEMPERATURE

Sl. No.	Data Bldg. Living Unit	Temp. from Met Office Max. Min.	Temp. at Ground	Survey Time	TEMP. IN AND OUT OF ROOMS ON DIRECTIONS EAST Exter.	EAST Inter.	WEST Exter.	WEST Inter.	NORTH Exter.	NORTH Inter.	SOUTH Exter.	SOUTH Inter.
C : EHL BLDG.-1												
	Date :21.06.2000:	30.8–23 8 .	30.0 C :	2:40								
10.	C16NE			2 . 15	—	—	—	—	31.6	31.9	—	---
11.	C16SE			1 : 40	—	—	---	—	—	—	31 7	31,7
12.	C06NE			1 : 25	—	—	—	—	31.7	31.7	—	—
13.	C06SE			12 :50	—	—	—	—	—	—	31.7	31.6
14.	C04NE			12 :22	—	—	—	—	31.1	30.7	—	—
15.	C04SE			12'10	—	—	—	—	—	—	30.7	30 6
D : RAZZAK COMPLEX												
	Date .22.06.2000:	32.4–23.4 :	29.9 C '	10:00								
16.	D07S			11.30	—	—	—	—	—		30 6	31 1
17.	D05S			10:55	—	—	—	—	—		31 7	31 6
18.	D04S			10:15	—	—	—	—	---		33.2	33.2
E : REZA COMPLEX												
	Date 22.06.2000 :	32.4–23.4 :	28.8 C :	2:40								
19	E08E			4:15	—	—	—	—	—		29 2	29.4
20	E06E			3:40	—	—	—	—	—		29.0	29 2
21	E02E			3.05	—	—	—	—	—		29.1	29.3
F : MONIHAR COMPLEX												
	Date '25.06.2000 :	30.6–23.9 :	30.3 C :	12:40								
22.	F07N			1:25	31.2	31.2	31.4	31.4	—		—	—
23.	F06N			1:00	30.3	30.2	30.2	30.5	—		—	—
24	F04N			12:15	30.9	30.4	30.9	30.5	—		—	—
G : SQUARE TOWER												
	Date :29.06.2000'	32 00–26.6 :	29.8 C:	10:40								
25	G14NW			11:00	---	--	31.3	31.2	—		—	---
26	G05NW			10:25	—	—	30.3	30.2	—		—	—
27.	G02NW			10:00	—	—	30.8	30.0	—		—	—

5.7.2. INTERNAL-EXTERNAL TEMPERATURE VARIATION AND CARDINAL DIRECTIONS:

In the above Table 5-52, there are variations between external and internal temperatures in each living unit. These variations have been found out and presented in Table 5-53 below. In all cases, case the external temperature has been considered as 0(Zere) and the internal temperature have been presented as above (by +ve) or below (by –ve) of this value.

Table 5-53 :

VARIATION OF EXTERNAL AND INTERNAL TEMPERATURE

Sl. No.	Date Bldg. Living Unit	EXTERNAL INTERNAL TEMP VARIATIONS IN CARDINAL DIRECTIONS EAST	WEST	NORTH	SOUTH
01.	A07SW	———	———	———	-.2
02.	A05SW	———	———	———	0
03.	A04SW	———	———	———	-.5
04	A04SE	———	———	———	+.1
05.	A04NE	———	———	+.3	———
06.	A04NW	———	———	+.2	———
07.	B9N	———	———	0	———
08.	B7N	———	———	+.2	———
09.	B4N	———	———	+.1	———
10.	C16NE	———	———	+.1	———
11.	C16SE	———	———	———	0
12.	C06NE	———	———	0	———
13.	C06SE	———	———	———	-.1
14.	C04NE	———	———	-.4	———
15.	C04SE	———	———	———	+.1
16.	D07S	———	———	———	+.3
17.	D05S	———	———	———	-.1
18.	D04S	———	———	———	0
19.	E08E	———	———	———	+.2
20.	E06E	———	———	———	+.2
21.	E02E	———	———	———	+.2
22.	F07N	0	0	———	———
23.	F06N	-1	+.3	———	———
24.	F04N	-5	+.4	———	———
25.	G14NW	———	-.1	———	———
26.	G05NW	———	-.1	———	———
27.	G02NW	———	-.8	———	———

As many as 30 readings of external temperature were taken in 27 living units The number of readings taken in various cardinal directions have been shown below :

CARDINAL DIRECTION	NUMBER OF EXTERNAL READINGS TAKEN
01. East	3
02. West	6
03. North	8
04. South	13
Total	30

In Table 5-54 below the temperature variation in various cardinal directions have been presented in descending order and the highest variations haves been shown in bold letters.

Table 5-54 :

NATURE AND EXTENT OF VARIATION OF INTERNAL AND EXTERNAL TEMPERATURE IN FOUR CARDINAL DIRECTIONS.

CARDINAL DIRECTION	NO. OF SPOTS	SPOTS OF MEASUREMENT 1	2	3	4	5	6	7	8	9	10	11	12	13
EAST .	3	0	-.1	-.5										
WEST .	6	+.4	+.3	0	- 1	- 1	-.8							
NORTH :	8	+.3	+ 2	+.2	+.1	+.1	0	0	-.4					
SOUTH:	13	+.3	+ 2	+ 2	+ 2	+.1	+.1	0	0	0	-.1	- 1	- 2	-.5

From Table 5-54 it may be seen that internal external temperature variation were in the range of + 4 to - .8 deg. C. Temperature inside rooms usually increases due to heat by such heat-producing agents es electrical and electronic gadgets, human body, radiation and convection from the walls and roof, cooking activities etc. However, the present study did not always find lower temperature outside. The cases of lower external temperature could have been caused due to in-coming cooler air In the Table 5-53 above it may be seen that out of 30 cases of internal-external temperature variations, there are 13 cases of increase, 10 cases of decrease and 7 cases with no change. In order to investigate if there exists any relation between external-internal temperature variation with cardinal direction, the findings from the above Table have been presented in Table 5-55 below. In this Table the cases of Increase, Decrease or No variation have been presented as percent of total number of cases. However, in expressing variation in each cardinal locations, those have been presented as percent of total cases in each category of variation.

Table 5-55 :

NATURE OF EXTERNAL-INTERNAL TEMPERATURE VARIATION IN FOUR CARDINAL DIRECTIONS

NATURE AND % OF VARIATION	CASES OF VARIATION		CARDINAL DIRECTION: EAST		WEST		NORTH		SOUTH	
	NO	(%)	NO	(%)	NO	(%)	NO	(%)	NO	(%)
Increase (43%)	13	(100)	00	-----	01	(8%)	05	(42%)	06	(50%)
Decrease (33%)	10	(100)	02	(20%)	04	(40%)	01	(10%)	04	(40%)
No Change(23%)	07	(100)	01	(14%)	01	(14%)	02	(29%)	03	(43%)
Total spots	30									

5.7.3 RELATING INTERNAL-EXTERNAL TEMPERATURE VARIATION WITH CARDINAL DIRECTION

Some notable points regarding variations of internal and external temperature in various cardinal locations, as found in Table 5-55 and 5-56 have been presented hereunder :

(a). In comparison with the external Temperature, the **Internal temperatures** were found to be **higher** in **43%** cases, **lower** in **33%** cases and **consistent** in **7%** cases.

(b). The **range of variation** of internal-external temperatures was between **+ 0.4** to **- 0.8 deg.C**.

(c) **Maximum cases of increase of** internal temperature happened in cardinal direction **South** (50%) , followed by North (42%) and West (8%).

(d) **Maximum cases of decrease of** internal temperature happened in cardinal direction **West** (40%) and **South** (40%), followed by East(20%) and North(10%)

(e) **Maximum cases of no change in** internal-external temperature happened in **South** (43%), followed by North(29%), East(14%) and West (14%).

(f). The **maximum increase of** internal temperature was **+.4 deg. C** in West cardinal direction

(g). The **maximum decrease** of internal temperature was **-.8 deg. C** in West cardinal direction.

5.7.4. INTERNAL-EXTERNAL TEMPERATURE VARIATION AND VERTICAL POSITION :

In order to find out if there exists any relationship between the external-internal temperature and vertical position the information presented in Table 5-52 have been analyzed and presented in Table 5-56 below.

Table 5-56 :

NATURE AND EXTENT OF VARIATION OF INTERNAL AND EXTERNAL TEMPERATURE IN FOUR VERTICAL CATEGORIES

VERTICAL CATEGORY	NO. OF SPOTS	SPOTS OF MEASUREMENT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TOP :	10	+.3	+.2	+.2	+ 1	0	0	0	0	-.1	-.2						
HIGH :	2	+.3	-.1														
LOW .	2	+.2	-.8														
MID :	16	+.4	+ 3	+.2	+.2	+.1	+.1	0	0	0	- 1	-.1	-.1	-.1	-.4	-.5	-.5
Total spots : 30																	

In order to find out if there exists any relation between external-internal temperature variation and vertical categories, the variations of external-internal temperature have been shown under four vertical position categories in Table 5-57 below.

Table 5-57 :

EXTERNAL-INTERNAL TEMPERATURE VARIATION IN FOUR VERTICAL CATEGORIES

NATURE AND % OF VARIATION	CASES OF VARIATION		VERTICAL CATEGORIES							
			TOP		HIGH		MID		LOW	
	NO	(%)	NO	(%)	NO	(%)	NO	(%)	NO	(%)
Increase (43%)	13	(100)	3	(23%)	1	(8%)	8	(62%)	1	(8%)
Decrease (33%)	10	(100)	2	(20%)	1	(10%)	6	(60%)	1	(10%)
No Change(23%)	07	(100)	4	(57%)	0	——	3	(42%)	0	——

5.7.5 RELATING INTERNAL-EXTERNAL TEMPERATURE VARIATION WITH VERTICAL POSITIONS :

Some notable points regarding variations of internal and external temperature in various vertical categories as found in Table 5-56 have been presented hereunder :

(a) Maximum **cases of increase** of internal temperature happened in Vertical category **Mid** (62%) , followed by Top (23%) category.

(b) Maximum **cases of decrease** of internal temperature happened in **Vertical** category **Mid** (60%), followed by Top (20%) category.

(c) Maximum cases of **no change** in internal-external temperature happened in **Top** (57%), followed by Mid (42%) category.

(d). Maximum **variation** of internal temperature higher than the external was **.4 deg. C** in the **Mid** vertical category.

(e). Maximum **variation** of internal temperature lower than the external temperature was **.8 deg. C** in the **Low** vertical category.

5.7.6. COMPARISON OF EXTERNAL TEMPERATURES BY METEOROLOGICAL DEPARTMENT AND THAT BY MEASUREMENT :

The measurement of Temperature near the building at the time of survey indicated the temperature of the micro-climate at that site and at that time. In may be interesting to know how far the temperature of the micro-climates near 7 buildings in 5 different sites vary from the temperature given by the meteorological department for that day and time. The Meteorological Department given maximum and minimum temperature of Dhaka on a 24 hour basis By using Evan's[1] monograph it is possible to substitute temperature given by the meteorological department for that day and time of survey and to compare the same with the measured data on the site.

Table 5.58 below shows the site, building surveyed, date and time of survey, Maximum and Minimum temperature given by the Meteorological Department for that day, substituted Meteorological department's temperature for the time and day of survey, temperature measured near the building on the date and time of survey and the variation of the substituted temperature over or below the measured temperature.

Table 5-58 :

COMPARISON OF EXTERNAL TEMPERATURES BY METEOROLOGICAL DEPARTMENT AND THAT BY MEASUREMENT

SITE / APARTMENT BUILDING	DATE OF SURVEY	TIME OF SURVEY	TEMPERATURE AS PER MET. DEPARTMENT MAX. MIN.	DERIVED TEMPERATURE	TEMP. MEASURED AT SITE	VARIATION
1 Old Dhaka / A Wahid. Bhaban	20.6.2000	11:20	31.7 - 25.0	30.36	32.1	1.74
2. Shantinagar / B : EHL Bldg-2	23.6.2000	12.00	31.8 - 25.5	30.96	30.0	0.96
3. Shantinagar / C . EHL Bldg -1	21.6.2000	2:40	30.8 - 23 8	30.5	32.1	1.6
4. Elephant Road / D . Razzak Complex	22.6 2000	10.00	32.4 - 23.4	28.7	29.9	1.2
5 Elephant road / E Reza Complex	22.6.2000	2:40	32.4 - 23.4	32.1	28.8	3.3
6. Farmgate / F : Monihar Complex	25 6.2000	12:40	30.6 - 23 9	30.3	30.3	00
7 Dhanmondi / G . Square Tower	29 6.2000	10:40	32.1 - 25.5	30.2	29.8	0.4

5.7.7. SUMMARY OF COMPARISON OF EXTERNAL TEMPERATURES BY METEOROLOGICAL DEPARTMENT AND BY MEASUREMENT :

Some notable points regarding variations of substituted Met. Office temperature data and that obtained in the site as revealed in Table 5-45 above have been presented hereunder

(a). The **Maximum** upper variation of the site temperature from the substituted one was found **3.3 deg. C.** at site **Elephant Road.**

(b) The **Maximum** lower variation of the site temperature from the substituted one was found **1.74 deg. C.** at site **Old Dhaka.**

(c). The **Minimum** variation between the two was found to be **00 (No change)** at site **Farm gate.**

(d) As per variation of temperature of the micro-climates, the above 7 building sites arranged in descending order are : (1) Elephant road – E, (2) Shantinagar – B, (3) Dhanmondi –G, (4) Farmgate – F, (5) Elephant Road - D (6) Shantinagar - C (7) Old Dhaka – A.

(e). The existence of **different variations at** the **same locality** (for example, both + 3 3 and -1.2 at Elephant Road, both +0.96 and – 1.6 at Shantinagar) indicates the existence of further micro-climatic variations in the same locality.

5.7.8 ANALYSIS OF INFORMATION AND SUGGESTIONS GIVEN BY THE USERS :

During investigation the users, specially the owners of high-rise apartments gave some information and suggestions regarding their problems and aspirations in high-rise apartments. The owners, in general opined that they could not have idea about the real situations inside the apartment before they came to live here. As regards to internal climate they told, they expected much better situation. From colorful plans, descent external views and drawings they could not have idea of the current situation and the colorful presentations of three-dimensional computer presentations were mis-leading. Their comments and opinions having direct or indirect relevance with internal climatic comfort have been discussed below.

(i) **PROBLEMS OF HAVING UNCOMFORTABLE CLIMATIC CONDITION INSIDE** : According to some users, the nice looking elevations, perspective views and large windows that once allured them to purchase such apartments, were later found useless, because the elevations were no more viewable due to presence of other buildings in the immediate surrounding, and the large windows could not be kept open for the reason of privacy After they started living, what mattered most were the internal climate, lighting and acoustical situations etc., about which they failed to form any prior idea.

(II) **PROBLEMS IN INTERNAL CLIMATES DUE TO CHANGES IN THE SURROUNDING AREAS** : According to some users, when they first came to live in the apartment the large windows on south ensured ventilation and the windowless wall on the west saved them from solar radiation and heat. But the situation was abruptly changed after apartments were constructed on these two sides. Little air came from the south and in the changed situation wind tended to enter from the west, but there was no window on this side.

(III) **PROBLEMS OF WARM, HUMID AND SUFFOCATING CONDITION IN ROOMS AT CENTRAL LOCATION** : According to some users, they find some of the internal rooms especially those in the central and western locations suffocating. The situation worsens further as more and more buildings sprawl up in the surrounding areas.

(iv) **PROBLEMS OF RADIATION OF HEAT FROM THE ROOF** : The problem of radiation of heat from the roof were reported by the users living on the top floors of high-rise apartments No user, however complained of radiation from walls. It may be mentioned here that all the apartments under this study had 10 Inch thick exterior walls.

(V) **PROBLEMS OF KEEPING THE WINDOWS OPEN** : According to some users, they cannot keep windows at certain locations open because of privacy and due to close location of adjacent buildings. The closing of windows solve visual and acoustic problems, but creates ventilation hazard. Use of curtains maintain ventilation to some extent, but cannot solve acoustic problems, especially due to high-pitch music coming from the near-by building.

(vi) **NATURAL LIGHT IN ROOMS** : In the Questionnaire the users were asked, whether there were adequate natural light at the center of the room and near the external window The findings in all the rooms and spaces of the living units under investigation are presented in Table 59 below.

Table 5-59 :

NATURAL LIGHTING AT CENTER AND NEAR WINDOW OF ROOM

SL. NO.	LIVING UNIT CODE	LIVING CENTER	ROOM WINDOW	MASTER CENTER	BED WINDOW	CHILD'S CENTER	BED WINDOW	GUEST'S CENTER	BED WINDOW	DINING CENTER	RM/SP. WINDOW
01.	A 7SW	NO.	NO	FAIR	GOOD	GOOD	GOOD	—	—	NO	NO.
02	A 5SW	POOR	POOR.	GOOD	GOOD.	GOOD	GOOD.	—	—	POOR	POOR
03	A 4SW	NO	NO.	FAIR	GOOD	GOOD	GOOD	—	—	NO	NO
04	A 4SE	POOR	NO.	POOR	GOOD.	GOOD	GOOD	—	—	POOR	NO.
05.	A 4NE	NO.	NO.	FAIR	GOOD.	GOOD	GOOD.	—	—	NO.	NO.
06.	A 4NW	POOR	POOR.	FAIR	GOOD.	GOOD	GOOD.	—	—	POOR	POOR
07.	B 9N.	GOOD	GOOD.	POOR	GOOD.	GOOD	GOOD.	GOOD	GOOD.	POOR	FAIR.
08.	B 7N.	GOOD	GOOD.	GOOD	GOOD.	FAIR	FAIR.	GOOD	GOOD.	POOR	NO..
09.	B 4N.	FAIR	GOOD.	GOOD	GOOD	FAIR	GOOD	GOOD	GOOD	POOR	NO..
10.	C16NE	POOR	FAIR	GOOD	GOOD	GOOD	GOOD.	GOOD	GOOD.	POOR	NO..
11.	C16SE	FAIR	GOOD	GOOD	GOOD.	GOOD	GOOD.	FAIR	GOOD.	POOR	NO.
12.	C6NE	POOR	GOOD.	POOR	FAIR.	GOOD	GOOD	FAIR	GOOD.	POOR	POOR.
13.	C6SE	FAIR	GOOD.	GOOO	GOOD.	GOOD	GOOD	FAIR	GOOD.	POOR	NO.
14.	C4NE	POOR	GOOD.	GOOD	GOOD	POOR	GOOD.	POOR	GOOD	POOR	POOR.
15.	C4SE	POOR	GOOD	FAIR	GOOD.	FAIR	GOOD.	FAIR	GOOD.	POOR	POOR
16.	D 7S	GOOD	GOOD.	GOOD	GOOD.	GOOD	GOOD.	GOOD	GOOD.	FAIR	GOOD
17.	D 5S	FAIR	GOOD	GOOD	GOOD.	GOOD	GOOD	GOOD	GOOD.	POOR	POOR
18	D 4S	FAIR	GOOD.	GOOD	GOOD.	GOOD	FAIR.	GOOD	GOOD.	POOR	NO.
19.	E 8E	FAIR	GOOD.	GOOD	GOOD	GOOD	GOOO.	GOOD	GOOD	POOR	NO..
20.	E 6E	FAIR	GOOD.	GOOD	GOOD.	GOOD	GOOD	GOOD	GOOD	POOR	NO.
21.	E 2E	FAIR	GOOD.	GOOD	GOOD.	FAIR	GOOD.	GOOD	GOOD.	POOR	NO..
22.	F7N	FAIR	GOOD.	GOOD	GOOD	FAIR	GOOD.	POOR	FAIR.	GOOD	GOOD
23.	F6N	FAIR	FAIR	POOR	FAIR.	GOOD	GOOD.	GOOD	GOOD	POOR	NO.
24.	F4N	FAIR	GOOD	GOOD	GOOD.	GOOD	GOOD.	GOOD	GOOD	POOR	NO.
25.	G14NW	GOOD	GOOD.	FAIR	GOOD.	GOOD	GOOD.	FAIR	GOOD.	POOR	NO.
26	G 5NW	POOR	GOOD.	FAIR	FAIR.	POOR	FAIR.	POOR	FAIR.	POOR	POOR
27.	G 2NW	FAIR	GOOD.	POOR	FAIR	FAIR	GOOD.	POOR	FAIR.	POOR	POOR

Coincidentally all the Dining rooms in this study are located at the central location, with no direct external opening. Also the living rooms in apartment building A (Wahiduzzaman Bhaban) are at the central location. All other rooms, however, have got external windows. In such a situation analysis have been drawn to find out the lighting situation in the central rooms and those at the periphery. This has been shown in Table-60 below.

Table 5-.60 :

SUMMARY OF NATURAL LIGHTING AT CENTRAL AND PERIPHERAL ROOMS

LOCATION OF ROOMS	NUMBER ROOMS	NATURAL LIGHTING CONDITION AT THE CENTER OF ROOM				NATURAL LIGHTING CONDITION NEAR EXTERNAL WINDOW			
		GOOD	FAIR	POOR	NO	GOOD	FAIR	POOR	NO
TOTAL	129	51	31	41	6	86	13	10	20
PERIPHERAL ROOMS	96	50	30	16	0	84	12	00	00
CENTRAL ROOMS	33	01	01	25	6	02	01	10	20

Regarding natural lighting conditions at the center, the following summary can be drawn from the above Table.

LIGHTING AT THE CENTER OF THE ROOM :

GOOD lighting condition was found in **79%** in case **of all** rooms
52% in case **of peripheral** rooms
and **03%** in case **of centrally located** rooms.

NO or Zero lighting condition was found **in 18%** in **case** of **all** rooms
None in case of **peripheral** rooms
and **61%** in case of **central** rooms

COMPARISON OF LIGHTING CONDITION NEAR EXTERNAL WINDOW AND CENTER.

While **67%** of the rooms indicated GOOD light **near the window**
only **40%** indicated the same at the **center** of the room.

5.8 CONCLUSION

The data's and information collected and presented in Chapter IV on Investigation have been analyzed and studied in this chapter to have more understanding of how climate acts in residential buildings The investigation and studies were concerned with (a) Living units in a number of locations in Dhaka city, (b) Rooms and spaces of a number of living units. The aspects of investigation concerned temperature and humidity in those spots. The analysis was aimed at finding out how the two elements of climate, viz. Temperature and Humidity varies from one locality to another and one rooms to another Another objective of study was to find out if there exists any relation of the physical characteristics, i.e location inside the city, cardinal location of the living unit, room or space under study, its vertical position etc And the final objective was to find out whether or how far the climatic comfort, as experienced by the users coincide with that of instrumental measurements. A number of important phenomenon have been found from the analysis and have been presented mostly in tabular form for easy understanding However, before those may be taken accepted and useful for the built-form designers, there is need for re-checking those especially on the context in which those were achieved. This work shall be done in the next chapter on Conclusion, such that the results of analysis and findings may have a strong and scientific base.

Chapter 6

CONCLUSION

Chapter 6
CONCLUSION

6.0 INTRODUCTION :

The aim of the project, "A STUDY OF FACTORS FOR THERMAL COMFORT IN RESIDENTIAL HIGH-RISE IN DHAKA CITY", as mentioned in the proposal was, 'to find out the factors responsible for comfort and discomfort in high-rise residential buildings in various locations of Dhaka city.' In addition, it was expected that the study would 'reveal if there exists any relationship between the inhabitants' feelings of thermal comfort and the location/ orientation of the rooms and their geometries, architectural design, etc.'.

The current chapter, being concluding one, shall discuss the important findings of this investigation related with and relevant to the formulation of guidelines and recommendations regarding the improvement of internal climates of high-rise apartments through architectural design. In addition recommendations will be formulated relating to design of high-rise apartments as well as for further studies to increase understanding of the thermal problems in such buildings

6.1 CONCLUSIVE FINDINGS :

The conclusive findings presented hereunder were obtained as direct result of the investigation as discussed in the chapters 4 and 5 of this work. They may be subdivided into findings obtained by (a) Instrumental measurements and analysis of the findings and (b) Discussion with users and collection of information. These shall be presented independently under headlines:

- 6.1.1 INSTRUMENTAL MEASUREMENTS AND ANALYSIS OF THE FINDINGS
- 6.1.2 DISCUSSION WITH USERS AND COLLECTION OF INFORMATION.
- 6.2 RECOMMENDATIONS
- 6.3 CONCLUSION

6.1.1 INSTRUMENTAL MEASUREMENTS AND ANALYSIS OF THE FINDINGS :

The various findings obtained by analyzing the results of measurements in the buildings under investigations are presented under the following heads :

i. Trend of Inter-space Temperature Variation in living Units
ii. Trend of Inter-space Humidity Variation in living Units
iii. Trend of Temperature variations of rooms/spaces
iv. Trend of Humidity variations of rooms/spaces
v. Trend of combined temperature-humidity variation in cardinal and vertical locations ;
vi Variations of External-Internal Climates.

A brief discussion of the above findings along with causes are presented hereunder :

i. **TREND OF INTER-SPACE TEMPERATURE VARIATION IN LIVING UNITS:** The temperature measured in various rooms of the living units indicated some variations. The difference between the maximum and minimum readings of Temperature in a living unit have been termed as Inter-space Temperature. The inter-space temperature variations as indicated in twenty-seven living units are summarized in Table 6.01:

Table 6-01

INTER-SPACE TEMPERATURE VARIATIONS

SL. NO.	LIVING UNIT	TEMPERATURE VARIATION (Deg.C)	SL. NO.	LIVING UNIT	TEMPERATURE VARIATION(Deg.C)	SL. NO.	LIVING UNIT	TEMPERATURE VARIATION (C)
01.	A07SW	0.3	10.	C16NE	0.8	19.	E8E	0.1
02.	A5SW	0.1	11.	C16SE	0.5	20.	E6E	0.2
03	A4SW	0.1	12.	C6NE	0.2	21.	E2E	0.2
04.	A4SE	0.3	13.	C6SE	0.5	22	F7N	0.4
05.	A4NE	0.1	14	C4NE	0.4	23.	F6N	0.2
06.	A4NW	0.1	15	C4SE	0.1	24.	F4N	0.3
07.	B9N	0.2	16.	D7S	0.3	25.	G14NW	0.5
08.	B7N	0.4	17.	D5S	0.2	26.	G5NW	0.2
09.	B4N	0.4	18.	D4S	0.2	27.	G2NW	0.4

In this study project the topmost floor of a building has been identified and coded as TOP (abbreviated as T), floor immediately below it as HIGH (or H), the lower two floors as LOW (or L) and others as MID(M). The Variation Indicators may be expressed by numerical numbers 1 to 8, for variation magnitude of 0.1 to 0.8 respectively. The investigated living units arranged in descending order of Inter-space variation of temperature are shown in Table 6-02.

Table 6-02

INTER-SPACE TEMPERATURE VARIATION INDICATORS	INDICATORS FOR INTER-SPACE TEMPERATURE VARIATION: LIVING UNITS								
6	C16NE (T)								
5	C16SE (T)	C6SE (M)	G14NW (T)	B7N (M)					
4	B4N (M)	C4NE (M)	F7N (T)	G2NW(L)	A07SW(T)				
3	A4SE (M)	D7S (T)	F4N (M)						
2	B9N (T)	C6NE (M)	D5S (M)	D4S (M)	E6E (M)	E2E (L)	F6N (H)	G5NW (M)	
1	A5SW (M)	A4SW (M)	A4NE (M)	A4NW(M)	C4SE (M)	E8E (T)			

In order to find out if there exists any relationship between Inter-space temperature variation and the cardinal and verticel locations of the apartments the above table may be re-arranged showing the Cardinal and Vertical locations of the units under their respective Inter-space temperature variation indicators, and this has been shown in Table 6-03 below.

Table 6-03

RELATION BETWEEN INTER-SPACE TEMPERATURE VARIATION AND CARDINAL AND VERTICAL LOCATIONS OF LIVING UNITS

	INDICATOR 6	INDICATOR 5	INDICATOR 4	INDICATOR 3	INDICATOR 2	INDICATOR 1
CARDINAL LOCATION	NE	SE, SE NW, N	N, NE, N, NW, SW	SE, S, N	N, NE, S, E, E, N, NW, S	SW, SW, NW, SE, E, NE
VERTICAL LOCATION	Top	Top, Mid Top, Mid	Mid, Mid Top, Low Top	Mid, Top, Mid	Top, Mid, Mid, Mid, Low, High Mid, Mid	Mid, Mid Mid, Mid Top, Mid

In case of CARDINAL LOCATION, the above Table shows that while NE Cardinal location showed the highest value (Temperature variation indicator) in one case, the same showed the lowest in another. The other cardinal locations also showed varying indicators in different cases. This indicates that, according to this study there exists no relation between inter-space Temperature variations and cardinal locations of units.

In the same way, in case of VERTICAL LOCATION the Table shows that while Top Vertical location showed the highest value in one case, the same showed also the lowest in another. Similar to cardinal locations, the other Vertical locations also showed varying indicators in different cases. This indicates that, there exists no relation between Inter-space Temperature variations and Vertical locations of units.

CONCLUSIVE STATEMENT : From the above findings of INTER-SPACE TEMPERATURE VARIATION IN LIVING UNITS it may be opined that,

Inter-space Temperature variations are independent of the Cardinal and Vertical locations of the living units.

ii. **TREND OF INTER-SPACE HUMIDITY VARIATION IN LIVING UNITS:** The humidity measured in various rooms of the living units indicated variations. The difference between the maximum and minimum readings of Humidity in a living unit have been termed as Inter-space Humidity variations. Humidity varied in the range of 0 to 3%, hence the indicators of Humidity variations may be assumed to be 0,1,2 and 3. In Table 6-04 below the 27 living units have been shown with their respective cardinal and vertical locations and Inter-space Humidity Variation indicators

Table 6-04

INTER-SPACE HUMIDITY VARIATION INDICATORS	INDICATOR OF INTER-SPACE HUMIDITY VARIATION — L I V I N G U N I T S							
3	A5SW(M),	F04N(M),	E02E(L),	G02NW(L)				
2	B4N(M),	C4NE(M),	C4SE(M),	D07S(T),	E08E(L),	F06N(H),	G14NW(T),	G05NW(M)
1	A7SW(T), C8SE(M),	A4SW(M), D05S(M),	A4SE(M), D04S(M),	B9N(T), E06E(M),	B7N(M), F07N(T)	C16NE(T),	C16SE(T),	C6NE(M),
0	A4NE(M),	A4NW(M).						

In order to find out if there exists any relationship between Inter-space Humidity variation and cardinal and vertical locations of the apartments the above table may be re-arranged showing the Cardinal and Vertical locations of the units under their respective Inter-space temperature variation indicators, and this has been shown in Table 6-05 below

Table 6-05

RELATION BETWEEN INTER-SPACE HUMIDITY VARIATION AND CARDINAL AND VERTICAL LOCATIONS OF LIVING UNITS	INDICATOR 3	INDICATOR 2	INDICATOR 1	INDICATOR 0
CARDINAL LOCATION	SW, N, E NW	N, NE, SE, S, E, N, NW, NW	SW, SW, SE, N, N, NE, SE, NE, SE, S, S, E, N	NE, NW
VERTICAL LOCATION	Mid, Mid, Low Low	Mid, Mid, Mid Top, Low, High, Top , Mid	Top, Mid, Mid, Top, Mid, Top, Top, Mid, Mid Mid, Mid, Mid, Top	Mid, Mid

In case of CARDINAL LOCATION, the above Table shows that while NW Cardinal locations showed the highest value (Humidity variation indicator), the same showed also the lowest one. The other cardinal locations also showed varying indicators in different cases. This indicates that, this study could not establish any relation between Inter-space Humidity variations and cardinal locations of units.

In the same way, in case of VERTICAL LOCATION the Table shows that while 'Mid' Vertical location showed the highest value in two cases, the same showed also the lowest in another two cases. The other Vertical locations also showed varying indicators in different cases. This indicates that, there exists no relation between Inter-space Humidity variations and Vertical locations of living units.

CONCLUSIVE STATEMENT . From the findings of INTER-SPACE HUMIDITY VARIATION IN LIVING UNITS it may be opined that,

> *Inter-space Humidity variations are independent of the Cardinal and Vertical locations of the living units.*

iii. TREND OF TEMPERATURE VARIATIONS OF ROOMS/SPACES :

TEMPERATURE VARIATION AND CARDINAL LOCATION - The rooms at various cardinal locations show difference in temperature and humidity because those are affected differently by the east, west or south sun, entrance and exit of air, transmission of heat through walls or roofs etc Thus, it is a matter of common experience that rooms of an apartment indicate independent climatic characteristics like Hot, Cool, Dry, Wet etc due to varying amount of Temperature and Humidity they get because of their cardinal locations. The Temperature and Humidity that one may measure in the rooms of an apartment are the composite affect of solar radiation, air temperature, air-movement, humidity etc. along with such internal modifiers as internal heat and humidity generation In addition, the internal climate is also affected by external modifier like the distinctively different micro-climates in small pocket areas in Dhaka city The measure of temperature and humidity in the rooms of a living unit is sure to reflect its natural climatic characteristics and the rooms at various cardinal locations are expected to reveal a trend. This project has created a scope to find out whether or to what extent the internal and external modifiers affect the natural trend of climate.

To find out the above fact, the rooms with temperature variation of .05 deg. C to .05 Deg. C above the average value has been shown as HOT and those below as COOL rooms. The cardinal locations of the HOT rooms as found by measurement are presented in descending order of value i e. from Hot to Cool in Table 6-06. In a similar way the cardinal locations of the COOL rooms have also been presented hereunder in descending order of value, i.e from Hot to Cool in the same table.

Table 6-06

CARDINAL LOCATIONS OF ROOMS (FROM HOT TO COOL)
HOT: CENTRAL, WEST, SOUTH-WEST, NORTH, SOUTH-EAST, SOUTH, NORTH-WEST, NORTH-EAST, EAST
COOL : WEST, CENTRAL, SOUTH, NORTH-WEST, NORTH, SOUTH-EAST, SOUTH-WEST, NORTH-EAST, EAST

In the absence of internal and external modifiers the cardinal locations found by the above two considerations should have shown exactly the same trend. In the above Table it is seen that the trend is as expected at the extremities, such that Central and West locations are still the Hottest and North-East and East locations are the Coolest. However, at some locations, the trend is not so predictable. This indicates that the internal and external modifiers have already modified the natural micro-climatic trends of rooms at some cardinal locations. The results, however, show that the natural climatic trend of the rooms with extreme values are still valid to a great extent.

CONCLUSIVE STATEMENT : Due to varying influences and affects of air-movement, exposure to solar radiation etc., it is natural for the rooms at various locations to show varying temperature, and thus to show a natural trend in such changes in various rooms of an apartment The above findings, however, could not show any such trend. This indicates that

The natural micro-climatic trends in terms of TEMPERATURE of rooms at various cardinal locations in apartment buildings in Dhaka city have been considerably changed due to internal modifiers and external micro-climatic affects.

TEMPERATURE VARIATION AND CARDINAL LOCATION - This investigation revealed the extent of relationship between the climatic characteristics of a room with its vertical position The cardinal location of rooms arranged in order of 'HOT to COOL' above and below the Average Temperature has been shown in Table 6-07

Table 6-07

VERTICAL LOCATIONS OF ROOMS (FROM HOT TO COOL)				
HOT :	HIGH,	MID,	TOP,	LOW
COOL :	LOW,	MID,	HIGH,	TOP

The above Table shows that while the trend of temperature variation in vertical location categories in case of HOT range is : HIGH, MID, TOP and LOW, the same in case of COOL range is LOW, MID, HIGH and TOP.

CONCLUSIVE STATEMENT : This above findings indicate non-existence of no relation between Temperature variation and Vertical locations of rooms So, it may be opines that,

Temperature variations in rooms/spaces of a living unit are independent of their Vertical locations.

IV. TREND OF HUMIDITY VARIATIONS OF ROOMS/SPACES :

HUMIDITY VARIATION AND CARDINAL LOCATION - In case of Humidity the rooms below average value have been classed as DRY and those above, as WET. In the above mentioned way the cardinal locations of rooms arranged from DRY to WET have been found as shown in Table 6-08

Table 6-08

CARDINAL LOCATIONS OF ROOMS (FROM DRY TO WET)								
DRY :	NORTH-EAST,	SOUTH & SOUTH-WEST,	WEST,	SOUTH-EAST,	NORTH-WEST,	CENTRAL,	NORTH & EAST	
WET .	NORTH-EAST,	NORTH-WEST, SOUTH,	WEST,	SOUTH-WEST,	SOUTH-EAST,	CENTRAL,	NORTH,	EAST

Similar to Temperature data, in case of Humidity also the natural climatic trend in not found to exist in its entirety

CONCLUSIVE STATEMENT : In Table No. 6.08 the natural trend may be found to exist in extreme cases, viz. North-East location is still seen to be most Dry and Central, East and North locations, most Wet So, it may be opines that,

> *The natural micro-climatic trends in terms of HUMIDITY of rooms at various cardinal locations in apartment buildings in Dhaka city have been considerably changed due to internal modifiers and external micro-climatic affects.*

HUMIDITY VARIATION AND VERTICAL LOCATION :

The readings relating Humidity variation with vertical locations are shown in Table 6 09.

Table 6-09

VERTICAL LOCATIONS OF ROOMS (FROM DRY TO WET)				
DRY :	LOW,	MID,	TOP,	HIGH
WET :	MID,	LOW,	TOP,	HIGH

The above Table shows that while the trend of Humidity variation in vertical location categories in case of HOT range is : LOW, MID, TOP and HIGH, the same in case of COOL range is . MID, LOW, TOP and HIGH Even though the last two values have coincidence, those were not sufficient to prove any definite trend.

CONCLUSIVE STATEMENT . This above findings could not prove the existence of any definite trend between Humidity variation and Vertical locations of rooms So, it may be opines that,

- *Humidity variations in rooms/spaces of a living unit may not have any relationship with their Vertical locations.*

v. TREND OF COMBINED TEMPERATURE-HUMIDITY VARIATION IN CARDINAL AND VERTICAL LOCATIONS :

By instrumental measurements some rooms were found both cool and dry, while others were not. The cardinal and vertical locations of such rooms arranged in descending order of "COOL+DRY" have been shown in the following Table.

Table 6-10

CARDINAL LOCATIONS OF COOL + DRY ROOMS (IN DESCENDING ORDER)
NORTH-EAST, SOUTH-WEST & EAST, SOUTH-EAST, NORTH-WEST, CENTRAL, SOUTH, WEST, NORTH
VERTICAL LOCATIONS OF COOL + DRY ROOMS (IN DESCENDING ORDER)
LOW, HIGH, TOP, MID

Even though there is possibility of North-East location to be cool and Dry, and the North to be Wet, it is less probable that West is WET and South-West is Hot. There is possibility that natural Temperature and Humidity conditions of these rooms were interfered by internal and external modifiers. However, the studies in this aspects are not adequate to give any conclusive statement.

vi. COMPARISON OF THE VARIATIONS OF INTERNAL-EXTERNAL TEMPERATURE.

The climates immediately outside the living unit were measured in the verandah or through the windows in all accessible directions and were compared with those in the nearest location inside the rooms The external readings were considered as 'base' and the variations of internal temperature were classed as Increase, Decrease or No change. The notable points of this comparison in Temperature are the following

(a) Internal temperature showed increase in 43% cases, Decrease in 33% and No change in 23% cases

(b) The extent of variations in four cardinal directions (i e. East, West, North and South) arranged in descending order are as follows :

Table 6 -11

COMPARISON OF EXTERNAL INTERNAL TEMPERATURES					
INCREASE :	South (50%),		North (42%),	West (08%),	East (00%)
DECREASE:	South (40%)	West (40%),	East (20%),	North (10%)	
NO CHANGE :	South(43%),		North(29%),	West (14%),	East (14%)

N.B. External Temperature has been considered as Base. Increase, Decrease or No change indicate readings of temperature inside.

The variation of external and internal Temperature depends upon a number of factors like time of measurement, direction of air movement, position of the sun, location of other buildings etc. In Dhaka city in the summer season air in general enters through the external windows on South, East or West and escapes through East, West and North, unless of course the direction is drastically changed by surrounding obstacles. Therefore there is the tendency to bring close equality between the external and internal values of temperature However, the temperature of air entering inside may either increase due to internal activities or decrease due to modification caused by the built-form The above Table demonstrates that in the tested cases no strong trend can be noticed in the external-internal temperature comparison. External temperature on South was found lower than the internal in 50% cases and in the North in 42% cases The Table further shows that in only 8% of cases was it found that temperatures in West facing rooms were higher than external, but this would be expected, as most of the readings were taken before 2 p.m., when the western rooms start receiving direct solar radiation and hence temperature hikes.

6.1.2 DISCUSSION WITH AND COLLECTION OF INFORMATION FROM THE USERS:

During investigation information were collected from user regarding their perception ('Coolest', 'Airiest', 'Hottest' etc) of rooms, if they have any problems like change of internal climates due to changes in the surrounding areas, any cases of warm, humid and suffocating condition in the rooms at central location, problem due to radiation of heat from wall or roof, problem in keeping the windows open etc.

The comparison between instrumentally favorable rooms and those favored by the users have been presented in 5.6 Chapter 5 (Page 144-146) Also the findings regarding user's responses have been presented in 4.8, Chapter 4 (Page 103-104) and also in 5.7.7 Chapter 5 (Page 155-156). For the purpose of having conclusive statement salient features of these two topics shall be discussed now,

I COMPARISON OF "COOL+DRY ROOMS" BY INSTRUMENTAL MEASUREMENTS WITH 'COMFORTABLE ROOMS' ADJUDGED BY THE USERS - The relatively "COOL+DRY ROOMS" as indicated by the instrument were compared with the "MOST COMFORTABLE OR COOL ROOMS" voted by the users. The notable findings of this comparison are the following :

(a) The Instrumental measurements and users' preferences coincided completely in only 33% cases

(b) Both the instrumental measurement and users' preference indicated North-East as the BEST or most preferable cardinal location.

(c) Both the instrumental measurement and users' preferences indicated West and South-West as the WORST or least preferable cardinal location.

(d) The instrumental measurements indicated "Cool+Dry" rooms at 'Central' cardinal location in 15% cases, where as the users voted for this location in 00% cases.

From the above findings the following conclusive statements may be drawn

CONCLUSIVE STATEMENTS :

(i) It was natural that all the "Cool+Dry" rooms as indicated by the instrument should have been adjudged 'Comfortable' by the users. But the two coincided only in 33% cases, indicating either the peculiarity of subjective variations or attachment of other factors with users' comfort conditions.

(ii) The general coincidence of Instrumental findings and Users' vote regarding BEST and WORST cardinal locations indicate that in spite of the presence of the internal and external modifiers, the micro-climate inside the rooms still continue to show the natural trend in extreme cases.

(iii) The users' zero vote for the Instrument's preferable 'Central' cardinal location indicate that the users attach such psychological factors as good views, natural light and air etc. with climatic comfort indices.

II FINDINGS FROM DISCUSSION WITH THE USERS - The users comments and complains have been discussed in Chapter 5 Page 144-145. Those problems in brief, along with suggestions shall be presented hereunder.

(I) PROBLEMS OF HAVING UNCOMFORTABLE CLIMATIC CONDITION INSIDE : The problem was, from the drawings and animations the owners could not get vivid and adequate picture, including probable internal climatic conditions at the time of purchase.

SUGGESTION : For the purpose of giving the intending purchaser every details of what they were going to have in their apartment, the system of "Mock-flat" is in practice in the developed countries for quite a long time It may be suggested to introduce this system in Bangladesh. Since this system in its exactness may be expensive,

> *It is suggested that each developer may be asked to construct at least one "Full-scale model" of the apartments, such that the purchasers may get a scope to examine the probable situation and have better ideas.*

(II) PROBLEMS IN INTERNAL CLIMATES DUE TO CHANGES IN THE SURROUNDING AREAS : These problems were caused due to construction of new buildings in the surrounding areas

SUGGESTION Whatever might be the then situation around, the immediate surrounding of an apartment building is liable to change with time, specially when there are vacant lands around. The above natured problems arise in case the architect designs a building without consideration of probable future developments in the surrounding areas.

> *It is suggested that the architect should design apartment buildings considering and simulating "optimal developments" in the immediate surrounding.*

(III) PROBLEMS OF WARM, HUMID AND SUFFOCATING CONDITION IN THE ROOMS AT CENTRAL LOCATION : Some users reported to have found the internal rooms especially those in the central and western locations suffocating.

SUGGESTION: The rooms at central location naturally suffers from lack of ventilation due to absence of adequate air in-let and out-let. The situation worsens with sprawling up of more buildings around.

It is suggested that techniques like ventilator, ventilation duct etc. be utilized to expel hot and stale air from rooms at central and odd locations.

(iv) PROBLEMS OF RADIATION OF HEAT FROM THE ROOF : The problem of radiation of heat from the roof were reported by the users living on the top floors only.

SUGGESTION: The radiation from roof can be minimized in a number of ways like (a) Construction of a second roof (example: Teacher Student Complex building of Dhaka University), (b) Use of hollow roof tiles (A project taken by the Departments of Architecture and Mechanical Engineering, BUET proved that hollow roof tile can considerably reduce transmission of heat through roof), (c) Use of shading devise like walls, plantation bed etc. to keep the roof shaded and cool.

It is suggested that the roof of the top floor be rendered heat-resistant by using suitable means.

(V) PROBLEMS OF KEEPING THE WINDOWS OPEN : According to some users, some windows cannot kept because of the close proximity of adjacent buildings make it difficult to maintain privacy.

SUGGESTION: Large clear windows, though having aesthetic appeal might create such problems regarding privacy.

Suggestions may be made to use windows with wide vertical or horizontal louvers, or smaller windows, slit-type windows, which might minimize the problem of views from the adjacent buildings. This may cut off in terms of daylight, in which cese some form of energy-saving supplementary lighting may have to be used. Altemately, rooms which are privacy-sensitive should be located at positions where distance between buildings is at a maximum.

(Vi) PROBLEMS OF LIGHTING INSIDE ROOMS :It has been seen in Chapter 7.7.7 that the rooms located at the central location lacks natural lighting. This study indicated that, while 67% of the rooms indicated GOOD light near the window only 40% indicated same at the center. In fact the dining room arranged in most cases at the central location get only diffused light from other rooms and at times from distant walls. Also it has been seen that rooms at the periphery enjoys better light, as were seen in the findings, at the center of rooms, GOOD lighting condition was found in 79% in case of all rooms, 52% in case of peripheral rooms and 03% in case of centrally located rooms.

SUGGESTION . Natural lighting in all the livable spaces is essential precondition of healthy environment. Even though not used for longer time the dining room is used by all the members of the family and fairly at one time. Also this one of the mostly used room for cross movement. It has been found that some designers have been successful to ensure some amount of natural light and ventilation and the users of such apartments appreciated the design.

> *Suggestions may be made that the designers should endeavor to ensure natural light and ventilation in all the rooms and especially in the rooms used by all the members.*

6.2 RECOMMENDATIONS :

The experience gained through this project has rendered it possible to make specific recommendations regarding the design of high-rise apartments in Dhaka city with due considerations of changed environment and micro-climates. The categorized recommendations are presented below :

(01) The field-survey of this project may be considered as a Post Occupancy Evaluation in limited scale for a given climatic aspect. In the absence of full-fledged Post Occupancy Evaluation (POE), it is not possible for architects and designers to have access to crucial information regarding internal environment and micro-climates in high-rise apartments created within high-rise apartments in Dhaka city In this context

> *It is recommended to introduce POE to get feedback from users so thet this information can be used as an effective means of improving the design considerations and technologies of such buildings.*

(02) In absence of the system of "Mock-flats" the purchasers cannot have prior ideas, especially regarding the internal climates of the apartments. Since construction of "Mock-flats" may be

expensive for the developers at this stage, because of the limited number of proto-type of apartments

It is recommended that each developer should be asked to complete construction of at least one life-size model of the type of apartments they are going to sell in the market, at the early stages of the project.

(03) Architects are required to design apartment buildings with due consideration of the existing situation. However, because a building constructed amidst 'unsaturated growth' of buildings around may face abrupt changes, affecting external and internal climates as surrounding areas develop, therefore

Recommendations are made to the effect that the architects should design such buildings with due consideration of "fullest possible growth" of buildings in the surrounding area.

(04) Architects in their design depend greatly upon air movement for expelling out hot and stale air. Construction of buildings at close proximity decreases air movement and creates problem in expelling hot air. In such a situation

It is recommended that traditional 'ventilators' at levels higher than the living zone within individual rooms, or 'ventilation ducts' of shafts running the entire height of the buildings leading from individual rooms/apartments, may be utilized for expelling hot and stale air.

(05) The users experienced that nice-looking elevations with large windows that was one of the persuasive forces for purchasing their apartments, soon turned useless since there was no adequate space around to see the elevations. What mattered more was the absence of windows at certain locations and problems of marinating privacy near large windows In such a situation it is recommended that while designing openings the architects should give more importance on internal climates than external views. In such a situation

It is recommended that climatically useful windows like small and slit type windows, windows placed over and below eye-levels, windows with wide horizontal and vertical louvers etc. may be used for air and light, considering the negative effects of too much sunlight penetration.

(06) It has been revealed that the climatic characteristics of rooms at various cardinal locations do not follow the expected natural trends due to much modification. In such a situation

> *It is recommended that the architects of apartments should not blindly follow the principle of relating 'activity pattern' with 'comfortable cardinal locations', because the second concept has suffered from considerable changes. Each site should be evaluated adequately for characteristic deviations from the general expected climatic trends.*

(07) It is a common experience that natural ventilation keeps the climatic situation inside rooms healthful by expelling hot air and bringing in fresh air. The retardation of air movement due to closely-spaced high-rise buildings have retarded this activity also. It has been found in case of some rooms the escape route of air is closed as soon the doors are closed. In such a situation

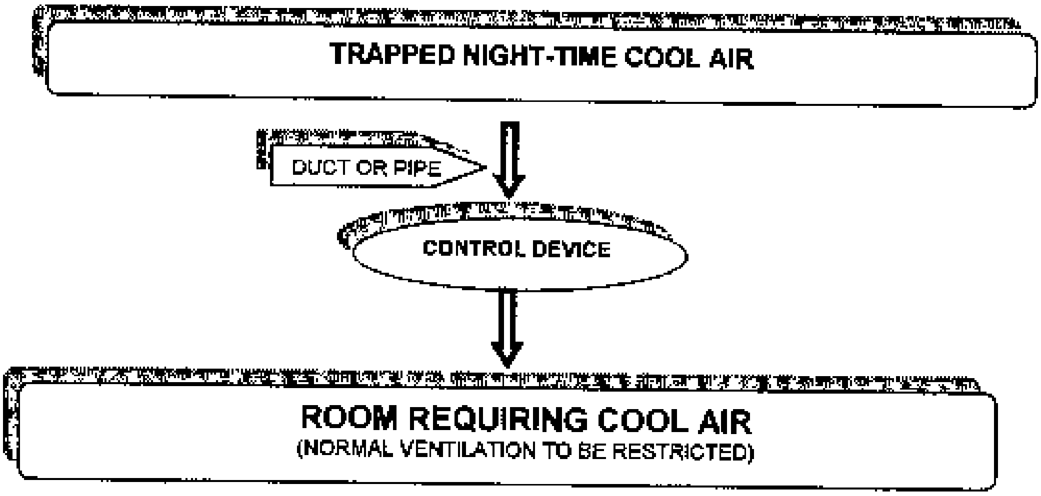
> *It is recommended to make use of fanlight, high-window, louvered wall etc. for the purpose of enhancing internal air-movement and exchange.*

(08) Inter-building spacing and building height determine air movement through the built-up areas As inter-building space prescribed by the Urban Development Authorities was originally formulated when the building density and building height in the city was low, these recommendations are not found to be adequate for present-day situations. The reduced air-movement due to present-day development results in pockets of stagnant hot and humid air in between buildings In such a reality

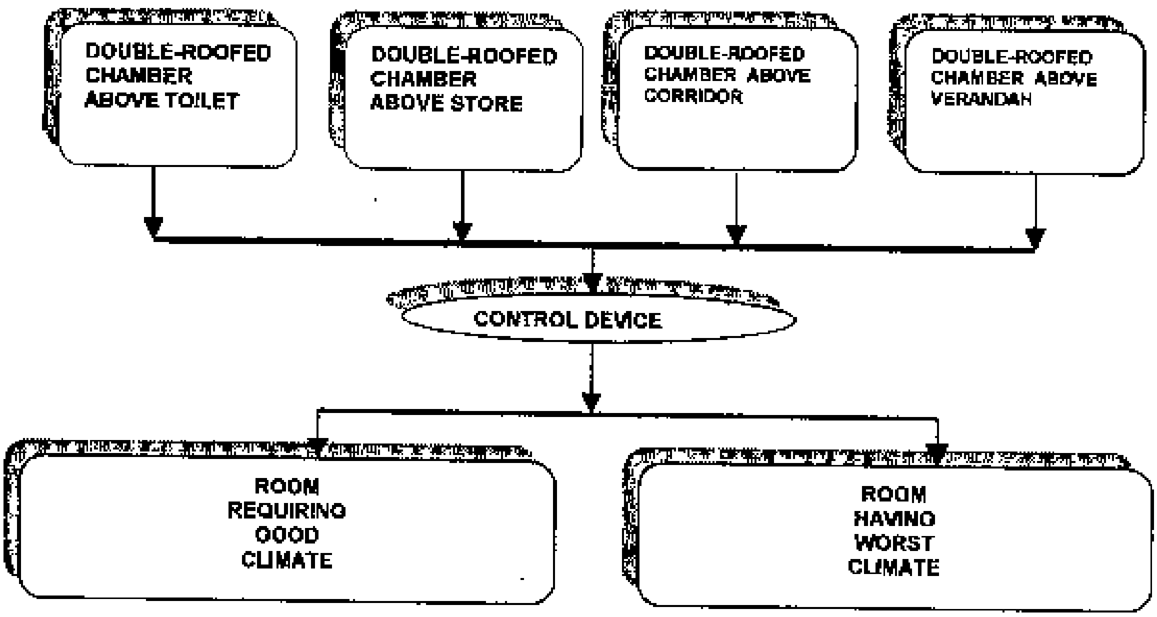
> *It is recommended that research and investigation should be carried out to find out how far the present recommendations and regulations regarding inter-building spacing can ensure favorable climatic conditions inside and out-side high-rise apartments.*

(09) With approximately 10 deg C diurnal difference displayed in the external temperature of the tested month, it is clear that while air temperature is very comfortable at night, it is about 3 to 3 degrees higher than the comfortable range during the hottest parts of the day. Such a situation leaves a scope of trapping cool night air in unusable spaces (say, in between double roof over

store room, toilet, corridor, verandahs etc.) and re-using this during hot times in any preferred room or in the one with worst climatic condition (Refer to Schematic Figure below)



COOL AIR AT HOT HOURS.



SCHEMATIC FIGURE SHOWING THE SYSTEM OF TRAPPING OF NIGHT-TIME COOL AIR IN CHAMBERS AND REUSING DURING HOT HOURS IN SELECTED ROOMS.

In such a context,

> *It is recommended that research and experiments be carried out to find out the effectivity of the re-use of trapped cool-air at hot hours for the purpose of improving the climatic situations inside high-rise apartments.*

(10). Because of the change of users of high-rise apartments from affluent to middle income people and scarcity of electric power in Dhaka city the need of the time is to design climate-friendly apartments which are energy-efficient. This can be done only after having in-depth knowledge of the various aspects of climate and understanding the climatic situations including problems prevailing in the apartments. This project is a study and investigation of the same and was to be done within limited time and logistic facilities. Even though the study and investigation have revealed some findings that may act as guides for the architects, it created the need and scope for further studies and investigations in this and other climate-related aspects. So,

> *Recommendations are made to undertake further research and study projects in the climatic aspect of building design in the greater benefit of the society. Studies to enhance the 'passive' aspects which can improve energy efficiency of the buildings stock is vital in order to keep 'active' energy usage to minimum levels.*

6.3 CONCLUSION:

Climate is an ever-changing phenomenon and any decision on it should come out as a result of long time observation and measurement. Any single measurement at one time at a few spots bears the possibility of inherent errors due to unseen or hidden factors. Since this one is the only study on this aspect of climate, it may not be wise to formulate general building design guidelines on its basis On the other hand, it is suggested to carry out further study and research projects on this and other aspects of climate for the purpose of formulating dependable guidelines.

This study was conducted with limited logistic support, manpower and equipments and within constrained time frame as allowed in the Master's program. Despite these limitations this project has indicated how the present trend of construction of high-rise apartments at close spacing have changed the micro-climates to such extent as to considerably affect the climates inside the buildings. It may be logically expected that the micro-climate inside the city would change further, if the present trend in building construction continues. Because of less land available in Dhaka for accommodating people, construction of high-rise buildings seems to be the lone acceptable option in the present context. Definitely such a situation calls for in-depth studies, investigations, experiments and researches on this important aspect of human habitation.

The moral responsibility of the Architects and designers of high-rise apartments is to ensure environment-friendly and user-friendly apartments for all types of users. Needless to mention that this can be achieved by optimum utilization of natural wealth like light, ventilation etc The increase of inter-building space can improve the situation of micro-climates by eradicating the creation of 'hot and warm' pockets in congested areas. Various techniques like change of window types and designs, use of ventilators and ventilation duct etc. are capable of improving the internal climates And lastly, 'the principle trapping and re-using cool air during hot hours' that has never been tried in this land has been proposed here as a means of for ensuring comfortable internal climates.

From his experience gained in this project this researcher finds reasons to be convinced that the micro-climates inside high-rise apartments in Dhaka city has changed considerably due to a number of reasons. Post Occupancy Evaluation conducted at regular intervals in such apartments may reveal the problems and inadequacies with further details. The publication of the findings of POE may increase understanding among architects and urban development authorities regarding the nature of problem. It is hoped that understanding of the related problems and the co-ordinated efforts by the Architects, Planners, Engineers, Urban Development Anthorities, academicians, apartment owners and users shall be instrumental in determining effective solutions, that will lead to better climatic situations inside future apartments.

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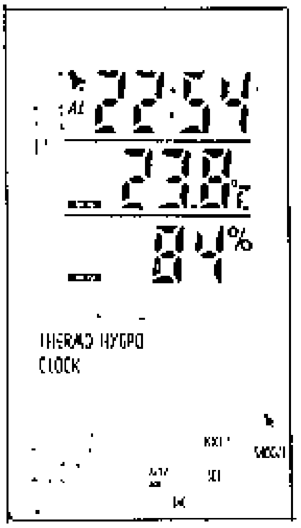
APPENDICES

APPENDIX - 01 SPECIFICATIONS AND INSTRUCTION MANUAL FOR THERMO-HYGRO CLOCK

INSTRUCTION MANUAL

THERMOMETER/HYGROMETER WITH ALARM CLOCK

maximum and minimum temperature and humidity records with optional daily reset feature



J412-CTH

FEATURES

- 3 rows LCD display.
- Clock (12 or 24 hour selectable) with snooze alarm function.
- Current time, Indoor temperature and humidity display simultaneously.
- °C or °F range selectable at any time.
- Maximum and Minimum temperature and humidity memory function with optional daily reset function.
- Temperature measuring range : -10°C to 50°C (23°F to 122°F) with 0.1°C(°F) resolution.
  Humidity measuring range : 20 - 99% with 1 % resolution.

INSTALLING AND REPLACING THE BATTERY

The thermometer uses one 'AAA' size battery (1.5V DC).
Follow these steps to install or replace the battery:

1. Open the battery cover, below the stand.
2. Insert the battery as indicated by the polarity symbols (+ and -) marked inside the battery compartment
3. Replace the battery cover.

OPERATION

TEMPERATURE AND HUMIDITY MEASURE

This unit will measure the temperature and humidity continuously unless the user is setting the clock or alarm. The temperature will be displayed in °C or °F unit. The unit can be selected by switching the °F/°C slide switch at the back of the unit.

DISPLAY

1. The upper LCD display shows either current time or alarm time(with AL on). The user can switch between them by pressing SET key. It also display the BELL icon which indicate the on/off status of the alarm.
2. The middle and lower display shows temperature and humidity respectively. The user can view the maximum and minimum temperature/humidity records by pressing MAX/MIN key. If the current temperature is above or below the measureable range, the HHH or LLL will be shown.

CLOCK DISPLAY

The clock can be in 12 or 24 Hour, the user can switch the Hour system and set the clock by following these steps:

1. Make sure that the current time is displaying in the upper LCD display by pressing SET key.
2. Press the SET key for about 2 seconds, the upper LCD display will show either 12 hr or 24 hr with blinking.
3. Press the INC key to toggle between 12 or 24 hour.
4. Press the SET key again, the current time will be shown again with Hour digits blinking.
5. Press the INC key to adjust Hour digits. Press and hold the key to advance the digits continuously.
6. Press the SET key again, the Minutes digits will blink.
7. Press the INC key to adjust Minute digits. Press and hold the key to advance the digits continuously in 5 increments step.
8. After finish setting, press the SET key to exit the setting mode or it will be exited automatically if the user doesn't press any key for 1 to 2 minutes.

ALARM and SNOOZE FUNCTION

Press the ✱ key for about 2 seconds to switch the on/off status of the alarm. The alarm will beep for 12 minutes at the preset alarm time. The user can press the **SNOOZE** key to stop beeping for 8 minutes. The alarm will then beep again. Alternatively, the user can stop the alarm by pressing any other key.

To set the alarm time, the user should follow these steps.

1. Make sure that the alarm time is displaying in the upper LCD display by pressing SET key, the AL icon is on.
2. Press the **SET** key for about 2 seconds, the Alarm Hour will blink.
3. Press the **INC** key to adjust the digits. Press and hold the key to advance the digits continuously.
4. Press the **SET** key again, the Alarm Minutes digits will blink.
5. Press the **INC** key to adjust the digits. Press and hold the key to advance the digits continuously in 5 increments step.
6. After finish setting, press the **SET** key to exit the alarm setting mode or it will be exited automatically if the user doesn't press any key for 1 to 2 minutes

RECALL MAXIMUM AND MINIMUM TEMPERATURE/HUMIDITY RECORDS

The user can recall the maximum and minimum temperature/humidity records by pressing the **MAX/MIN** key. To recall them, the user can follow these steps.

1. When the current temperature/humidity is displaying, Press the **MAX/MIN** key to view the maximum temperature in the middle LCD display and maximum humidity in the lower LCD display. Press **RESET** key to reset the maximum record to the current temperature/humidity.
2. Press the **MAX/MIN** key again to view the minimum temperature in the middle LCD display and minimum humidity in the lower LCD display. Press **RESET** key to reset the minimum record to the current temperature/humidity.
3. Press the **MAX/MIN** key again, the current temperature and humidity will be shown in the middle and lower LCD display respectively.

DAILY MAXIMUM AND MINIMUM TEMPERATURE/HUMIDITY RECORDS RESET

This function guaranteed the maximum and minimum temperature/humidity records are measured within the current day. If the user concern the maximum and minimum temperature/humidity of the current day, he/she could enable the function by setting the DAILY slide switch at the back of the unit to ENABLE. The maximum and minimum temperature/humidity records will be reset to the current temperature/humidity at 0:00 everyday.

USE OF THE SUPPLIED STAND

Flip out the plastic stand on the rear of the unit for table standing. Stand the unit on a flat surface

WALL-MOUNTING THE UNIT

Follow these steps to mount the unit on the wall

1. Drive a screw into the wall at the desired location until the head extends 3.5mm from the wall
2. Locate into the hanger slot on the back of the thermometer until it locks into place

DESIGN AND SPECIFICATIONS ARE SUBJECTED TO CHANGE WITHOUT NOTICE.

QUESTIONNAIRE SURVEY ON USERS' RESPONSES

Project : **A STUDY INTO THE CLIMATIC ASPECTS OF RESIDENTIAL HIGH-RISE IN DHAKA**

PART - ONE

(APPLICABLE FOR THE BUILDING)

Location of the building : Address : Name : ....

Road .. .. House No. ....

No. of Floors .... No. of units per floor ....

Date on which surveyed : .. / .../ 2000.

i. Measurement of outdoor Temp. & Humidity on all sides; Recording Time :......... A.M./P.M.

Front *(E W N S)* Temp ......Deg. Hum. .... %

Left *(E W N S)* Temp ...Deg. Hum .... %

Right *(E W N S)* Temp. .... Deg. Hum. .... %

Rear *(E W N S)* Temp. .... Deg Hum. .... %

ii. The Building has got external walls on sides - *East, West, North, South, NE, NW, SE, SW*

iii. Measurement of outdoor Temp. & Humidity at the entrance at the time of leaving :

Recording Time .... Temp. .... Deg. Hum. ....

....

(SKETCH A LOCATION MAP HERE)

PART - TWO

(APPLICABLE FOR EACH APARTMENT)

Label/Code .... Floor : ... Location : *(E W N S)* Contact Tel. No. ....

1. GENERAL INQUIRY :

A. How long have you been you living in this house ? .... Years .... Months

B. Are you the owner or rent payer ? *Owner / Rent payer /* Other ....

C. In summer how would you describe your house ? *Cool/ Comfortable/ Warm/ Hot*

D. Is there air-flow in the rooms ? *Yes / No*

E. Identify the coolest room in your house (location in plan) ....

F. Identify the airiest room in your house (location in plan) ....

G. In winter how would you describe your house ? *Cool / Comfortable / Warm / Hot*

H. Identify the hottest room in your house in winter (location in plan) . . ..

I. Which in your opinion was the hottest month in (a) 1999 ? *March /April / May / June/ July / August*

(b) 2000? *March /April / May / June /July /August*

J. Did you ever feel (a) your building wall hot or to radiate heat ? *Yes / No.*

(b) your building roof hot or to radiate heat ? *Yes / No*

ENUMERATOR Please mark the dresses of the respondents at the time of Interview.

(Formal dress / Pant / Shirt / Lungi / Shinglet / Others (specify)

....

....

2. INFORMATION ABOUT INDEPENDENT ROOMS/SPACES :

LIVING ROOM

(Abbreviated as LR)

A. Physical structure :

LABEL	MATERIAL	FINISHES	COATING	COLOUR	REMARK
Wall 01	....	....	....	....	....
Wall 02	....	....	....	....	....
Wall 03	....	....	....	....	....
Wall 04	....	....	....	....	....
Roof	....	....	....	....	....
Floor	....	....	....	....	....

Details of Window : Window – 1 size : .... X .... Open to Exterior / Verandah
Window – 2 size : .... X .... Open to Exterior / Verandah
Sunshade (in case of external window) : *No / Top / Box / Three-sided / others*
Frame material : *Aluminum / Steel / Wood /* Others
Shutter material : *Glass / Timber / Others*
Type of glass : *Plain / Frosted / Ground / Designed /* Others
Netting : *Yes / No*
Grille : *Yes / No.*

B. Facilities :

Electric fans : 36"/48" .... Nos. Exhaust fans : No / Yes (size ....)
Air-conditioner : Yes. (Size ... Tons. Type : *Split / Window) / No*
Electric Lights (consider only those which are kept on at the time of survey)
Incandescent Bulb : ....Watt ....Nos .... Watt ....Nos. .... Watt ....Nos.
.... Watt ....Nos. .... Watt .... Nos. .... Watt .... Nos.
Tube Light : .... Feet .... Nos. .... Feet......Nos. .... Feet ....Nos
Chandelier *Yes / No. /* Others(Specify) ....
Window curtain : *Yes* (Type / color ....) */ No*
Floor : Carpeted : *Yes / No*
Matted *Yes / No. /* Others (Specify) ....

C. User's response during hot months

1. No. of people usually occupying the room/space : *01 / 02 / 03 / 04/ 05 / 06/07/ 08/ 09/ ....*
2. Most comfortable time of the day : *Morning, Noon, After-noon, Evening, Night, Late-night*
3. Most un-comfortable time of the day : *Morning, Noon, After-noon, Evening, Night, Late-night*
4. Temperature in the hottest days : *Unbearable, Moderate, Satisfactory, Others* ....
5. Feeling of humidity : *Extremely humid, Moderate, Satisfactory,* Others
6. Feeling of Sweating : *Extreme sweating, Moderate, Satisfactory,* Others......
7. Feeling of ventilation : *Excellent, Satisfactory, Non-satisfactory,* Others ....

8a. How is natural light at the center of the room ? : *Good / Fair / Poor*
8b. How is natural light near the external window ? : *Good / Fair / Poor*

9. Do you have problems in keeping the windows open ? *Yes / No*
(If Yes, specify the reasons) ....
....

D. Measurement of Indoor Temperature and Humidity :

At the center of the room :	Temp ....Deg. C.	Hum. .... %
Near Front Wall	Temp ....Deg. C.	Hum. ....%.
Near Rear Wall	Temp ....Deg C	Hum. .... %
Near Right Wall	Temp ....Deg. C.	Hum. ....%.
Near Left Wall	Temp ....Deg. C	Hum ....%.
Near Window-01:	Temp ...... Deg. C.	Hum. ...... %.
Near Window-02:	Temp ....Deg. C.	Hum. ....%.
Near Window-03 :	Temp ...... .Deg. C.	Hum. ....%.
Near Window-04:	Temp ....Deg. C.	Hum. ....%.
Near Door-01:	Temp ....Deg C	Hum. ....%
Near Door- 02 .	Temp ....Deg. C	Hum .... %
Near Door-03:	Temp ....Deg. C.	Hum. ....%.

MASTER BED ROOM

(Abbreviated as MB)

- **A. Physical structure** : (PREVIOUS QUESTIONS REPEATED)
- **B. Facilities** : (PREVIOUS QUESTIONS REPEATED)
- **C. User's response during hot months** : (PREVIOUS QUESTIONS REPEATED)
- **D. Measurement of indoor Temperature and Humidity** : (PREVIOUS QUESTIONS REPEATED)

CHILDREN'S BED ROOM

(Abbreviated as CB)

- **A. Physical structure** : (PREVIOUS QUESTIONS REPEATED)
- **B. Facilities** : (PREVIOUS QUESTIONS REPEATED)
- **C. User's response during hot months** : (PREVIOUS QUESTIONS REPEATED)
- **D. Measurement of indoor Temperature and Humidity** : (PREVIOUS QUESTIONS REPEATED)

GUEST'S BED ROOM

(Abbreviated as GB)

- **A. Physical structure** : (PREVIOUS QUESTIONS REPEATED)
- **B. Facilities** : (PREVIOUS QUESTIONS REPEATED)
- **C. User's response during hot months** : (PREVIOUS QUESTIONS REPEATED)
- **D. Measurement of indoor Temperature and Humidity** : (PREVIOUS QUESTIONS REPEATED)

DINING ROOM/SPACE

(Abbreviated as D)

- **A. Physical structure** : (PREVIOUS QUESTIONS REPEATED)
- **B. Facilities** : (PREVIOUS QUESTIONS REPEATED)
- **C. User's response during hot months** : (PREVIOUS QUESTIONS REPEATED)
- **D. Measurement of indoor Temperature and Humidity** : (PREVIOUS QUESTIONS REPEATED)

E. Enumerator Please sketch a rough furniture layout

F. Enumerators comment : (Perceive the following in the space without fan/AC)

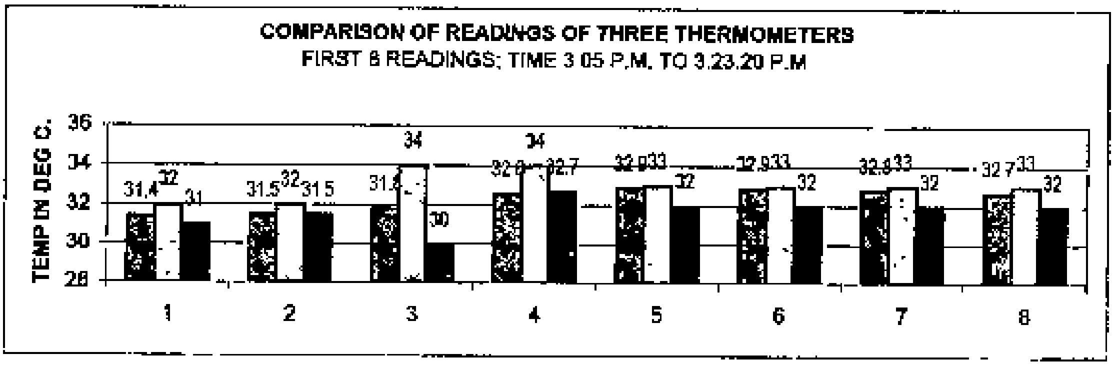
AIR MOVEMENT : *Perceptible/ Imperceptible*
TEMPERATURE : *Hot/ Comfortable/ Cool*
DAMPNESS : *Whether Convenient in indoor conditions or not*
Any stain on walls : *Yes or No.*

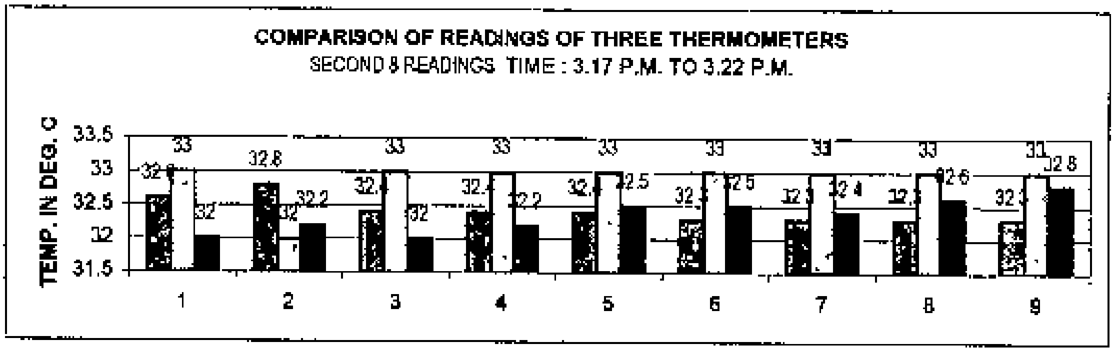
COMMENT ON PERCEIVED HUMIDITY OF SPACE ....
....
....

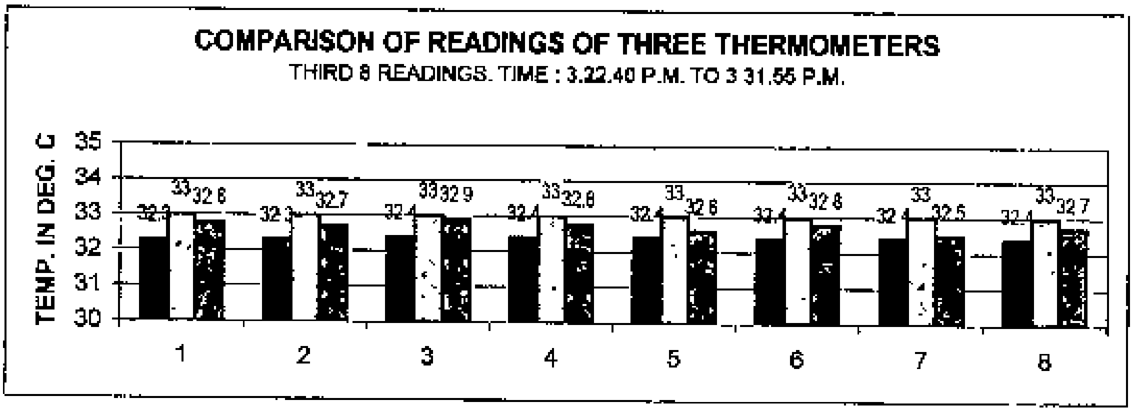
DOCUMENTATION : Survey conducted by : .... Date ....

Supervised by .... Date ....

Appendix 4-02 COMPARISON OF READINGS BY THREE THERMOMETERS

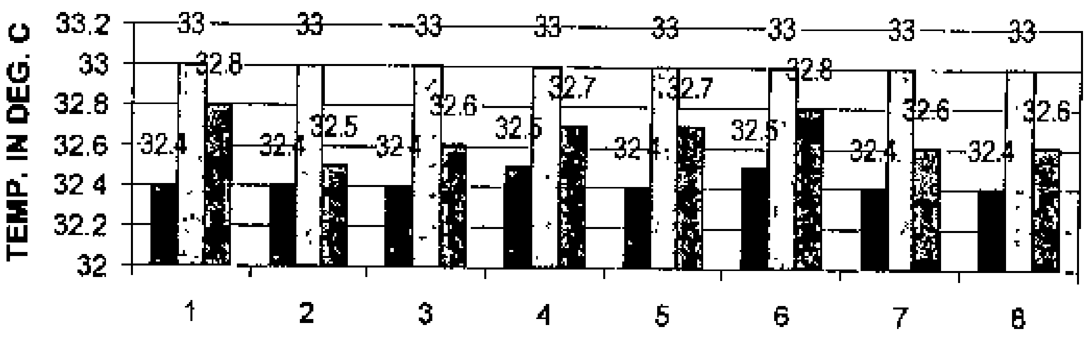






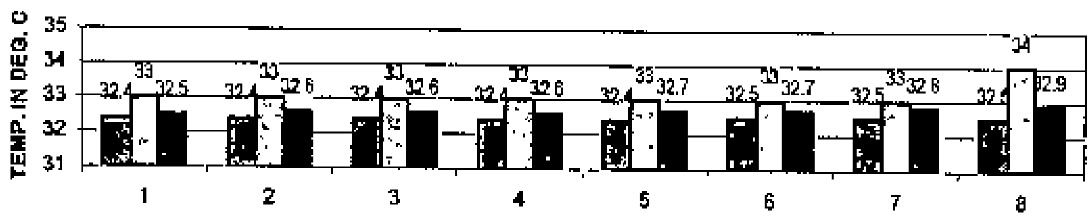
COMPARISON OF READINGS OF THREE THERMOMETERS

FOURTH 8 READINGS. TIME : 3.34.05 P.M TO 3.42.15 P.M.



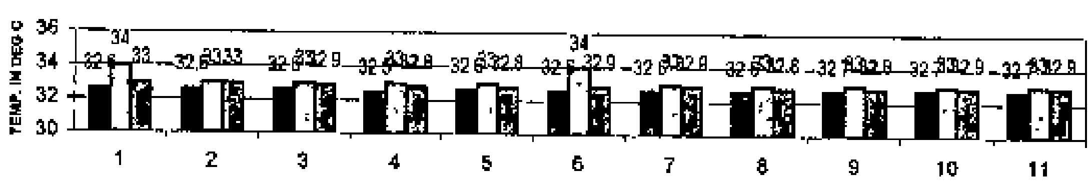
COMPARISON OF READINGS OF THREE THERMOMETERS

FIFTH 8 READINGS. TIME : 3.43.00 P.M. TO 3.50 10 P.M.

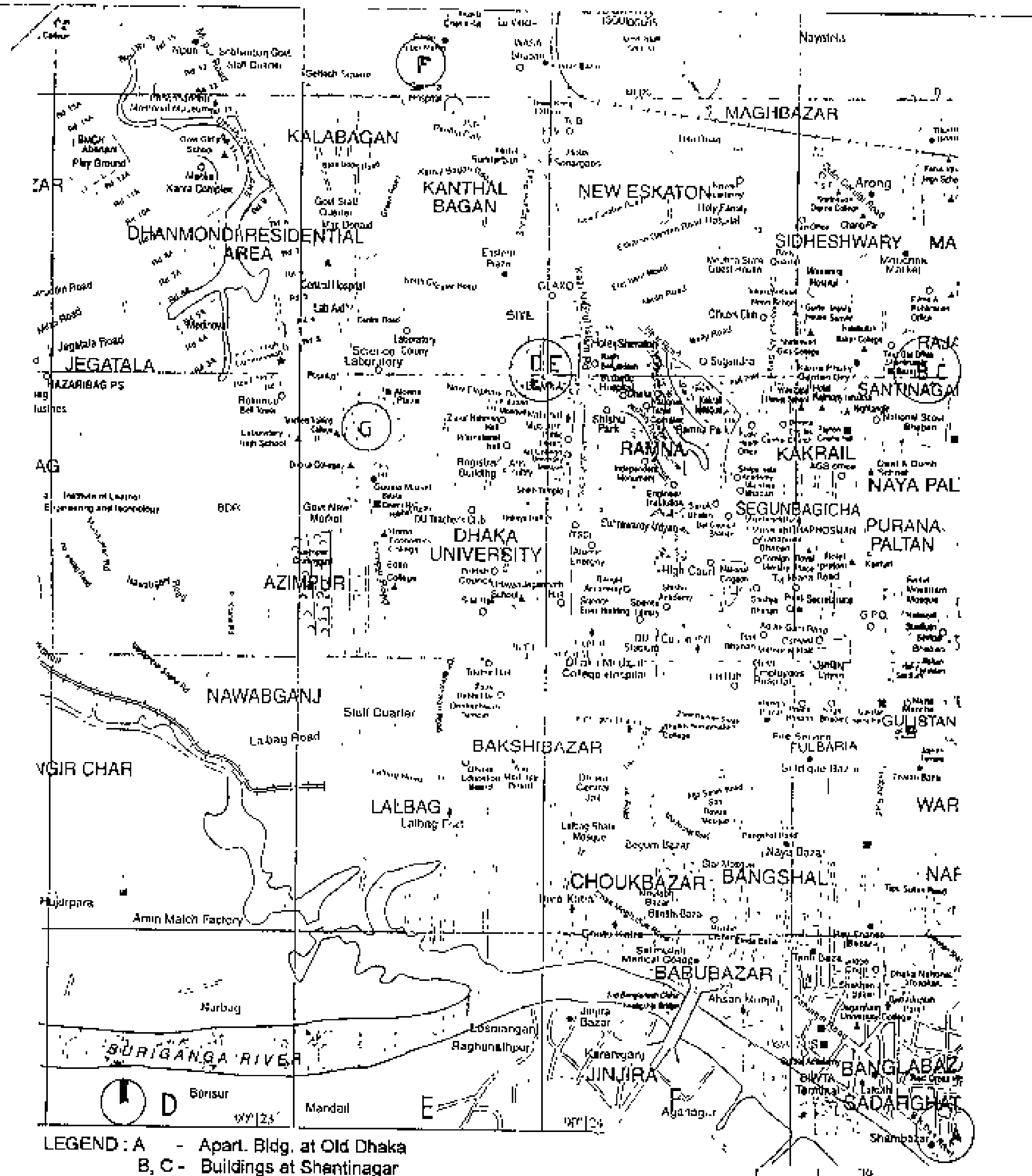


COMPARISON OF READINGS OF THREE THERMOMETERS

LAST 11 READINGS. TIME . 3.50 40 P.M. TO 4 05.00 P.M.



Appendix 4 - 03 SITE PLAN (LOCATIONS OF APARTMENTS IN DHAKA CITY)



LEGEND : A - Apart. Bldg. at Old Dhaka

B, C - Buildings at Shantinagar

D, E - Buildings at Elephant Road

F - Building at Farmgate

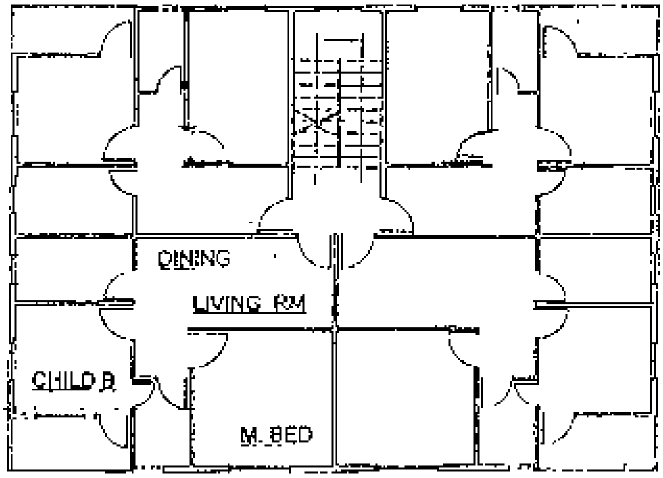
G - Building at Mirpur Road, Dhanmondi.

Appendix 4 - 04 UNIT PLANS WITH TEMPERATURE AND HUMIDITY READINGS

Dining 30.9C 90%
Living 30.9C 90%

Child 30.6C 89%
Master 30.8C 89%

Exter. Temp 30.8C
Exter. Hum 88%

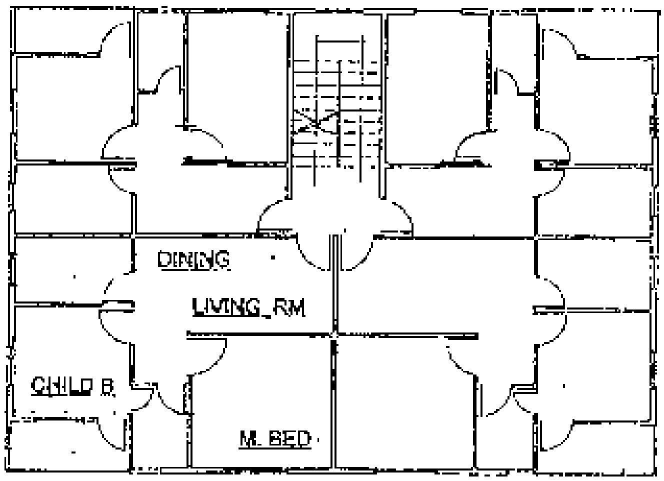


CODE : **A 07 SW** WAHIDUZZAMAN BHABAN PLAN : 7th Floor

Dining 30.7C 90%
Living 30.7C 86%

Child 30.6C 87%
Master 30.6C 90%

Exter. Temp 30.6C
Exter. Hum 86%

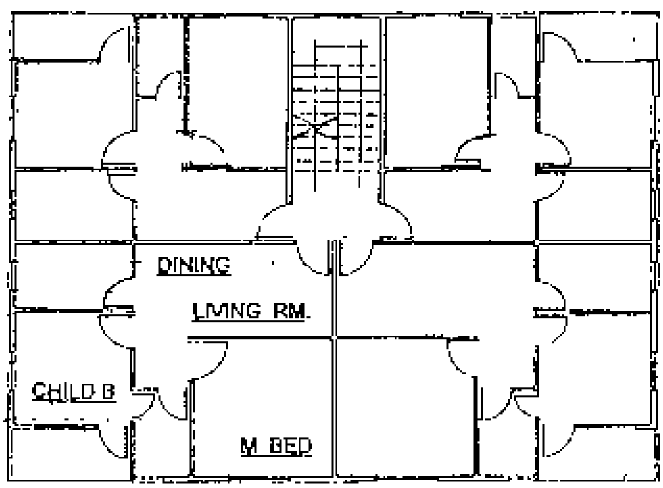


CODE : **A 05 SW** WAHIDUZZAMAN BHABAN PLAN . 5th Floor

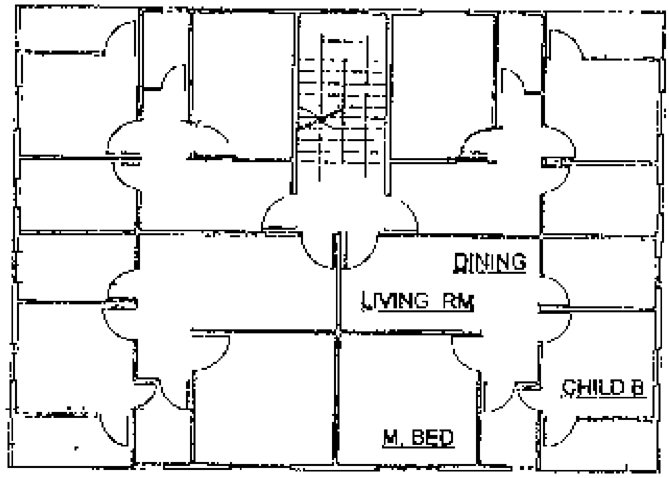
Dining 30.0C 85%
Living 30.0C 85%

Child 29.9C 86%
Master 29.9C 86%

Exter. Temp. 30.4C
Exter. Hum. 84%



CODE : **A 04 SW** WAHIDUZZAMAN BHABAN PLAN : 4th Floor

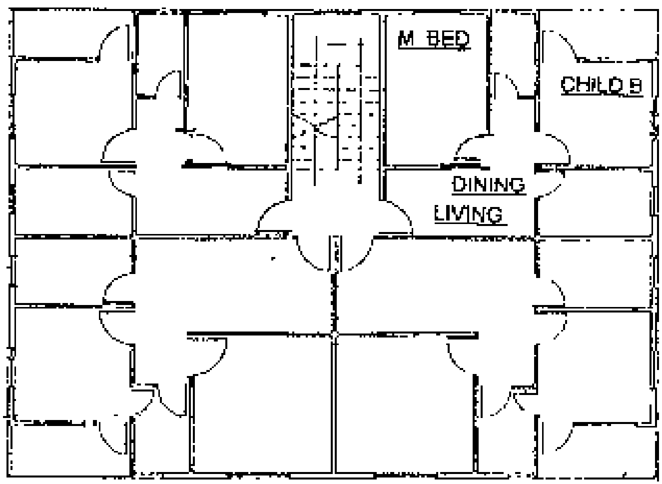


30 9C 90% Dining
30 9C 90% Living

30.6C 89% Child
30.8C 89% Master

Exter. Temp 30.5C
Exter. Hum. 88%

CODE : **A 04 SE** WAHIDUZZAMAN BHABAN PLAN . 4th Floor



30.3C 86% Master
30 4C 86% Child

30 4C 86% Dining
30 4C 86% Living

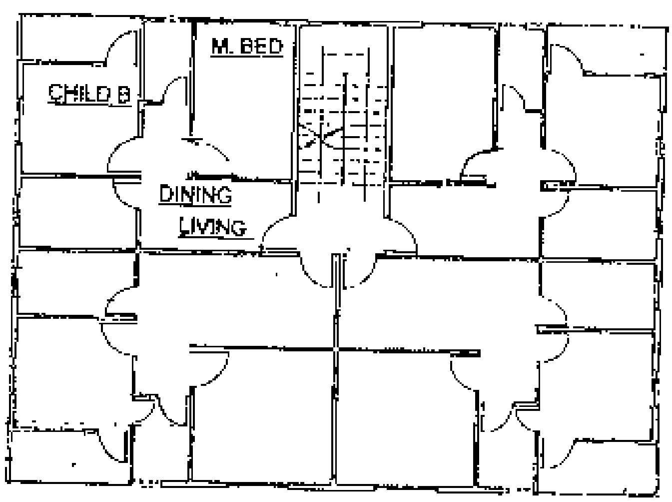
Exter Temp 30.1C
Exter. Hum. 85%

CODE . **A 04 NE** WAHIDUZZAMAN BHABAN PLAN . 4th Floor

Master 30.7C 86%
Child 30 7C 86%

Dining 30 8C 83%
Living 30.8C 83%

Exter. Temp. 30.5C
Exter Hum 82%



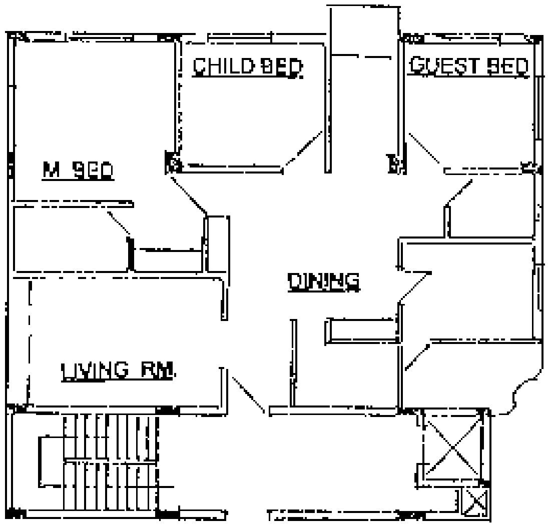
CODE : **A 04 NW** WAHIDUZZAMAN BHABAN PLAN : 4th Floor

Child 31.8C 94%
Guest 31.7C 93%

Master 31 7C 94%

Dining 31 9C 94%
Living 31 8C 94%

Exter Temp 31 7C
Exter Hum 94%



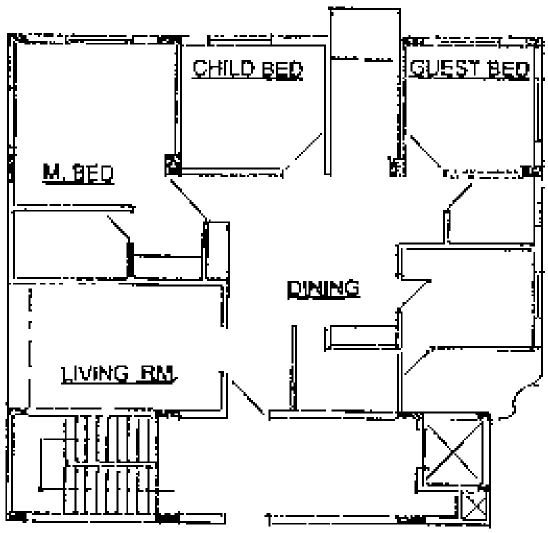
CODE : **B 09 N** EHL BUILDING - 1 PLAN : 9th Floor

Child 33.0C 92%
Guest 32 8C 91%

Master 33 0C 91%

Dining 32.9C 91%
Living 33 2C 92%

Exter. Temp 32 8C
Exter. Hum. 91%



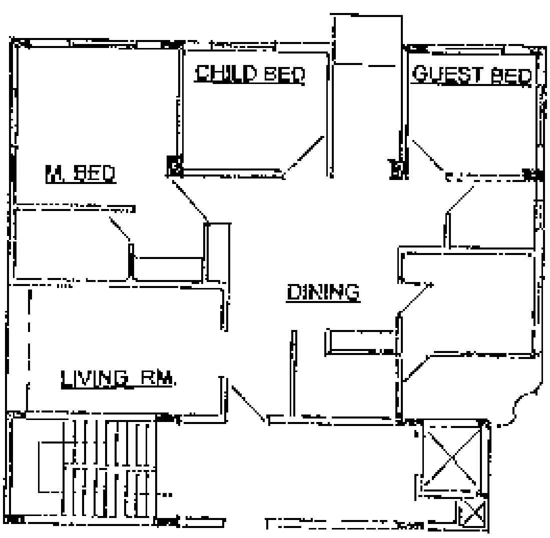
CODE : **B 07 N** EHL BUILDING - 1 PLAN · 7th Floor

Child 33 0C 92%
Guest 32.7C 91%

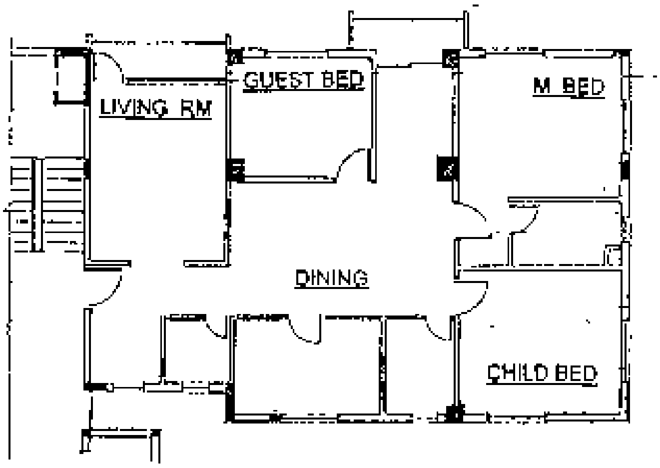
Master 32.8C 90%

Dining 33.1C 94%
Living 33 0C 91%

Exter. Temp 32 7C
Exter. Hum. 90%



CODE : **B 04 N** EHL BUILDING - 1 PLAN · 4th Floor



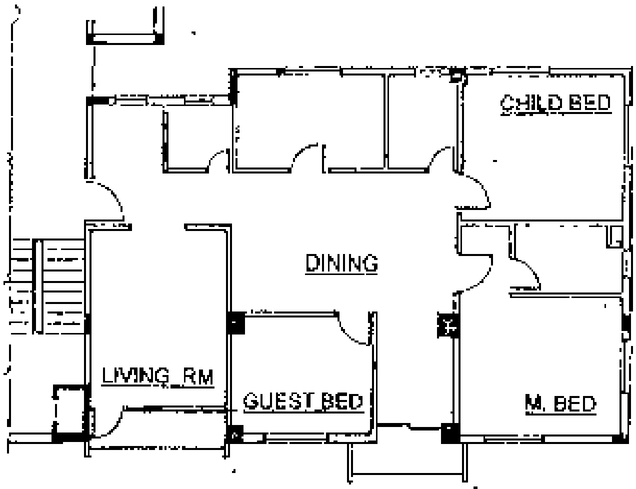
31.9C 92 % Master
32 0C 92% Guest
32.6C 92% Living

31.8C 92% Dining

31 9C 91% Child

Exter. Temp 31.8C
Exter Hum 91%

CODE: **C 16 NE** EHL BUILDING - 2 PLAN : 16th Floor



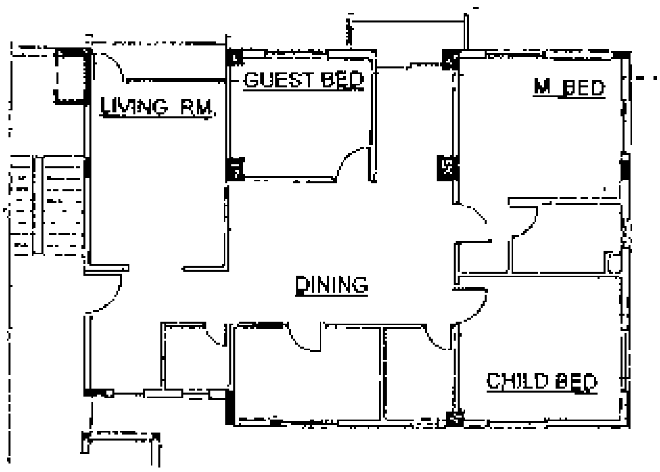
31 9C 92% Child

32.1C 92% Dining

31.9C 91% Living
31 6C 91% Guest
31 8C 92% Master

Exter Temp 38 7C
Exter Hum 91%

CODE: **C 16 SE** EHL BUILDING - 2 PLAN : 16th Floor



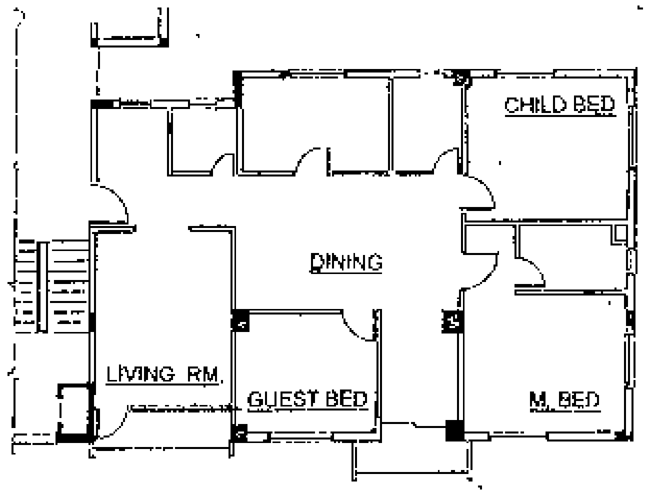
31.6C 92 % Master
31 6C 91% Guest
31 8C 91% Living

31.7C 92% Dining

31 7C 92% Child

Exter. Temp 31 5C
Exter Hum 91%

CODE. **C 06 NE** EHL BUILDING - 2 PLAN 6th Floor



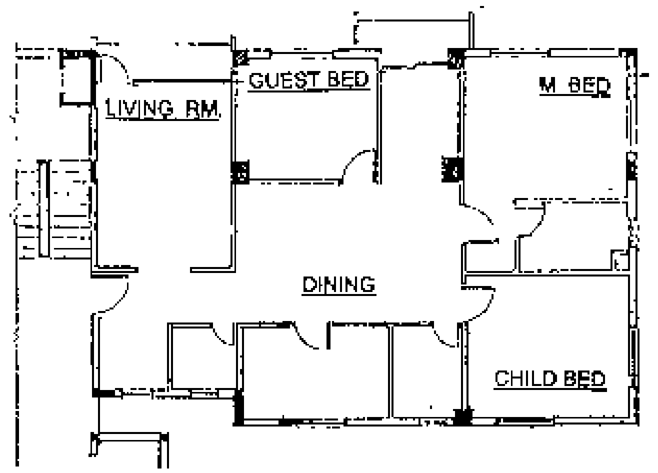
31 8C 92% Child

32.0C 93% Dining

32.2C 93% Living
32 2C 93% Guest
31.7C 92% Master

Exter. Temp. 31 8C
Exter. Hum. 92%

CODE : **C 06 SE** EHL BUILDING - 2 PLAN : 6th Floor



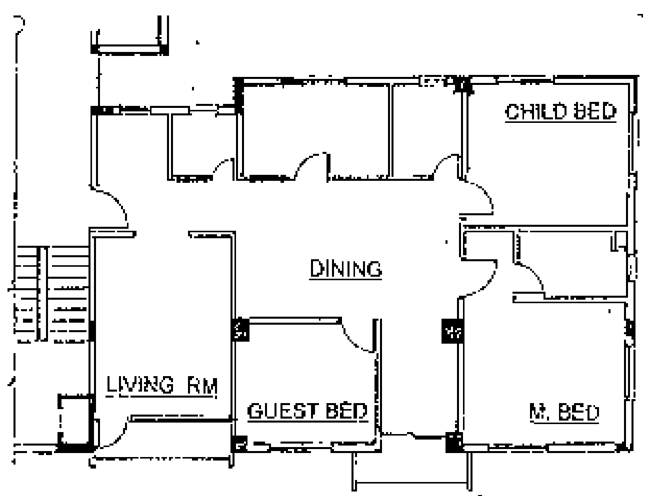
30 9C 91 % Master
30 7C 92% Guest
31 1C 93% Living

31.0C 91 Dining

30 7C 92% Child

Exter. Temp. 31.1C
Exter. Hum. 92%

CODE **C 04 NE** EHL BUILDING - 2 PLAN : 4th Floor



30.8C 93% Child

30.9C 93% Dining

30 8C 93% Living
30.8C 92% Guest
30 9C 94% Master

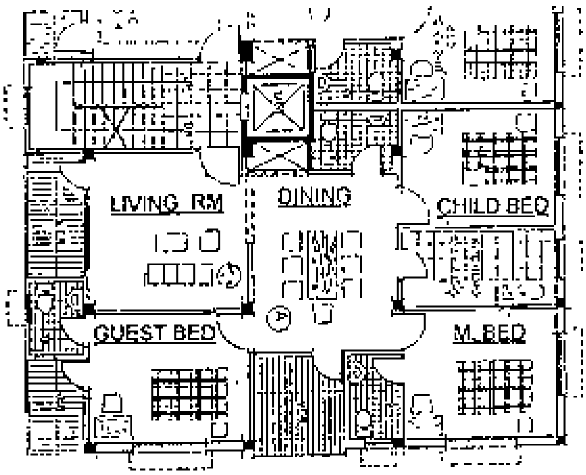
Exter. Temp. 30 7C
Exter. Hum. 92%

CODE : **C 04 SE** EHL BUILDING - 2 PLAN : 4th Floor

Living 31.1C 94%%
Dining 31.1C 94%
Child 30 9C 92%

Master 30.9C 93%
Guest 31.2C 94%

Exter. Temp. 30 8C
Exter Hum 92%



CODE : **D 07 S**

RAZZAK COMPLEX

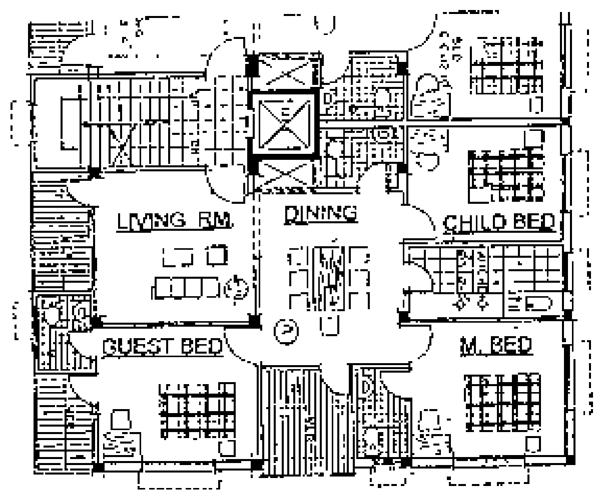
PLAN : 7th Floor

Child 31.6C 95%
Guest 31.8C 94%

Master 31.7C 95%

Dining 31 6C 95%
Living 31 8C 94%

Exter. Temp. 31.9C
Exter Hum. 94%



CODE . **D 05 S**

RAZZAK COMPLEX

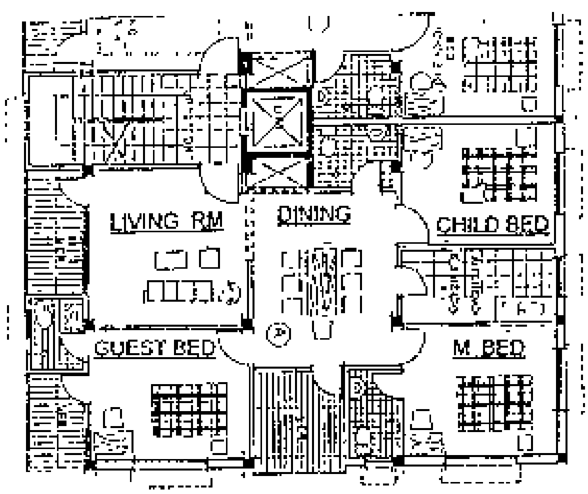
PLAN · 5th Floor

Child 33.3C 95%
Guest 33.2C 95%

Master 33 4C 95%

Dining 33 2C 94%
Living 33 4C 95%

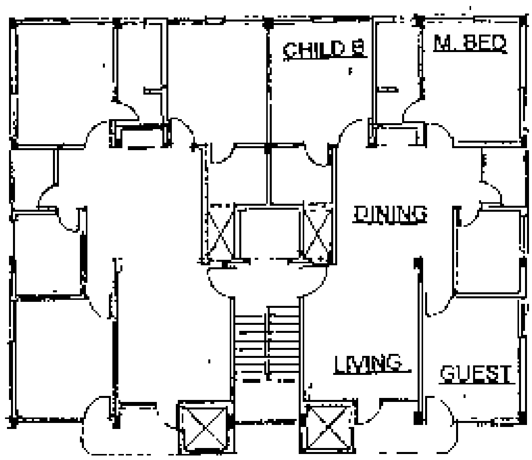
Exter. Temp. 33.2C
Exter. Hum 94%



CODE : **D 04 S**

RAZZAK COMPLEX

PLAN · 4th Floor



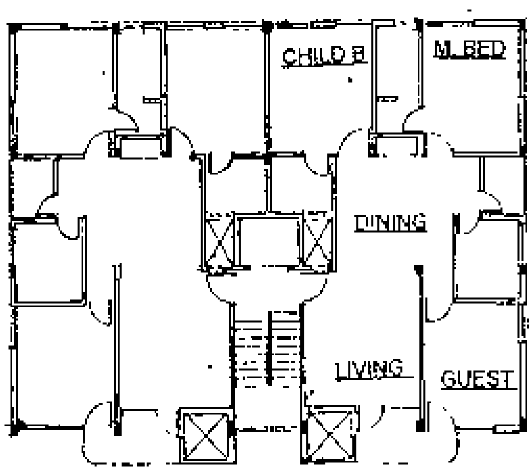
29.3C 85% Child
29.3C 85% Master

29.4C 86% Dining

29.4C 84% Living
29.4C 86% Guest

Exter. Temp. 29.2C
Exter. Hum 84%

CODE : **E 08 E** REZA COMPLEX **PLAN : 8th Floor**



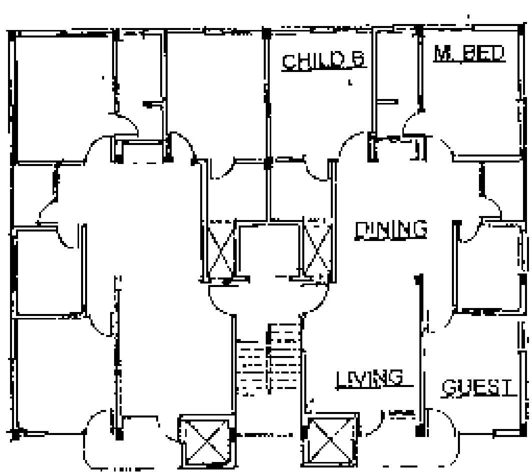
29.2C 86% Child
29.1C 85% Master

29.2C 86% Dining

29.2C 85% Living
29.3C 86% Guest

Exter. Temp. 29.0C
Exter. Hum. 84%

CODE : **E 06 E** REZA COMPLEX **PLAN : 6th Floor**



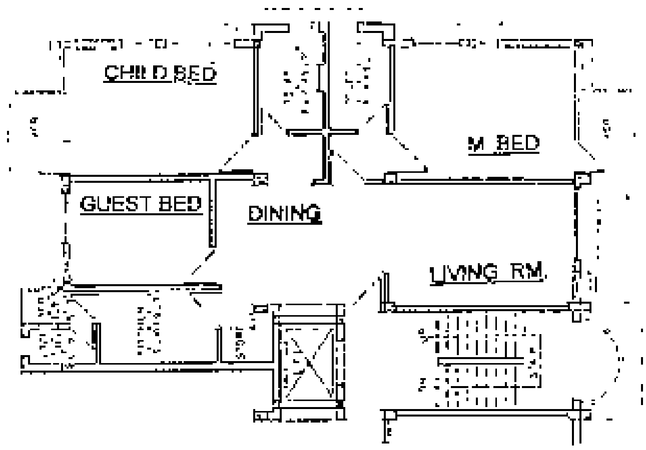
29.4C 84% Child
29.2C 82% Master

29.3C 85% Dining

29.3C 85% Living
29.3C 84% Guest

Exter. Temp 29.1C
Exter. Hum 81%

CODE : **E 02 E** REZA COMPLEX **PLAN : 2nd Floor**



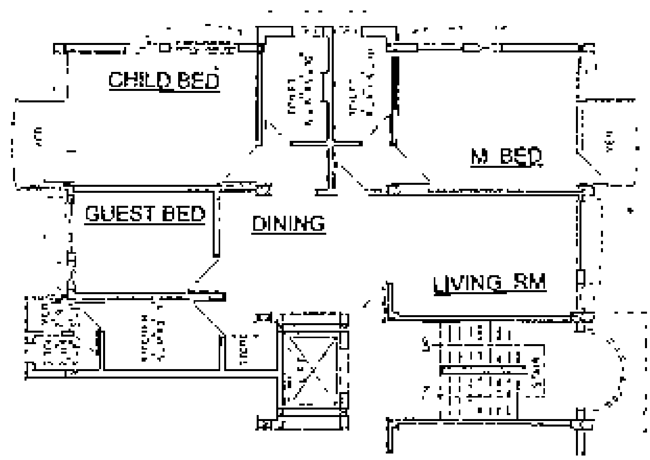
31.4C 85% Child

31 2C 84% Master

31.5C 85% Dining
31 3C 85% Living
31 6C 84% Guest

Exter Temp E·31.2C
W·31 4C
Exter Hum E.W. 84%

CODE : F 07 N MOHINAR COMPLEX PLAN : 7th Floor



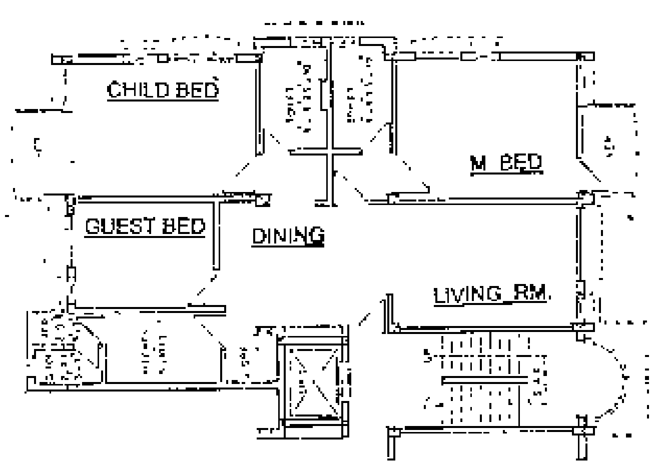
30 5C 85% Child
30 2C 83% Master

30 4C 85% Dining

30 2C 84% Living
30 6C 85% Guest

Exter. Temp E.30.3C
W:30.2C
Exter. Hum E.W:84%

CODE : F 06 N MOHINAR COMPLEX PLAN : 6th Floor



30.5C 88% Child
30.4C 88% Master

30 7C 87% Dining

30 2C 87% Living
30 6C 85% Guest

Exter. Temp. E:30.9C
W:30.9C
Exter. Hum E W:84%

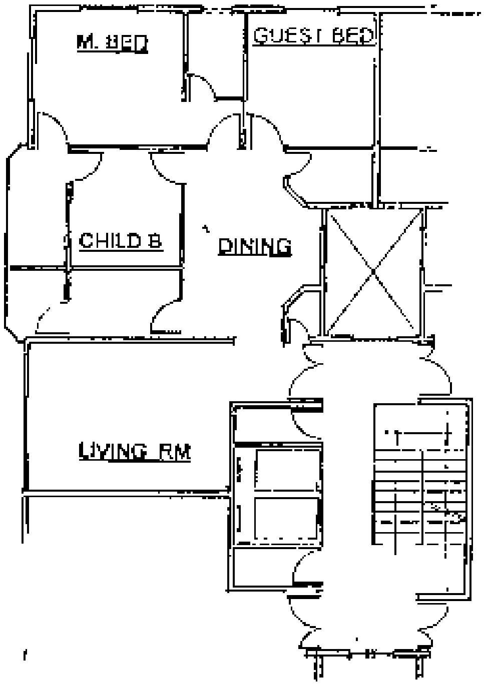
CODE · F 04 N MOHINAR COMPLEX PLAN : 4th Floor

Master 31.1C 84%
Guest 30.0C 85%

Child 31.2C 84%
Dining 31 3C 83%

Living 31.5C 84%

Exter. Temp 31.3C
Exter. Hum. 84%



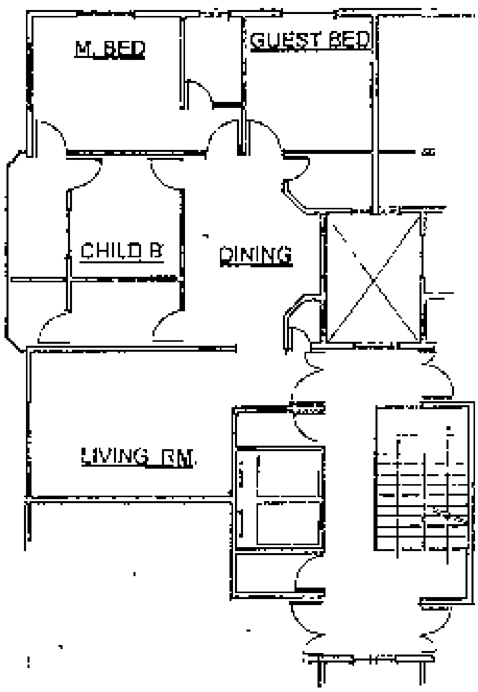
CODE : **G 14 NW** SQUARE TOWER PLAN : 14th Floor

Master 30 2C 86%
Guest 30.2C 85%

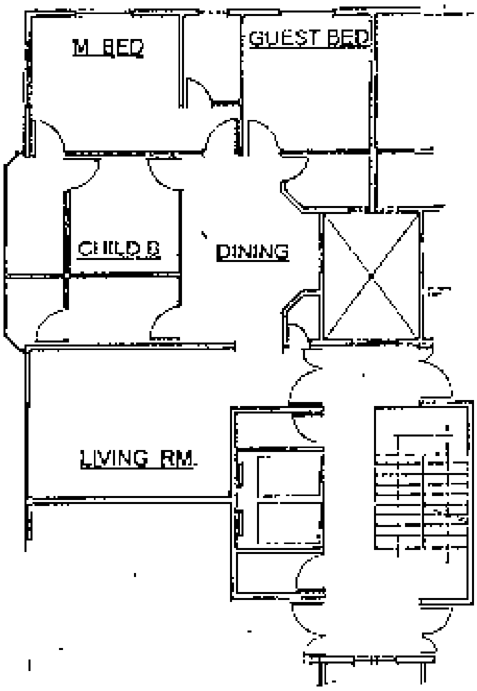
Child 30.2C 87%
Dining 30.1C 86%

Living 30.3C 87%

Exter. Temp. 30 3C
Exter. Hum. 86%



CODE : **G 05 NW** SQUARE TOWER PLAN : 5th Floor



Master 30 1C 86%
Guest 30.2C 88%

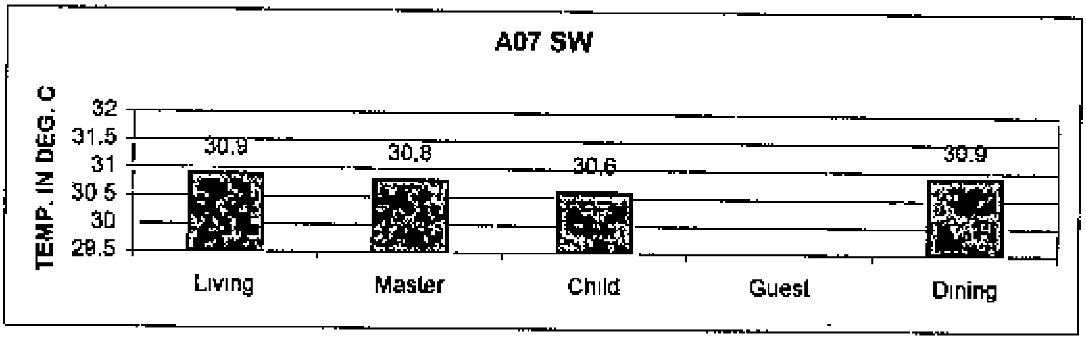
Child 30.0C 85%
Dining 29 9C 86%

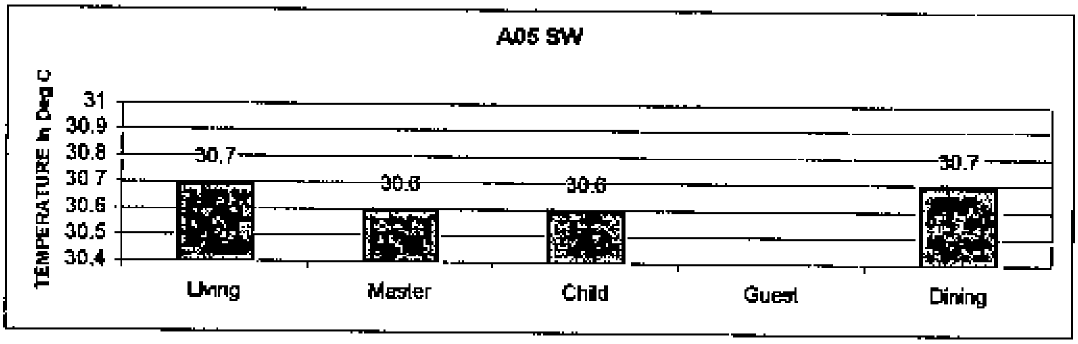
Living 29.8C 86%

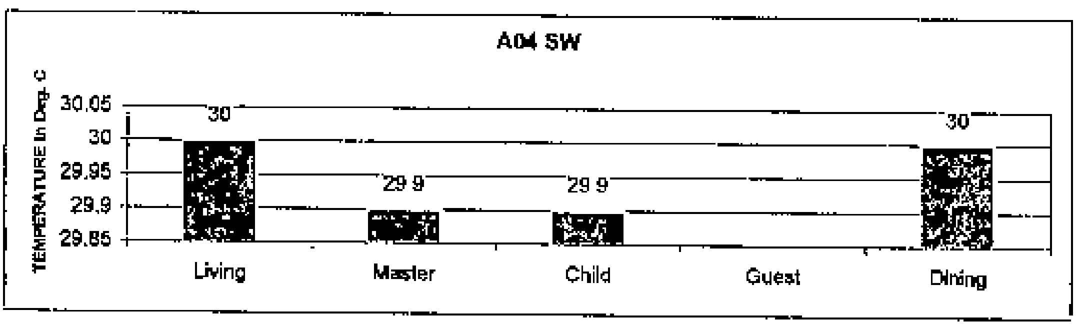
Exter Temp 30.8C
Exter Hum 85%

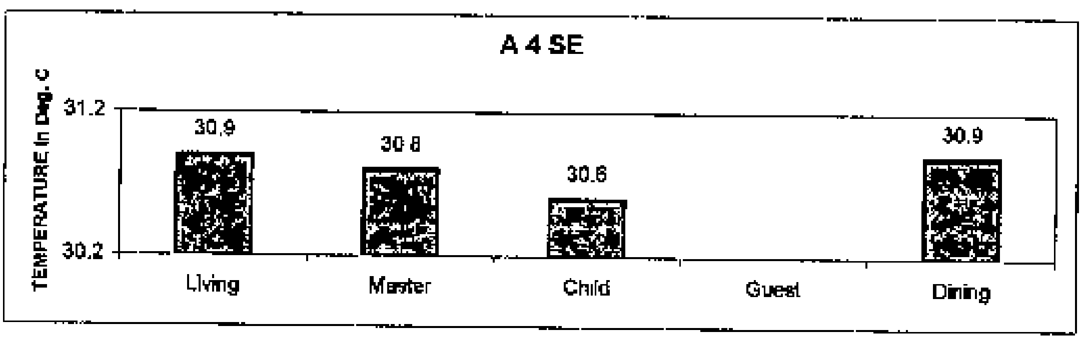
CODE : **G 02 NW** SQUARE TOWER PLAN : 2nd Floor

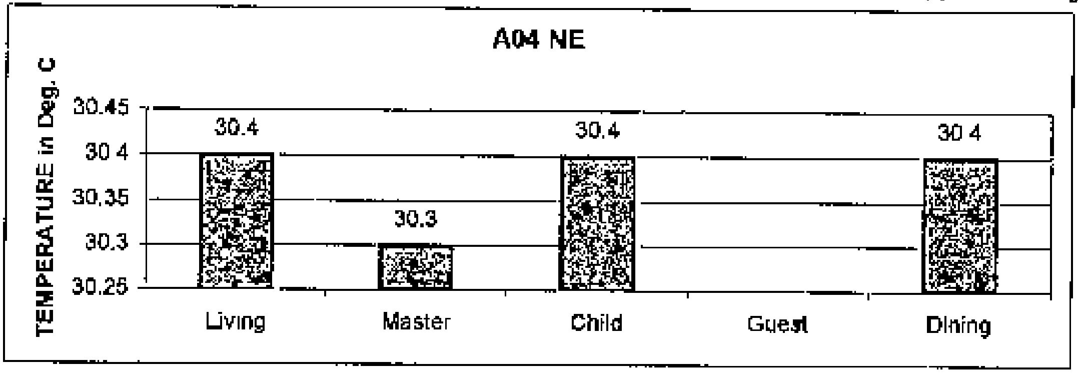
Appendix 4-04 (a) VARIATIONS OF TEMPERATURE IN VARIOUS ROOMS AND SPACES IN THE LIVING UNITS

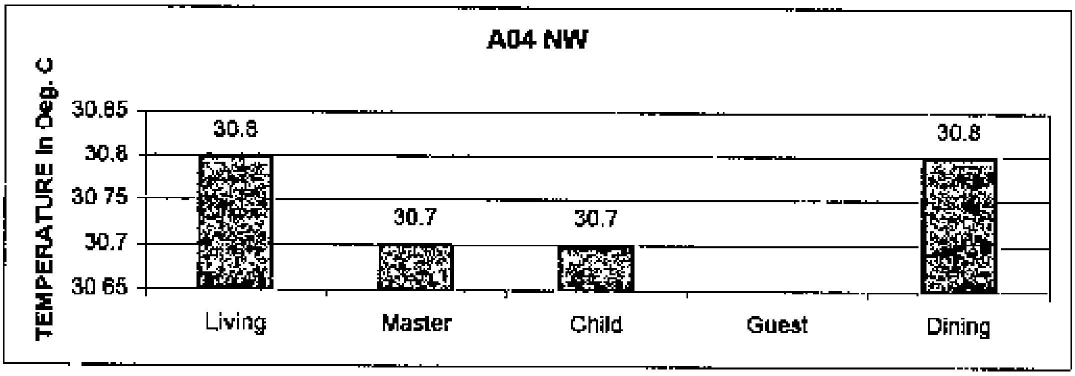


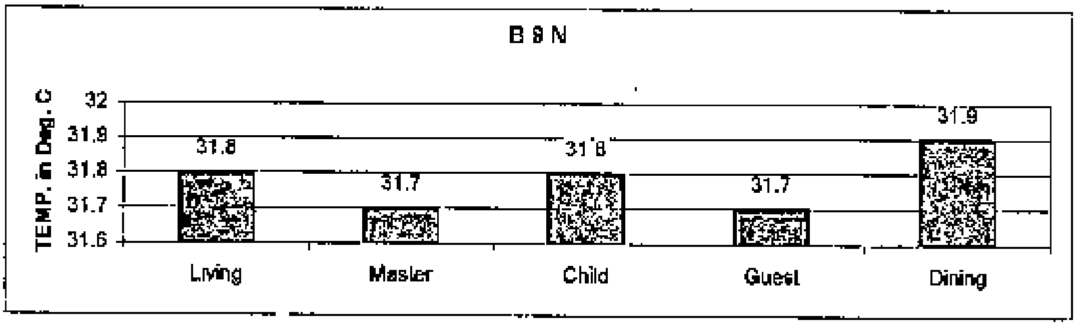


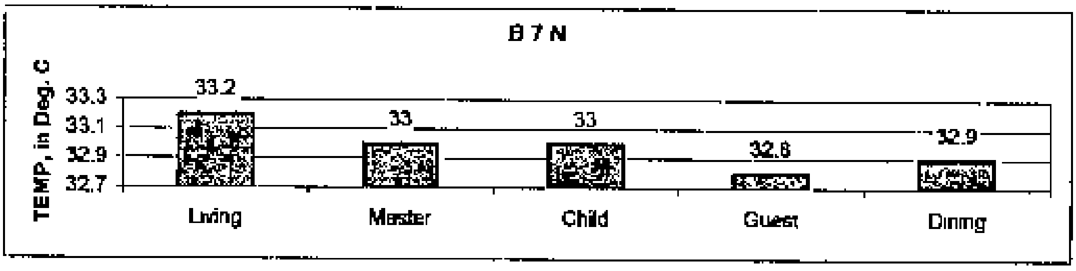


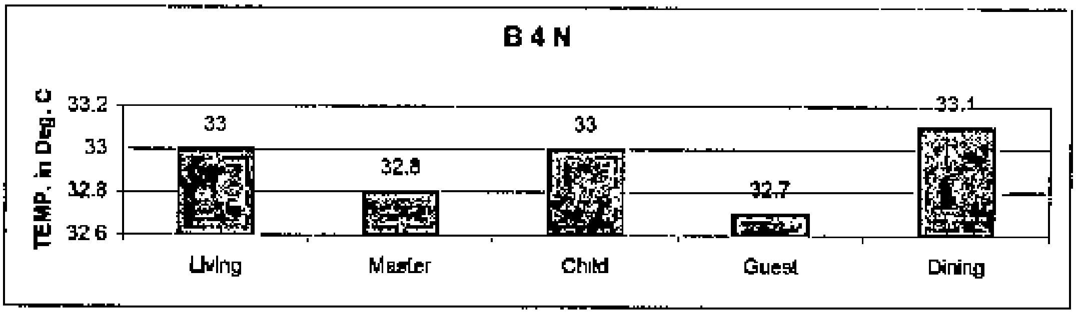


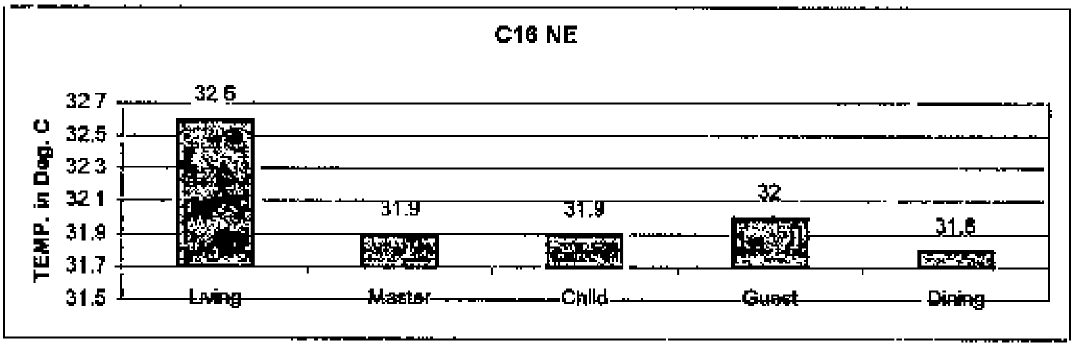

A04 NE
TEMPERATURE in Deg. C
30.45
30 4
30.35
30.3
30.25
30.4
30.3
30.4
30 4
Living
Master
Child
Guest
Dining

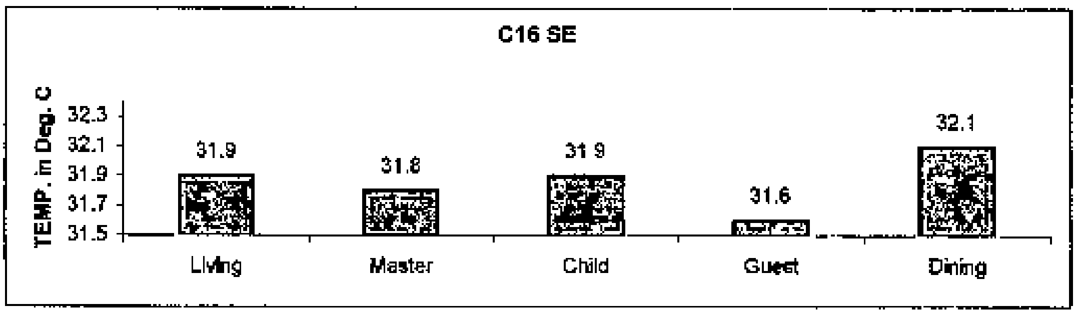

A04 NW
TEMPERATURE in Deg. C
30.85
30.8
30 75
30.7
30 65
30.8
30.7
30.7
30.8
Living
Master
Child
Guest
Dining

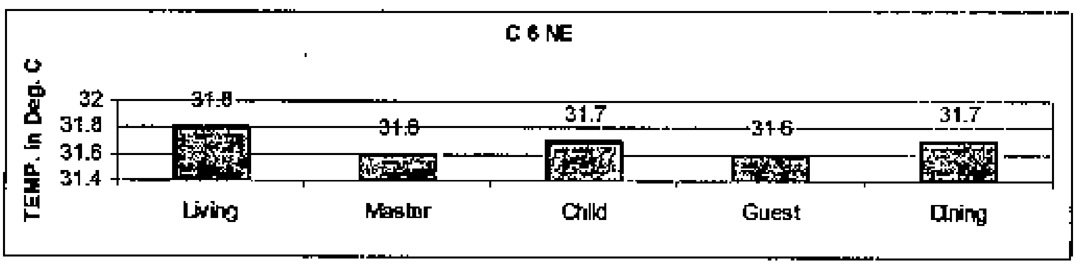

B 8 N
TEMP. in Deg. C
32
31.9
31.8
31.7
31.6
31.8
31.7
31.8
31.7
31.9
Living
Master
Child
Guest
Dining

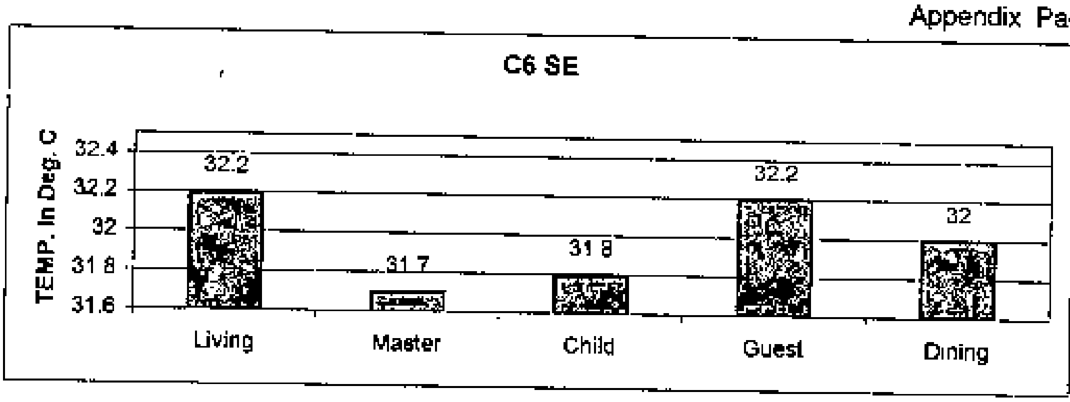

B 7 N
TEMP, in Deg. C
33.3
33.1
32.9
32.7
33.2
33
33
32.8
32.9
Living
Master
Child
Guest
Dining

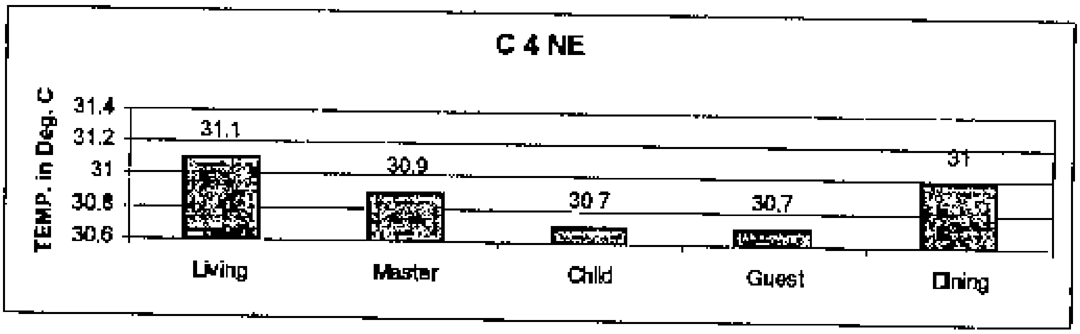

B 4 N
TEMP. in Deg. C
33.2
33
32.8
32.6
33
32.8
33
32.7
33.1
Living
Master
Child
Guest
Dining

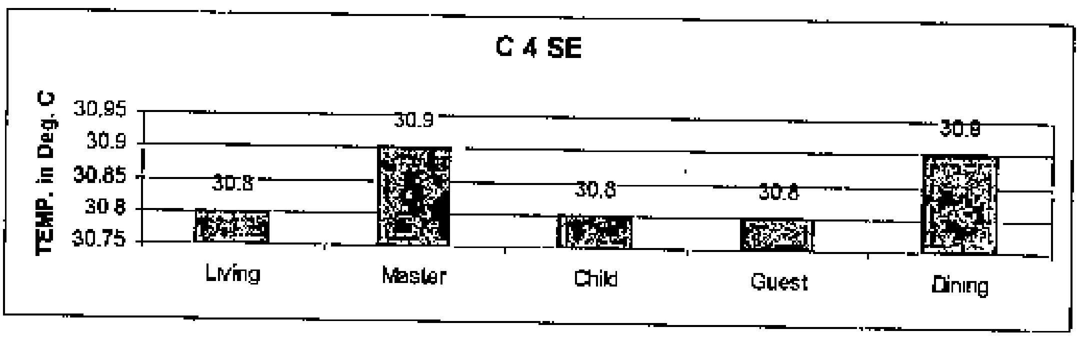

C16 NE
TEMP. in Deg. C
32.7
32.5
32.3
32.1
31.9
31.7
31.5
32.6
31.9
31.9
32
31.8
Living
Master
Child
Guest
Dining

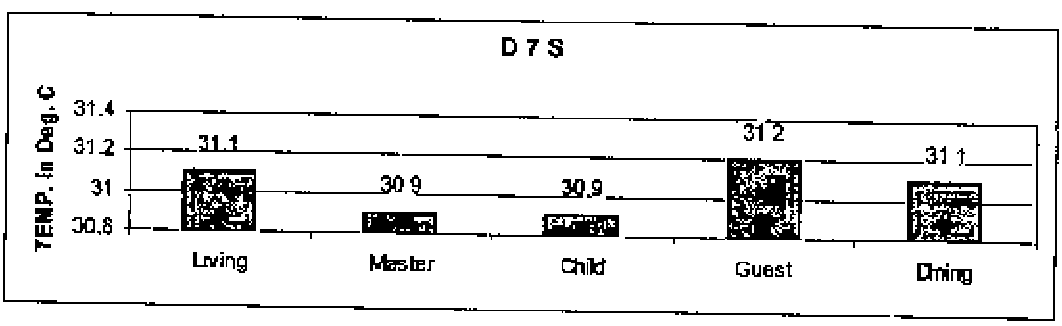

C16 SE
TEMP. in Deg. C
32.3
32.1
31.9
31.7
31.5
31.9
31.8
31.9
31.6
32.1
Living
Master
Child
Guest
Dining

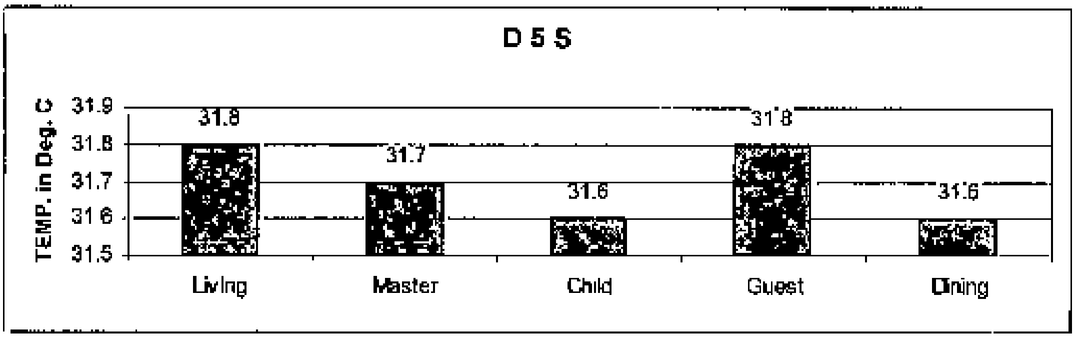

C 6 NE
TEMP. in Deg. C
32
31.8
31.6
31.4
31.8
31.6
31.7
31.6
31.7
Living
Master
Child
Guest
Dining

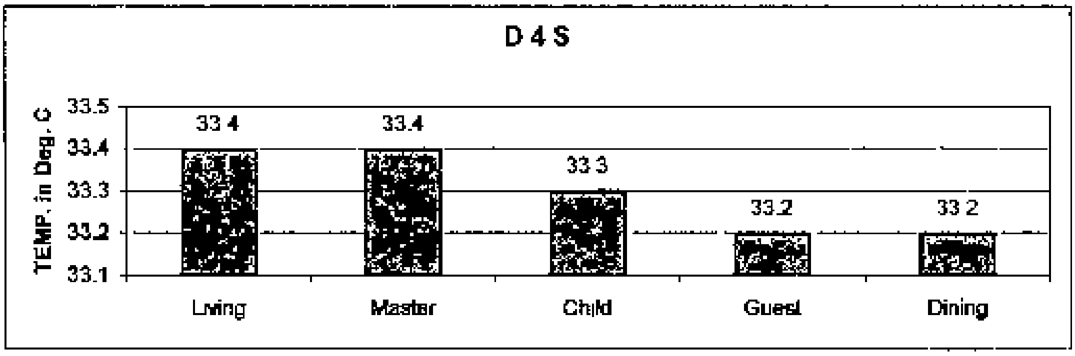

C6 SE
TEMP. In Deg. C
32.4
32.2
32
31.8
31.6
32.2
31.7
31.8
32.2
32
Living
Master
Child
Guest
Dining

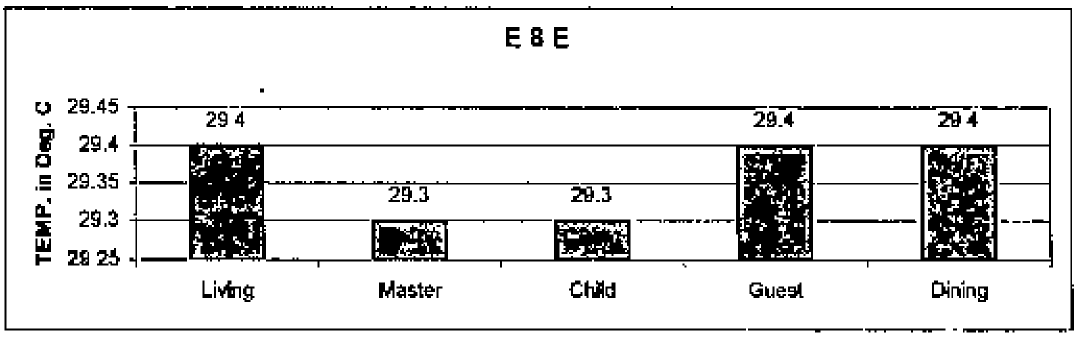

C 4 NE
TEMP. in Deg. C
31.4
31.2
31
30.8
30.6
31.1
30.9
30.7
30.7
31
Living
Master
Child
Guest
Dining

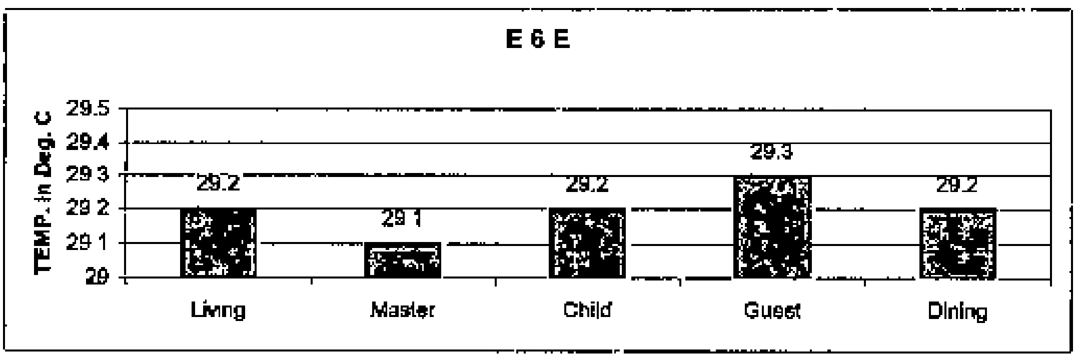

C 4 SE
TEMP. in Deg. C
30.95
30.9
30.85
30.8
30.75
30.8
30.9
30.8
30.8
30.9
Living
Master
Child
Guest
Dining

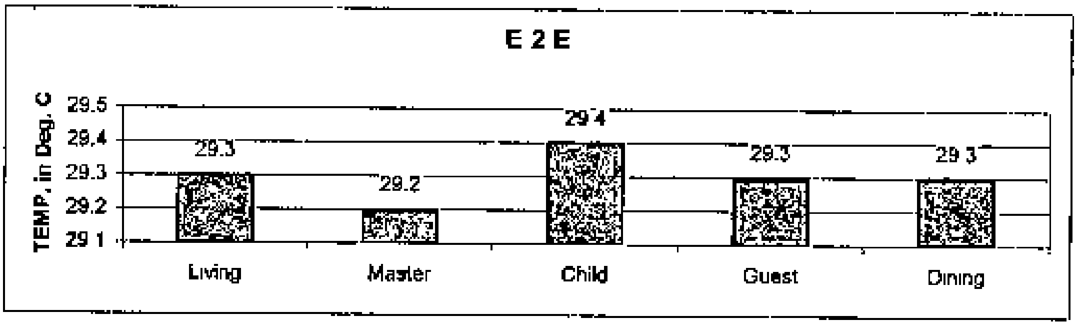

D 7 S
TEMP. in Deg. C
31.4
31.2
31
30.8
31.1
30.9
30.9
31.2
31.1
Living
Master
Child
Guest
Dining

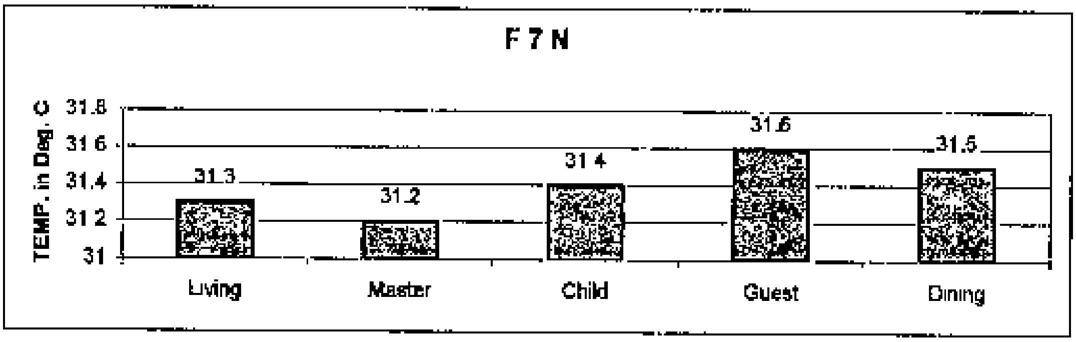

D 5 S
TEMP. in Deg. C
31.9
31.8
31.7
31.6
31.5
31.8
31.7
31.6
31.8
31.6
Living
Master
Child
Guest
Dining

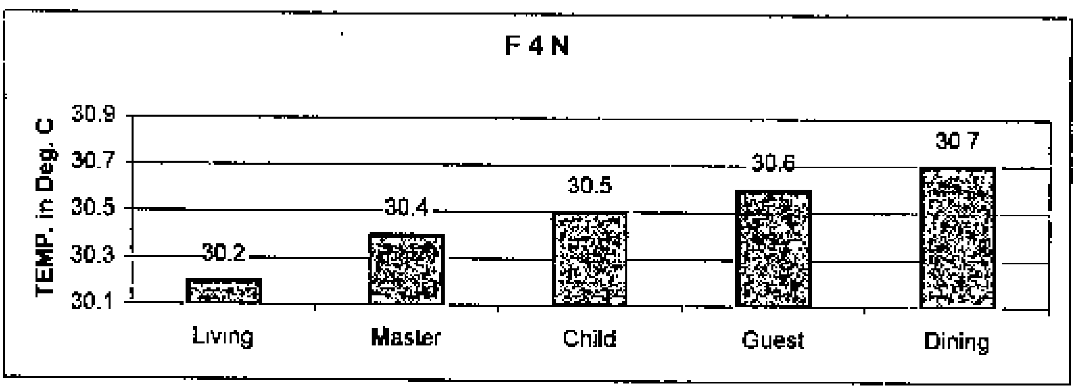

D 4 S
TEMP. in Deg. C
33.5
33.4
33.3
33.2
33.1
33.4
33.4
33.3
33.2
33.2
Living
Master
Child
Guest
Dining

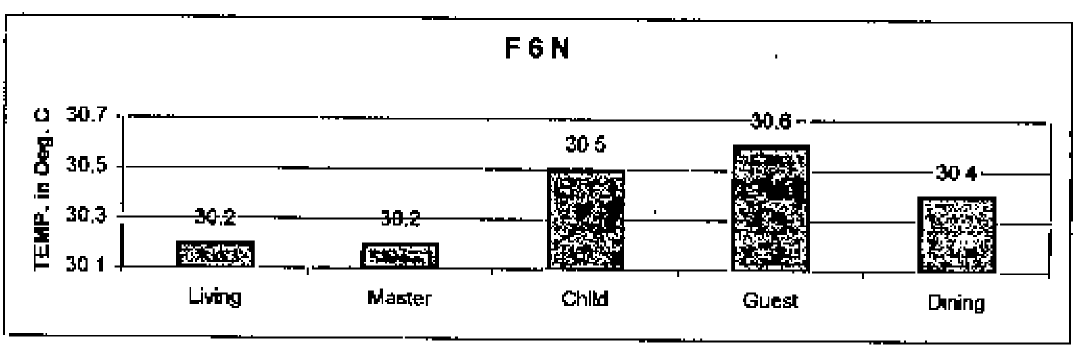

E 8 E
TEMP. in Deg. C
29.45
29.4
29.35
29.3
29.25
29.4
29.3
29.3
29.4
29.4
Living
Master
Child
Guest
Dining

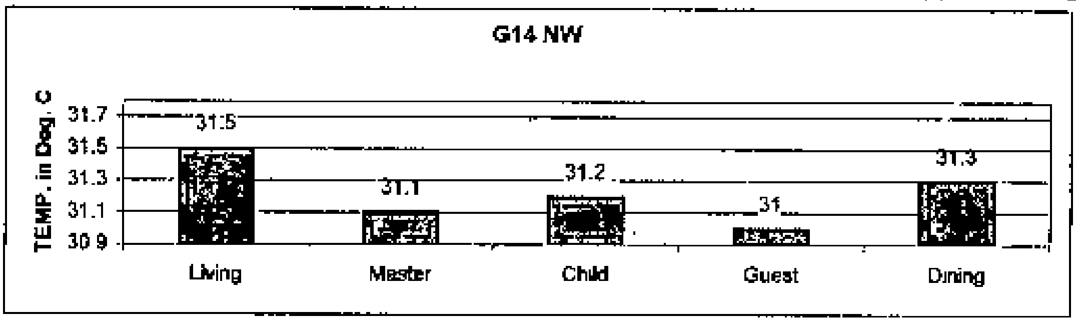

E 6 E
TEMP. in Deg. C
29.5
29.4
29.3
29.2
29.1
29
29.2
29.1
29.2
29.3
29.2
Living
Master
Child
Guest
Dining

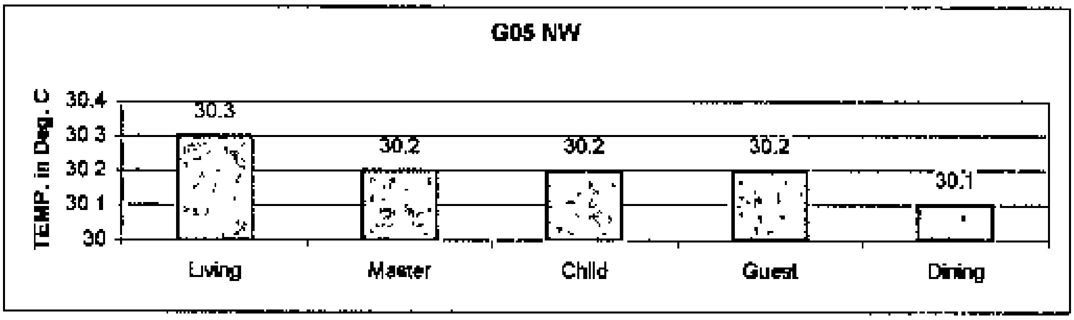

E 2 E
TEMP. in Deg. C
29.5
29.4
29.3
29.2
29 1
29.3
29.2
29 4
29.3
29 3
Living
Master
Child
Guest
Dining

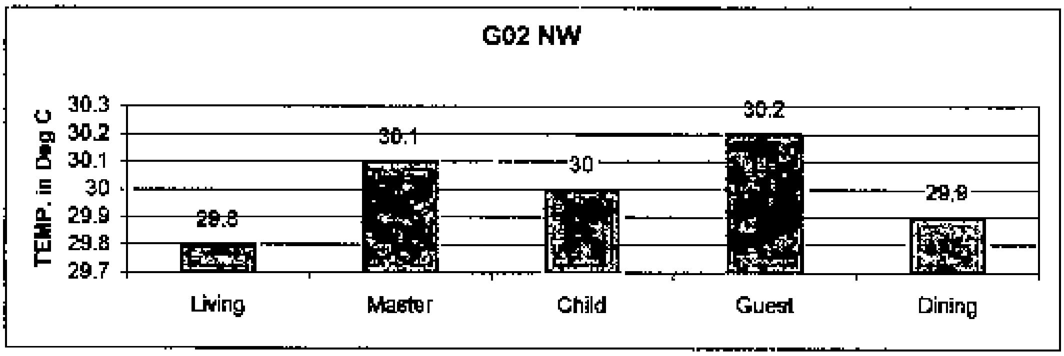

F 7 N
TEMP. in Deg. C
31.8
31 6
31.4
31 2
31
31.3
31.2
31 4
31.6
31.5
Living
Master
Child
Guest
Dining


F 4 N
TEMP. in Deg. C
30.9
30.7
30.5
30.3
30.1
30.2
30.4
30.5
30.6
30 7
Living
Master
Child
Guest
Dining

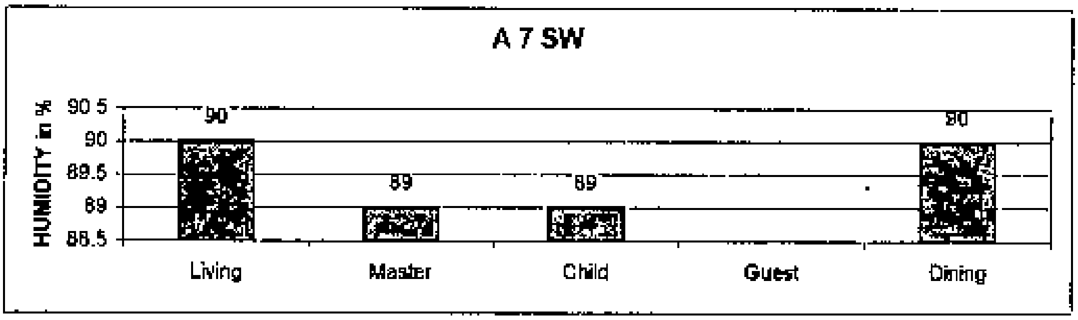

F 6 N
TEMP. in Deg. C
30.7
30.5
30.3
30 1
30.2
30.2
30 5
30.6
30 4
Living
Master
Child
Guest
Dining

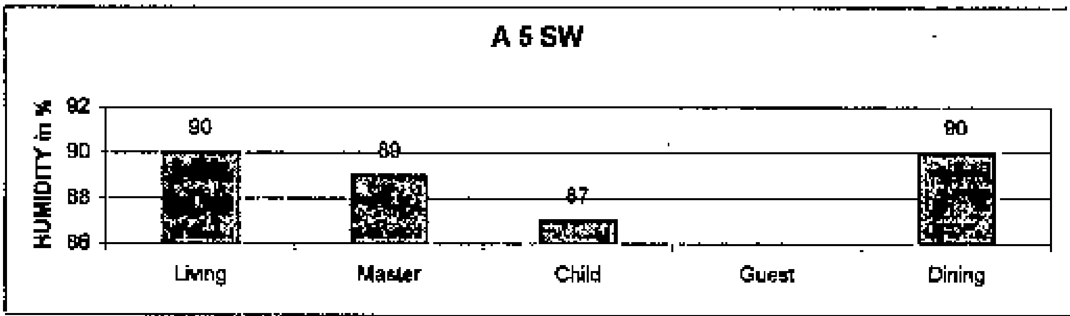

G14 NW
TEMP. in Deg. C
31.7
31.5
31.3
31.1
30.9
31.5
31.1
31.2
31
31.3
Living
Master
Child
Guest
Dining

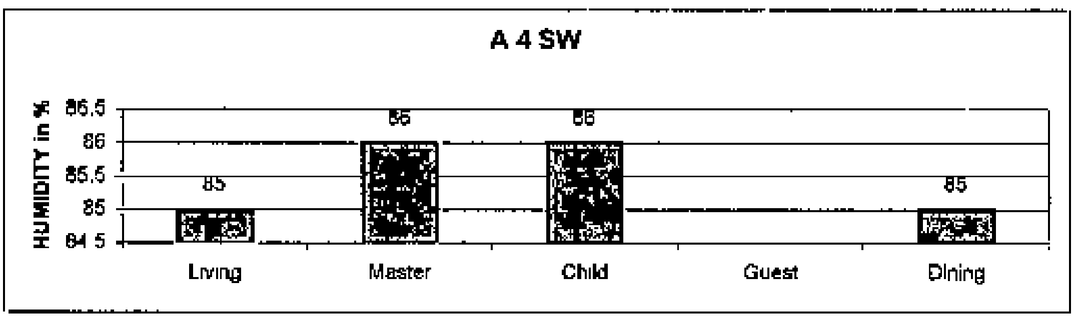

G05 NW
TEMP. in Deg. C
30.4
30.3
30.2
30.1
30
30.3
30.2
30.2
30.2
30.1
Living
Master
Child
Guest
Dining

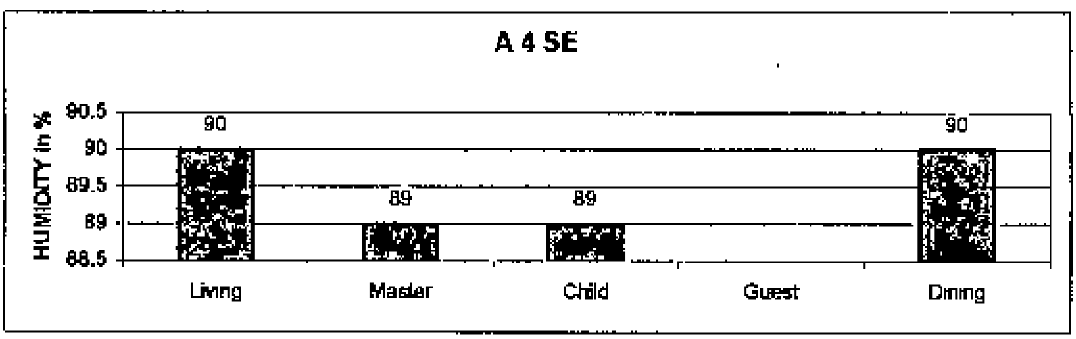

G02 NW
TEMP. in Deg C
30.3
30.2
30.1
30
29.9
29.8
29.7
29.8
30.1
30
30.2
29.9
Living
Master
Child
Guest
Dining

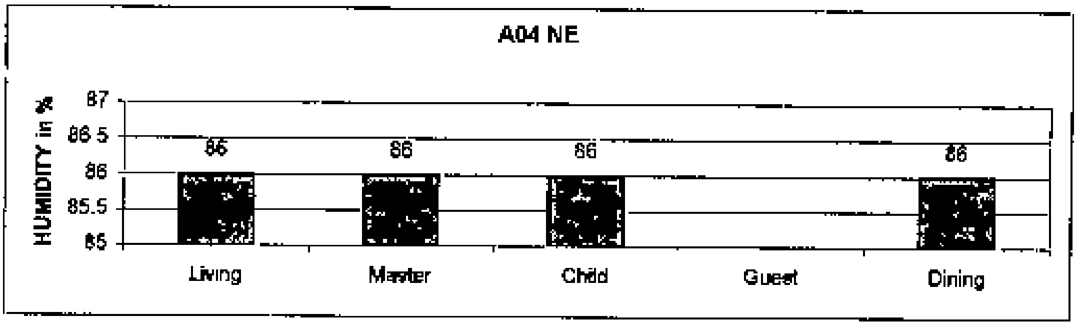
Appendix 4-04 (b) VARIATIONS OF HUMIDITY IN VARIOUS ROOMS AND SPACES IN THE LIVING UNITS

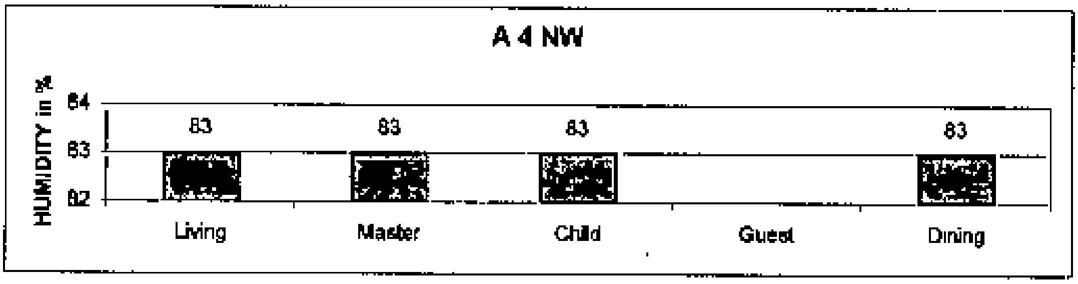


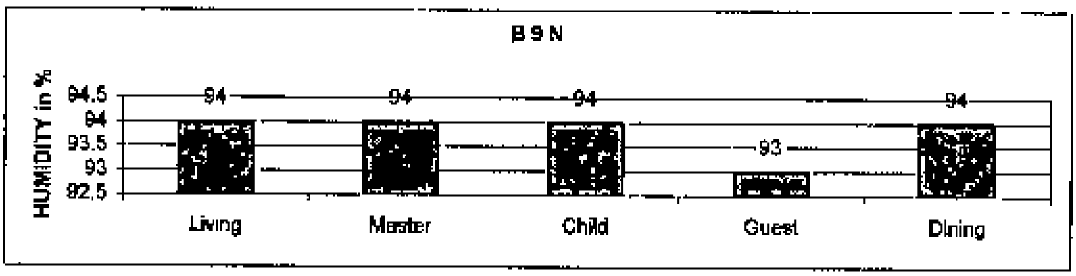


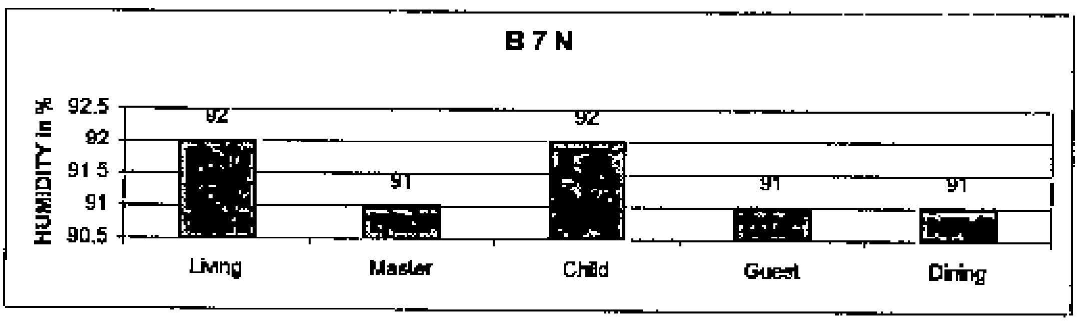


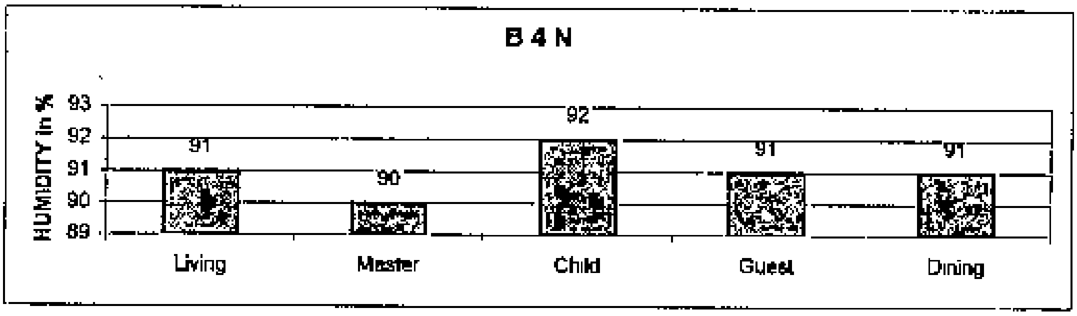


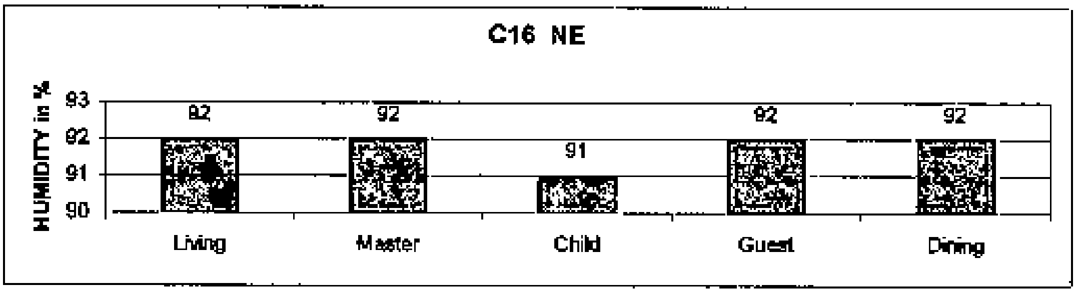

A04 NE
HUMIDITY in %
87
86.5
86
85.5
85
86
86
86
86
Living
Master
Child
Guest
Dining

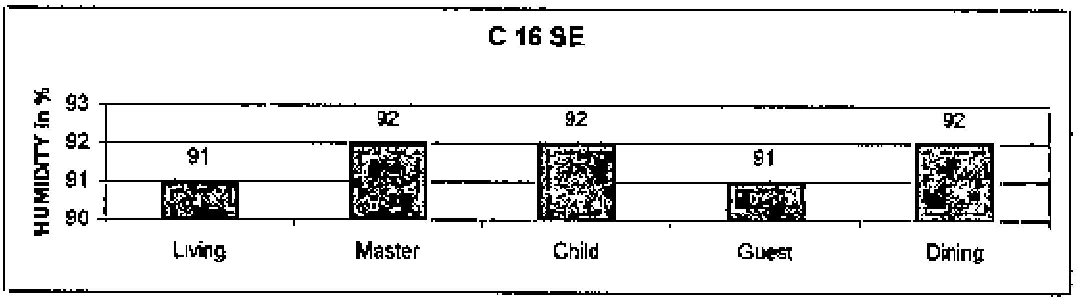

A 4 NW
HUMIDITY in %
84
83
82
83
83
83
83
Living
Master
Child
Guest
Dining

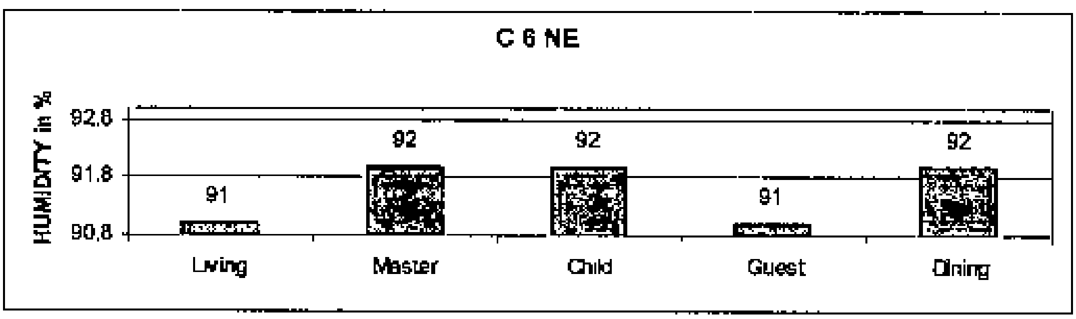

B 9 N
HUMIDITY in %
94.5
94
93.5
93
92.5
94
94
94
93
94
Living
Master
Child
Guest
Dining


B 7 N
HUMIDITY in %
92.5
92
91.5
91
90.5
92
91
92
91
91
Living
Master
Child
Guest
Dining


B 4 N
HUMIDITY in %
93
92
91
90
89
91
90
92
91
91
Living
Master
Child
Guest
Dining


C16 NE
HUMIDITY in %
93
92
91
90
92
92
91
92
92
Living
Master
Child
Guest
Dining


C 16 SE
HUMIDITY in %
93
92
91
90
91
92
92
91
92
Living
Master
Child
Guest
Dining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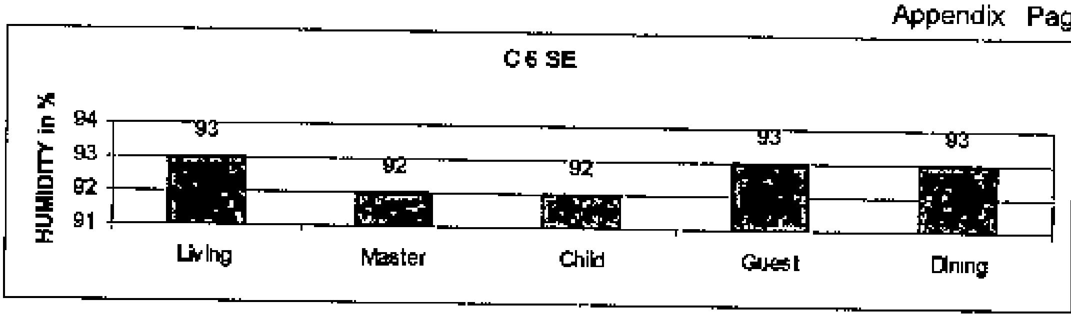
Living
Master
Child
Guest
Dining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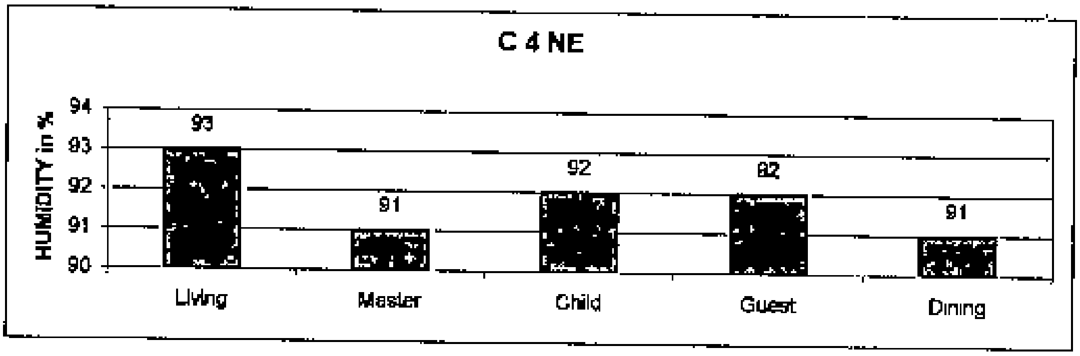
Master
Child
Guest
Dining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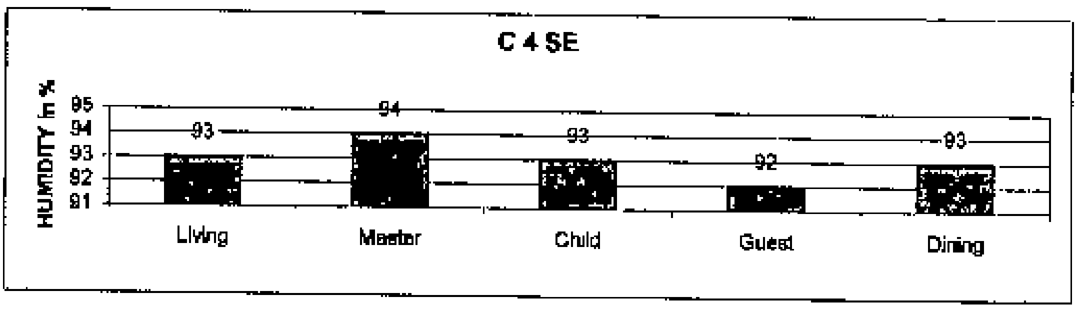
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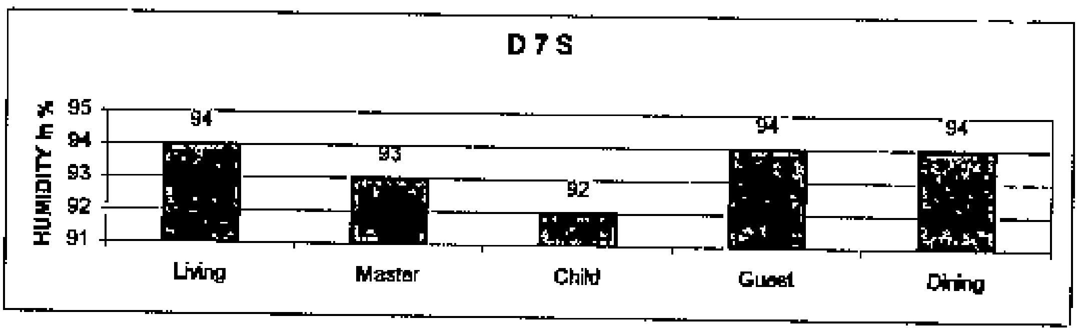
Guest
Dining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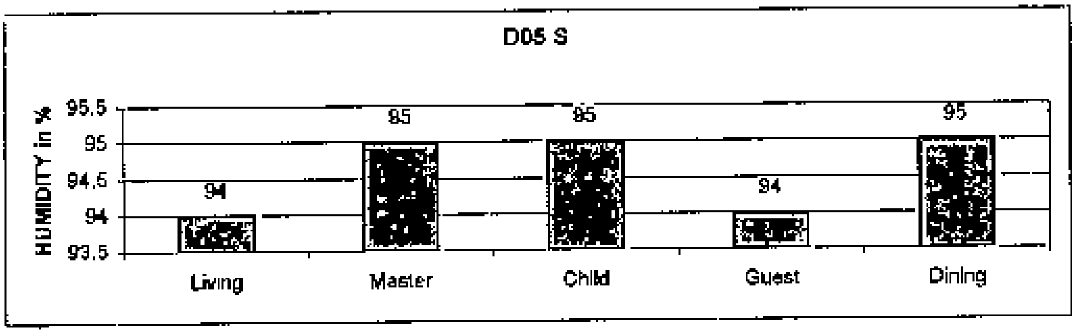
Dining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94.5
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93.5
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95
95
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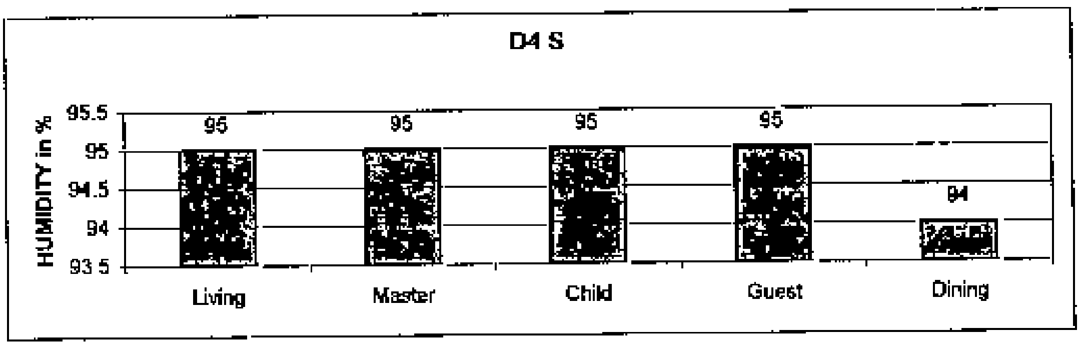
Child
Guest
Dining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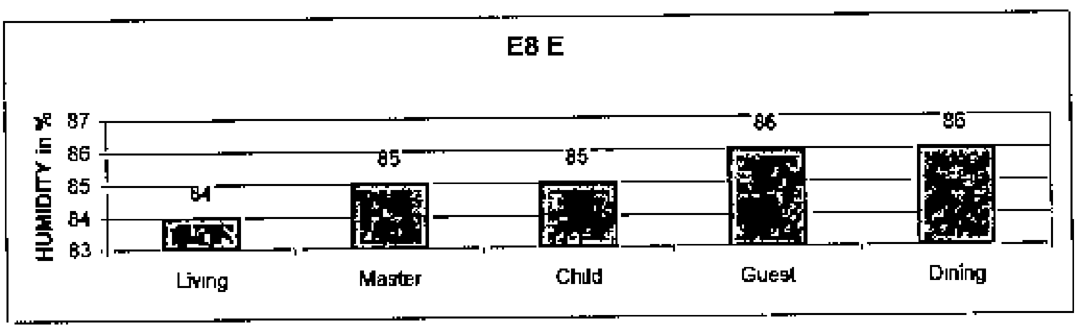
Guest
Dining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HUMIDITY in %
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86
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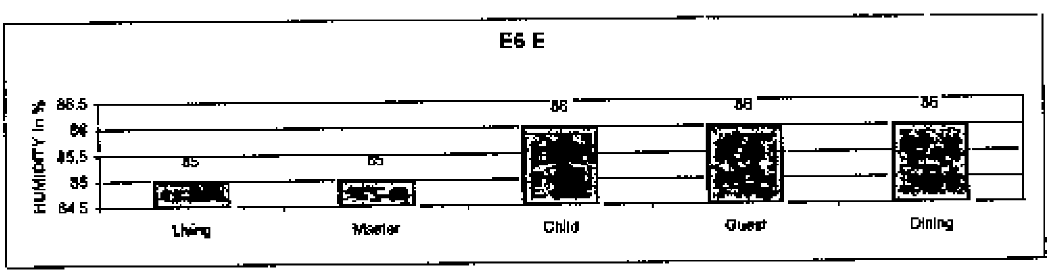
Living
Master
Child
Guest
Dining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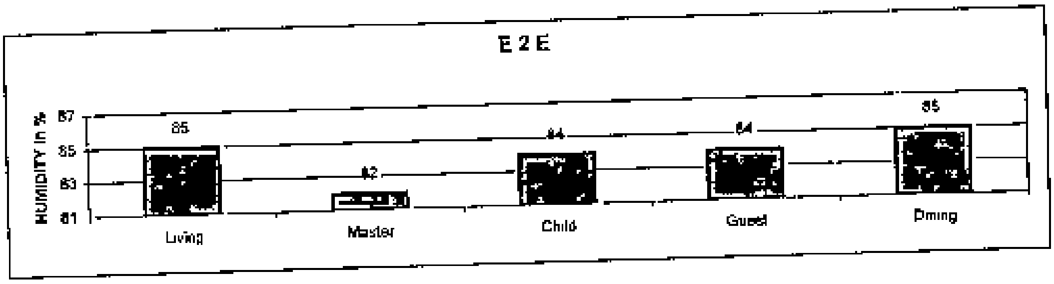
HUMIDITY in %
Child
Dining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HUMIDITY in %
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84
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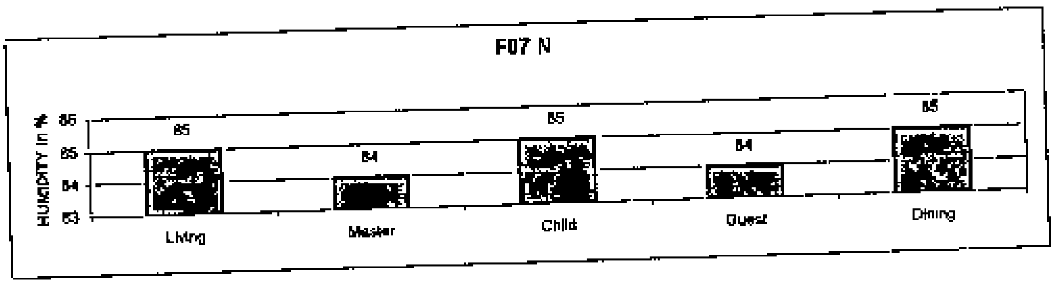
Living
Master
Child
Guest
Dining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85
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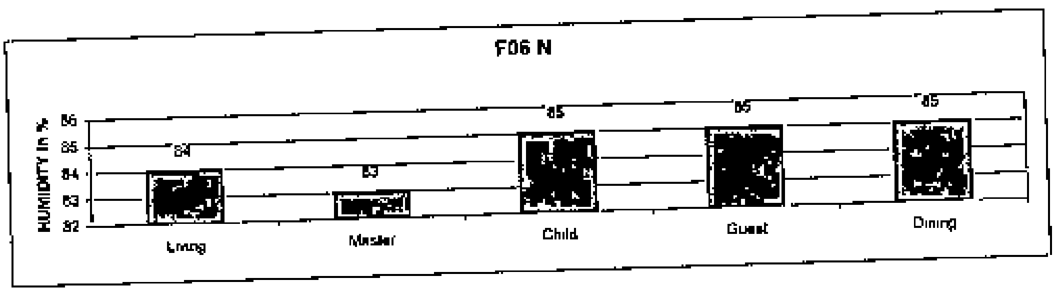
85
Living
Master
Child
Guest
Dining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85
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85
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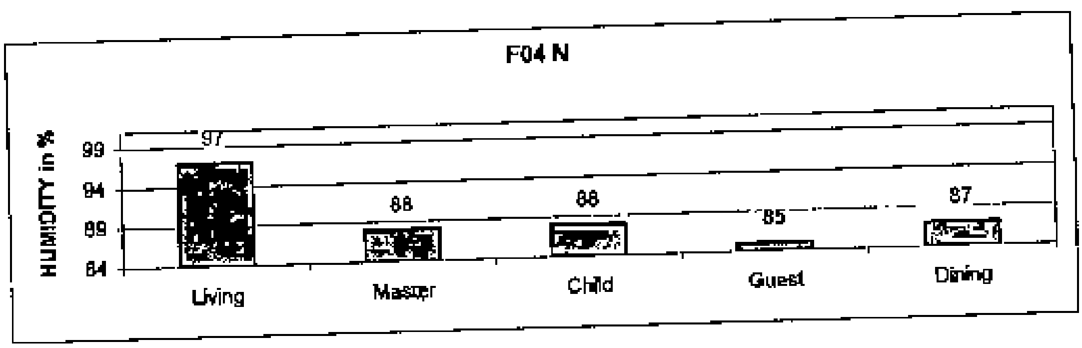
Master
Child
Guest
Dining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HUMIDITY in %
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85
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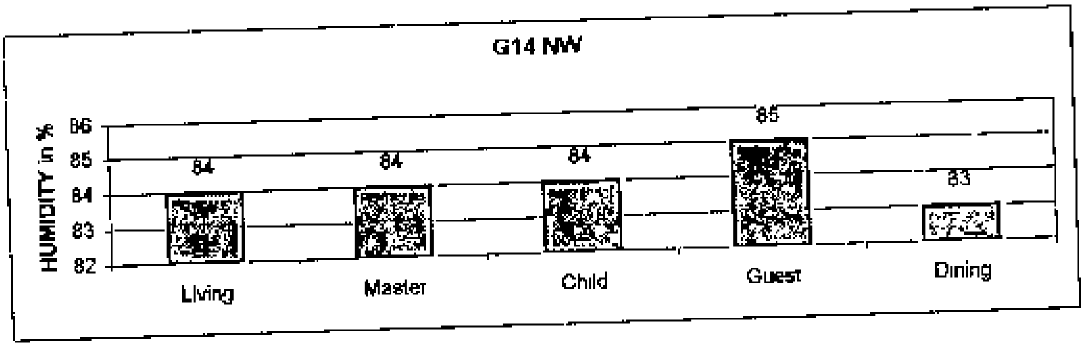
Living
Master
Child
Guest
Dining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HUMIDITY in %
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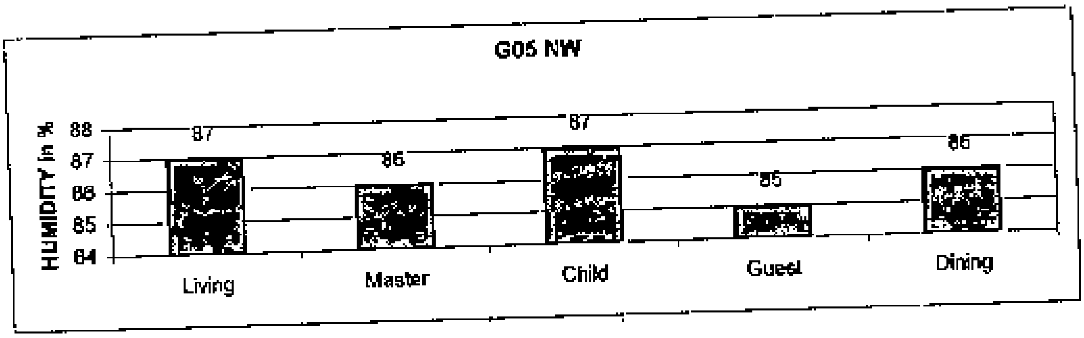
83
Living
Master
Child
Guest
Dining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HUMIDITY in %
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84
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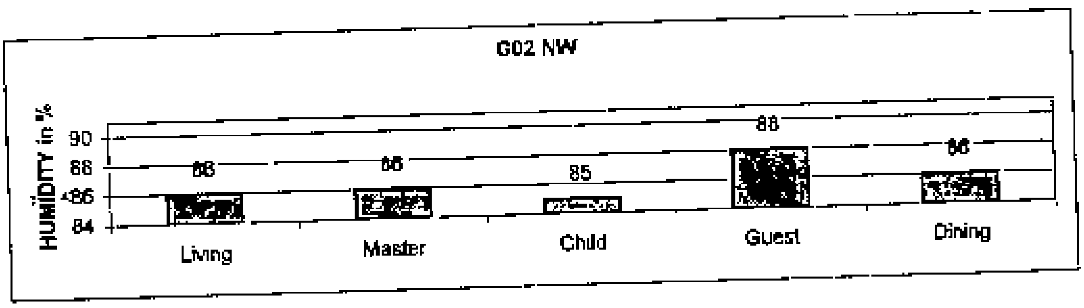
86
87
85
86
Living
Master
Child
Guest
Dining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HUMIDITY in %
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86
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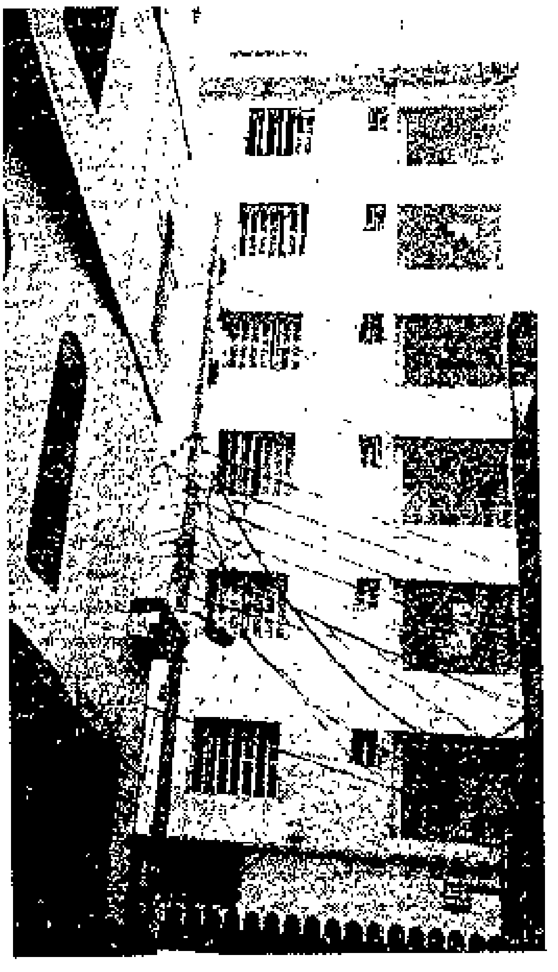
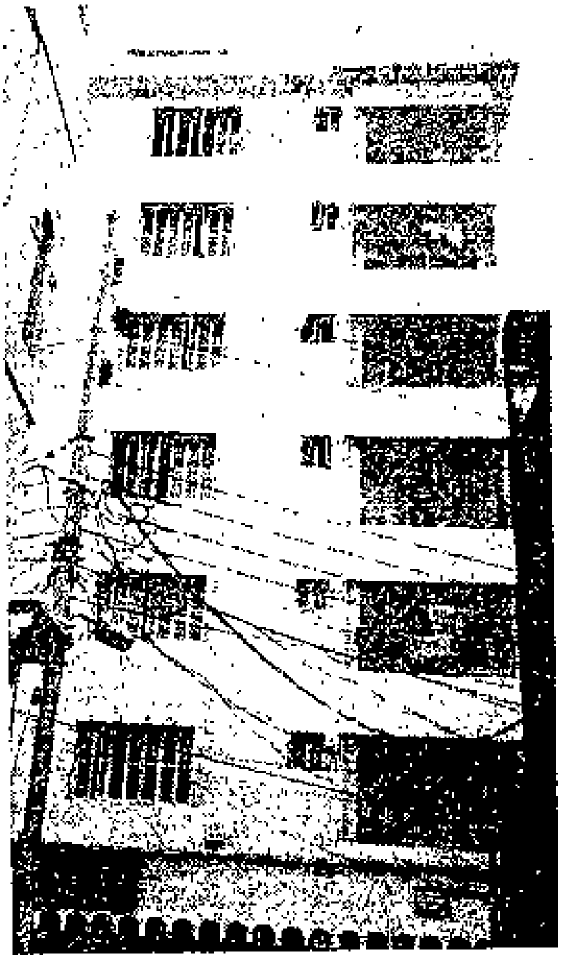
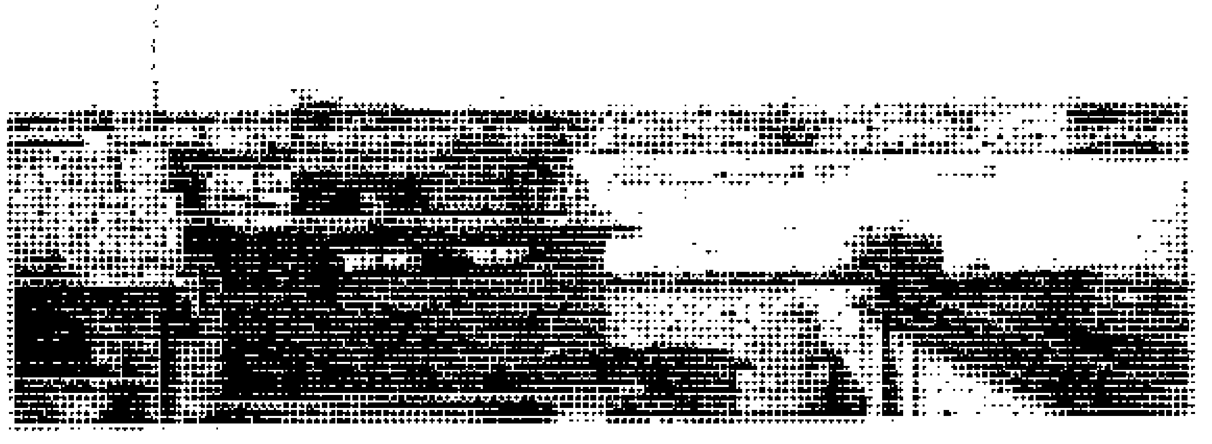
86
86
85
88
86
Living
Master
Child
Guest
Dining

APPENDIX - 03 EXTERNAL VIEWS OF APARTMENT BUILDINGS



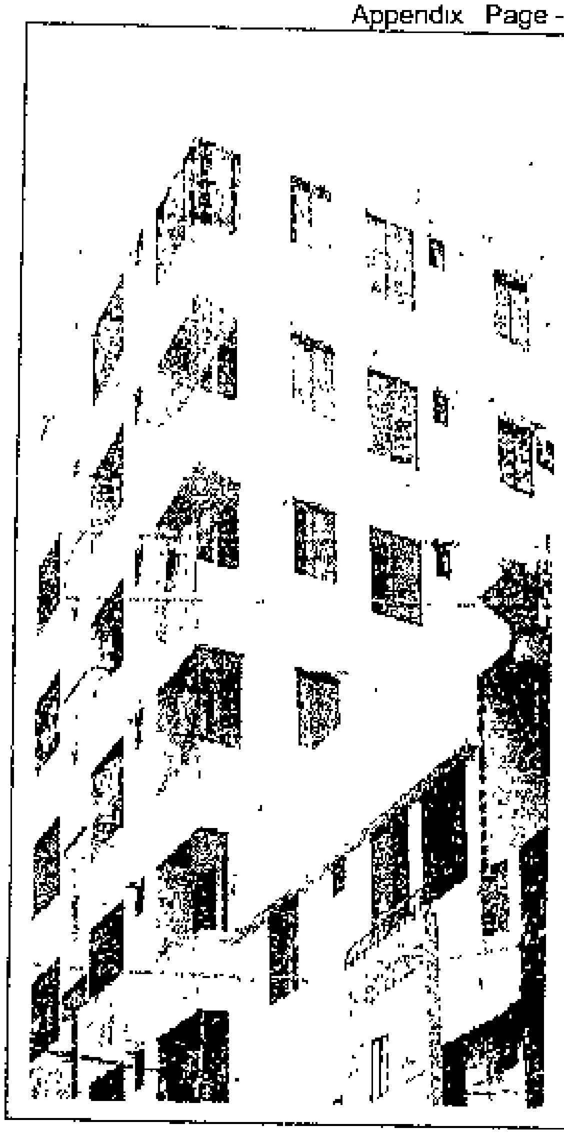


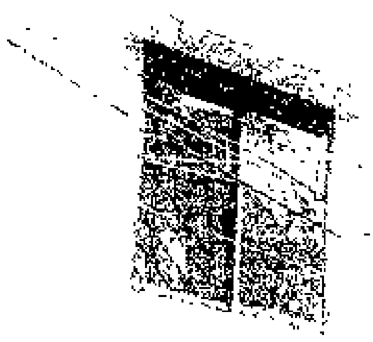


WAHIDUZZAMAN BHABAN, AT B.K.DAS ROAD DHAKA

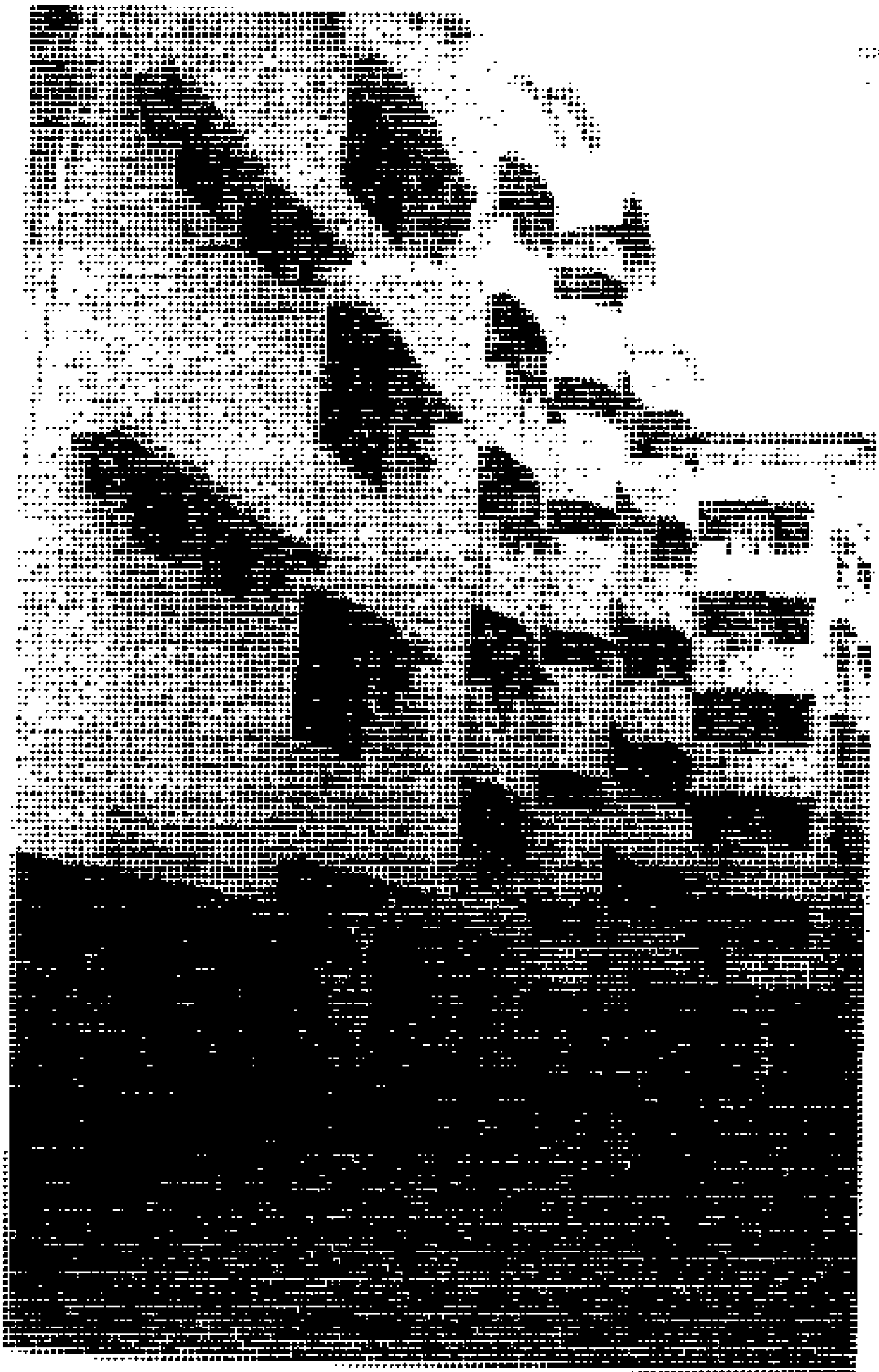
RIVER ON SOUTH (BELOW)

EHL-1 AND EHL-2 BUILDINGS AT SHANTINAGAR



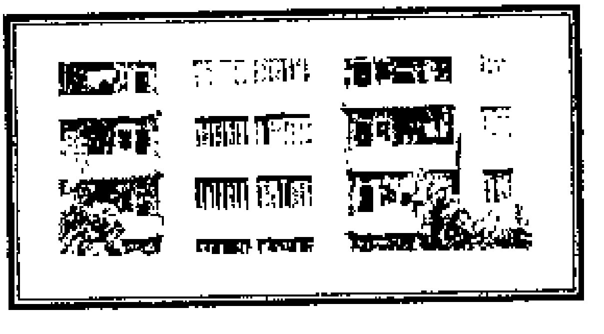


RAZZAK & REZA COMPLEX AT ELEPHANT ROAD DHAKA
WINDOWS OF REZA COMPLEX



MONIHAR-SHELTECH BUILDING AT MONIPURIPARA, FARMGATE

SQUARE TOWER
AT MIRPUR ROAD
DHAKA



APPENDIX - 05 : MINIMUM VENTILATION RATES WHERE DENSITY OF OCCUPATION IS KNOWN

Table V Minimum ventilation rates where density of occupation is known

Air space per person (m^3)	Fresh air supply per person (litre/s) Recommended (smoking permitted)	Recommended (no smoking)	Minimum
3	22·6	17·0	11·3
6	14·2	10·7	7·1
9	10·4	7·8	5·2
12	8·0	6·0	4·0

SOURCE - NEW METRIC HANDBOOK Edited by Patricia Tutt and David Adler Published by The Architectural Press, London1970 Page - 384

APPENDIX - 06 : HEAT PRODUCTION BY PEOPLE

Table VI Heat production by people

Degree of activity	Total adult male heat production (W)
Seated at rest	115
Light work	140
Walking slowly	160
Light bench work	235
Medium work, dancing	265
Heavy work	440

SOURCE - NEW METRIC HANDBOOK Edited by Patricia Tutt and David Adler Published by The Architectural Press, London1970 Page 384

APPENDIX - 07 : INFILTRATION THROUGH WALLS

Table VII Infiltration through walls in litre/(m^2s)

Type		Pressure difference (Pa) 12.5	25	50	75	100
One brick	plain	0.425	0.765	1.36	2.04	2.38
	plastered	0.004	0.007	0.012	0.017	0.023
1½ brick	plain	0.425	0.680	1.19	1.70	2.04
	plastered	0.001	0.003	0.004	0.008	0.009
Lath and plaster		0.008	0.013	0.019	0.025	0.027

SOURCE : NEW METRIC HANDBOOK Edited by Patricia Tutt and David Adler Published by The Architectural Press, London1970. Page 384

APPENDIX - 08 : WINDOW INFILTRATION CO-EFFICIENTS

Table IX Window infiltration coefficients (C) in litre/(m s Pa)

Window type	C
Horizontally or vertically pivoted, weather-stripped	0.05
Horizontally or vertically sliding, weather-stripped	0.175
Horizontally or vertically pivoted or sliding, no weather-stripping	0.25

SOURCE NEW METRIC HANDBOOK. Edited by Patricia Tutt and David Adler. Published by The Architectural Press, London1970. Page . 385

APPENDIX - 09 : PRESSURE DIFFERENCE ACROSS A BUILDING FROM WIND

Building height m	Total difference in Pa Open country wind speed 9 m/s	Suburban 5.5 m/s	City centre 3 m/s
10	58	21	6
20	70	31	11
30	78	38	15
40	85	44	21
50	90	49	23
60	95	55	26
70	100	59	31
80	104	63	34
90	107	67	37
100	111	71	40

SOURCE NEW METRIC HANDBOOK. Edited by Patricia Tutt and David Adler Published by The Architectural Press, London1970. Page : 385

APPENDIX - 10 : RECOMMENDED DESIGN VALUES FOR INTERNAL ENVIRONMENTAL TEMPERATURES AND EMPIRICAL VALUES FOR AIR FILTRATION AND VENTILATION ALLOWANCES

Table XIII Recommended design values for internal environmental temperatures and empirical values for air infiltration and ventilation allowance (for normal sites and winter heating)

Type of building	t_{ei} (°C)	Air infiltration rate (h^{-1})	Ventilation allowance (W/m³ °C)
Art galleries and museums	20	1	0.31
Assembly halls, lecture halls	18	½	0.17
Banking halls			
Large (height > 4 m)	20	1	0.31
Small (height < 4 m)	20	1½	0.50
Bars	18	1	0.31
Canteens and dining rooms	20	1	0.31
Churches and chapels:			
Up to 7000 m³	18	½	0.17
> 7000 m³	18	¼	0.08
Vestries	20	1	0.31
Dining and banqueting halls	21	½	0.17
Exhibition halls			
Large (height > 4 m)	18	¼	0.08
Small (height < 4 m)	19	½	0.17

APPENDIX - 11 : MECHANICAL VENTILATION RATES FOR VARIOUS TYPES OF BUILDINGS

Table XIV Mechanical ventilation rates for various types of building

Room or building	Recommended air change rates* (h^{-1})
Boilerhouses and engine rooms	15–30
Banking halls	6
Bathrooms, internal	6*
Battery charging rooms	up to 5†
Canteens	8–12‡
Cinemas	6–10‡
Dance halls	10–12‡
Dining and banqueting halls, restaurants	10–15†
Drying rooms	up to 5
Garages, public (parking)	6† minimum
repair shops	10† minimum
Hospitals, treatment rooms	6
operating theatre	15–17
post-mortem room	5
(for further details see Hospital Building notes)	
Kitchens, hotel and industrial	20–60†
local authority	up to 10†
Laboratories	4–6
Laundries	10–15
Lavatories and toilets, internal	6–8†
Libraries, public	3–4‡
book stacks	1–2
Offices, internal	4–6‡
Sculleries and wash ups, large scale	10–15†
Smoking rooms	10–15
Swimming baths,	
bath hall	
changing areas	10
Theatres	6–10‡

SOURCE: NEW METRIC HANDBOOK. Edited by Patricia Tutt and David Adler. Published by The Architectural Press, London 1970. Page . 387

Notes
The recommended air change is intended to include the air for combustion. The actual requirements should be checked in all cases in relation to the particular equipment installed
Under GLC and other regulations, a minimum outdoor air rate of 8 litre/s per person is required See note after Cinemas
(470–570 litre/s input)
The stated air change rates may be used for preliminary design, but should be checked against requirements related to the installed equipment
Inlet air change rate must be checked against extraction rate via fume cupboards
See Factories Act
The recommended rate of air change applies to normal public toilet areas incorporating both wcs and wash basins, etc. For small or congested toilet areas, comprising only wcs and urinals, a better basis is 10 litre/s per m² of floor area. In any case, the extract points should be situated over the wcs and urinals and the extraction rate will correspond to 19–24 litre/s per point. An inlet supply will be required to the lobby with a louvred connecting door
Criterion is the air circulation around books to prevent mould formation. Air volume required depends on disposition of air inlets in shelving to maintain positive air movement. Humidity and SO_2 control may be required
The London Building Act requires not less than 6 litre/s per occupant or per 4.7 m² of floor area, whichever provides the greater ventilation rate
Ventilation rates must be related to the control of condensation. Criterion is the water area and recommended basis is 20 litre/s per m² of water surface, plus a margin (say 20%) to allow for effect of wet surrounds. See also MOHLG Design Bulletin No. 4
Extract from this space should be via clothes storage baskets
See note after Cinemas

SOURCE. NEW METRIC HANDBOOK Edited by Patricia Tutt and David Adler Published by The Architectural Press, London 1970. Page . 385

Table XIII Recommended design values for internal environmental temperatures and empirical values for air infiltration and ventilation allowance (for normal sites and winter heating) *(continued)*

Type of building	t_i (°C)	Air infiltration rate (h^{-1})	Ventilation allowance ($W/m^3\,°C$)
Factories			
Sedentary work	19		
Light work	16		
Heavy work	13		
Fire stations; ambulance stations			
Appliance rooms	15	½	0·17
Watch rooms	20	½	0·17
Recreation rooms	18	1	0·33
Flats, residences, and hostels			
Living rooms	21	1	0·33
Bedrooms	18	½	0·17
Bed-sitting rooms	21	1	0·33
Bathrooms	22	2	0·67
Lavatories and cloakrooms	18	1½	0·50
Service rooms	16	½	0·17
Staircase and corridors	16	1½	0·50
Entrance halls and foyers	16	1½	0·50
Public rooms	21	1	0·33
Gymnasia	16	¾	0·25
Hospitals:			
Corridors	16	1	0·33
Offices	20	1	0·33
Operating theatre suite	18–21	½	0·17
Stores	15	½	0·17
Wards and patient areas	18	2	0·67
Waiting rooms	18	1	0·33
(See also DHSS Building Notes)			
Hotels			
Bedrooms (standard)	22	1	0·33
Bedrooms (luxury)	24	1	0·33
Public rooms	21	1	0·33
Corridors	18	1½	0·50
Foyers	18	1½	0·50
Laboratories	20	1	0·33
Law courts	20	1	0·33
Libraries			
Reading rooms (height > 4 m)	20	½	0·17
(height < 4 m)	20	¾	0·25
Stack rooms	18	½	0·17
Store rooms	15	¼	0·08
Offices			
General	20	1	0·33
Private	20	1	0·33
Stores	15	½	0·17
Police stations:			
Cells	18	5	1·65
Restaurants and tea shops	18	1	0·33
Schools and colleges:			
Classrooms	18	2	0·67
Lecture rooms	18	1	0·33
Studios	18	1	0·33
(See also DES Bulletins)			
Shops and showrooms:			
Small	18	1	0·33
Large	18	½	0·17
Department store	18	¼	0·08
Fitting rooms	21	1½	0·50
Store rooms	15	½	0·17
Sports pavilions:			
Dressing rooms	21	1	0·33
Swimming baths:			
Changing rooms	22	½	0·17
Bath hall	26	½	0·17
(See also MOHLG Design Bulletin 4)			
Warehouses			
Working and packing spaces	16	½	0·17
Storage space	13	¼	0·08

APPENDIX - 12 : U-VALUES FOR VARIOUS CONSTRUCTION

Construction		U Value (W/m^2 °C) Sheltered	Normal (Standard)	Severe
A External walls, masonry construction				
Brickwork				
1 Solid wall, unplastered	105 mm	3·0	3·3	3·6
	220 mm	2·2	2·3	2·4
	335 mm	1·6	1·7	1·8
2 Solid wall, with 16 mm plaster on inside face				
(*a*) With dense plaster	105 mm	2·8	3·0	3·2
	220 mm	2·0	2·1	2·2
	335 mm	1·6	1·7	1·8
(*b*) With lightweight plaster	105 mm	2·3	2·5	2·7
	220 mm	1·8	1·9	2·0
	335 mm	1·4	1·5	1·6
3. Solid wall, with 10 mm plasterboard lining fixed to brickwork with plaster dabs	105 mm	2·6	2·8	3·0
	220 mm	1·9	2·0	2·1
	335 mm	1·5	1·6	1·7
4 Cavity wall (unventilated) with 105 mm outer and inner leaves with 16 mm plaster on inside face	260 mm			
(*a*) With dense plaster		1·4	1·5	1·6
(*b*) With lightweight plaster		1·3	1·3	1·3
5 As 4, but with 220 mm outer leaf and 105 mm inner leaf	375 mm			
(*a*) With dense plaster		1·2	1·2	1·2
(*b*) With lightweight plaster		1·1	1·1	1·1
Brickwork/lightweight concrete block				
6. Cavity wall (unventilated), with 105 mm brick outer leaf 100 mm lightweight concrete block inner leaf and with 16 mm dense plaster on inside face	260 mm	0·93	0·96	0·98
7. As 6, but with 13 mm expanded polystyrene board in cavity		0·69	0·70	0·71
Lightweight concrete block				
8 Solid wall, 150 mm aerated concrete block, with tile hanging externally and with 16 mm plaster on inside face		0·95	0·97	1·0
9 Cavity wall (unventilated) with 75 mm aerated concrete block outer leaf, rendered externally, 100 mm aerated concrete block inner leaf and with 16 mm plaster on inside face 50 mm cavity		0·82	0·84	0·86
Concrete				
10 Cast	150 mm	3·2	3·5	3·9
	200 mm	2·9	3·1	3·4
11 Cast, 150 mm thick, with 50 mm woodwool slab permanent shuttering on inside face finished with 16 mm dense plaster		1·1	1·1	1·1
12 As 11, but 200 mm thick		1·1	1·1	1·1
13. Pre-cast panels, 75 mm thick		3·9	4·3	4·8
14. As 13, but with 50 mm cavity and sandwich lining panels composed of 5 mm asbestos-cement sheet, 25 mm expanded polystyrene and 10 mm plasterboard		0·79	0·80	0·82
15 Pre-cast sandwich panels comprising 75 mm dense concrete, 25 mm expanded polystyrene and 150 mm lightweight concrete		0·71	0·72	0·73

Table XVII U values for various constructions *(continued)*

Construction	U Value (W/m² °C) Sheltered	Normal (Standard)	Severe
5 With mullion projecting inside and outside			
Panel construction 2	1.3	1.5	1.6
,, ,, 3	1.9	2.1	2.4
Curtain walling panelling with 10% bridging by metal mullions 150mm × 50mm wide			
6 With mullion projecting outside, flush inside			
Panel construction 2	1.2	1.2	1.3
,, ,, 3	1.7	1.7	1.8
7 With mullion projecting inside and outside.			
Panel construction 2	2.2	2.5	3.0
,, ,, 3	2.7	3.1	3.6
D Glazing, without frames			
Single window glazing	5.0	5.6	6.7
Double window glazing with air space			
20mm or more (¾in)	2.8	2.9	[illegible]
12mm (½in)	2.8	3.0	[illegible]
6mm (¼in)	3.2	3.4	3.8
3mm (⅛in)	3.6	4.0	4.4
Triple window glazing with air space			
20mm or more (¾in)	1.9	2.0	2.1
12mm (½in)	2.0	2.1	2.2
6mm (¼in)	2.3	2.5	2.6
3mm (⅛in)	2.8	3.0	3.1
Roof glazing skylight	5.7	6.6	7.9
Horizontal laylight with skylight or lantern light over			
Ventilated	3.5	3.8	4.2
Unventilated	2.8	3.0	3.3

E Typical windows

Window type	Fraction of area occupied by frame	U values for stated exposure (W/m² °C) Sheltered	Normal	Severe
Single glazing				
Wood frame	30%	3.8	4.3	5.0
Metal frame	20%	5.0	5.6	6.7
Double glazing,				
Wood frame	30%	2.3	2.5	2.7
Metal frame with thermal break	20%	3.0	3.2	3.5

Construction	U Value (W/m² °C) Sheltered	Normal (Standard)	Severe
F Pitched roofs (35° slope)			
1. Tiles on battens, roofing felt and rafters, with roof space and aluminium foil-backed 10mm plasterboard ceiling on joists	1.4	1.5	1.6
2. As 1, but with boarding on rafters	1.3	1.3	1.3
3 As 2, but with 50mm glass-fibre insulation between joists	0.49	0.50	0.51
4 Corrugated asbestos-cement sheeting	5.3	6.1	7.2
5 As 4, but with cavity and aluminium foil-backed 10mm plasterboard lining	1.8	1.9	2.0

Table XVII U values for various constructions *(continued)*

Construction	U Value (W/m² °C)		
	Sheltered	Normal (Standard)	Severe
16. Pre-cast panels 38 mm on timber battens and framing with 10 mm plasterboard lining and 50 mm glass-fibre insulation in cavity (Assumed 10% area of glass fibre bridged by timber)	0·61	0·62	0·63
B External walls, framed construction			
Tile hanging			
1. On timber battens and framing with 10 mm plasterboard lining, 50 mm glass-fibre insulation in the cavity and building paper behind the battens (Assumed 10% area of glass fibre bridged by timber)	0·64	0·65	0·66
Weatherboarding			
2. On timber framing with 10 mm plasterboard lining, 50 mm glass-fibre insulation in the cavity and building paper behind the boarding (Assumed 10% area of glass fibre bridged by timber)	0·61	0·62	0·63
Corrugated sheeting			
3. 5 mm thick asbestos-cement (No allowance has been made for effect of corrugations on heat loss)	4·7	5·3	6·1
4. As 3, but with cavity and aluminium foil-backed plasterboard lining	1·7	1·8	1·9
5. Double-skin asbestos-cement with 25 mm glass-fibre insulation in between	1·1	1·1	1·1
6. As 5, but with cavity and aluminium foil-backed plasterboard lining	0·76	0·78	0·79
7. Aluminium:			
(a) Bright surface outside and inside	2·4	2·6	2·9
(b) Dull surface outside bright surface inside	2·6	2·8	3·0
8. As 7, but with cavity and aluminium foil-backed plasterboard lining:			
(a) Bright surface outside	1·7	1·8	1·9
(b) Dull " "	1·8	1·9	2·0
9. Plastic-covered steel	5·0	5·7	6·6
10. As 9, but with cavity and aluminium foil-backed plasterboard lining	1·8	1·9	2·0
C External walls, curtain wall construction			
Composite cladding panels			
1. Comprising 25 mm expanded polystyrene between 5 mm asbestos-cement sheets set in metal framing, 50 mm cavity, 100 mm lightweight concrete block inner wall, finished with 16 mm plaster rendering on inside face (Assumed 5% area of expanded polystyrene bridged by metal framing)	0·79	0·81	0·83
2. Obscured glass, 38 mm expanded polystyrene cavity 100 mm lightweight concrete back-up wall, dense plaster	0·51	0·51	0·52
3. Stove-enamelled steel sheet, 10 mm asbestos board, cavity, 100 mm lightweight concrete back-up wall, dense plaster	1·1	1·1	1·1
Curtain walling panelling with 5% bridging by metal mullions, 150 mm × 50 mm wide			
4. With mullion projecting outside flush inside			
Panel construction 2	0·8	0·9	0·9
" " 3	1·4	1·4	1·5

Table XVII U values for various constructions (*continued*)

Construction	U Value (W/m² °C) Sheltered	Normal (Standard)	Severe
6. Corrugated double-skin asbestos cement sheeting with 25mm glass fibre insulation between (No allowance has been made for effect of corrugations on heat loss)	1·1	1·1	1·2
7. As 6, but with cavity and aluminium foil-backed 10mm plasterboard lining ventilated air space	0·79	0·80	0·82
8. Corrugated aluminium sheeting	3·3	3·8	4·3
9. As 8, but with cavity and aluminium foil-backed 10mm plasterboard lining	1·8	1·9	2·0
10. Corrugated plastic-covered steel sheeting	5·7	6·7	8·1
11. As 10, but with cavity and aluminium foil-backed 10mm plasterboard lining, ventilated air space	1·9	2·0	2·1
G. Roofs, flat or pitched			
1. Asphalt 19mm thick or felt/bitumen layers* on solid concrete 150mm thick (treated as exposed)	3·1	3·4	3·7
2. As 1, but with 50mm lightweight concrete screed and 16mm plaster ceiling	2·1	2·2	2·3
3. As 2, but with screed laid to falls average 100mm thick	1·7	1·8	1·9
4. Asphalt 19mm thick or felt/bitumen layers* on 150mm thick autoclaved aerated concrete roof-slabs	0·87	0·88	0·89
5. Asphalt 19mm thick or felt/bitumen layers* on hollow tiles 150mm thick	2·1	2·2	2·3
6. As 5, but with 50mm lightweight concrete screed and 16mm plaster ceiling	1·5	1·6	1·7
7. As 6, but with screed laid to falls, average 100mm thick	1·4	1·4	1·5
8. Asphalt 19mm thick or felt/bitumen layers* on 13mm cement and sand screed, 50mm woodwool slabs on timber joists and aluminium foil-backed 10mm plasterboard ceiling, sealed to prevent moisture penetration	0·89	0·90	0·92
9. As 8, but with 25mm glass-fibre insulation laid between joists	0·59	0·60	0·61
10. Asphalt 19mm thick or felt/bitumen layers* on 13mm cement and sand screed on 50mm metal edge reinforced woodwool slabs on steel framing, with vapour barrier at inside	1·4	1·4	1·5
11. As 10, but with cavity and aluminium foil-backed 10mm plasterboard ceiling below steel framing (Bridging effect of framing neglected. Assumed that aluminium foil acts as vapour barrier)	0·88	0·90	0·92
12. Asphalt 19mm thick or felt/bitumen layers* on 13mm fibre insulation board on hollow or cavity asbestos-cement decking, with vapour barrier at inside	1·4	1·5	1·6
13. As 12, but with 25mm glass-fibre insulation in cavity, with vapour barrier	0·72	0·73	0·74
14. Felt/bitumen layers* on 25mm expanded polystyrene on hollow or cavity asbestos decking, with vapour barrier	0·85	0·87	0·89

Table XVII U values for various constructions (*continued*) 392

Construction	U Value: Heat flow downwards		U Value: Heat flow upwards
15. Asphalt 19 mm thick or felt/bitumen layers* on 13 mm fibre insulation board on metal decking, with vapour barrier	2·1	2·2	2·3
16. Felt/bitumen layers* on 25 mm expanded polystyrene on metal decking, with vapour barrier	1·1	1·1	1·1

* The difference between the thermal resistance values of 19 mm of asphalt and three layers of roofing felt set in bitumen is sufficiently small to be ignored

Construction	Heat flow downwards		Heat flow upwards
H Intermediate floors			
Wood			
20 mm wood floor on 100 mm × 50 mm joists, 10 mm plasterboard ceiling,	1·5		1·7
allowing for 10% bridging by joists	1·4		1·6
Concrete			
150 mm concrete with 50 mm screed	2·2		2·7
with 20 mm wood flooring	1·7		2·0
Hollow tile floors			
with 50 mm dense concrete over and between tiles			
tile thickness 150 mm	1·7		2·0
200 mm	1·6		1·9
250 mm	1·5		1·8
as above with 20 mm wood flooring			
tile thickness 150 mm	1·4		1·6
200 mm	1·3		1·5
250 mm	1·2		1·4
J Ground floors			
Concrete on ground or hardcore fill			1·13
with grano, terrazzo or tile finish			1·13
with wood block finish			0·85
Timber boards on joists, space ventilated one side			1·70
with parquet, lino or rubber cover			1·42
Timber boards on joists, space ventilated on more sides			2·27
with parquet, lino or rubber cover			1·98
with 25 mm fibreboard under boarding			1·08
with 25 mm corkboard under boarding			0·95
with 25 mm corkboard under joists or forming cavity			0·79
with 50 mm strawboard forming cavity (between joists)			0·85
with double sided aluminium foil draped over joists			1·42

SOURCE : NEW METRIC HANDBOOK Edited by Patricia Tutt and David Adler Published by The Architectural Press, London 1979 Page : 390-392

APPENDIX - 13 : THERMAL PROPERTIES OF BUILDING MATERIALS.

Table XVIII Thermal properties of building materials

Material	Density kg/m³	Thermal resistivity m.K/W	Thermal conductivity W/(m.K)	Vapour resistivity MN s/(g m.)
Brickwork		0·69–1·38	0·72–1·45	25–100
outer leaf	1700	1·19	0·84	
inner leaf	1700	1·61	0·62	
Bricks, common				35–52
sandlime				45–370
Clay tiles	1900	1·2	0·81	
Concrete blocks	600	5·3	0·19	30–160
aerated, outer leaf	750	4·2	0·24	
inner leaf	750	4·5	0·22	
Clinker blocks				2000–2400
Concrete, gravel	2100	0·69	1·45	200
lightweight	1200	2·4	0·42	30–160
aerated	500	6·25	0·16	30–60
Rendering, cement/sand	2100	0·83	1·2	100
Lime mortar				45–50
Plaster	1300	2·08	0·48	60
lightweight	600	6·24	0·16	
Plasterboard	950	6·24	0·16	35–55
Timber	650	6·93	0·144	45–75
weatherboarding	650	7·1	0·14	
Plywood		6·93	0·144	1500–6000
Fibreboard	240–400	15·2–18·7	0·053–0·066	15–60
Hardboard	1010	6·93	0·144	450–750
Woodwool	560	8·66	0·115	15–40
Compressed strawboard	260–350	9·7–11·8	0·085–0·103	45–75
Asbestos board	700	9·1	0·11	
Asbestos cement sheeting	1500	2·8	0·36	
Asphalt	1700	[illegible]	0·50	
Roofing felt	960	5·3	0·19	
Mineral wool	50	25·6	0·039	1·1
Glass fibre	25	28·6	0·035	
Expanded polystyrene	25	27·72	0·036	100–600
Foamed urea formaldehyde	12	27·72	0·036	20–30
Foamed polyurethane (open and closed cell)	30	38·5	0·026	30–1000
Expanded ebonite	64	27·72	0·036	11000–60000
Glass, window	2500	0·95	1·05	
Stone granite	2600	0·34	2·92	
limestone	2100	0·65	1·53	
sandstone	2200	0·77	1·30	

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APPENDIX - 14 : SURFACE RESISTANCES OF BUILDING ENVELOPE

Table XIX Surface resistances R, m²K/W

Surface	High emissivity* E = 0·9	Low emissivity E = 0·05
Internal surfaces, R_{si}		
Walls, heat flow horizontal	0·123	0·304
Ceilings or roofs, flat or pitched Floors, heat flow upwards	0·106	0·218
Ceilings and floors, heat flow downward	0·150	0·562
Outside surfaces, R_{so}		
Walls, sheltered†	0·08	0·11
normal exposure	0·055	0·067
severe exposure	0·03	0·03
Roofs, sheltered	0·07	0·09
normal exposure	0·045	0·053
severe exposure	0·02	0·02
Floor, underside exposed to air	0·09	

* Emissivities: ordinary building materials 0·9
dull aluminium 0·2
polished aluminium 0·05

† Exposures. Sheltered—up to third floor in city centres wind speed 1 m/s
normal—most suburban and country buildings, up to eighth floor in city centres wind speed 3 m/s
severe—buildings on the coast, exposed on hill sites, above five floors in suburbs or country, above eight floors in city centres wind speed 9 m/s

SOURCE : NEW METRIC HANDBOOK. Edited by Patricia Tutl and David Adler. Published by The Architectural Press, London1970. Page . 393

APPENDIX - 15 : SURFACE RESISTANCE OF UNVENTILATED AIR-SOACES

Table XX Thermal resistance of unventilated air spaces

Type of air space Width	Surface emissivity	Thermal resistance* Heat flow horizontal or upwards (m² °C/W)	Downwards (m² °C/W)
5 mm	High	0·11	0·11
	Low	0·18	0·18
20 mm or maximum	High	0·18	0·2
	Low	0·35	1·06
High emissivity plane and corrugated sheets in contact		0·09	0·11
Low emissivity multiple foil insulation		0·62	1·76

* Includes internal boundary surfaces

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APPENDIX - 16 : THERMAL RESISTANCE OF VENTILATED AIR-SPACES

Table XXI Thermal resistance of ventilated air spaces

Width 20mm minimum	Thermal resistance* (m^2 °C/W)
Space between asbestos cement or black metal cladding with unsealed joints and high emissivity lining	0·16
Do with low emissivity lining	0·3
Space between flat ceiling and pitched roof with covering of asbestos or black metal	0·14
Do with bright aluminium covering	0·25
Space between flat ceiling and unsealed tiles	0·1
Do with felt sarking and boarding	0·15
Space between the tiles and sarking felt	0·12
Space behind tiles on tile-hung wall	0·12
Airspace in cavity wall	0·16

* Includes internal boundary surfaces

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APPENDIX - 17 : SOLAR GAIN IN BUILDINGS

Table XXII Solar gain (as measured by additional cooling loads)

Window type	Solar gain (W/m^2) for orientations: east	south	west
Single glazing unshaded	510	371	478
Single glazing with internal venetian blinds	328	305	303
6 mm clear float double glazing with internal venetian blinds	265	302	301
6 mm 'Spectrafloat' and 6 mm clear float with internal venetian blinds	220	250	250
6 mm 'Antisun' and 6 mm clear float with internal venetian blinds	195	221	224
Suncool 26/22 (gold)	113	132	135

SOURCE : NEW METRIC HANDBOOK Edited by Patricia Tutt and David Adler. Published by The Architectural Press, London1970. Page . 393