MODELLING THERMAL PERFORMANCE OF BUILDINGS IN COMPOSITE CLIMATE OF INDIA

A THESIS

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By

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CANDIDATE'S DECLARATION

I hereby certify that the work, which is being presented in the thesis, entitled "MODELLING THERMAL PERFORMANCE OF BUILDINGS IN COMPOSITE CLIMATE OF INDIA" in fulfillment of the requirements for the award of the degree of Doctor of Philosophy submitted in the Department of Architecture and Planning of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during the period from July 2004 to October 2007 under the supervision of Prof. R. K. Jain, Associate Professor.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this institute or any other University.

(RAJEEV GARG)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

Indoor thermal conditions in buildings can be improved by judicious selection of building components. However, this study is limited to study of thermal performance of parameters i.e. orientation of building, roof type, walls & fenestrations, sunshades, thermal mass and ventilation rate. It is possible to study the influence of these parameters on the indoor environment by evolving a Model. It will facilitate the building designers to study the relative merits of various building designs for the parameters to achieve an optimum building design in the context of thermal comfort.

The composite climate of India prevails in northern part of the country, which experiences uncomfortable conditions almost for 06 months during summer. During this period, majority of population depend to harness the natural means of cooling. People use auxiliary means for cooling like air circulators as they cannot afford to spend large amount on air conditioning. In Indian context, thermal performance of the building can be judged by the maximum/minimum indoor air temperature during peak hours (hours in which max./min. temperature occurs outside in summer & winter respectively) and temperature profiles (Outdoor Vs Indoor) for different rooms of a particular building during different seasons of the year. Therefore, in the Indian context, model should indicate the free fluctuations of the internal room temperature for outdoor temperature fluctuations.

All basic building parameters, as stated above, have their contribution for the thermal comfort in buildings. Further, this has been revealed from literature survey that research work carried out so far (particularly in India) by the other agencies / individuals in this field is limited only in quantification of thermal

performance of a single building element or one design parameter at a time. However, no research work suggests a model to quantify the integrated effect of building components, as stated above, on thermal performance of building for the composite climate. The computer programs like Energy Plus & TRNSYS are being used for energy analysis in developed countries, however use of these tools in India is limited for reasons which have been discussed in this research work subsequently. Therefore, there is a need for research to evolve a model that quantifies the effect of above parameters.

This research work intends to evolve a model that quantifies the effect of orientation of building, roof type, walls & fenestrations, sunshades, thermal mass, ventilation rate and outer ambiance on thermal performance of building in an integrated manner. Objectives of this research work are _

- To develop building simulation model by which thermal performance of internal spaces of a building can be assessed in quantitative terms.
- To observe thermal performance of a particular building design with variations in the characteristics like materials, thickness of walls, fenestrations & sunshades etc.
- To finally recommend the set of optimum variables (favorable parameters) that affect thermal performance of internal spaces.

Scope of this Research work would be confined to develop the relevant Model in order to analyze the thermal performance of buildings and to quantify the effect of elements like thermal mass of walls & roof, sunshades/ overhangs; fenestrations on indoor environment in composite climate of INDIA, specially for low-rise residential buildings. The research concentrates on computation and prediction of indoor temperature (DBT) of different rooms of a particular building under normal conditions. Climatic data of Roorkee (2005), as recorded by

Meteorological department of National Institute of Hydrology, Roorkee has been used in order to prepare the weather data files for representative day i.e. 21 day of each month.

Building, space and other standard as recommended by National Building Code of India 1983 (SP – 7) has been followed. Model has been prepared by considering Forward Approach as described by ASHRAE, which has been formulated on the basis of computational method basically suggested by Indian Code SP*: 41 (S & T) – 1987 (Handbook on Functional Requirements of Buildings)* for Heat Transmission through Building Sections. Further, in order to prepare mathematical model Heat Balance Theory has also been taken into consideration. Most of the assumptions are supported by ASHRAE or by prEN 15255:2007 (E) *Thermal performance of buildings - Sensible room cooling load calculation - General criteria and validation procedures.*

Mathematical model of the system can be broadly divided in following sub-groups for better understanding _

- Modeling of the SUN
  - Azimuth, Altitude & Declination
- Time Calculations
  - Equation of Time ,
  - Apparent (local) solar time (A_{ST})
  - Apparent solar time of sunset (H_{SS}),
  - Apparent solar time of sunrise (H_{SR})
- Modeling of Solar Radiation (Heat Influx)
  - Direct Normal solar radiation (I_{DN})
  - Angle of incidence of solar radiation on the surface (i)
  - Direct solar radiation (I_D), Diffuse Solar Radiation (I_d),

- Sol-air-temperature (T_{SOL})

Thermal Equilibrium of a Multiple Zone (Room) System involves following computations_

- Development Of System Property Matrices
  - Development of Heat Capacity [H_C] Matrix
  - Development of Conductivity Matrix [U]
- Development of Heat Load Vector {H_L}
  - Inflow From Outer Elements Due To Solar Load
  - Inflow from Floor
  - Inflow due to Equipments Load,
  - Inflow due to Occupants Load
  - Internal Heat Balance
  - Inflow due to Air Changes
- Modeling of thermal equilibrium (System Heat Balance)
- Time marching scheme for hourly calculation of system temperatures

A Computer Programme has been prepared incorporating the Model structure in order to produce output data by processing the input data. The program has been prepared in FORTRAN -90 by adopting Modular (structured) Approach. 24 Subroutines and 14 Functions have been formulated in order to accomplish this research. General Output File, Temperature Output File, Solar Calculation File and Shading Calculation File are generated for every simulation study by the programme.

To determine the level of precision of results, a reference house of ROORKEE has been selected. Actual temperature readings were recorded on hourly basis in 05 different rooms of that house as well as outdoor temperature was recorded for the same period. The same house with constructional details and specifications was used for indoor temperature simulation from the evolved computer programme. The results of this exercise conclude that the model is capable of predicting Thermal Performance of Buildings within tolerable limits.

Model has been developed to have the following characteristic features_

- It is flexible enough to support a wide range of building design, construction types & materials.
- Climatic data file of any Indian city (if prepared) can be attached to the model; however, as default settings, the weather data file of Roorkee is attached to the model.
- It can predict the thermal performance of different rooms for any hour of the year in the form of Ti (DBT) of that room.
- Effect of Fenestrations, sun shading devices and air velocity prevailing outside can be quantified on thermal environment of any room.
- Results can be obtained for varying ambient ground reflectivity.
- Model accounts for the heat capacity of thermal masses present in rooms.
- Occupants' body heat load & Heat generated by the appliances within the rooms is considered on hourly basis.
- Variable air changes per hour in any room can be considered for different period of the day or night.
- Input files can be prepared in a short time and output files can be obtained in simple format.
- Thermal Time lag can be observed on graph (To vs Ti) using output data.
- Results can be obtained for the following design parameters / building elements keeping an individual or a set of parameters as variable(s)_
  - FENESTRATIONS: Size on different walls & properties of glazing.
  - GROUND REFLECTIVITY

- HEIGHT of BUILDING / ROOMS
- HEIGHT of PARAPET over the roof.
- ORIENTATION of BUILDING: With respect to Cardinal Points
- PROJECTIONS / SUNSHADES: Width & Type on different faces.
- ROOF: Material & Treatment.
- VENTILATION RATE : Air change per hour
- WALL: Material Properties & Thickness.

The research culminates with the application of model on three different buildings. Results have been obtained by these exercises for full year; however, results for the month of January & June were analyzed critically. Relevant data & graphs thus produced were analyzed in order to derive inferences form the exercises.

As a result of this research work, the Model has been developed in order to determine (in quantitative terms) Thermal Performance of Buildings in Composite Climate of India. Input data preparation method has been made user friendly in easy to use simplified manner. Model provides an opportunity for architects and building designers to formulate their ideas when design is in conceptual stage. With this model, it is possible to study the relative merits of various designs for the same site and to evolve an optimum building design in the context of thermal comfort for composite climate of India.

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It is my foremost duty to thank without naming my academic guide, my personal mentor and my financial supporter for inspiration, encouragement and continual moral support to pursue Doctoral Research Studies. I would like to thank Lord Ganesha, the almighty for giving me the faith, insight, health and strength to carry on.

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CONTENTS

ACRONYMS AND NOMENCLATURE

$\propto$: Altitude of the Sun

δ: Declination of the Sun

A : Apparent Solar Constant

A_{CPH} : Air Changes per Hour

a : Surface Absorptivity

a_s : Azimuth of Sun

A_{ST} : Apparent Solar Time

a_W : Wall Azimuth

B : Atmospheric Extinction Coefficient

C : Sky Diffuse Factor

C : Thermal Conductance

e : Surface Emmissivity

ET : Equation of Time

f_i : Coefficient of Heat Transfer at inner surface

f_o : Coefficient of Heat Transfer at outer surface

H : Air to surface conductivity

H_{inC} : air to surface conductivity (inside ceiling surface)

H_{inF} : air to surface conductivity (inside floor surface)

H_{inO} : air to surface conductivity (Outside surface)

H_{inV} : air to surface conductivity (inside vertical surface)

H_s : Hour angle of Sun

H_{SR} : Apparent Solar Time of Sunrise

H_{SS} : Apparent Solar Time of Sunset

HT : Height of Room / Wall

i : Angle of incidence

I_d : Diffuse Solar Radiation

I_D : Direct Solar Radiation

I_{DN} : Direct Normal Solar radiation

L : Latitude of the Place

N : Day of the Year

N_{FLOOR} : Number of Floors

N_{OUT} : Number of Outer Ambiances

N_{ROOM} : Number of Rooms

N_{SLAB} : Number of Slabs

P_{RA} : Plan Rotation Angle

r : Surface Reflectivity

r_g: Reflectivity of Ground Surface

S_h : Shading on Surface (fraction)

SHGC : Solar Heat Gain Coefficient

ß : Angle of Surface from Horizontal

T_i : Internal Room Temperature

T_o : Temperature of Outside Air

T_S : Sol-air Temperature

U : Conductivity of the Element

U_{ab} : Air-to-air Transmittance between Rooms a & b

U_{Fi} : Air-to-air Transmittance between Floor upper & lower surfaces

U_{Ri} : Air-to-air Transmittance between Roof outer surface & inside surface

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CHAPTER 1

THE RESEARCH CONTEXT

1.0 INTRODUCTION

From ancient times all living beings have made a great amount of efforts to fulfill their requirements in food and shelter according to the local conditions in which they live. Through the centuries, man has created and refined his habitat through an intuitive and instinctive process. In India, we find many types of vernacular dwellings exhibiting use of local building materials with varied construction skills in different climatic regions. These vernacular dwellings exhibit the history of human endeavors and innovations through his countless efforts with the aim to make his shelter more comfortable than previous version. In the modern technological era, where our shelters have become 'a machine to live in', the architects challenge have been to identify means of achieving comfortable indoor living environment with minimum or no use of mechanical devices.

The primary purpose of building design and choice of materials is the creation of a comfortable indoor environment, which is conducive to the well being of the occupants [30]. In the present age of energy exigency, it is important that the buildings are designed in such a manner that minimum energy is required during usage. In this context, proper selection of materials and sections for various building elements in a specific climate is significant to achieve comfortable living and working conditions. The requirements for designing thermally comfortable building depend on control and/or flow of solar radiation / heat into the building, necessity of which depends on the prevailing season and hence knowledge of climatic factors is important.

India possesses a large variety of climates ranging from extremely hot desert regions to high altitude locations with severely cold conditions similar to northern Europe. Within India, it is possible to define six regions with distinct climates. The six climates are normally designated as Hot and Dry, Warm and Humid, Moderate, Cold and Sunny, Cold and Cloudy and Composite. The Composite climate of India prevails in most of the northern part of the country, which experiences uncomfortable conditions during summer almost for 06 months in view of thermal comfort.

The criteria of allocating any location in India to one of the first five climate zones are that the defined conditions prevail for about six months. In cases where none of these categories can be identified for six months or longer, the climatic zone is called Composite. On this basis, Bansal and Minke (1988), originally produced the Climatic Zones in India Map by evaluation of the mean monthly data from 233 weather stations, and then delineating the six climatic zones. The zone in which Composite climate prevails in India has been shown in Fig. 1.1, in this chapter.

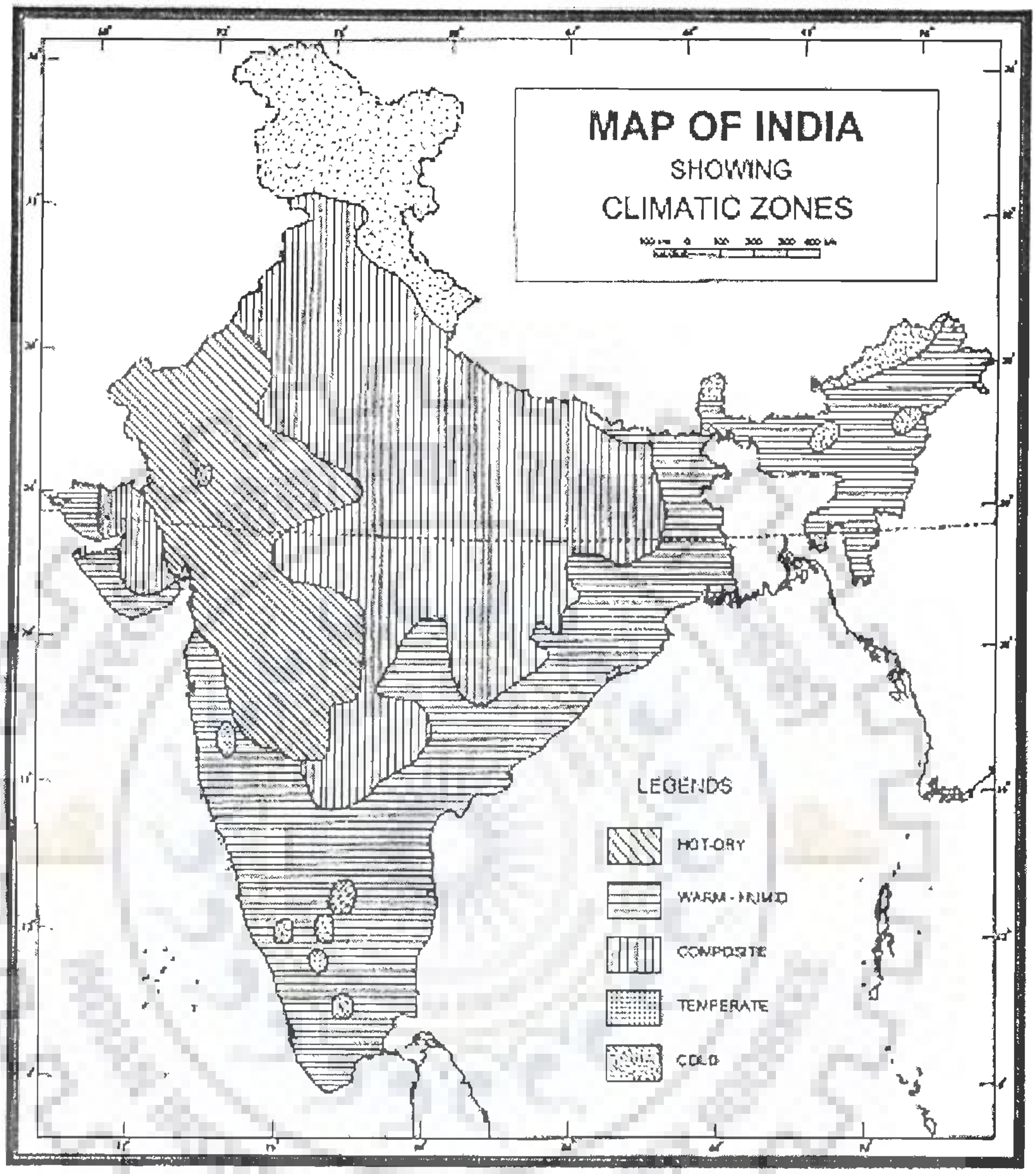
India being a tropical country faces extreme temperatures (to the order of 42 to 45^{0}C) during summer season in Composite Climate zone. In this zone, uncomfortable summer season prevails most part of the year (April to September) and uncomfortable winter season prevails only for 02 months (December & January). Thermally comfortable conditions prevail during rest part of the year. Thermal comfort depends upon three basic climatic factors.

i. Air Temperature (DBT in ^{0}C)

ii. Relative Humidity (RH in %)

iii. Air Velocity (measured in m/s)

Fig. 1.1 : Climatic Zones of India (National Building Code of India 2005)



Based upon Survey of India Outline Map printed in 1993. © Government of India Copyright, 2005

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhattisgarh & Madhya Pradesh have not been verified by Governments concerned.

According to thermal comfort standards as recommended by ASHRAE, 80 % of all adults dressed for winter indoor conditions find temperatures acceptable between 20-23.5^{0}C, a relative humidity of 30 to 60% and air velocity at 0.15 to 0.25 m/sec. National Building Code of India [78] specified thermal comfort standards in view of Indian composite climate, which can be studied from Table 1.1.

Table 1.1: Thermal Comfort Conditions as recommended by NBC 2005.

DBT ^0C	RELATIVE HUMIDITY						
	30%	40%	50%	60%	70%	80%	90%
	Wind Speed in m/s for THERMAL COMFORT						
28	*	*	*	*	*	*	*
29	*	*	*	*	*	0.06	0.19
30	*	*	*	0.06	0.24	0.53	0.85
31	*	0.06	0.24	0.53	1.04	1.47	2.10
32	0.20	0.46	0.94	1.59	2.26	3.04	+
33	0.77	1.36	2.12	3.00	+	+	+
34	1.85	2.72	+	+	+	+	+
35	3.2	+	+	+	+	+	+
36	+	+	+	+	+	+	+

NBC also recommends just acceptable warm conditions which have been given in Table 1.2:

Table 1.2: Just acceptable warm conditions as recommended by NBC 2005.

DBT ^0C	RELATIVE HUMIDITY						
	30%	40%	50%	60%	70%	80%	90%
	Wind Speed in m/s for JUST ACCEPTABLE WARM CONDITIONS						
28	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*
30	*	*	*	*	*	*	*
31	*	*	*	*	*	0.06	0.23
32	*	*	*	0.09	0.29	0.60	0.94
33	*	0.04	0.24	0.60	1.04	1.85	2.10
34	0.15	0.46	0.94	1.60	2.26	3.05	+
35	0.68	1.36	2.10	3.05	+	+	+
36	1.72	2.70	+	+	+	+	+

* Not Required

\+ Higher than those acceptable in practice (velocity discomfort)

1.1 THERMAL PERFORMANCE OF BUILDINGS & GOVERNING PARAMETERS

Thermal performance of buildings is an extensive subject. This section gives an overview of thermal performance and explanations of common terms. Thermal performance of a Building can be judged by the Maximum Indoor Temperature prevailing inside rooms during peak hours (hours in which max./min. temperature occurs outside) and Temperature Profiles (Outdoor Vs Indoor) for different rooms in the different seasons during the year. Other scholars[85][*1] also consider Maximum Indoor Temperature as indices of Thermal Performance of Buildings. However, in this research context, Thermal Performance of a Building can be judged by the Maximum/Minimum Indoor Temperature occurred during peak hours (hours in which max./min. temperature occurs outside) and Temperature Profiles (Outdoor Vs Indoor) for different rooms in the different months of the year. Therefore, model should be developed that indicate the free fluctuations of the internal room temperature for known/assumed outdoor temperature fluctuations. Further, Time lag is also an important factor for consideration in this context. The developed Model is based on the concept that Thermal Performance of a Building can be judged by the Maximum Indoor Temperature during peak hours and Temperature Profiles (Outdoor Vs Indoor) for different rooms in the different months of the year.

In context of this research, thermal performance can be defined as the result of the process whereby the prevailing outdoor climate is modified by the design, layout, orientation and construction materials of the building to create the indoor thermal environment. Majority of population of this country like to harness the natural means of heating & cooling. Within their resources, some people also

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*Name of the author is not mentioned, however paper has been downloaded from <http://www.agrement.co.za/criteria/bwtherm.html>

use auxiliary means for cooling like air circulators (fans), as they are unable to spend large amount of money in initial investment and running cost on air conditioning systems.

The thermal performance of buildings is affected by a complex relationship between all components of the structure, and the environment. Major design parameters / building elements of this relationship include the following:

ORIENTATION:

The amount of solar radiation received by the building envelope depends on the orientation of the building with respect to cardinal points. During the day, solar radiation produces external temperatures which are higher than ambient DBT, and which vary around the building envelop in accordance with orientation and exposure to the sun. It is proven fact that north facing (long axis parallel to East-West line) thermally perform better in summer as well as in winters. Since all the buildings cannot face north practically, hence orientation has been considered a variable in this research study in order to find out solutions for varied orientations.

WINDOWS:

They occupy a large percentage of the perimeter of the building. Their thermal performance depends very much upon their size and the properties of glazing. In a residential building, most heat gain / loss occurs through the windows. This happens not only because of the low heat resistance of glass but also because of air infiltration. The undue air infiltration accounts for majority of heat loss in winters and unwanted heat gain in summer. Conductive heat loss through glazing can be reduced significantly by increasing the number of glass panes.

ROOF:

Roofs receive significant amount of solar radiation throughout the day. Careful attention needs to be paid next to the conduction of heat through the roof. In winter, warm air inside the building tends to rise and if it meets a cold ceiling or poorly insulated roof, will cool quickly and will fall again as cold air. Thus a heat loss cycle is setup. In summer, situation becomes worse as roof can get hot during the day and sooner or later, this heat will enter and affect the thermal environment of whole building.

SHADING DEVICES:

They are provided in the form of fixed sunshades and operable overhangs on outer faces of the building. Thermal performance is affected by their existence / operation. Solar radiation received by the building envelope can be controlled by the provision of shading devices on external faces. External shading devices can be provided in the form of large overhangs at roof level, projections at window / lintel level. The may be horizontal, inclined or vertical members.

BUILDING MATERIALS:

Materials of which the walls and roof are constructed affect not only steady state heat transfer, but also the transient response of the internal environment to daily external temperature changes. In this respect mass and specific heat of material are important physical properties. Heat storage is usually accomplished by using the sensible heat capacity of material. It has been experienced that indoor thermal environment is significantly affected by the wall thickness.

VENTILATION RATE:

Ventilation is an important parameter, depending both upon wind velocity, direction and site exposure, and on the management of operable area of windows and doors. It has been observed that ventilation rate (including air infiltration) significantly affect the indoor air temperature in summer as well as in winters.

Apart form the above mentioned, there are some more parameters that affect thermal performance of buildings which are being enlisted as follows_

- Height of Rooms
- Height of Parapet over roof

- Surface to Volume Ratio of the envelope
- Landscape elements around the buildings
- Ground reflectivity around the building
- Heat load due to appliances
- Heat load due occupants
- Surface absorptivity of outer envelope
- Surface reflectance of outer elements

To quantify the influence of these various design aspects / building elements (variables) computer model has been developed to simulate the thermal performance of the entire building system. However, effect of landscape elements on thermal performance has not been incorporated while developing the model, since it is an uncertain phenomenon and tedious to quantify.

1.2 OBJECTIVES

A set of objectives has been framed in order to accomplish the task_

- To develop a building simulation model by which thermal performance of internal spaces of a building can be assessed in quantitative terms (DBT).
- To observe thermal performance of a building design with variations in the characteristics of design parameters / building elements like materials, thickness of walls, fenestrations & sunshades, roof etc.
- To finally recommend the set of optimum variables (favorable parameters) that affect thermal performance of internal spaces in view of composite climate.

1.3 SCOPE OF WORK

There are some models / programs which can accomplish the task, as the model that has been developed under this research work. However, this research work is characterized by a fresh approach towards interpretation / application of data and subsequently by the discovery of facts (in terms of results by the exercises based on conceptual buildings using the model). Scope of this research work is confined to develop the relevant Model in order to analyze the Thermal Performance of Buildings and to quantify the effect (through exercises by using the model) of Elements like Thermal Mass of Walls & Roof, Sunshades/ Overhangs; Fenestrations on indoor environment in Composite Climate of INDIA, specially for low-rise Residential Buildings (belonging to all the economic groups).

This research study is confined to the building elements that are fixed in construction and hence internal shading devices like curtains and Venetian blinds have not been considered for modelling. As well as design parameter SVR (Surface to Volume Ratio) has not been exercised, since research findings are available on this issue. Though, some researchers suggests thermal comfort indices in the form of Effective Temperature (ET) and Tropical Summer Index (TSI), however, National Building Code of India* recommends that the discomfort due to high relative humidity in air when temperature is also high can be counteracted to a great extent by circulation of air with electric fans and it would be better to shift emphasis on protection from solar radiation when temperatures are high. And hence, this work concentrates on prediction of indoor temperature (DBT) of different rooms of a building under normal conditions. This research does not integrate day light requirements in buildings for various uses. Model has been developed in view to analyze thermal performance of buildings & elements and not for Hygro-thermal performance, which considers effect of humidity in addition to temperature.

For Modelling purpose, three units of 01 Room, 04 Rooms and 09 Rooms have been taken for study to select the optimum variables. Recommendations

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* National Building Code of India 2005, Part -8, Section 01, p-10.

have been made on the basis of results of the study (exercises) carried out with the help of model for these units. Climatic data of Roorkee (2005), as recorded by Meteorological department of National Institute of Hydrology, Roorkee has been used in order to prepare the weather data files for representative day i.e. 21 day of each month. For Building Design, Space and other Standard recommendations of National Building Code of India 1983 (SP – 7) have been followed.

1.4 METHODOLOGY

The significance of designing buildings with climatic considerations was established by Givoni [27]. Different concepts were developed and practiced for designing buildings for different climatic conditions throughout the world. Isolated attempts were made by various scholars in order to quantify the effect of individual design parameters or building elements on internal thermal environment on buildings. With the advent of advanced computers, models have been developed for indoor thermal environment simulation and energy analysis. However, use of these models in India is limited for reasons, which have been discussed in this research work.

This research work was taken to scientifically determine the effect of different design parameters and various building elements on thermal performance of buildings in an integrated manner. This task consists of the following step:

1. STUDY of available literature on the following subjects_

   Thermal Comfort in Indian context

   Thermal properties of Building Materials

   Climatic Design of Buildings

   Vernacular Architecture (India)

Solar Heat Gain on Building Envelop

Heat Transfer through the Building Elements (section of walls / windows /roof etc.)

Isolated efforts of various scholars in this field

Design Parameters effecting Thermal Performance of Buildings

Study of available Simulation Models developed so far

2. MODELLING (DEVELOPMENT OF MODEL)

Conceptualization of Model

Formulation of Mathematical Model

Computer Programming for computation

Validation of the Model

3. USE OF MODEL (EXERCISES)

Study of Thermal Performance of 03 Buildings with variations in design parameters & characteristic of Building Elements.

Analysis of Data as obtained by point 3.1 and inferences.

4. RECOMMONDATIONS

Methodology can be graphically represented in the form of a chart, which has been given as Appendix-1.

1.5 LIMITATIONS

Research in the field of *Thermal Performance of Buildings* require knowledge of inter departmental subjects like Architectural Design, Building Construction, Climatic Design of Buildings, Solar Radiation, Heat Gain and Heat Transfer, Computer Programming, Mathematical Matrices and Vectors. Being an architect depending on individual efforts, it was a difficult task for me to study all the related subjects' up to the perfection. However, the task was accomplished with the exhaustive study of these subjects and help of experts related to these fields.

Every model is based on certain assumptions and these assumptions may differ from ground realities (slightly or drastically). This model has been developed in view of Indian Composite Climate keeping in mind the type of building construction that is commonly practiced in Composite Climate zone of India. It is expected that model will predict precise results, however, results may not be precise if the same model is used for other climatic zones i.e. Cold Hilly Areas, Warm Humid Coastal Climates. Accuracy of results of the model will be based on preparation of input data file with the correct Information regarding building geometry and description of building elements /materials.

Development of a model and its results depends upon detailing of various steps to be followed and accuracy of data to be used. In this research work, while developing the model, some limitations were observed which are being enlisted as hereunder.

- Climatic data of Roorkee, as recorded by the meteorological department of National Institute of Hydrology, Roorkee (year 2005) has been used in order to prepare the weather data file of Roorkee.
- Most of the building elements like Walls, Fenestrations, Sunshades, Floor / Thermal Mass, Roof, Parapet etc can be modeled easily. However, elements like cornices, corbels, offsets, elevation ornamental details and small niches in the walls cannot be modeled for thermal performance.

Architect / user has to assume equivalent thermal mass to be added in the respective zone.

- Model does not account for any landscape feature (plants / water body) associated with the building design.
- Model is based on certain assumptions, which have been discussed in Chapter 5.

1.6 RELEVANCE OF RESEARCH TOPIC

The design of buildings is a complex process in which the architects and building designers make decisions concerning the different aspects (environmental, economy, structural, functional, safety and aesthetic) related to the building in view of occupants' comfort. The choices are narrowed down from preliminary designs to final scheme through a succession of steps, which involve conceptualization, evaluation and execution of scheme. Predicting the thermal performance of buildings involves the handling of a large number of inter-related parameters. This research work concerns with the thermal performance of the building envelope and is meant to answer specifically the architect's questions_

(a) What are the design aspects and building specifications for thermal comfort such that there is minimum deviation in indoor thermal environment from desired comfort conditions in view of composite climate?

(b) What would be the indoor temperature (computed / predicted) if the building were constructed with particular set of specifications and recommended design parameters?

It has been revealed from literature survey that research work carried out so far by the other agencies / individuals in this field is limited only in quantification of thermal performance of a single building element or design parameter at a time. Central Building Research Institute Roorkee, has carried out significant research on thermal performance of individual building elements but has not touched the above mentioned aspects i.e. thermal performance of parameters in an integrated manner. However, no research work suggests a model to quantify the integrated effect of Orientation of building, Roof type, Walls & Fenestrations, Sunshades, Thermal mass and Ventilation rate on Thermal Performance of building in an integrated manner for the composite climate like that of India. Though computer program like Energy Plus & TRNSYS are being used for energy analysis in developed countries, however use of these tools in India is limited for reasons, which have been discussed in this research work subsequently. Although, these programs consume a great deal of time and effort in computational terms, however, they still rely on designers' intuition and experience to achieve optimum solutions for a design problem. Therefore, there is a need for research (in Indian context) in order to evolve a model that quantifies the effect of above parameters on Thermal Comfort in an integrated manner.

Buildings should be designed for composite climate, in a manner so that the building envelop receives the minimum solar radiation in summer and maximum solar radiation in winters, This requirement can be achieved by providing sunshades and projections of calculated width over fenestrations on different faces of the building. Further, building envelop should be designed so that it cools faster in summer nights and retains warmth of internal spaces in winter's nights, which can be controlled by maintaining the different rate of ventilation in the building. Wall thickness and properties of wall material also play a role in this phenomenon. All these varying qualities of building envelop in view of thermal comfort can be achieved by judicious consideration of design parameters i.e. orientation of building, wall thickness, fenestration area on different faces of the building envelop, sunshades/ projections over fenestrations and walls, by controlling the ventilation rate in the building, may be different during day and night. When designer has limited or no choice of orientation, designer has to depend upon other parameters to achieve thermal comfort in buildings. In the same manner designer may have some constraints for a particular parameter, and may have flexibility with others.

In India, most of the architects and building designers are designing buildings (non air conditioned) with the conventional approach and knowledge thumb rules in order to achieve thermal comfort in buildings. Though some models / programs are available through which architects and building designers can judge the relative merits of their design/concepts in quantitative terms, however, no such simulation model is in common practice in India, because of the reasons (basically economical & technical) which I have explained in this thesis subsequently. Therefore, there is a need to develop a model that can be adopted in India by the architects and building designers. This research work intends to evolve a Model, with a fresh approach, that quantifies the effect of orientation of building, roof type, walls & fenestrations, sunshades, thermal mass, ventilation rate and outer ambiance on thermal performance of building in an integrated manner.

Indoor temperatures of different rooms / zones of a building can be calculated in view of outdoor climatic conditions, taking into account the thermal resistance and thermal capacity of the building materials together with the outdoor climatic conditions. Using such method it is possible to compute the indoor thermal temperature and to judge it against the requirements of thermal comfort parameters [24]. It is thus possible to study the influence of various design variables i.e. orientation, exposure of walls & roof, insulation and thermal mass, multistory construction, glass area, and ventilation rate on the indoor environment in an integrated manner. This will enable to evolve an optimum building design in the context of thermal comfort.

This research work intends to develop a model, which simulates the thermal performance of the buildings taking into account design variables related to the building's envelope. In India, any individual or organization has not developed such a model. This research is relevant because a model has been developed with a fresh approach, which is useful to determine the optimum design variables that achieve the best thermal comfort conditions.

This research work is aimed that a model be evolved in order to quantify the thermal performance of buildings in composite climate of India, which will enable the architects and building designers to choose proper design parameters to improve indoor thermal environment of buildings for thermal comfort. With the use of the developed model, architects and building designers will get an opportunity to judge the thermal performance of their design concepts. Model will be useful for practical use and finally in designing of the buildings with the following characteristics_

- Rely on natural means of heating and cooling harnessing the diurnal temperature range in summer and winter.
- Provide a comfortable indoor thermal environment in hot or cold climates.
- Down-scaling the thermal design requirements.
- Considerably less energy consumed by heating and cooling systems.
- Cost reduction for procurement and maintenance of economized heating and cooling equipment.

In view of the points mentioned above, it is clear that research in this field is important and research topic is relevant. Further, the researchers can use the model also, in order to quantify the thermal performance of their new concepts in terms of building design with the use of innovative building materials.

1.7 ORGANIZATION OF RESEARCH REPORT

This research work consists of nine chapters. Brief description of each chapter is being presented as follows_

Chapter one deals with Introduction of the subject, describing the objectives, scope, methodology and literature survey. It thus forms the comprehensive view of overall research work that has been carried out.

Chapter two discusses the Literature survey that has been carried out by various journals, books, reports and internet.

Chapter three presents two cases that have been studied. One case study is in the context of small residential buildings of warm humid climate of Sri Lanka. Another is in the context of Vernacular dwellings of China.

Chapter four contains the data that have been considered and used in this research work. This chapter discusses the climatic data, metabolic heat generation rate, properties of building materials and heat load of appliances apart from solar database.

Chapter five comprises introduction of model, modelling approach, methods and assumptions taken into consideration for the development of model and description of mathematical model equations for different computations and preparation of computer programme.

Chapter Six explains the operationalization of model, capabilities of the model, method of preparation of input files and illustrates different types of output files, samples of which have been provided in relevant appendix.

Chapter seven unfolds the validation criteria, method and results of theoretical and experimental validation, comparison of results and inferences of the validation exercises.

Chapter eight comprises some exercises based on conceptual buildings and their results. Data analysis and inferences for the exercises also form a part of the chapter.

Chapter nine concludes the research work with discussions on observations and recommendations. Scope for further research has also been discussed in this chapter.

Bibliography has been given at the end of the thesis in alphabetic order of the authors names. In the body of the text, a reference has been indicated by a number in parenthesis as [12].

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

The stock of existing ideas on the subject and research work carried out so far in this field (by various researchers and organizations) has been taken, bibliography of which is there at the end of the thesis report. In India, Central Building Research Institute, Roorkee has carried out research on thermal issues related with the buildings. Relevant literature pertaining to research findings of C.B.R.I. Roorkee is available in form of Building Research Notes (B.R.N.) and Building Digests (B.D.), which were studied. Research work carried out by other scholars and organizations were studied through *The Journal of Indian Building Congress* and *The Journal of Indian Institute of Architects*. International journals *Architectural Science Review* and *Building and Environment* were studied in order to review the research work carried out at international level. A few doctoral research study reports belonging to this research field that are available on Internet were also studied. State of art was also determined by the latest publications of PLEA 2006 (Passive and Low Energy Architecture, Conference Papers). Basic fundamentals of Heat transfer and Heat calculations, Climatic Design aspects and related subject matter was studied by the books available in the Departmental Library of Department of Architecture and Planning and Central Library of IIT Roorkee. Library of Central Building Research Institute, Roorkee was also referred in order to study the books, literature and journals. A brief discussion on the literature review that has been studied is available in this chapter subsequently.

2.1 REVIEW OF RESEARCH WORK (State of Art)

Mathur and Chand [69] discussed the relevant efforts made by Govt. of India to enable to design and construct the buildings with energy efficiency considerations. This paper is a testimony to the fact that necessity for design of functional and energy efficient buildings has been very well recognized in India also. The paper suggests that efforts are needed to design buildings that would function in conformity with climate and not against it. This paper is indicative of the relevance of research in this field.

Sharma and Sharafat [102] described the methodology for assessment of solar radiation on buildings, which is an important part of prediction of thermal performance of buildings. The paper describes that total solar radiation on a surface under clear sky conditions is comprised of three components, namely, Direct Radiation (I_D), Diffuse Sky Radiation (I_d) and Ground Reflected Radiation (I_{GR}). Methodology and suggested formulas have been used in this research work.

Agarwal [1] discussed the passive solar concepts incorporated in the ancient Indian treatises on Building Designs and describes their relevance in view of modern age energy efficient buildings. It has been emphasized that proper orientation of building, appropriate size and type of fenestrations and use of massive walls (thermal mass) are a few considerations that were practiced in ancient times in order to achieve thermal comfort in buildings.

Sharma [101] attempted to measure certain parameters, which help in evaluating the thermal performance of few historical buildings of Lucknow (composite climate zone). This study reveals that in the historical buildings (Roshan-Ud-Duala Kothi & Jannat-Ki-Khirki), amplitude of indoor air temperature was not more than 5.6^{0}C while the outdoor temperature fluctuation was of the order of 18^{0}C. The maximum indoor temperature was 8^{0}C lower in summer and 3-4^{0}C higher in winters than outdoor maximum temperature. Further, time lag of 6-8 hours was observed in these historical buildings. This research study is important because these experimental results clearly indicate that the judicious use of building elements helps considerably in modifying the stress of the climate.

Jayasinghe [48] carried out research in order to determine the influence of roof orientation, roofing materials and exterior surface colours of the roof on indoor thermal comfort of a single story house subject to warm humid climatic conditions.

Chand and Agrarwal [17] discussed the thermal performance of building sections in different thermal climatic zones of the country. In this research note, thermal performance index has been worked out based on periodic heat flow theory. However, recommendations have been made for three climatic zones, namely, Hot and Dry (1), Hot and Humid (2) and Warm Humid (3). Recommendations have not been made for the composite climate.

ASHRAE [6] recommended the methodology; relevant equations and formulas for heat gain calculation in buildings together with the standards of thermal comfort and properties of different building materials. Data for calculation of solar heat gain on buildings (Solar Data) in different months have been considered in this research work.

Larsen [61] presented the program SIMEDIF, a code conceived for the design and simulation of the thermal transient behavior of buildings. The code has been developed for the hour-by-hour thermal behavior simulation of buildings with the aim to calculate the indoor temperatures of a multi-room building. This work does not provide any example of building simulation study and results thus obtained by the program.

Milne [72], a pioneer in this field, evolved a design tool that helps architects understand and resolve the multiple variables involved in determining a building's thermal performance. This research work focus on cooling performance. The work demonstrates a graphical technique that displays the consequences of each individual architectural design decision on the building's thermal performance using SOLAR – 5 in association with other computer program developed by him. Milne realized and describes the complex phenomenon of mutual interactions of variables / architectural design parameter and their effect on thermal performance of buildings. The work mentions "Improving a building's cooling performance is not simply a function of adding more insulation or more thermal mass, although all these help, but only up to a point. There are many variables that sometimes help and sometimes harm, such as the rate of air change, the size of windows, the ratio of surface area to volume." He also mentioned that cooling performance might be degraded by many issues beyond the designer's immediate control. Adding still further to the difficulty of this problem is the fact that many design variables interacts with each other in complex ways.

Jain, Kannongo and Goyal [44] studied the power consumption and temperature profiles in glazed building. In this study, they carried out energy simulation on a zone of a building by varying the window glazing in terms of its area, type of glazing and its orientation. The study is carried out for Indian climatic conditions (using the weather data of New Delhi) with the simulation software TRANSYS. The study of the yearlong simulation for the air-conditioned zone shows that the power consumption in east direction with single glazing is highest and power consumption in north direction with double-glazing is lowest.

Lyons [66] analyzed window performance for Human Thermal Comfort has for the climatic conditions of California. Prasad [86] quantified solar heat gain through window systems. The work concentrates on the thermal performance in view of a single parameter i.e. window systems. Thermal performance & energy saving analysis of glazed windows has been done nicely by Singh & Bansal [8] in Indian context. In this research study, thermal performance of single glazed window has been compared with double-glazing, double glazing (low E) and triple glazing windows.

Gamage [25] carried out study on Thermal performance of suburban residential condominiums for warm humid climate of Sri Lanka. The research concludes that with the judicious selection of design parameters of orientation, shape, window size, selection of materials during the summer season, one may be able to achieve about 31.7^{0}C in the peak heat time (14.00 hrs).

Safarzadeh and Bahadori [93] quantified passive cooling effect of courtyard in Iranian context employing energy analysis software developed for that purpose. The passive cooling features considered were the shading effects of courtyard walls and two large trees planted immediately next to the south wall of the building, the presence of a pool, a lawn and flowers in the yard. It was concluded that these features alone couldn't maintain thermal comfort during the hot summer hours in Tehran, but reduce the cooling energy requirement of the building to some extent. These features have an adverse effect of increasing the heating energy requirements slightly. The same saving in cooling energy needs of the building can be obtained through many features such as wall and roof insulation, double glazed windows, Persian blinds and special sealing tapes to reduce infiltration. It was also finding out that these features save heating energy requirements as well.

Senanayake [99] carried out study on means of achieving thermal comfort in small Urban Houses in Sri Lanka. In this study, a house for an upper income young couple in Colombo has been analyzed with the DEROB-LTH in order to derive better design solutions for comfortable living. The study reveals that the tile as a roofing material and the walls of plastered bricks painted with white emulsion is the best possible among the studied materials. The use of shading devices can also be recommended. This research study has been discussed in detail in the next chapter as a case study.

Paul [84] attempted study on Modelling of thermal performance, which basically reviews and comments the relevant legislative requirements for the control of thermal transfer value of building envelopes in Hong Kong.

Hendron [35] made attempt in order to determine Thermal Performance of Un-vented Attics in Hot-Dry Climates. The paper addresses the energy related effects of un-vented attics in hot-dry climates based on field testing and analysis conducted by NREL. However, the research has been concluded in general _"Weather conditions, duct leakage, roof R-value, attic air-exchange rate, and roof solar heat absorption all play important roles in determining whether or not energy savings are achieved with an un-vented attic. Because of these sensitivities, it is difficult to recommend specific sets of conditions where un-vented attics save energy."

Sawhney & Paul [98] established the weightage percentage of passive design measures in composite climate of India. This research concludes that orientation and envelope materials are the most important factors in designing for energy efficiency. Orientation (heat load upto 790 kW for case study) has a very high impact on heat gain as compared to envelop material (heat load 76 kW) and day lighting (heat load 3 kW). It can be inferred that thermal performance of buildings should be given high priority than to day-lighting performance in composite climate of India.

Sahu [94], in a recent research work, clearly mentions that "No data available on thermal performance of building envelopes. Whatever data has been published until now refers to individual building components." However, this research study is limited to computation of solar heat gain to the building envelop in terms of W/m^2 that too on specific orientation with rotation angle of 45^0. This work also suggests some design guidelines for the architects.

Gratia [32] and Herde presents a program, namely 'OPTI', created to help architects to take account the impact of design choices on energy consumption. The program provides annual thermal needs and thermal comfort (winter and summer) in relation with orientation, building footprint, window area and type, insulation level, presence of shading devices, ventilation strategy and thermal mass. The program is based on many parametric studies realized with a dynamic thermal program. However, the design tool is based on Belgian climatic weather data recorded by the Belgian Royal Institute of Meteorology, Uccle. The program cannot account for actual consumption since building user behaviors are varied. Nevertheless, it helps architects to take into account the impact of design choices on energy consumption while designing the project.

2.2 RESEARCH SCENARIO IN INDIA

All basic building elements like walls, windows, sunshades & projections, roof etc. have their contribution for the thermal comfort in buildings. It has been revealed from literature survey that research work carried out so far by the other agencies / individuals in this field is limited only in quantification of thermal performance of a single building element or design parameter at a time. Central Building Research Institute Roorkee, has carried out significant research on thermal performance of individual building elements but has not touched the above mentioned aspects i.e. thermal performance of parameters in an integrated manner. However, no research work suggests a model that quantify the integrated effect of orientation of building, roof type, walls & fenestrations, sunshades, thermal mass and ventilation rate on thermal performance of building for the composite climate like that of India. Though, computer program like Energy Plus & TRNSYS are being used for energy analysis in developed countries like USA & Australia, however, use of these tools in India is limited for reasons that I have discussed in this chapter subsequently.

Performance prediction with respect to energy and environment impact may require massive computations, depending upon the building and the accuracy desired. Now, sophisticated computer based simulation program for computation of the energy requirements for lighting, heating, cooling & ventilation. A variety of tools are available, most of which are in the form of rating system based on sets of predefined criteria.

Most sophisticated simulation tools that offer potential for high accuracy (like Energy Plus and TRANSYS) are very hard to use. Reliable and effective use requires knowledge and understanding of the underlying models and incorporated assumptions. They usually require the preparation of input files, which require description of the building and its context using specific syntax and keywords.

Papamichael [83] verify that the learning period for the preparation of input file can be several months long and even then, the preparation of input files may take several days to few weeks, depending on the complexity of design. The same is true with the output of most tools, which is usually in the form of alphanumeric tables that are hard to understand and interpret. Further, in order to get desired results, one may require a combination of tools.

Since different tools use different formats, the uses of multiple tools require repetitive description of the building in different formats making the task more complex and confusing. A thermal simulation tool may require description of the building in the terms of thermal mass & thermal barriers with thermal properties such as Absorbance, U-value & SHGC etc. An artificial lighting simulation tool may require description in the terms of building geometrical spaces with optical properties such as transmittance & reflectance. These repetitive descriptions are time consuming and be avoided.

New simulation tools with graphical interfaces are also being developed such as ENERGY PLUS & TRNSYS with improved modeling capabilities. However, it is a tedious task to get the Indian buildings modeled in their format & to get results from them for composite climate of India. Further, they are uneconomical for Indian laboratories. Most of the sophisticated tools require detailed information about the building material's properties, fixtures to be installed, operation schedule of the fixtures, settings of thermostats & sensors etc. which are usually not available during the initial phase of building design.

Continuous demand for better buildings in terms of comfort and environmental impact has led to development of new strategies and technologies. The development and pressure to design climatically responsive, energy efficient and environment friendly buildings has created the need for the development of an appropriate model which can help the architects to make simulation an integral part of the design process.

The fleet of the software today available is helpful only in the later stage of design when the possibilities for practical improvements in the buildings are finished [46]. They only help the designer to refine their ideas but not help to formulate them. Tools are required today which function when the design is in conceptual stage. An ideal model should assist the design process, taking the design from the infancy stages to detailed working drawings. Misra and Hukmani

[75] also confirm the above-mentioned barriers to the adoption of new software tools and clearly illustrates that these tools include difficult learning curves and the extensive data input requirements.

Zmeureanu [122] undertook an exercise (study) to evaluate the capabilities of four energy analysis softwares (namely, HOT 2000, CODYBA, BLAST and TRNSYS) to predict the energy performance of an existing house to be remodelled. He could find that in spite of large difference in the modelling approaches used by the above mentioned four softwares, the estimate of space heating loads vary by 18 % of the average value of estimate. It has also been mentioned in concluding remarks that "It is also important to note that although much time and effort can be spent on developing an input file which accurately predicts the actual energy performance, assuming that the energy savings are also well predicted, there is nonetheless a large uncertainty associated with the prediction of renovation costs of existing house." It can be safely said that many models and programs are available for energy analysis, however, their availability, training, use and reliability of results is still a matter of concern if they are used in Indian context as they are for the energy analysis for space heating.

Model so developed for Indoor temperature simulation should be simple and flexible. It should be based on default but changeable standard assumptions and must be able to predict thermal performance of composite climate as prevailing in north India.

Most simulation models available today are too expensive to be used by majority of architects. People with deep pockets buy the software and have people delegated only to train, test and use them. Remaining all either try to get the free versions supplied by the companies, which are obviously not very helpful since they have a few bugs or not so user friendly older version.

Thermal & environment simulations are not in practice in India, since these factors, till today, come much after economy, aesthetics and security. Though these factors are important and must be considered in order to facilitate environmental sustainability. This is the need of the day that Indian architects must adopt thermal simulation as an integral part of design process in order to save nations energy. It can be summarized that there is a need of research on the issues related to thermal comfort and energy calculations in India in order to design and built more comfortable energy efficient buildings. This research work would add a step ahead in Indian building research activities, particularly related with thermal comfort issues.

CASE STUDIES

3.0 INTRODUCTION

Today, living in an urban environment demands efficient utilization of scarce resources. In this context the maximum utilization of energy has become the most important as well as crucial criteria. Architect's role is essential to design buildings that can create maximum possible comfortable living conditions. Research and efforts are being made in various climatic regions all over the world in order to find out energy efficient design solutions. Case studies are important because they present the State of Art in research field in a realistic and justified manner. Since no literature pertaining to research work in the context of Composite Climate is available, hence research work carried out for other climatic zones (*Warm-Humid* in Sri Lanka and *Mansoon*, so called in China), which is available in the form of research papers in International journals. This chapter consists two such studies. First case study is based on the results obtained by the computer program for a residential unit in the context of warm-humid climate of Sri Lanka. Another case study is based on experimental measurements in the context of Chinese vernacular dwelling.

3.1 CASE STUDY – 01

Senanayake [99] carried out study on means of achieving thermal comfort in small Urban Houses in Sri Lanka. In this study, a house for an upper income young couple in Colombo has been analyzed with the DEROB-LTH in order to derive better design solutions for comfortable living. It was meant to help in identifying design parameters of such dwellings, which can be studied modified and developed to achieve inexpensive passive cooling techniques in a developing country i.e. Sri Lanka.

The project selected is a house for an upper income young couple at Kollupitiya near the Temple trees, just 1.5 km away from Colombo. The site is 6.0 m in extent and bounded by the road from the east and residential plots on remaining three sides. It is a flat land and no trees within the site or in close proximity. The couple is young professionals. A housemaid visits every morning for preparation of food and cleaning and leaves before noon.

The design consists of a multi purpose large room with the parking space for the car, the little pantry with the dining and the attached living within the ground floor. The first floor consists of the bedroom and the toilet. The second floor consists of the study and two terraces on two sides.

The Urban Development Authority Building Guide Lines mainly governed the design constraints. The land non-buildable minimum 3 m from the rear and 1 m from the front allows to build up to the boundaries from the other two sides. This gives two large blind walls at side ends adjoining the neighboring residences. Light and ventilation is not allowed from these two sides. The overhangs are maximized up to 0.5 m. The size of the plot made the car park inside the house. The couple may use this space for private functions occasionally. They specially required large openings for the breeze and the second floor with two outdoor terraces for the study.

3.1.1 The Program (DEROB-LTH)

The program adopted in the study is Dynamic Energy Response of Buildings: *DEROB-LTH*, which is modified and developed as a Windows version by the University of Lund, Sweden. It is used to study the dynamic behaviour of buildings with respect to heating and cooling energy demands, temperatures and thermal comfort. In this study the *DEROB-LTH* is used to analyze the thermal comfort of the described project and thereby derive better design solutions for comfortable living.

3.1.2 Scope & Limitations of the Study

Simple requirements, small tight site and building codes enabled a simple, small design. But during the study it was necessary to have limitations and there by limit the scope of the study. It helped the study to be more practical, within the limitations of the program and the time as well.

a. Since the rising temperature is more crucial in a warm humid climate of Sri Lanka, the study was carried out to analyze the Indoor Thermal Comfort only. Only the month of April with a usual highest temperature in Year 2001 is considered as more beneficial.

b. The design comprises of three floors namely, the Ground Floor, First Floor and the Second Floor. The study aims to carry out the Comfort Levels of Ground Floor and the Second Floor only.

c. The use of conventional materials that have a higher demand in the building industry is considered more practical.

d. The size and position of openings were not considered due to the smaller width of the site and required largest possible windows. It has been assumed that the design achieves natural ventilation.

e. Shading Walls, which represent the immediate adjoining buildings, are considered as having maximum possible height of 3 stories therefore gives shade to the building.

Fig. 3.1 : Ground Floor and First Floor Plans

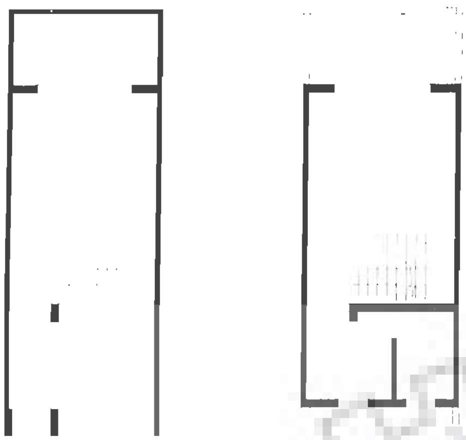
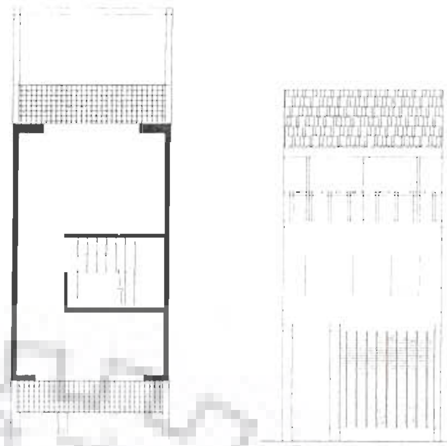


Fig. 3.2 The Second Floor Plan and Elevation



3.1.3 The Method of Study

The DEROB-LTH was used to create the Base Model from the original design. The site locates at latitude of 80° N and longitude of 7° E with an altitude of 7m. The design faces to the East-West therefore orientates at a 90° angle from the North- South axis. Following are considered as,

Volume 1 The Ground Floor

Volume 2 The Second Floor

Since the First Floor is eliminated in calculations, for simplification it was not included in the Base Model either.

Table 3.1 : Parameters of Volume 1

Vol.	Bldg. element	Material	Thick	Conductivity	S. Heat	Density	Absorptivity		Emissivity	
			mm							
1	Floor	Earth	300	1.4	0.22	1900		70		87
		Sand	150	0.4	0.24	1200				
		R. Concr.	100	1.38	0.26	2100				
		C. Mortar	15	0.93	0.29	1800				
		Cer Tiles	25	0.95	0.25	2000				
	Walls	Brick	225	0.5	0.2	1300	70	70	87	87
	(Opaque)									
	Doors	Timber	38	0.16	0.75	900	70	70	87	87
	(Opaque)									
	Window	Glass	6							
	(Transp.)									
	Roof	Min. Wool	500	0.04	0.24	50	0	0	87	87
	(Adeab.)	Rein.Conc.	50							
		C. Mortar	8							
	S. Wall		225				70	20	87	87

Table 3.2 : Parameters of Volume 2

Vol.	Bldg. element	Material	Thick	Conductivity	S. Heat	Density	Absorptivity		Emissivity	
			mm							
2	Floor	Min. Wool	250	0.04	0.24	50	0	0	87	87
		Rein.Conc.	50	1.38	0.25	2100				
		C. Mortar	8	0.93	0.29	1800				
		Tiles	12	0.95	0.25	2000				
	Walls	Brick	225	0.5	0.2	1300	70	70	87	87
	(Opaque)									
	Doors	Timber	38	0.16	0.75	900	70	70	87	87
	(Opaque)									
	Window	Glass	6							
	(Transp.)									
	Roof	Rein.Conc.	50	1.38	0.25	2100	0	0	87	87
	(0 angle)									
		C. Mortar	8							
	S. Wall		225				70	20	87	87

3.1.4 Internal Loads

The life patterns of the young couple and the housemaid who comes in the mornings during a period of 24 hours was considered in determining the internal loads separately for the two volumes. Internal Loads were calculated by using AIOLOS program.

3.1.5 Infiltration

8 ACPH (air changes per hour) were maintained during daytime and night respectively. Following Tables illustrates the rate of air changes (during different hours of the day) and internal load (in W) maintained in the building.

Table 3.3 : Rate of Ventilation (ACPH) in Volume 1.

Hour	Infiltration (ACPH)	Internal Loads (W)
1 to 6	8	70
7 to 12	8	400
13 to 18	8	
19 to 24	8	170

Table 3.4 : Rate of Ventilation (ACPH) in Volume 2.

Hour	Infiltration (ACPH)	Internal Loads (W)
1 to 6	8	105
7 to 12	8	
13 to 18	8	
19 to 24	8	210

All above, with consideration of the Year 2001 Climatic Data for Colombo, Mahoney Table and the Bio-climatic Givoni tables, with use of the DEROB-LTH the Volumes 1 & 2 of the Base Model were simulated separately. It helped to derive the Operative Temperature, Indoor Temperature and the Outdoor Temperature of the selected project.

It was revealed that the maximum and the minimum operative temperatures in the Volume 1 were 29.8° C at 16.00 hours and 25.9° C at 6.00 hours respectively. Maximum and the minimum operative temperatures of the Volume 2 were 33.9° C at 15.00 hrs and 27.4° C at 7.00 hours respectively. Therefore Temperature of the Volume 2 is always higher than the temperature of the Volume 1.

3.1.6 Simulations

The models for parametric studies were decided according to a schedule. There was one specific major parameter as following,

Orientation: 1. The house facing the East-West angle- 90° (Similar to Base Model) 2. The house facing the North-South angle-0°

Other than above the Base Model was differed in each study by one parameter (in conventional materials) at a time only.

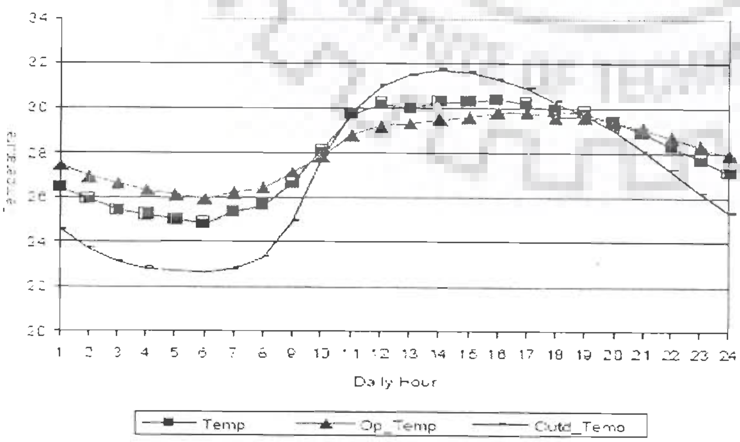


Fig. 3.3. Temperature of Base Model Vol 1

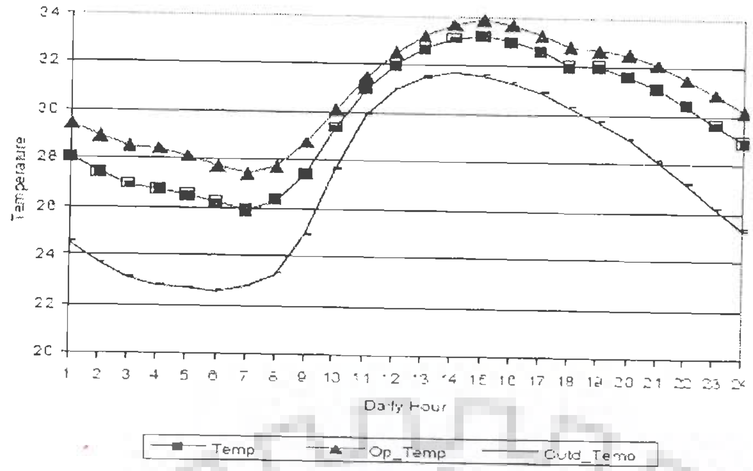


Fig. 3.4 : Temperature of Base Model Vol. 2

East -West Orientation - 90° (Orientation similar to Base Case)

Model One

Reinforced concrete shading devices up to 0.5 m added to volume 1. Reinforced concrete shading devices up to 1m added to volume 2. (Depth of the shading device was changed according to the building guidelines of the Urban Development Authority of Sri Lanka).

Result	Vol. 1	Vol. 2
Base Model (without shading)	29.8°	33.9°
Model One (with shading)	29.8°	33.4°
Temperature Difference	0.0°	0.5°

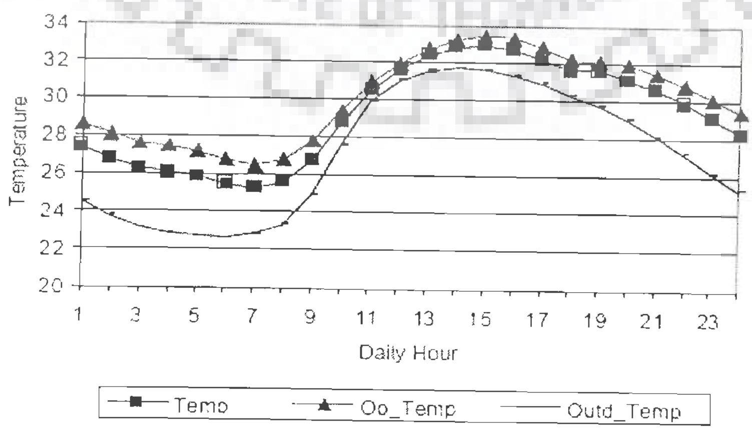


Fig. 3.5: Temperature of Model 1 Vol.1

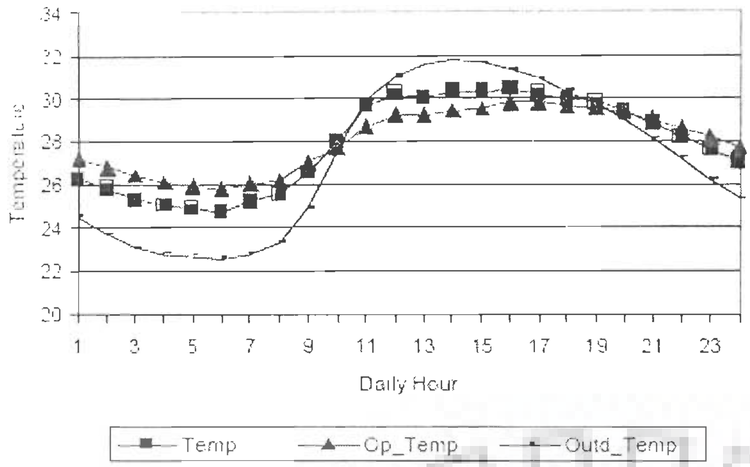


Fig. 3.6: Temperature of Model 1 Vol. 2

Remarks

Shading devices give a lower temperature in the Volume 2

Model Two

Brick walls were plastered with 15 mm cement-lime plaster in both volumes 1 & 2

Plaster was coloured in white emulsion paint.

Result	Vol. 1	Vol. 2
Base Model (only brick)	29.8°	33.9°
Model Two (brick, plaster, white)	28.9°	32.5°
Temperature Difference	0.9°	1.4°

Remarks

When plastered and white painted, a significant low temperature is shown in both volume 1 & volume 2.

Relevant temperature profiles are shown in Fig. 3.7 & Fig. 3.8.

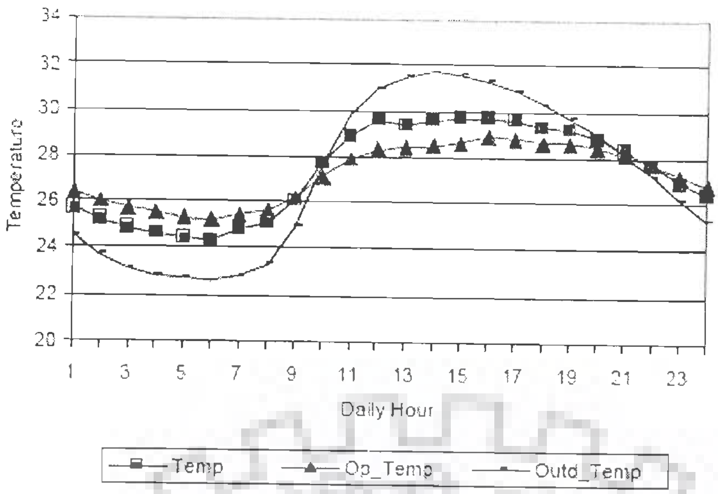


Fig. 3.7: Temperature of Model 2 Vol.1

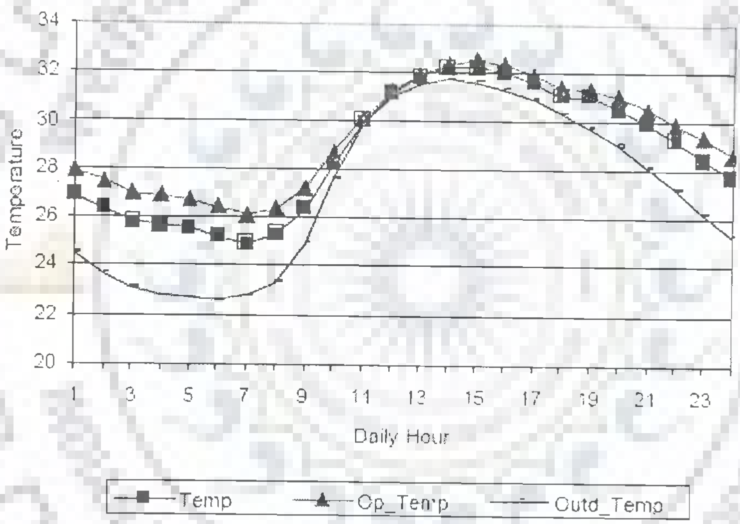


Fig. 3.8: Temperature of Model 2 Vol.2

Model Three

Concrete flat shading devices changed to the asbestos 18° angle shading devices in volume 1. Volume 3 was not considered. Concrete flat roof changed to Asbestos Roof in 18° angles in volume 2

Result	Vol. 1	Vol. 2
Base Model (concrete flat)	29.8°	33.9°
Model 3 (asbestos 18° angle)	29.8°	32.9°
Temperature Difference	0.0°	1.0°

Remarks

Adding shading devices does not affect the volume 1.

Asbestos shading devices at the upper floor give a significant lower temperature in the Volume 2.

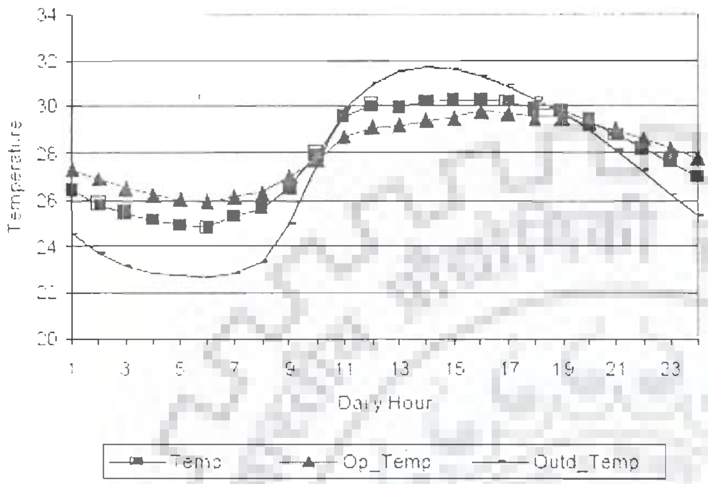


Fig. 3.9: Temperature of Model 3 Vol.1

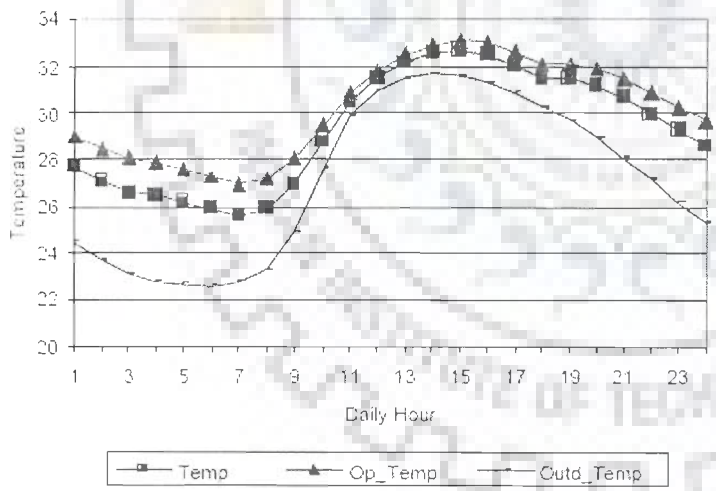


Fig. 3.10: Temperature of Model 3 Vol.2

Model Four

Concrete flat shading devices changed to Tile on timber frame 30° shading devices in volume 1. Volume 3 was not considered.

Concrete flat roof changed to Tile roof on timber frame 30° in volume 2

Result	Vol. 1	Vol. 2
Base Model (concrete flat)	29.8°	33.9°
Model Four (tile 30° angle)	29.7°	32.3°
O. Temperature Difference	0.1°	1.6°

Remarks

Tile roof on the timber framework give a lower (than the asbestos roofing) temperature in volume 2.

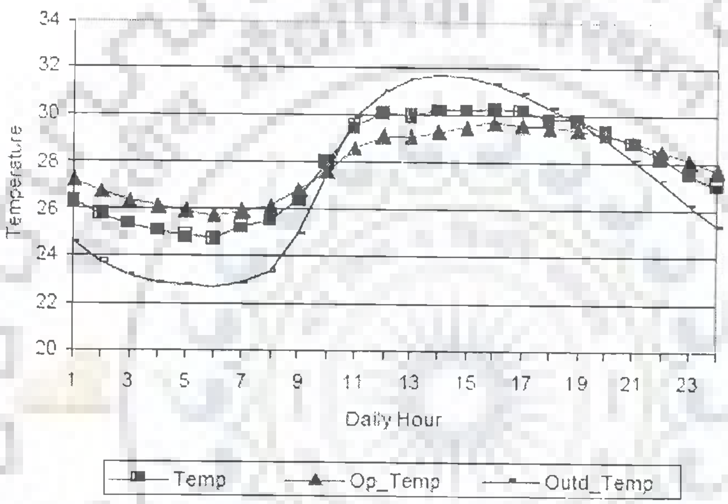


Fig. 3.11: Temperature of Model 4 Vol.1

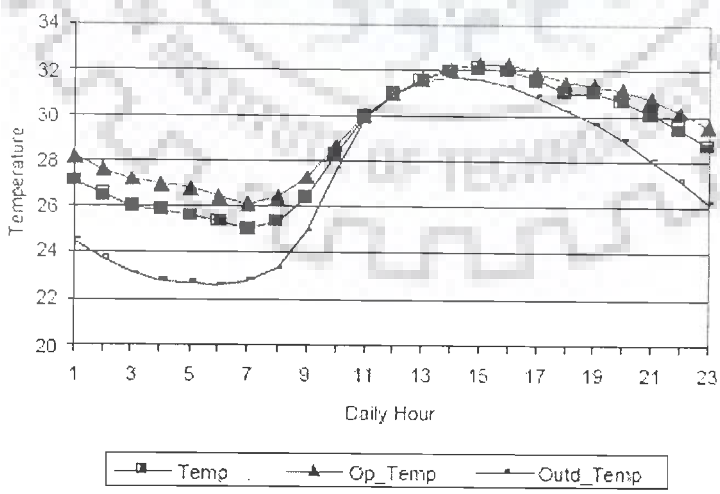


Fig. 3.12: Temperature of Model 4 Vol.2

North-South Orientation-0°

Model Five

Orientation was changed to East-West only.

Result	Vol. 1	Vol. 2
Base Model (E-W)	29.8°	33.9°
Model Five (N-S)	29.7°	32.5°
Temperature Difference	0.1°	1.4°

Remarks

Orientation to the N-S axis gives a significant lower temperature in the volume 2.

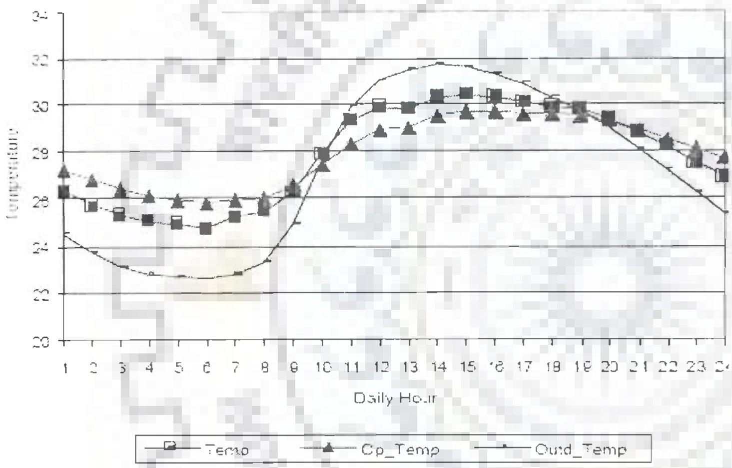


Fig. 3.13: Temperature of Model 5 Vol.1

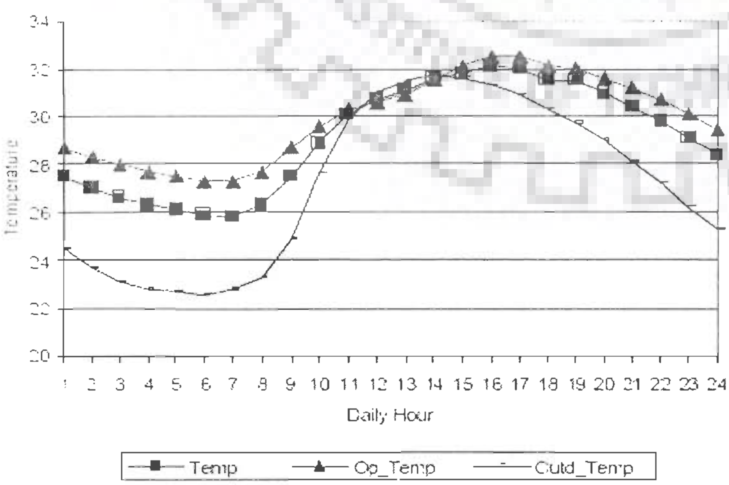


Fig. 3.14: Temperature of Model 5 Vol.2

Model Six

Reinforced concrete shading devices up to 0.5 m added to volume 1. Reinforced concrete shading devices up to 1m added to volume 2. (Depth of the shading device was changed according to the building guidelines of the Urban Development Authority of Sri Lanka)

Result	Vol. 1	Vol. 2
Base Model (E-W, no shading)	29.8°	33.9°
Model Six (N-S, with shading)	29.7°	31.7°
O. Temperature Difference	0.1°	2.2°

Remarks

Orientation to the N-S axis with the concrete flat shading gives a good high (same as above) temperature difference in the volume 2.

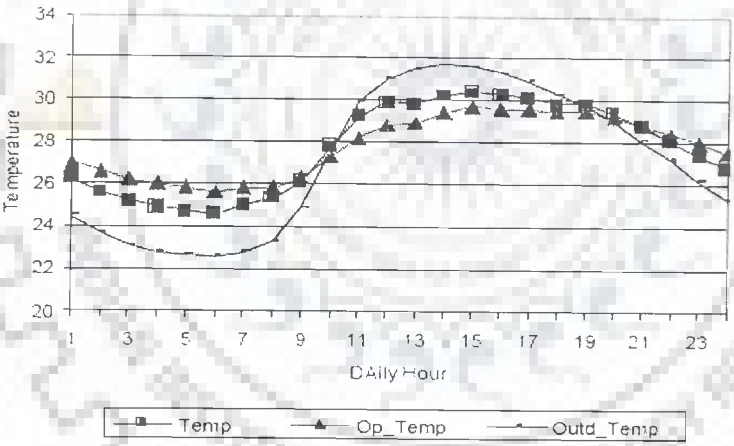


Fig. 3.15: Temperature of Model 6 Vol.1

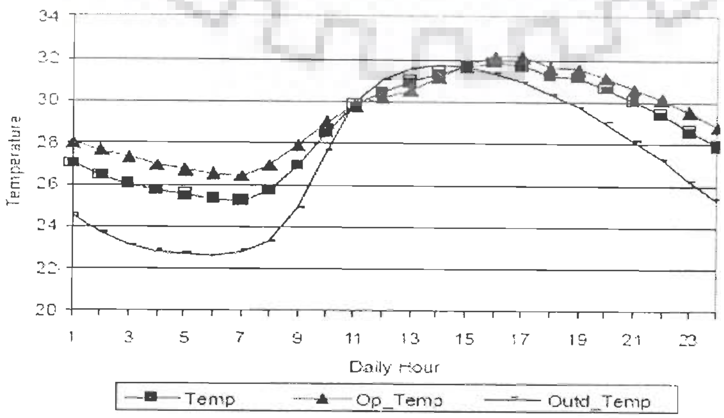


Fig. 3.16: Temperature of Model 6 Vol.2

Model Seven

Both, Volumes 1 & 2 are in plastered brick walls. Plaster was coloured in white

emulsion paint

Result Vol. 1 Vol. 2

Base Model (N-S, brick only) 29.8° 33.9°

Model Seven (E-W, with plaster) 28.8° 31.1°

O. Temperature Difference 1.0° 2.8°

Remarks

Orientation to the N-S axis and the brick plaster with white paint gives the highest temperature difference between the indoor and the outdoor.

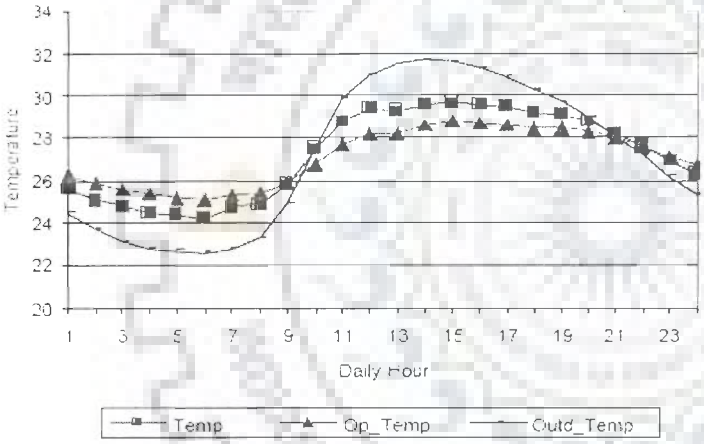


Fig. 3.17: Temperature of Model 7 Vol.1

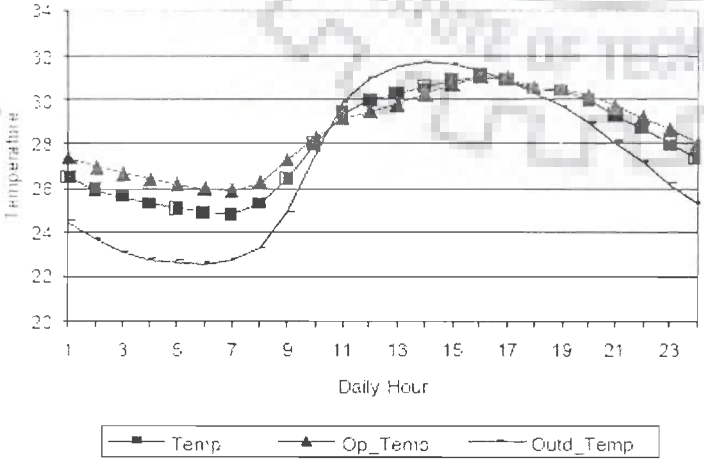


Fig. 3.18: Temperature of Model 7 Vol.2

Model Eight

Concrete flat shading devices changed to the asbestos 18° angle shading devices in Concrete flat roof changed to Asbestos Roof in 18° angles in both volumes 2

Result	Vol. 1	Vol. 2
Base Model (concrete flat)	29.8°	33.9°
Model 8 (asbestos 18° angle)	29.6°	31.8°
Temperature Difference	0.2°	2.1°

Remarks

Orientation to the N-S axis gives a good higher temperature difference in the Volume 2.

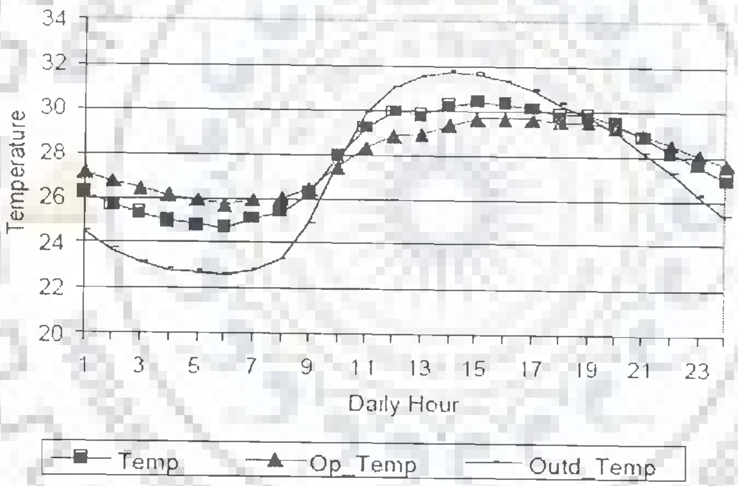


Fig. 3.19: Temperature of Model 8 Vol.1

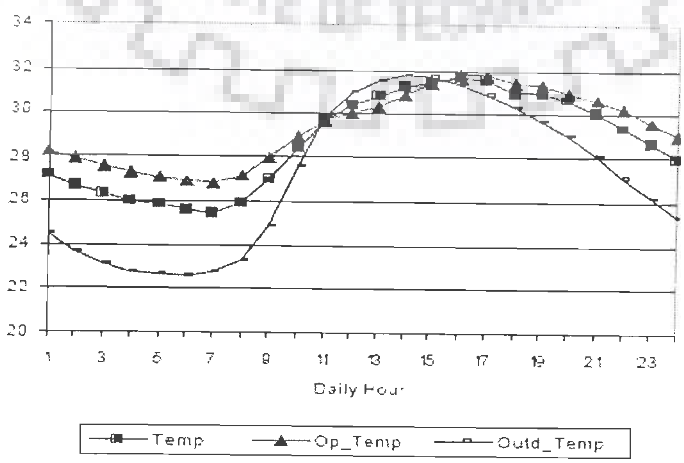


Fig. 3.20: Temperature of Model 8 Vol.2

Model Nine

Concrete flat shading devices changed to Tile on timber frame 30° shading devices in volume 1. Concrete flat roof changed to Tile roof on timber frame 30° in volume 2.

Result	Vol. 1	Vol. 2
Base Model (concrete flat)	29.8°	33.9°
Model Nine (tile 30° angle)	29.5°	31.1°
Temperature Difference	0.3°	2.8°

Remarks

Orientation to the N-S axis and tile roof on timber framework gives the highest temperature difference between the indoor and the outdoor of the volume 2.

East -West Orientation versus North South Orientation

Next all the models were compared to analyze the operative temperature difference of the two orientations. Following are the results.

	Vol. 1	Vol. 2
Base Model (E-W, brick only)	29.8°	33.9°
Model Five (N-S)	29.7°	32.5°
Temperature Difference	0.1°	1.4°
Model One (E-W with shading)	29.8°	33.4°
Model Six (N-S with shading)	29.7°	31.7°
Temperature Difference	0.1°	1.7°
Model Two (E-W brick, white)	28.9°	32.5°
Model Seven (N-S brick, white)	28.8°	31.1°
Temperature Difference	0.1°	1.4°
Model Three (E-W asbestos 18°)	29.8°	32.9°
Model Eight (N-S asbestos 18°)	29.6°	31.8°

Temperature Difference	0.2°	1.1°
Model Four (E-W tile 30° angle)	29.7°	32.3°
Model Nine (N-S tile 30° angle)	29.5°	31.1°
Temperature Difference	0.2°	1.2°

General Remarks

Orientation

The study indicates that when the house is faced to North-South Orientation -0° the Operative temperature is always lower than the house faced to East-West orientation -90°.

Shading Devices

When the shading are added the temperature of the Volume 2 decreased greatly.

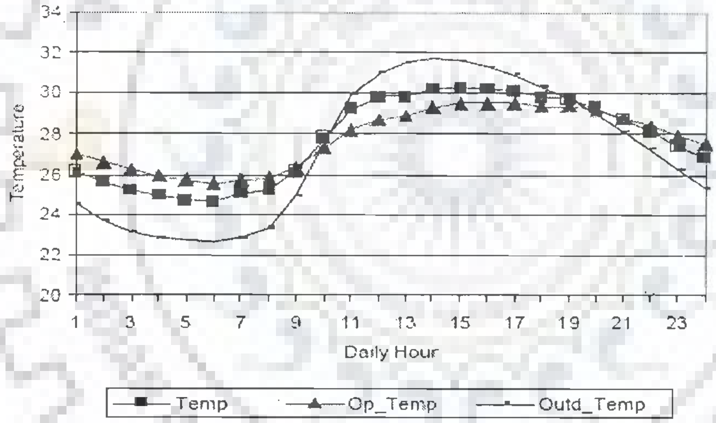


Fig. 3.21: Temperature of Model 9 Vol.1

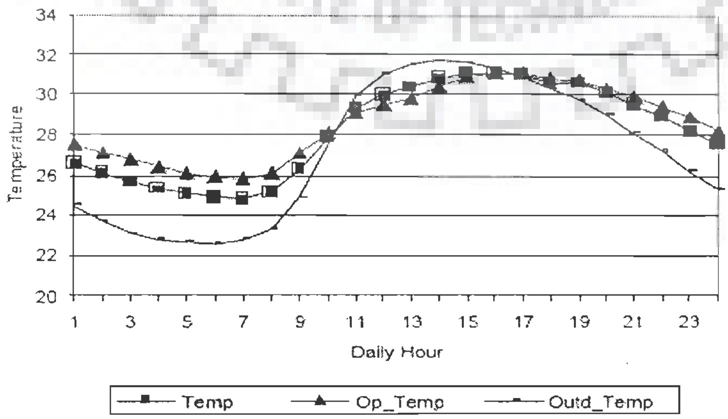


Fig. 3.22: Temperature of Model 9 Vol.2

Walls

When the walls are plastered and white emulsion painted the temperature lowered Immensely by 2.8° C.

Roof

Both the Asbestos 18° roof and the Tile 30° give a lower operative temperature than the flat concrete roof. Tile 30° roof (31.1°C) gives a low temperature than the Asbestos °18 roof (31.8°C). Tile 30° roofs, instead of the flat concrete roof allowed the temperature to lower immensely by 2.8° C.

3.1.7 Conclusions of Case Study 01

Today living in an urban environment demands efficient utilization of scarce resources. In this context the maximum utilization of energy has become the most important as well as the most crucial criteria. In positive response, the public contribution is essential. Architects' role in this sense is to design buildings that can create maximum possible comfortable living conditions.

In a warm-humid climate and a developing country like Sri Lanka the possible and the low cost manner is to achieve passive thermal comfort. The study carried out above attempted to derive good solutions in selecting the best possible material among the conventional building materials used in the country. The study reveals that the tile as a roofing material and the walls with plastered brick walls, painted in white emulsion is the best possible among the studied materials. The use of shading devices also can be recommended. Most of all the important criteria are the orientation of the building to the North-South Axis where direct sunlight does not penetrate in to the indoor volumes. But any of the designs are not within the comfort zone (17° C to 25° C) in Colombo. Therefore a minimum amount of possible mechanical thermal means should be used.

3.2 CASE STUDY 02

Study on the thermal performance of the Chinese traditional vernacular dwellings in summer has been carried out by Borong, Gang, Peng, Ling, Yingxin and Guangkui [9]. This study is based on the field measurements of the thermal environment parameters and a long-term auto-recorder of the indoor and outdoor temperature at four typical traditional vernacular dwellings at Wannan area in summer. With the analysis of the fine structures design such as the dooryard, the structure of the double-pitched roof and the eaves by the measurements of temperature, wind velocity, etc. some design principles of the traditional vernacular dwellings in Wannan area are revealed. It has been established by this study and results that sun shading and insulation are of great importance while the natural ventilation is just considered as an auxiliary approach in these dwellings. So the strategy of ventilation design is to restrain the natural ventilation at daytime and to boost it at night. Aimed at a quantitatively study of the thermal performance of the traditional vernacular dwellings and a clarification of those controversial issues, a detailed field study of several typical traditional vernacular dwellings has been done.

3.2.1 Outline of the measurements

The field test includes a measurement of temperature, humidity and velocity. Table 3.5 shows the instruments for all corresponding parameters. Shading device was used at the beginning of the measurements of outdoor temperatures.

The core area of Wannan vernacular dwellings locates near the north latitude 30° and belongs to the subtropical belt monsoon wet climate. The characteristics of such climate are hot in summer and warm in winter with humid air and full rainfalls. The measured houses have most of the typical characteristics of traditional Wannan vernacular dwellings.

Table 3.5 : Measured parameters and instruments

Measured parameter	Instrument	Precision (°C)	Notes
Temperature of indoor/outdoor air	RH auto-logger thermometer	±0.2	Auto acquisition per 5 min
Wet bulb temperature of in door and outdoor air	Assmann psychrometer	±0.05	Manual acquisition per 30 min
Temperature of envelop surface	Thermal couple	±0.1	Manual acquisition per half an hour
Air velocity	Hot ware anemoscope	±5% of the measured value	Auto acquisition per 6 s
Temperature of black ball	Standard black ball ther-mometer	±0.2	Auto acquisition per 5 min

Four typical traditional vernacular dwellings with different orientation, floor and space layout were selected for the field measurement, among which two traditional vernacular houses and one modern house have been selected to complete a long-term field study, shown in Table 3.6.

Table 3.6 : Information of the measured buildings

Building's name	Orientation	Floors	Long-term measurement	Notes
Zhaolan House	South–north	2	Yes	Built at Ming Dynasty, about 400 years ago
Huai Sutang House	East–west	1	No	Built at Qing Dynasty, about 200 years ago
Cheng Meitang House	South–north	2	No	Built at Qing Dynasty, about 200 years ago
Jiqing House	South–north	2	Yes	Built at Qing Dynasty, about 200 years ago
Zhongxiu Hotel	South–north	2	Yes	Modern concrete building, built about 5 years ago

And the plan view and the section view of one of these four vernacular dwellings are shown in Fig. 3.23 (on next page). The spots with a circle number show where the velocity is measured and the others mean temperature-measuring spots. The shading part at the plan view indicates the dooryard.

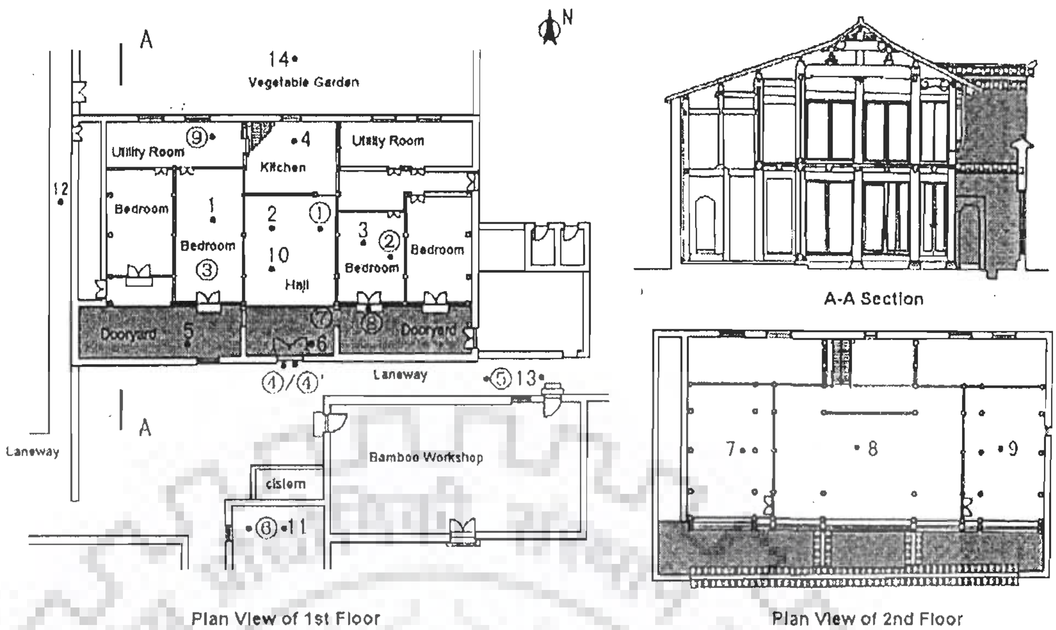
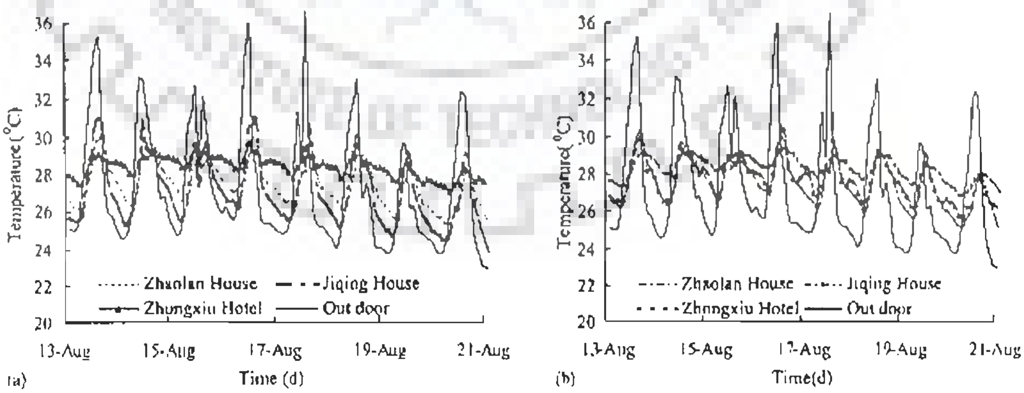


Fig. 3.23: Plan and Section of Vernacular Dwelling

3.2.2 Results and analysis

Comparison of the thermal performance between the traditional vernacular dwellings and the modern houses. For nearly the same indoor heat source, comparison can be done for about 1 month temperature results measured from different rooms of the Zhaolan House, Jiqing House and the modern house named Zhongxiu Hostel, shown in Fig 3.24 (a) & (b).



2. Comparison of air temperatures from the long-term measured results. (a) The air temperature at bedroom; (b) the air temperature at the hall.

Fig. 3.24: Comparison of air temperatures from the long-term measured results. (a) The air temperature at bedroom; (b) the air temperature at the hall.

From the results, the whole day mean temperatures of the hall and bedroom of traditional buildings are 1.5 °C lower than the modern house. But for the mean temperature at daytime, especially during the several hours near midday, traditional buildings are about 1–2 °C higher than modern house and for the mean temperatures at night the indoor temperatures of the former are 3–4 °C lower than the latter, which is closer to the outdoor ambient temperature. The whole day temperature fluctuating breadths of the traditional houses and the modern house are 4–6 and 2 °C, respectively. So it clearly shows that during the daytime the temperatures of traditional houses are not lower than those of modern houses. This contradicts to the previous statement from literature, which says the old houses are cooler than modern houses in summer.

3.2.3 Relationship between the shading and thermal insulation design and the indoor thermal environment

Shading and thermal insulation are important considerations in vernacular house design to avoid solar radiation and it is easy to find various vivid examples in Wannan area. For envelop design, the wall of traditional vernacular dwellings at Wannan area, which external surface is pasted up with white plasma, is about 300 mm thick and usually has a structure of emplectum or general brick with local clay as materials. The first floor of the building is usually covered with greenish marble or three-ply soil. For space layout, the traditionally important rooms such as the hall and the bedrooms with a large depth are often bounded by walls with wood-siding and the external walls are usually minimized. The bedrooms are usually located next to the hall and often have an overhead wood floor, which is about 30–40 cm higher than the floor of hall and can yield an effect of damp-proof and dehumidification with ventilation outlet at the wall footing. Houses with two or more floors are common in Wannan area, the primary function of the floors above two is for storage purpose. But obviously, they can also serve as an insulation layer for the building.

The measured temperature reveal that the diurnal air temperature of the second floor is higher than that of the first floor in summer. The temperature difference is above 2.5 °C with a maximum value of 4 °C. Furthermore, due to different kinds of shading and ventilation arrangement, there are temperature differences among different rooms at the same floor and the maximum difference can be above 2 °C. For example, if the dooryard is covered with a bamboo curtain, the temperature will be lower than without a bamboo curtain.

It is very common that the roofs of the traditional vernacular dwellings are designed as a double-pitched raft and with an overhead double layer tiled structure, which is named Wang Brick by local people. From the measured results of the external and internal surface of the raft, it was inferred that the internal surface temperature is just 35 °C and the external surface temperature is 45 °C when the outdoor air temperature is 36 °C high. The outdoor air temperature begins to decrease more rapidly after 2 p.m.; and as a result of that, the temperatures of the external and internal surface of the raft also began to decrease quickly. About 6 p.m. the temperatures of the external and internal surface of the raft are almost equal to the outdoor air temperature. In a word, the raft with the "Wang Brick" structure has a considerable desirable effect both on good insulation and quick cooling.

The ceiling height of a traditional vernacular house, which is often above 6 m, is usually higher than modern houses (e.g. The hall height of Jiqing House is about 6.6 m), but the measured temperature distribution in vertical direction does not show a significant effect of the ceiling height. The maximum temperature differences are below 1.5 °C. Also, if compared with the long-term measured hall temperature results, it can be concluded that the taller the hall, the higher its diurnal temperature, such as in Jiqing House and Zhaolan House. So again, this contradicts to earlier conclusions in literature stating that the taller the ceiling height the cooler in the room.

The air temperature around the dwellings is also measured. The results show that at the daytime the temperature at the south laneway is always more than 2 °C lower than the temperature at the raft and the vegetable garden, while the situation is reverse at night. The reason for this is the compact layout of the traditional vernacular dwellings at Wannan area. The compact laneway shades the direct solar radiation and produces a cool thermal sensation in the daytime of summer. More important is that, although the air temperature is lower than the one in the open area, it is still higher than the indoor air temperature and could not give people a cooler feeling generally. So the saying that there are some cool sinks around the buildings and they could be used to cool the room is questionable.

The results of measurement of the internal surface temperature of the envelope shows that the lowest temperature is at 24 °C under the overhead. The next is at the deepest spot in the hall at about 26 °C. Generally speaking, the temperature of the internal surface of the envelope and the floor surface is both lower than the air temperature in most of the daytime and then can produce a cool thermal sensation in summer.

Different from the traditional dooryard named "all water merged into the hall" at the Huizhou area, the dooryard of the dwellings at Wannan area has a structure of linear type and its width is about 2.5–3 m. Clearly, it is so called linear type because the dooryard is like a tall wall located at the south of the prime room about 2.5 m away, which is similar to the layout of the north residential quadrangle with a tall wall at the south. Apparently, its main function is to shade the solar radiation, just like the bamboo curtain installed at the dooryard. On the other hand, day-lighting should also be considered besides sun shading. Thus, the Hood of traditional vernacular dwellings at Wannan area is selected for a proper length about 1.5 m with the compromise between sun shading and daylighting. The other feature of the dooryard at Wannan area is its landscape. For instance, there is always boulder strip paving, vegetable, dish garden and aqueduct in the dooryard and its cooling effect of transpiration is obvious.

From the statistics of the indoor temperature distribution as time, it shows that about 70% of the time the indoor air temperature of the different first floor rooms of Zhaolan House is lower than 28 °C while the maximum temperature of outdoor air is about 38 °C. So, it seems that the indoor temperature at the first floor of the traditional vernacular dwellings is satisfactory with the combined effects of sun shading and insulation.

3.2.4 Natural ventilation designs and the indoor thermal environment

There is a very common saying (in China) that the main reason for the traditional vernacular dwellings to keep cool in summer is the good ventilation. In fact, if the "cool" here refers to the indoor air temperature, then when the daytime outdoor temperature is higher than the indoor temperature, which is very common at Wannan area in summer, good ventilation just brings more heat into the room and "destroy" the indoor thermal environment. So, the above saying is questionable. Furthermore, the analysis of the layout of the dwellings can lead to the same conclusion. For example, there is little design to create an efficient way for the cross ventilation in the typical traditional dwellings except the second floor. Even the Zhaolan House that has so many doors and windows, neither bedroom nor hall has doors or windows in the same axial line. There is a small window in the south wall at the dooryard, but it is not often open.

What is especially worth mentioning is that the layout of vernacular dwellings at Wannan area is a pattern of compact arrangement. However, this typical arrangement generally applied in dry and hot climate should not be used in the wet and hot climate. Besides to assuring safety and privacy, such arrangement also can decrease the master velocity and restrain the pressure induced ventilation. And it is definitely an advantage for people in summer to reduce hotter air into the room in the daytime.

On the other hand, there is another mechanism providing a good thermal environment for people at night. In fact, the thermal pressure natural ventilation or the density difference induced ventilation is the main advantage in the design of the traditional dwellings at Wannan area. With the linear type dooryard, the bamboo curtain and a constrictive and reducing opening, there is a density difference between the air at the dooryard and in the other areas. Then with the "stack effect" the hot air goes out from the opening of dooryard and cool air enters into the room successively. At daytime, the outdoor air temperature is higher than the indoor air. So the thermal pressure ventilation cannot run efficiently in the whole building. On the other hand, the pressure-induced ventilation is also restrained at daytime because of the compact arrangement of the vernacular dwellings here. With limited natural ventilation the dwelling can get a relatively low temperature and its thermal environment is congenial. At night the effect of the thermal pressure ventilation is obvious when the outdoor air temperature is lower than indoor air. Thus, with the successive entering of cool air from outdoor, the room can get a satisfactory thermal environment.

The above measured results and analysis revealed the design strategy of the traditional dwellings at Wannan area, of which sun shading and insulation are of great importance while the natural ventilation is just considered as an auxiliary approach. So the strategy of the ventilation design is to restrain the natural ventilation during the daytime and to boost it at night.

3.2.5 Conclusions from the Study 02

The field measurement and analysis gives more accurate understanding of the summer thermal environment of the Chinese traditional vernacular dwellings at Wannan area. Some wrong or one-sided views about these vernacular dwellings, such as the temperature distribution in the high rooms, the temperature of “cool laneway” and its cooling effect on the indoor room, and the relationship between ventilation and indoor air temperature, are also clarified.

In summary, there are two main conclusions from this study. First, the strategy of the design is to consider the sun shading and insulation in the first place and there are various methods of shading and insulation including the materials and structure of envelops and the roof, the layout of the room and design of the dooryard. Second, natural ventilation is just an auxiliary facility for a better indoor thermal environment. In summer, the design strategy is to restrain the ventilation during the daytime and to boost it at night with thermal pressure induced ventilation.

3.3 INFERENCES FROM CASE STUDIES

Case studies presented in this chapter are testimony to the fact that people are becoming conscious about achieving thermal comfort in residential buildings with the minimum use of energy required for the heating and cooling. The researchers are conducting experiments in order to find out optimized design solutions while depending upon natural means of heating and cooling in different climatic zones of the world. Efforts are also being made in order to develop computer models and simulation programs for the architects and building designers through which they can find out energy efficient solutions for their projects. However, there is uncertainty and contradiction of opinion regarding the quantification of thermal performance of building elements and design parameters. Some scholars recommend enhanced natural ventilation in the buildings during nighttime, though the concept was not scientifically established. Authors of case study 02 have scientifically proved the criteria. Similarly, scholars have different opinions about the effectiveness and quantification of thermal performance of design parameters and building elements. However, it is clear that the design variables which have been considered in this research work, namely, Orientation, Wall thickness, Fenestrations, Sunshades, Roof type and Ventilation Rate stands significantly in the research field of the present decade. Efforts are required to judge the effectiveness of these variables and to quantify their effect in varied climatic conditions / zones.

Most of the scholars (including the authors of above 02 case studies) have considered Dry Bulb Temperature (DBT) in ^{0}C in order to analyze the thermal performance of buildings. In this research thesis, the same criteria have been taken into consideration. Further, thermal performance has been analyzed in view of temperature profiles (24 hours) of Outdoor Temperature Vs Indoor Temperature. In this research study, the same connotation has been taken into consideration. It is also clear form the case studies that need of such a model is there that facilitate the architects to judge varied design concepts on a particular site in order to find out an optimum solution.

CHAPTER 4

DATABASE

4.0 INTRODUCTION

The developed simulation model require substantial input describing detailed building geometry, properties of materials used in different layers/sections (walls, roof, floor, fenestration) in the building constructions, weather data, thermal capacity of articles and heat load of appliances in different rooms. To make the program easier for the user during the design process, default values has been set for the input. Some standard brick wall sections, RCC roof / slab sections, floor section as commonly practiced in India has been incorporated in the model. As per the building requirements, user can choose the different values as per the required building specifications. Data has been obtained majourly from two major sources. National Building Code of India (2005) has been referred as the primary data source and ASHRAE Standatrds (2001) has been considered as secondary data source. Various types of data (i.e. climatic data, properties of building materials and heat load of occupants and appliances) used in this research study is compiled in this chapter.

4.1 CLIMATIC DATA

The primary weather related variable influencing the heat load of a building is Solar Radiation. The effect of solar radiation is more pronounced and immediate in its impact on exposed non-opaque surfaces. For practical evaluation, it is necessary to know the duration of sunshine and hourly solar intensity on various external surfaces on representative days of the season. This data is essential to determine total heat gain on building envelope.

{Source: ASHRAE Handbook (2001) Fundamentals Table 16, p-29.17}

Table 4.1: Solar Data for different months of the year

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A (W/m^2)	1230	1215	1186	1136	1104	1088	1085	1107	1151	1192	1221	1233
B	0.142	0.144	0.156	0.18	0.196	0.205	0.207	0.201	0.177	0.160	0.149	0.142
C	0.058	0.06	0.071	0.097	0.121	0.134	0.136	0.122	0.092	0.073	0.063	0.057

Where

A = Apparent Solar Constant

B = Atmospheric extinction coefficient

C = Sky diffuce factor

Data is used in the calculations of Direct, Diffuse and Total Solar radiation on building envelope.

Climatic data of Roorkee (2005), as recorded by Meteorological department of National Institute of Hydrology, Roorkee has been used in order to prepare the weather data files for representative day i.e. 21 day of each month. This data has been reproduced (on hourly basis) as hereunder in Table 4.2.

Table 4.2 : Climatic data of Roorkee (year 2005)

MONTH ↓ ←------------------------ HOURLY TEMPERATURE (1 – 24) ------------------------→

MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12
Jan	10.5	10.5	10.0	9.0	8.0	7.5	7.5	7.5	8.0	8.5	9.0	13.5	17.0
Feb	11.0	10.0	9.5	9.0	8.5	8.0	8.0	8.0	8.5	11.0	12.5	16.0	18.0
Mar	17.5	17.0	17.0	16.5	16.0	16.0	16.0	15.5	17.0	20.0	22.5	25.0	26.0
Apr	23.5	22.5	22.0	21.0	20.0	20.5	19.5	19.0	20.5	26.0	29.5	32.0	34.0
May	26.0	26.0	25.0	24.5	24.5	24.0	24.5	25.0	27.0	30.5	32.0	34.0	35.5
Jun	31.0	31.0	30.5	29.5	29.0	29.0	29.0	30.5	32.0	34.5	36.0	37.0	38.0
Jul	27.5	27.0	27.0	27.0	27.0	26.5	26.0	26.0	27.0	30.0	31.0	31.5	32.0
Aug	28.0	27.5	27.5	27.0	26.5	26.5	26.5	26.5	27.0	30.0	29.5	30.0	32.0
Sep	28.0	27.5	27.5	27.5	27.0	26.5	26.0	26.0	26.5	28.5	30.5	32.0	32.5
Oct	20.5	20.0	20.0	19.0	18.5	18.5	18.5	18.0	19.0	21.5	22.5	24.0	26.5
Nov	13.0	12.5	12.0	11.5	11.0	11.0	10.5	10.0	10.5	13.0	16.0	21.0	24.0
Dec	11.5	11.0	10.5	10.0	9.0	8.5	8.0	7.5	7.5	10.0	14.0	18.0	20.5

MONTH	13	14	15	16	17	18	19	20	21	22	23	24
Jan	18.0	18.5	19.5	18.5	17.0	14.5	13.5	12.0	11.5	10.5	10.5	10.5
Feb	19.5	19.5	20.5	20.5	19.5	18.0	16.0	14.0	13.5	12.0	11.5	11.0
Mar	26.0	27.5	28.5	29.0	28.0	26.5	19.0	18.5	18.0	17.5	17.5	17.5
Apr	35.0	36.0	36.5	36.5	36.0	34.5	31.5	28.5	28.5	28.0	26.0	23.5
May	36.5	38.0	37.5	37.5	37.0	35.0	30.0	28.0	27.5	27.5	26.5	26.0
Jun	39.0	39.5	40.0	39.0	39.0	39.0	36.0	32.0	31.5	31.5	31.0	31.0
Jul	33.0	33.5	33.5	33.5	33.0	32.5	32.0	29.5	28.0	27.5	27.5	27.5
Aug	32.5	33.0	33.5	33.0	32.0	31.5	30.5	30.0	29.5	29.0	28.5	28.0
Sep	33.5	34.0	34.0	35.0	34.5	33.0	31.0	30.5	29.5	29.0	28.5	28.0
Oct	27.5	27.5	27.5	27.0	26.0	24.5	23.0	22.0	21.0	20.5	20.5	20.5
Nov	25.5	27.0	27.0	26.0	22.0	18.5	17.0	15.5	15.0	14.0	13.5	13.0
Dec	20.5	22.0	22.5	22.0	20.0	17.0	15.0	14.0	13.0	12.5	12.0	11.5

4.2 METABOLIC HEAT GENERATTION RATE

Metabolic heat rate varies over a range, depending on the activity, the person and the condition under which the activity is being performed. Data regarding Typical Metabolic Heat Generation (W/m^2) for Various Activities (performed by an adult) has been reproduced as hereunder_

{Source: ASHRAE Handbook (2001) Fundamentals Table 04, p-8.7}

Activity	Heat Generation (W/m^2)
Resting/Sleeping	40
Seating (Reading)	60
Standing (Relaxed)	70
Walking (1.2 m/s)	150
Cooking/House Cleaning	115

4.3 WATTAGE RATING OF ELECTRICAL APPLIANCES

This data is necessary to calculate the heat load of appliances in different rooms of the building. Wattage rating of commonly used home appliances as recommended by Bureaue of Energy Efficieny (Ministry of Power, Govt. of India) is being reproduced in Table 4.3.

(Source: Bureau of Energy Efficiency Ads/BEE/04/2005)

Table 4.3 : Wattage rating of Domestic Appliances

DEVICE	Capacity & Size	Wattage	Electricity Consumption in kWh (01 Hour / day)
Bulb		25	0.75
		40	1.2
		60	1.8
		100	3
CFL	5 Watt	7	0.21
	9 Watt	11	0.33
	11 Watt	13	0.39

	25 Watt	27	0.81
Fluorescent Tube Lights (48")	With Copper Choke	55	1.65
	With Electronic Choke	35	1.05
Night Lamp		15	0.45
Ceiling Fan	36" / 48"	50	1.5
	56"	60	1.8
	60"	70	2.1
Table Fan	12" / 16"	40	1.2
Electric Iron	Domestic	700	21
	Commercial	1000	30
Immersion Rod	Domestic	1000	30
Geyser	15-50 Lit.	2000	60
Air Conditioners	1.0 Ton	1400	42
	1.5 Ton	1800	54
Air Cooler		170	5.1
Refrigerator	Small	225	7.2
	Large	300	9.0
Toaster		800	24
Electric Kettle	1000 Watt	1000	30
Mixer-Juicer		450	13.5
Washing Machine	Automatic	325	9.75
	Semi-Automatic	200	6
Vacuum Cleaner		700	21
Radio		15	0.45
Tape Recorder		20	0.6
TV		120	3.6
Computer		150	4.5
Mosquito Repellent		5	0.15

4.4 THERMAL PROPERTIES OF BUILDING MATERIALS

Thermo-physical properties of commonly used building materials at Mean Temperature of 50^{0}C are given as hereunder in Table 4.4. This data is used in the calculation of U values for various building sections.

{Source : SP : 41 (S & T) Handbook of Functional Requirements of Buildings – Part – 2, (1987), Table 2, p -37}

Table 4.4 : Thermo-Physical properties of Building Materials

S. No.	Material	Density Kg/m^3	Themal Conductivity W/(mK)	Specific Heat Capacity kJ/(kg.K)	Specific Heat Capacity W.hr/(m^3.K)
1	AC Sheet	1520	0.245	0.84	354
2	Alluvial Soil	1958	1.211	0.84	456
3	Black Cotton Clay	1899	0.735	0.88	464
4	Brick Tile	1892	0.798	0.88	462
5	Burnt Brick	1820	0.811	0.88	445
6	Cellular Concrete	704	0.188	1.05	205
7	Cement Mortar	1648	0.719	0.92	421
8	Cement Plaster	1762	0.721	0.84	411
9	Dense Concrete	2410	1.74	0.88	589
10	GI Sheet	7520	61.06	0.50	1044
11	Glass	2350	0.814	0.88	574
12	Gypsum Plaster	1120	0.512	0.96	298
13	Lime Concrete	1646	0.73	0.88	402
14	Mud Brick	1731	0.75	0.88	423
15	Mud Phuska	1622	0.519	0.88	396
16	Partical Board	750	0.098	1.30	270
17	Plywood	640	0.174	1.76	312
18	RCC	2288	1.58	0.88	559
19	Sand	2240	1.74	0.84	522
20	Saw Dust	188	0.051	1.00	52
21	Tar Felt	2.3 kg/m^2	0.479	0.88	562
22	Timber	720	0.144	1.68	336
23	Wood Wool Board	674	0.108	1.13	212

4.5 SURFACE CONDUCTANCE FOR VARIOUS WIND VELOCITIES

The U values of building sections can be computed with a knowledge of thermal conductivities of the building sections, their thickness and their surface resistance. For all practical purposes in building design certain constant values of surface resistance are assumed in U value calculation.

{Source : SP : 41 (S & T) Handbook of Functional Requirements of Buildings – Part – 2, (1987), Table 3, p -38}

Table 4.5: Surface Conductance for various wind velocities

S. No.	Wind Velocity	Position of Surface	Direction of Heat Flow	Surface Conductance W/m^2K
1	Still Air	Horizontal	Up	9.26
		Sloping 45^0	Up	9.08
		Vertical	Horizontal	8.29
		Sloping 45^0	Down	7.49
		Horizontal	Down	6.13
2	Moving Air			
	24 km/h	Any Position	Any Direction (winter)	34.06
	12km/h	Any Position	Any Direction (summer)	22.71

SP : 41 [107] recommends the average value of f_i for building material surface that is about 9.30 W/m^2K for still air and for wind velocity of 8.0 km/h, f_o is 19.90 W/m^2K.

4.6 SOLAR HEAT GAIN COEFFICIENT FOR FENESTRATIONS

Glass transmits radiation in varying degrees within the wavelength region of 0.3 to 4.8 μm and is opaque to both very short wave and long wave radiations. Total solar heat gain through fenestration consists of the directly transmitted solar radiation plus inward-flowing fraction of the solar radiation that is absorbed in the glazing system. The solar heat gain coefficient (SHGC) combines the transmitted solar radiation and the inward flowing fraction of the absorbed radiation.

Normal incidence SHGC used to rate and characterized glazing systems is not sufficient for determining solar heat gain for load calculations. SHGC differs for varied incidence angles of radiation. Values of SHGC for some standard glazing types have been given in table 4.6.

{Source: ASHRAE Handbook (2001) Fundamentals Table 13, p-30.26}

Table 4.6: SHGC for various glazing systems.

				SHGC for Incidence Angles						
S.No.	Glazing System	Glass Thickness	Visible Transmittance	00	40	50	60	70	80	Hemis. Diffuse
1	Uncoated Single Glazing	3.0 mm CLR	0.90	0.86	0.84	0.82	0.78	0.67	0.42	0.78
2		6.0 mm CLR	0.88	0.81	0.80	0.78	0.73	0.62	0.39	0.73
3		3.0 mm BRZ	0.68	0.73	0.71	0.68	0.64	0.55	0.34	0.65
4		6.0 mm BRZ	0.54	0.62	0.59	0.57	0.53	0.45	0.29	0.54
5		3.0 mm GRN	0.82	0.70	0.68	0.66	0.62	0.53	0.33	0.63
6		6.0 mm GRN	0.76	0.60	0.58	0.56	0.52	0.45	0.29	0.54
7		3.0 mm GRY	0.62	0.70	0.68	0.66	0.61	0.53	0.33	0.63
8		6.0 mm GRY	0.46	0.59	0.57	0.55	0.51	0.44	0.28	0.52

9	Reflective Single Glazing	SS on CLR 8%	0.80	0.19	0.19	0.19	0.18	0.16	0.10	0.18
10		SS on CLR 14%	0.14	0.25	0.25	0.24	0.23	0.20	0.13	0.23
11		SS on CLR 20%	0.20	0.31	0.30	0.30	0.28	0.24	0.16	0.28
12		SS on GRN 14%	0.12	0.25	0.25	0.24	0.23	0.21	0.14	0.23
13		TI on CLR 20%	0.20	0.29	0.29	0.28	0.27	0.23	0.15	0.27
14		TI on CLR 30 %	0.30	0.39	0.38	0.37	0.35	0.30	0.20	0.35

ASHRAE also recommends SHGC for double and triple glazed systems as well as low- e Glazing for Aluminum and other framed windows. In case of modeling with advanced glazing systems, users can obtain data from ASHRAE standards.

MODEL (Framework for Model)

5.0 INTRODUCTION

A model can be defined as the mathematical representation of a process, device or concept, by means of a number of variables which are required to represent the inputs, outputs and internal state of the process, and a set of equations describing the interactions of these variables. Eykhaff (1974) defined Model as *a representation of the essential aspects of an existing system, which presents knowledge of that system in usable form.* Some more concepts defining a Model are being mentioned as follows_

1. An analytical tool, a simplified representation or description of a system.
2. A physical or mathematical representation of a process that can be used to predict some aspect of the process.
3. A mathematical model of interactions of many variables. It is used in simulations for relating various components together or can be a stand alone tool to evaluate different approaches using different assumptions.
4. A representation of a system that allows for investigations of the properties of the system and in some cases, prediction of future outcomes.

Performance prediction involves the development of models that behave similarly in the way that the actual building would if it was built. Such models range from images in our minds, to sketches, drawings, scale models, manual and computer base calculations. Thermal Performance prediction requires massive computations, depending upon the building and the accuracy desired. Aim of this research study is to develop a Model through which internal temperature of different rooms of a building can be predicted, particularly for Composite Climate of India.

Internal Temperatrature Simulation require exhaustive calculations in order to determine the following parameters:

1. Area and Volume calculations for various building elements like walls, windows, roof, floor, room air etc.
2. U-Value determination for Building Elements / sections.
3. Shadow Area on each of the outer building elements for each hour of the day.
4. Total Solar Radiation received by various elements of the building throughout the day.
5. Sol-air Temperature for outer surfaces of the Building Envelop.
6. Heat Transmitted through the building elements to inner spaces.
7. Non-Solar Heat gain in different zones (Occupants' heat load, Appliances Heat Load, Heat Gain due to Air Changes)
8. Total Heat Gain by the different zones due to Solar & Non-Solar heat gain.
9. Heat gained thro' the floor.
10. Rise in temperature of Building elements as a result of total heat gain by various rooms.
11. Balancing of Heat Gain & maintaining the Thermal Equilibrium between different zones of the building.
12. Rise in temperature of internal air (T_i) in different zones as a result of the above.

It is worth mentioning in a mathematical model, both the Heat Gain or Heat Loss are always considered as a Heat Gain. In case of Heat Loss, it is considered with negative sign (-) in order to enable the systematic computations.

5.1 MODELLING APPROACH

Following points have been considered while preparing the Model.

a. The Model should be simple and flexible.

b. It should be based on realistic/ standard assumptions and must be able to predict thermal performance of buildings in composite climate as prevailing in most part of India.

c. Model should allow easy management of the design parameters / building elements and should result in unambiguous output in the form of internal room temperature (**Ti**) of each room.

d. Input data preparation should be user (architects) friendly.

e. Model should be able to predict the thermal performance of conceptual layouts, when the design is still vague. An ideal model should assist the design process, taking the design from the infancy stages to detailed working drawings.

f. Verandahs & Courtyards are important features of Indian buildings and model should be able to judge the Thermal Performance of verandah & courtyards also.

g. It should be possible to obtain results for individual building elements as well as for a combination of different elements so that Thermal performance of various building elements can be judged in an integrated manner.

h. Model should be able to predict Internal Temperature of different zones/rooms of a building and should enable to determine the effect of any change in any variable of any room on the Internal Room Temperature of any room.

i. Model should be able to produce results in such a way that the effect of various design parameters and different types of building elements on thermal performance of buildings can be quantified.

It has been tried to take stock of existing ideas/models and relevant literature available on the subject and finally:

- A Model has been prepared by considering Forward Approach as described by ASHRAE.
- The heat transmittion across the sections in the model has been formulated on the basis of computational method suggested by Indian Code SP*: 41 (S & T) – 1987 (Handbook on Functional Requirements of Buildings)* for Heat Transmission through Building Sections. Further, Heat Balance Theory has also taken into consideration in the model.
- Most of the assumptions taken into consideration are supported by ASHRAE or by prEN 15255:2007 (E) *Thermal performance of buildings - Sensible room cooling load calculation - General criteria and validation procedures.*

5.2 HEAT BALANCE METHOD OF INDOOR TEMPERATURE CALCULATIONS

The estimation of Internal Temperature for a space involves calculating a surface-to-surface conductive, convective and radiative heat balance for each room surface and a convective heat balance for room air. ASHRAE (Chapter 29.20) describes the theory of Heat Balnce Model, which is being summarized as below.

The heat balance model can be viewed as four distinct processes:

a. Outside Face Heat Balance

b. Wall Conduction Process

c. Inside Face Heat Balance

d. Air Heat Balance

5.3 ASSUMPTIONS IN THE MODEL

All models require some assumptions and therefore may have a tolerance in the output results. The major assumptions incorporated in the model are:

- The air in a thermal zone is well mixed and has a uniform temperature throughout the zone. ASHRAE has established that this assumption is valid over a wide range of conditions.
- The surfaces of the room (walls. Windows, doors, floor etc.) have uniform surface temperature.
- The Thermo physical properties of all the materials composing the enclosure elements are constant.
- The surfaces of the room have uniform diffuse radiating surface.
- The surfaces of the room have unidirectional heat conduction within.
- The distribution of heat due to internal gains is uniform.
- Solar incident radiation on any wall is uniformly spread over the entire wall surface.
- Each wall may be exposed to different ground condition (reflectivity) outside the building.
- Air of the room has constant RH i.e. 50% at 24°C. Effect of varied moisture content in air is negligible (for the pupose to thermal calculations).
- The evolution during an hour is assumed to be linear between the previous and subsequent hour.

- Earth has a uniform temperature below all the floors. In the study, it has been taken as 24^0C at a depth of 1.0m from FFL, however, being an input data, it can be changed.
- Outside temperature is considered as recorded by National Institute of Hydrology for 21^{th} day of each month for the year 2005 for ROORKEE. However, being an input data, it can be changed to that of any city.

prEN 15255:2007 (E) ***Thermal performance of buildings - Sensible room cooling load calculation - General criteria and validation procedures*** supports most of the aforesaid assumptions for a model/calculation procedure for determination of indoor air temperature of the room.

5.4 MATHEMATICAL MODEL

Mathematical model of the system has been divided in following groups for structured programming of the model:

1. Modeling of the SUN (in cardinal coordinate system)
    - Azimuth
    - Altitude
    - Declination
2. Time Calculations
    - Equation of Time (ET)
    - Apparent (local) solar time (A_{ST})
    - Apparent solar time of sunset (H_{SS})
    - Apparent solar time of sunrise (H_{SR})
3. Modeling of Solar Radiation (Heat Influx)
    - Direct Normal solar radiation (I_{DN})
    - Angle of incidence of solar radiation on the surface (i)
    - Direct solar radiation (I_D)

- Diffuse Solar Radiation (I_d)
- Sol-air-temperature (T_S)

4. Development of System Property Matrices
    - Development of Heat Capacity Matrix [H_c]
    - Development of Conductivity Matrix [U]
5. Development of Heat Load Vector {HL}
    - Inflow From Outer Elements Due To Solar Load
    - Inflow from Floor
    - Inflow due to Equipments Load
    - Inflow due to Occupants Load
    - Inflow due to Air Changes
6. Modeling of thermal equilibrium (System Heat Balance)
7. Time marching scheme for hourly calculation of system temperatures

In order to make the model flexible enough, programming approach as followed in Finite Element Method has been adopted. Analogy with Finite Element Method, as used in the program, has been described at the end of the chapter. Now, each of the group is being discussed in detail, parameterwise.

5.4.1 MODELING OF THE SUN

For calculating the direct solar radiation and for calculation of shadow area due to shading devices and parapets on outer surfaces, position of Sun in cardinal coordinate system being followed in the model is required. In the local sky, the Sun can be located in Azimuth-Altitude system. Calculation of these require the declination of the Sun also, hence, it too is required to be determined. These can be calculated as:

Azimuth of the sun (a_s)

Azimuth of the Sun is the horizontal angular distance between the two great circles passing through the Sun and the South point. It is dependent on the Hour Angle (H_s) of the Sun and can be determined as:

$$a_s = \text{Sin}^{-1}\left\{\frac{Sin(H_s)*Cos(\delta)}{Cos(\propto)}\right\} \qquad \text{if Cos}(H_s) > \frac{Tan\delta}{TanL}$$

$$a_s = 180 - \text{Sin}^{-1}\left\{\frac{Sin(H_s)*Cos(\delta)}{Cos(\propto)}\right\} \qquad \text{if Cos}(H_s) < \frac{Tan\delta}{TanL}$$

$$a_s = 90 \qquad \text{if Cos}(H_s) = \frac{Tan\delta}{TanL}$$

Where

a_s = Azimuth of sun

H_s = Hour angle of the sun = 15 * (AST – 12)

δ = Declination of the sun

$\propto$ = Altitude of the sun

L = Latitude of the place

AST = Apparent solar time

Altitude of the sun ($\propto$)

Altitude of the Sun is the angular distance of the Sun from the Horizon. It can be calculated as:

$\propto$ = Sin (L) * Sin (δ) + Cos (L) * Cos (δ) * Cos (H_s)

Where, L, δ and H_s are as defined above.

Declination of the sun (δ)

Declination of the Sun is the angular distance of the Sun from the Celestial Equator. It is a function of the day of the year (N) and can be calculated as:

δ = 23.45 Sin{360 * (284 + N) /365}

Though, declination changes over the day also on hour to hour basis but this change is negligible. Therefore, it has been assumed as constant for any day of the year (N), but day to day variations in the value of declination have been considered, which is reasonable for the purpose of this study.

5.4.2 TIME CALCULATIONS

Normally, we appreciate time in terms of some standard time, e.g., IST in India. However, the position of Sun in the local sky is goverened by the Apparent Solar Time (AST), which is different than standard time. Therefore, to convert IST to AST, some conversion equations are required to be used, which are as follows:

Equation of Time

Equation of Times (ET) defines the time diffenence between the mean Sun (which controlls the standard time) and apparent Sun at Standard Meridian . If apparent Sun is ahead of mean Sun than ET is +ve, otherwise, ET is –ve. The ET is calculated as:

$$ET = 0.165 \text{ Sin } (2 * B) - 0.126 * \text{Cos } (B) - 0.025 * \text{Sin } (B)$$

Where,

B = 360 * (N-81) / 364

N = Day of the year

Apparent (local) solar time (AST)

AST depends on the Equation of Time and difference between Standard Meridian of the region and Local Meridian of the place. It is calculated as:

$$AST = Time - (L_{STD} - L_{LCL})/15. + ET$$

Where,

Time = Standard Time

L_{STD} = Standard Longitude of the Region (82.5° E for India)

L_{LCL} = Local Longitude of the Place

As all the calculations are time consuming, it is prudent not to do the Sun related calculations when Sun is not in the sky, i.e., before Sun Rise and after the Sun Set. Therefore, calculation of apparent solar time of sunset and sunrise is also required. These are calculated as:

Apparent solar time of sunset (H_{SS})

$H_{SS} = Cos^{-1}\{Tan(L) * Tan(\delta)\}$

Apparent solar time of sunrise (H_{SR})

$H_{SR} = - H_{SS}$

5.4.3 SOLAR RADIATIONS

Intensity of the normal solar radiations received at any point of the earth surface depends upon the distance of earth from the Sun (which, inturn depends upon the day of the year), clearness of the sky (assumed to vary on monthly basis, as per general sky conditions) and altitude of the Sun. The radiations received by a building element further depends on the incidence angle of the radiation on the element surface. Besides the direct solar radiation, diffused radiations from the sky and reflected radiations from the ground are also received by a building element. Though the diffused and reflected radiations are much less in comparison to the direct radiation, these becomes important in a shaded area as a shading device normally cuts only the direct radiations. All these radiations are calculated as follows:

Direct Normal solar radiation (I_{DN})

Direct normal solar radiation is the radiation received per unit area by a surface which is normal to the direction of radiation, or, normal to a line joining a place and the Sun. It is calculated as:

$$I_{DN} = A\, e^{\left(\frac{-B}{Sin(\alpha)}\right)}$$

Where, A & B are solar constants (variable with months) and are given below for 21th of each month:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A (W/m2)	1230	1215	1186	1136	1104	1088	1085	1107	1151	1192	1221	1233
B	0.142	0.144	0.156	0.18	0.196	0.205	0.207	0.201	0.177	0.160	0.149	0.142

Angle of incidence of solar radiation on the surface (i)

Angle of incidence (i) of solar radiation on any surface is the angle between the line joining the Sun with any point on the surface and normal to that surface at that point. It is calculated as:

$i = Cos^{-1}\{Cos(\propto) * Cos(a_s - a_w) * Sin(\beta) + Sin(\propto) * Cos(\beta)\}$

where

a_w = Wall azimuth

β = Angle of inclination of surface from horizontal

Direct solar radiation (I_D)

Direct solar radiation (I_D) received by any surface is the radiation received per unit area of the surface. It is dependent on the angle of incidence of solar radiation to the surface and is calculated as:

$I_D = I_{DN} * Cos(i)$ if $i \leq 90$

$= 0$ if $i > 90$

Diffuse Solar Radiation

Due to the dust particles and gases present in the sky, a part of the solar radiation gets scattered and is received by the element surfaces as sky diffuse solar radiation. Further, when the balance direct solar radiation hits the ground, part of it gets reflected from the ground and is received as ground diffue radiation by the element surfaces. Out of these, sky diffuse is direction independent and hence received by all the element surfaces, whether horizontal or vertical ir-respective of presence of any shading device. However, ground diffuse, as reflected from the ground, is directional and received only by the vertical surfaces. Further, as the shading device is normally horizontal & on the upper edge of openings/walls, they do not cut the ground diffuse and it is recived by all vertical element surfaces, ir-respective of the presence of any shading device. These radiation components are calculated as:

Sky diffuse radiation (I_{SDF})

$I_{SDF} = C * Y * I_{DN}$ for Vertical surfaces

$I_{SDF} = C * I_{DN} * (\frac{1+Cos(\beta)}{2})$ for non-Vertical surfaces

Where

$Y = 0.55 + 0.437 * Cos(i) + 0.313 * cos^2(i)$ if $Cos(i) > -0.2$

$= 0.45$ if $Cos(i) \leq -0.2$

C = Constant for each month & day and given below for 21th of each month:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
C	0.58	0.06	0.071	0.097	0.121	0.134	0.136	0.122	0.092	0.073	0.063	0.057

Ground diffuse radiation (I_{GDF})

$$I_{GDF} = I_{DN} * \{C + Sin(\propto)\} * rg * \left(\frac{1+Cos(\beta)}{2}\right)$$

where

rg = Reflectivity of the ground

Total diffused radiation (I_d)

Total diffused radiation is the summation of sky diffuse radiation and ground diffuse radiation. In equation form, it can be written as:

I_d = Sky Diffuse + Ground Diffuse

Sol-air-temperature (T_S)

The effect of all the radiations incident on any surface is to increase the surface temperature. Surface temperature is also dependent on the ambient temperature, absorptivity of the surface and coefficient of heat transfer at outer surface. Besides that, surface also emits some radiation in the sky. For vertival surfaces, the same is received back also due to ambient interaction, however, for horizontal surfaces, some part of the emitted radiation is permanently lost in the far sky and causes a cooling effect on the surface. The effective temperature of the surface as a result of the above is called as Sol-air temperature (T_s) and calculated as:

$$T_S = T_O + \frac{\{I_D(1-Sh)+I_d\}*a}{f_O} - \frac{63*Cos(\beta)}{f_O}$$

Where

a = Absorptivity of the surface

Sh = Shading parameter

= 0 for completely exposed surface

= 1 for completely shaded surface

= 0-1 for partially shaded surface

f_O = Coefficient of heat transfer at outer surface

5.4.4 THERMAL EQUILIBRIUM OF A MULTIPLE ZONE (ROOM) SYSTEM

In any thermal system, the net heat (heat gained – heat lost) gained by the system is used to increase the temperature of the system. In the context of buildings consisting of a number of thermal zones in the form of rooms and isolated spaces, heat gained and heat stored can be determined as discussed below.

Heat gain in a room can be classified as:

(a) Solar Heat Gain through

Roof, Walls, Doors/Windows and

(b) Non-Solar Heat Gain through

Floor

Equipments (Appliances) Load

Occupants

Ventilation (Air Changes per Hour)

Internal Heat Balancing with the other Rooms

Heat Stored in a Room can be calculated from:

(a) Heat Capacity of

Walls, Roof, Floor, Doors & Windows,

Articles in the room,

Air volume and

(b) Temperature change in the room

Basic Equation for Thermal equilibrium of a Single Body can be written as:

Heat Stored = Heat inflow or

$H_C * \Delta T = \Delta H_L$

Where

H_C = Heat Capacity of Body

ΔH_L = Heat gain (Thermal Load) over a time Δt

ΔT = Change in temperature of the body over a time Δt

For building having multiple thermal zones (rooms/enclosures), the equation can be expanded as:

$[H_C] * \{\Delta T\} = \{\Delta H_L\}$

$[H_C]$ = Heat capacity matrix of the system

$\{\Delta T\}$ = Vector of changes in temperature of the system (rooms) over a time Δt

$\{\Delta H_L\}$ = Vector of Thermal load applied to the system (building) over a time Δt

= inflow from outer elements + inflow from floor + heat inflow due to internal heat balancing + heating due to equipments $\{\Delta H_e\}$ + heating due to occupants $\{\Delta H_O\}$ + heat inflow due to air changes $\{\Delta H_A\}$

Hence, if $[H_C]$, $\{T\}$ & $\{\Delta H_L\}$ are known, $\{\Delta T\}$ can be calculated over the time Δt, and temperature at the end of time Δt can be calculated as:

$\{T_{t+\Delta t}\} = \{T_t\} + \{\Delta T\}$

where,

$\{T_t\}$ = Vector of system temperature at the beginning of time Δt

$\{T_{t+\Delta t}\}$ = Vector of system temperature at the end of time Δt

Further, heating due to equipments $\{\Delta H_e\}$ & heating due to occupants $\{\Delta H_O\}$ can be calculated directly from equipment & occupancy data, whereas, calculation of inflow from outer elements, floor and that due to air changes & internal balancing is intricate procedure and needs further deliberations.

For calculating inflow from outer elements, floor and that due to internal balancing, conductivity matrix of the system [U] is also required.

Therefore, now the main aim is to calculate heat capacity matrix, $[H_C]$ and conductivity matrix [U] of the system & $\{\Delta H_L\}$ for each hour of the day (assuming Δt = 1 hour, which is reasonable time step for the purpose). Then using the above mentioned equations, {T} can be calculated for each hour of thae day.

5.4.5 DEVELOPMENT OF SYSTEM PROPERTY MATRICES

As aleady has been indicated, modeling approach used in the proposed model is analogous to that used in Finite Element Method, where, all the calculations are done in Matrix form. This aproach not only provides flexibily in modeling of various elements but also enables systematic computer programming of the model. Therefore, development of system property matrices, viz, Heat Capacity Matrix, $[H_c]$ and Conductivity Matrix, [U] of the elements becomes important for the modeling of a building system.

5.4.5.1DEVELOPMENT OF Heat Capacity $[H_C]$ MATRIX

In a building, any element (wall, floor, roof, door etc.) separate two thermal zones (rooms, enclosures etc.), say 1 & 2

For a general element, Heat capacity matrix, $[H_C]_e$ can be written as

$$[H_C]_e = \begin{bmatrix} H_{C11} & H_{C12} \\ H_{C21} & H_{C22} \end{bmatrix}$$

where

H_{C11} = Heat stored on zone 1 side of element due to 1^0C rise in temperature of zone 1.

H_{C12} = Heat stored on zone 1 side of element due to 1^0C rise in temperature of zone 2.

H_{C21} = Heat stored on zone 2 side of element due to 1^0C rise in temperature of zone 1.

H_{C22} = Heat stored on zone 2 side of element due to 1^0C rise in temperature of zone 2.

For Building Elements, due to rise in temperature of a zone, heat is stored in the same zone only, therefore

$H_{C21} = H_{C12} = 0$

Hence,

$$[H_C]_e = \begin{bmatrix} H_{C11} & 0 \\ 0 & H_{C22} \end{bmatrix}$$

Calculation of H_{C11} & H_{C22} is element specific and has been given in Appendix-3 at the end.

Once the $[H_C]_e$ for all the elements has been calculated, $[H_c]$ for the building can be calculated as

$$[H_C] = \sum_{e=1}^{n} [H_C]_e$$

Where,

n = total number of elements in the building

This is a Boolean Matrix Summation, as done for Finite elements in Finite Element Analysis for assembly of elements, where order of the matrices on two sides are not same and $[H_C]_e$ on RHS are assembled (added) to the global $[H_C]$ matrix as per their zonal (nodal) incidences.

5.4.5.2 DEVELOPMENT OF CONDUCTIVITY MATRIX [U]

In a building, any element (wall, floor, roof, door etc.) separate two thermal zones (rooms, enclosures etc.), say i & j.

Rate of heat flow through an element from zone i to j can be expressed as:

$\Delta H_i = U (T_j - T_i)$

where,

ΔH_i = Rate of heat flow in zone i from zone j

U = Conductivity of the element

T_i = Temperature of zone i

T_j = Temperature of zone j

Similarly, rate of heat flow through an element from zone j to i can be expressed as:

$\Delta H_j = U (T_i - T_j)$

where,

ΔH_j = Rate of heat flow in zone j from zone i

the above equations can be written in matrix form as:

$$\begin{Bmatrix} \Delta H_i \\ \Delta H_j \end{Bmatrix} = \begin{bmatrix} -U & U \\ U & -U \end{bmatrix} * \begin{Bmatrix} T_i \\ T_j \end{Bmatrix}$$

or,

$\{\Delta H\} = [U]_e * \{T\}$

where,

$[U]_e = \begin{bmatrix} -U & U \\ U & -U \end{bmatrix}$ = Conductivity matrix of element between zone i & j

$\{\Delta H\} = \begin{Bmatrix} \Delta H_i \\ \Delta H_j \end{Bmatrix}$ = Heat flow vector of element between zone i & j

$\{T\} = \begin{Bmatrix} T_i \\ T_j \end{Bmatrix}$ = Temperature vector of element between zone i & j

Once the $[U]_e$ for all the elements has been calculated, [U] for the building can be calculated as

$$[U] = \sum_{e=1}^{n} [U]_e$$

This is a also Boolean Matrix Summation, done in the same way as for $[H_C]_e$ Matrix. Calculation of U for the element is element specific and has been given in Appendix- 2 at the end.

5.4.6 DEVELOPMENT OF HEAT LOAD VECTOR, $\{H_L\}$

Heat load vector for a thermal zone (Room/enclosure etc.) in a building consists of the following thermal loads:

i) Solar heat load through envelop elements (external walls, roof, fenestrations etc.).

ii) Inflow of heat from the floor.

iii) Heat generated by the equipments/ appliances in the zone.

iv) Heat generated by the occupants in the zone.

v) Heat gain due to air changes

vi) Heat gained fron adjoining zones.

Total heat gain for a zone is summation of all the above mentioned heat loads, however, depending upon the conditions, some of the above mentioned loads may be zero for a particular zone. The vector containing the heat loads for all the zones in a system is termed as heat load vector.

Further, calculation of heat load vector involves the average temperatures of zones/ambiance over the assumed time step. The sol-air temperatures for any surface can be calculated for any given time using the ambient temperature data and solr calculations. However, inside temperatures are not known in advance at the end of the time step. Hence, while deriving the equations for the heat load vector components, wherever average internal temperatures are involved, these are expressed as sum of internal temperature at the beginning of the time step and half the increase in the same over the time step. This formulation enbles the explicit calculation of increase in temperature over the time step, as will be discussed subsequently.

Now, each of the above mentioned thermal load will be discussed in detail in the paragraphss, which follows_

5.4.6.1 INFLOW FROM OUTER ELEMENT DUE TO SOLAR LOAD (ΔH_S)

Heat inflow due to so solar load on an outer/enveloping element, (ΔH_S)can be calculated as:

$\Delta H_S = U_e (T_{OUT} - T_{in}) \Delta t$

where,

ΔH_S = Heat inflow due to so solar load on an enveloping element

U_e = Conductivity of the element

T_{OUT} = Average Sol-air-temperature of element surface

T_{in} = Average Inside temperature of the zone

Δt = Time step being considered

For an hour from time t_i to $t_i + \Delta t_i$, (written in notations as i to i+1 for simplicity, as Δt_i has been considered as 1 hour in the analysis), the equation can be written as:

$$\Delta H_S = U_e\left(\frac{T_{OUT,(i+1)} + T_{OUT,(i)}}{2} - T_{in(i)} - \frac{\Delta T_{in,(i)}}{2}\right)$$

or

$$\Delta H_S = U_e\left(\frac{T_{OUT,(i+1)} + T_{OUT,(i)}}{2} - T_{in,(i)}\right) - \frac{U_e * \Delta T_{in,(i)}}{2}$$

Where,

$T_{OUT,(i)}$ = Ambient temperature at time t_i

$T_{OUT,(i+1)}$ = Ambient temperature at time $t_i + \Delta t_i$

$T_{in,(i)}$ = Inside temperature of zone at time t_i

$\Delta T_{in,(i)}$ = Increase in temperature of zone at time t_i

For a zone (room) having n elements, the euation can be summed up for all elements (walls, roof, floor, door, window etc.) as:

$$\Delta H_S = \sum_{j=1}^{n} U_{e,(j)}\left(\frac{T_{OUT,(i+1),(j)} + T_{OUT,(i),(j)}}{2} - T_{in,(i)}\right) - \frac{\sum_{j=1}^{n} U_{e,(j)} * \Delta T_{in,(i)}}{2}$$

or

$$\Delta H_S = \Delta H_{SOL,(i)} - 0.5 * U_{OUT} * \Delta T_{in,(i)}$$

where

$\Delta H_{SOL,(i)}$ = Solar load for hour (i) to (i + 1), assuming internal temperature to be constant (same as that at I, i.e., $T_{in,(i)}$).

$U_{e,j}$ = Conductivity of j^{th} outer element in the room

$\Delta T_{in,i}$ = rise in inside temperature for time (i) to (i + 1)

U_{OUT} = effective conductivity of the room surfaces w.r.t. the outer surfaces of external elements of the room, i.e., ambience

$$= \sum_{j=1}^{n} U_{e,(j)}$$

Using the above eqution, the equation for a system having multiple zones can similarly be written in matrix form as,

$$\{\Delta H_S\} = \{\Delta H_{SOL}\}_{(i)} - 0.5[U_{OUT}]\{\Delta T_{in}\}_{(i)}$$

Where

$\{\Delta H_S\}$ = Vector of net solar load for hour (i) → (i + 1),

$\{\Delta H_{SOL}\}_{(i)}$ = Vector of solar load for hour (i) → (i + 1), assuming internal temperature to be constant (same as that at i).

$[U_{OUT}]$ = Conductivity matrix of outer elements. A diagonal matrix having effective conductivity of all zones w.r.t. the ambience, U_{OUT} in the diagonal of the matrix.

$\{\Delta T_{in}\}$ = Vector of rise in inside temperature for time (i) to (i + 1)

5.4.6.2 INFLOW FROM FLOOR form Time (i) to (i +1)

Heat gained through a single floor element can be expressed as:

$$\Delta H_f = U_{floor} * (T_{earth} - Ti - 0.5\ \Delta T_i)$$

or

$$\Delta H_f = \Delta H_{floor} - 0.5 * U_{floor} * \Delta T_i$$

where,

ΔH_f = Heat inflow from floor

ΔH_{floor} = Heat inflow from floor, assuming internal temperature to be constant (same as that at i, i.e., $T_{in,(i)}$).

= $U_{floor} * T_{earth}$

U_{floor} = Conductivity of the floor

T_{earth} = Temperature of earth

T_i = Internal Temperature at time i

ΔT_i = Temperature rise from time i to (i+1)

For a multi zone system, the equation can be expressed in matrix form as:

$\{\Delta H_f\} = \{\Delta H_{floor}\}_i - 0.50[U_{floor}]^*\{\Delta T\}_i$

where,

$\{\Delta H_f\}$ = Vector of Heat inflow from floors

$[U_{floor}]$ = Conductivity matrix of the floors

$\{\Delta T_i\}$ = Vector of Internal Temperature rise from time i to (i+1)

$\{\Delta H_{floor}\}_i$ = Vector of Heat inflow from floors, assuming internal temperatures to be constant (same as that at i).

5.4.6.3 INFLOW DUE TO EQUIPMENTS LOAD

Heat generated due to the equipments/appliances working in zone/room can be calculated as:

$\{\Delta H_e\} = \Delta t_i$ * Equipment Load/hour,

where,

$\{H_e\}$ = heat generated due to the equipments/appliances

Equipment loads for various household appliances/equipments have been given in Chapter 4 (Database).

5.4.6.4 INFLOW DUE TO OCCUPANTS LOAD

Heat generated due to the occupants present in zone/room can be calculated as:

$\{\Delta H_O\} = \Delta t_i * N_{OCCUP}$ * Load/Occupant/hour,

where,

$\{H_O\}$ = heat generated due to occupants present in the room/zone

N_{OCCUP} = Number of occupants present in the room/zone from time (i) to (i+1)

Occupants load for different conditions of working have been given in Chapter 4 (Database).

5.4.6.5 INTERNAL HEAT BALANCE $\{\Delta H_{int}\}$

Heat flow from one thermal zone to the other due to the difference of temperature amongst them in known as internal heat balance of the system. It can be calculated for time i to i +1using equation in 2.4.5.2 as:

$$\{\Delta H_{int}\} = [U_{int}] * \{T_i + 0.5\ \Delta T_i\}$$

or

$$\{\Delta H_{int}\} = [U_{int}] * \{T_i\} + 0.5[U_{int}] * \{\Delta T_i\}$$

where,

$\{H_{int}\}$ = internal heat flow form time i to i +1

$[U_{int}]$ = Conductivity matrix of all internal elements (walls, doors etc.)

5.4.6.6 INFLOW DUE TO AIR CHANGES form Time (i) to (i +1)

During the ventilation, air at ambient temperature enters the room and in turn, air at room temperature is expelled from the room. The temperature difference in the incoming & outgoing air during the air changes results in heat gain in the associated room/zone. For a single room, the heat gain during ventilation can be expressed as:

$$\Delta H_A = H_{CRA} * \Delta t * N_{ACPH} * (T_{OUT,AV} - (T_{in} + 0.5\ \Delta T_{in}))$$

$$= H_{CRA} * \Delta t * N_{ACPH} * (T_{OUT,AV} - Ti) - 0.5 * H_{CRA} * \Delta t * N_{ACPH} * \Delta T_{in}$$

or,

$$\Delta H_A = \Delta H_{AC,i} - 0.5 * U_{AC} * \Delta T_{in}$$

where,

ΔH_A = Heat inflow due to air changes during time ΔT_{in}

$\Delta H_{AC,i}$ = Heat inflow from outside due to air changes, assuming internal temperature to be constant (same as that at i, i.e., T_{in})

$= U_{AC} * (T_{OUT,AV} - T_{in})$

U_{AC} = Effective Conductivity between room and outside due to air changes

= $H_{CRA} * \Delta t * N_{ACPH}$

H_{CRA} = Heat Capacity of Room Air

N_{ACPH} = No of air changes per hour

Δt = time step from time i to (i+1), considered as 1 hour in the analysis

T_i = Internal Temperature at time i

ΔT_i = Temperature rise from time i to (i+1)

$T_{OUT,AV}$ = Average Outside Temperature from time i to (i+1)

= $(T_{OUT,i} + T_{OUT,i+1})/2$

$T_{OUT,i}$ = Outside Temperature at time i

$T_{OUT,i+1}$ = Outside Temperature at time (i+1)

For a multi zone system, the equation can be expressed in matrix form as:

$\{\Delta H_A\} = \{\Delta H_{AC}\}_i - 0.50[U_{AC}]*\{\Delta T_{(i)}\}$

where,

$\{\Delta H_A\}$ = Vector of Heat inflow due to air changes

$[U_{AC}]$ = Conductivity matrix between rooms and outside due to air changes

$\{\Delta T_i\}$ = Vector of Internal Temperature rise from time i to (i+1)

$\{\Delta H_{AC}\}_i$ = Vector of Heat inflow from outside due to air changes, assuming internal temperature to be constant, (same as that at i, i.e., $\{T_{in,(i)}\}$)

= $[U_{AC}]*\{ \{T_{OUT,av}\} - \{T_{in}\} \}$

5.4.6.7 HEAT LOAD VECTOR

Now, the heat load vector for the complete system (building), duely accounting for all the thermal loads described above can be written as:

$\{H_L\} \quad = \{\Delta H_S\} + \{\Delta H_f\} + \{\Delta H_e\} + \{\Delta H_O\} + \{\Delta H_{int}\} + \{\Delta H_{AC}\}$

This, will be used as heat load of the building during the subsequent paragraphss.

5.4.7 SYSTEM HEAT BALANCE

Heat gained by a system over a time Δt_i is used to raise the temperature of the system. Thus, heat gained by the system is equal to the heat stored in the system. Hence, heat balance equation for the complete system at hour i can be written as:

$$[H_c]*\{\Delta T_i\} = \{H_L\}$$

OR

$$[H_c]*\{\Delta T_i\} = \{\Delta H_S\}_i + \{\Delta H_f\}_i + \{\Delta H_e\}_i + \{\Delta H_{OC}\}_i + \{\Delta H_{int}\}_i + \{\Delta H_A\}_i$$

$$= \{\Delta H_{SOL}\}_i - 0.50[U_{OUT}]*\{\Delta T\}_i + \{\Delta H_{floor}\}_i - 0.50[U_{floor}]*\{\Delta T\}_i$$

$$+\{\Delta H_e\}_i + \{\Delta H_{OC}\}_i + [U_{int}] * \{T_i\} + 0.5[U_{int}] * \{\Delta T_i\}$$

$$+ \{\Delta H_{AC}\}_i - 0.50[U_{AC}]*\{\Delta T\}_i$$

OR

$$[[H_c] + 0.5[U_{OUT}] + 0.5[U_{floor}] +0.50[U_{AC}] - 0.5[U_{int}]]*\{\Delta T_i\}$$

$$= \{\Delta H_{SOL}\}_i + \{\Delta H_{floor}\}_i + \{\Delta H_e\}_i + \{\Delta H_{OC}\}_i + \{\Delta H_{AC}\}_i + [U_{int}] * \{T_i\}$$

OR

$$[H_c^*] * \{\Delta T\}_i \quad = \{\Delta H_T\}_i$$

where,

$$[H_c^*] \qquad = [H_c] + 0.5[U_{OUT}] + 0.5[U_{floor}] +0.50[U_{AC}] - 0.5[U_{int}]$$

$$\{\Delta H_T\}_i \qquad = \{\Delta H_{SOL}\}_i + \{\Delta H_{floor}\}_i + \{\Delta H_e\}_i + \{\Delta H_{OC}\}_i + \{\Delta H_{AC}\}_i + [U_{int}] * \{T_i\}$$

If, temperatures in a system at time i, $\{T\}_i$ are known, then by solving the equation, $\{\Delta T\}_i$ can be calculated.

Now temperature at (i +1) can be calculated as

$$\{T\}_{i+1} = \{T\}_i + \{\Delta T_i\}$$

The above procedure enables explicit calculations of system temperatures, as for calculating $\{T\}_{i+1}$ from $\{T\}_I$, no iterations are required.

5.4.8 TIME MARCHING SCHEME

For calculating temperature after time Δt

Let

$\{T_i\}$ = temperature of system at time t_i &

$\{T_i + \Delta T_i\}$ = temperature of system at time $t_i + \Delta t_i$,

= $\{T_i\} + \{\Delta T_i\}$

$\{\Delta T_i\}$ = change in temperature of system from time t_i to $t_i + \Delta t_i$,

As at the beginning of the analysis, system temperatures are not known, T_i is assumed at starting point and need to be confirmed / modified during iterations over the day.

To start the calculations, internal temperatures $\{T_i\}$ at zero hours $\{T\}_0$ is assumed same as ambient temperatures for all rooms with a time lag of 6 hours, i.e.,

$\{T\}_0$ = Ambient temperature at 18 hours for all zones

Using the procedure described above, since now $\{\Delta T\}_i$ can be calculated explicitly for each hour of the day, an explicit time marching scheme can be employed to calculate internal temperature for 1-24 hours & calculated $\{T\}_{24}$ is compared with initially assumed $\{T\}_0$.

Now, fractional change in {T} over a cycle of 24 hours can be calculated as:

$$\varepsilon = \frac{\left\| \{T\}_{24} - \{T\}_0 \right\|}{\left\| \{T\}_0 \right\|}$$

When change in the two estimated temperatures, ε is below a threshold limit (<0.0001), iterations are stopped & using that $\{T\}_{24}$ as $\{T\}_0$, final system temperatures are calculated by the program and reported as output.

5.5 Analogy with Finite Element Method

The procedure developed here is very much similar to that used in Dynamic Finite Element Analysis, usually deployed for analyzing complicated structural systems. This makes the technique very flexible and amenable to computer programming. The similarity in two techniques can be defined as:

S.N.	Item/Variable in present technique	Analogous Item/Variable in Finite Element Method
1	Heat Capacity Matrix, $[H_c]$ & $[H_c^*]$	Stiffness Matrix, [K]
2	Heat Inflow : Solar, floor etc, $\{H_L\}$	Applied loads, {P}
3	Change in internal Temperatures, $\{\Delta T\}$	Displacements, $\{\delta\}$
4	Basic Equation of Equilibrium: $[H_c^*]\{\Delta T\} = \{H_L\}$	$[K]\{\delta\} = \{P\}$
5	Internal temperatures, $\{T_i\}$	Nodal Coordinates, {x}
6	Walls, door, windows, roof, floor	Finite Elements
7	Thermal Zones in building	Nodes of Finite Element mesh
8	Time step	Time step in dynamic analysis
9	Prescribed Outside Sol-Air temperatures and earth temperatures	Displacement Boundary Conditions

5.6 COMPUTER PROGRAMMING

A Computer Programme has been prepared incorporating the Model structure described above. The programme has been prepared in FORTRAN -90 by adopting Modular (structured) Approach, which consist of 24 Subroutines and 14 Functions to accomplish the task, which are being enlisted as hereunder:

5.6.1 SUBROUTINES

5.6.1.1 DATA INPUT/GENERATION SUBROUTINES

These subroutines read/generate the input data and carry out primary data processing for enabling the use of data by other routines.

COORD : Deals with Coordinate data of nodes

PROPWL : Reads wall properties & generates associated properties, (U-value)

PROPFL : Reads floor properties & generates associated properties

PROPSB : Reads slab properties & generates associated properties

PROPMT : Deals with material properties

PROPRM : Deals with Room Properties

PROPSC : Reads sections' properties and generates associated properties

GNDAT : Deals with Data Generation Modules (Nodes Data)

GMDAT : Deals with Data Generation Modules (Members Data)

5.6.1.2 EQUATION SOLVER

BANSOL : Equation Solver for Banded Matrixes. This is Banded matrix equation solver based on GAUSS Elimination Method. It is used in solving the system equations

5.6.1.3 HEAT LOAD VECTOR CALCULATIONS

These subroutines calculates the heat load vector for the system at a given time for the given day

NSHLV : Non solar heat load vector

SHLV : Solar heat load vector

HLV : Heat load vector (TOTAL)

5.6.1.4 **SYSTEM PROPERTY MATRICES**

These routines carryout the assembley of system property matrices, viz., Conductivity and Heat capacity matrices.

ASSEM1 : Assembles Conductivity and Heat Capacity Matrixes

ASSEM2 : Make the corrections in view of air-changes

5.6.1.5 **ITERATION CONTROLER**

RTSOL :This subroutine essentially performs the time marching calculations for calculating the system temperatures for the day and controls iterative calculations of internal room temperatures.

5.6.1.6 **SHADOW CALCULATIONS**

These subroutines performs the shadow area calculations.

SHADOA : Calculates shadow area on all outer elements

SHADOR : Calculates shadow of parapet on Roof

CLIPSR : Clipping algorithm for roof

CLIPSW : Clipping algorithm for wall

CLIP : General clipping algorithm

SHADOW : Shadow of Shading Device on Wall

PUSH : Vector Handling Module for clipping algorithm

PACKC : Vector Handling Module for clipping algorithm

5.6.2 FUNCTIONS

5.6.2.1 CALCULATION OF POSITION OF THE SUN

These functions calculates various coordinate and time related data requred to locate the Sun position.

FAZI : Calculates the azimuth of Sun

FALT : Calculates the altitude of Sun

FDESC : Determines the declination of Sun

FET : Deals with equation of time

FSOLTM : Calculates the Local Solar Time (A.S.T.)

FSNSAT : Calculates time of sunset

FSNRIS : Calculates time of sunrise

THETA : Calculates wall azimuth

5.6.2.2 SOLAR RADIATION CALCULATIONS

These functions calculates solar radiation data at a given time for the given day.

FSRDN : Determines Direct Normal Solar Radiation

FSDR : Determines Direct Solar Radiation

FSRDF : Calculates Total Solar Radiation

FSOLAT : Calculates Sol Air Temperature

FSHG : Calculates Fenestrations' Solar Heat Gain

FTOUT : Interpolates outside (ambient) temperature for given hour and day

CHAPTER 6

APPLICATION OF MODEL

6.0 INTRODUCTION

The developed simulation model require substantial input describing detailed building geometry, properties of materials used in different layers/sections (walls, roof, floor, fenestration) in the building constructions, weather data, thermal capacity of articles and heat load of appliances in different rooms. To make the program easier for the user during the design process, default values has been set for the input. Some standard brick wall sections, RCC roof / slab sections, floor section as commonly practiced in India has been incorporated in the model. As per the building requirements, user can choose the different values as per the required building specifications. The output from the model is obtained on an hourly basis which can be used for detailed studies of temperatures in order to analyze thermal performance of buildings. Model has been so developed that less time is required in the preparation of input data file. Further, results are obtained on hourly basis for full year enabling the user to analyse the thermal performance of building quickly to achieve optimized design. Further, the capabilities, limitations and functioning (preparation of input data file) of the model together with the illustrations of output data files has been discussed in this chapter subsequently.

6.1 CAPABILITIES OF THE MODEL

Model has been developed keeping in mind to have the following characteristic features and capabilities.

- Model is flexible enough to support a wide range of building design, construction types & materials apart form the commonly practiced materials in India.
- Climatic data file of any Indian city (if prepared) can be attached to the programme, however, weather data file of Roorkee is attached to the programme as default settings.
- Model can predict the thermal performance of different rooms for any hour of the year.
- Predicts thermal performance of different rooms in the form of Ti (DBT) of that room.
- Effect of sun shading devices on thermal environment of any room can be quantified.
- Effect of Air velocity prevailing outside can be monitored on internal air temperature.
- Effect of fenestrations on the thermal performance of different rooms can be assessed.
- Results can be obtained for varying ambient ground reflectivity.
- Earth / Floor temperature can be modified for different months.
- Model accounts for the heat capacity of thermal masses / articles present in the different rooms.
- Occupants' body heat load can be incorporated on hourly basis in any room.
- Heat generated by the appliances within the rooms is considered on hourly basis.
- A room having a non-rectangular shape (may be T, H, L shape) can also be modeled with the program.

- Thermal performance of a multistory building can also be analyzed by the model.
- Input files can be prepared in a short time, whereas other tools can not do so and output files can be obtained in simple format. This feature can save considerable time.
- Variable air changes per hour in any room can be considered for different period of the day or night.
- Thermal Time lag can be observed on graph (To vs. Ti) obtained using output data.
- Results can be obtained with the following variables_
    1. FENESTRATIONS: Size on different walls & properties of glazing.
    2. GROUND REFLECTIVITY
    3. HEIGHT of BUILDING / ROOMS
    4. HEIGHT of PARAPET over the roof.
    5. ORIENTATION of BUILDING: With respect to Cardinal Points
    6. PROJECTIONS / SUNSHADES: Width on different walls.
    7. ROOF: Material & Treatment.
    8. VENTILATION RATE : Air change per hour
    9. WALL: Material Properties & Thickness.

6.2 LIMITATIONS OF THE MODEL

Every model is based on certain assumptions and these assumptions may differ from ground realities (slightly or drastically). This model has been developed in view of Indian Composite Climate keeping in mind the type of building construction that is commonly practiced in Composite Climate zone of India. It is expected that model will predict precise results, however, results may not be precise if the same model is used for other climatic zones i.e. Cold Hilly Areas, Warm Humid Coastal Climates. Accuracy of results of the model will be based on preparation of input data file with the correct Information regarding building geometry and description of building elements /materials. However, some of the features / building elements may not be modeled like skirting, cornices, corner offsets or projections, ornamentation on walls, small niches in the walls, sunshades if provided inclined etc. For such features, corrective measures can be taken while defining thermal capacity of each room. In case of inclined sunshades, thickness of the sunshade may be given in conformity with the inclination as a corrective measure.

6.3 INPUT DATA FILE PREPARATION

The thermal performance of the building, which is to be analyzed is to be graphically represented in a CAD programme and output should be obtained in the form of a hard copy/print. Every junction / corner of walls will be considered as Node and their coordinates with respect to origin (preferably it may be a corner / node of the building) are to be determined. Every wall will be given a unique number. Every wall should be considered from starting node node (i) to ending node (j) in positive coordinate system. Start point of any fenestration from node (i) of that wall to be determined. Height & of each wall will be defined in meters. Suitable section (as per specifications) will be assigned to each wall. Different walls may be assigned different sections. Further, fenestration will be defined in terms of its width on wall, sill level and lintel levels with respect to finished floor level. Suitable section (as per properties of glazing) will be assigned to each fenestration and other openings like doors. Similarly, a sunshade or projection over fenestration will be defined in terms of start point of sunshade with respect to start point of respective wall, its total length on wall, its width and level on wall with respect to finished floor level.

Every room / zone is to be given a unique number. Graphical representation in view of the model illustrating different nodes and their coordinates, walls, fenestrations and openings, room nos. of Reference Unit no. 4RFF (Ground Floor & First Floor) is shown in Fig. 6.1.

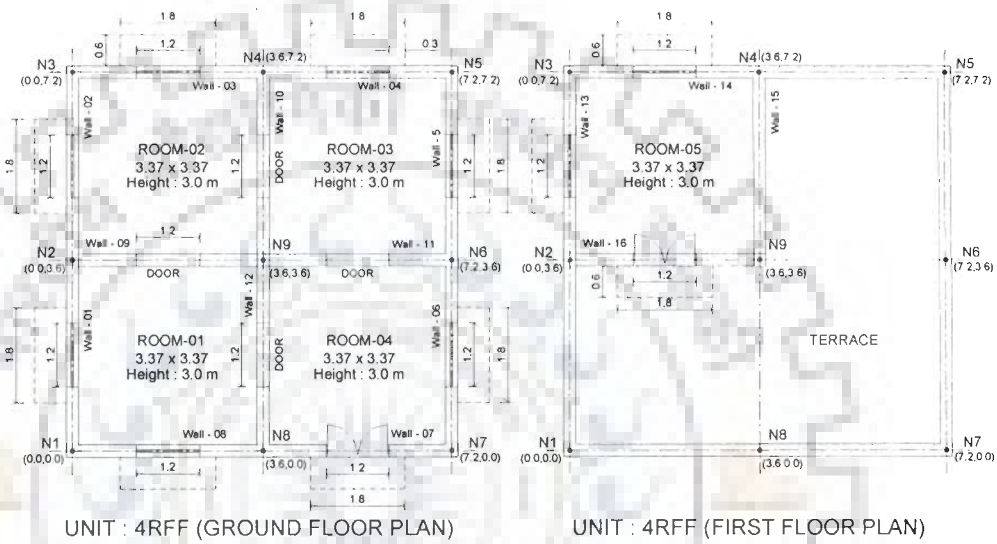


Fig. 6.1 : Ground Floor and First Floor Plan of Unit 4RFF

Input data file has been prepared in the following format.

Input data file of Exercise on Reference Unit **4RFF6** is being presented for better understanding.

(data in BOLD letters is to be filled)

DEFINE UNIT NAME : **4RAa6**

DEFINE CLIMATIC DATA FILE **ROORKEE**

8 No of materials

SURFACE COEFFICIENTS

Hin.v	Hin.c	Hin.f	Hout
8.29	**6.13**	**6.25**	**17.3**

DEFINE PROPERTIES OF MATERIALS

No. Heat Capacity Conductivity Absorptive Material Name

	(W.hr./m3.K)	(W/m.K)	(ratio)	
1	445	0.81	0.80	Brick
2	411	0.72	0.45	Plaster
3	590	1.74	0.65	Concrete
4	396	0.52	0.45	Mud Phuska
5	522	1.74	0.45	Sand
6	312	0.17	0.25	Plywood
7	574	0.81	0.29	Glass
8	560	1.58	0.65	RCC

1 No. of Outer Ambiances

0.2 Ground Reflectivity

DEFINE SECTION (MAX. 50 Nos.)[+]

5 Total No of Sections Defined

SECTION - 01

3 No of layers in section

0.01 2 Thickness Material

0.23 1 Thickness Material

0.01 2 Thickness Material

SECTION - 02

4 No of layers in section

0.01 2 Thickness Material

0.23 1 Thickness Material

0.01 2 Thickness Material

0.01 6 Thickness Material

SECTION – 03 (for Fenestrations)

0[+] No of layers in section

DEFINE PROPERTIES OF GLAZING[*]

[+] though N no. of materials and composite sections can be defined in the program, however, in view of certain limitations of commonly available / used computer hardware in India (particularly RAM & processor capacity), limit has been defined.

[*] 0 implies that default data will be used by the program.

3.18 : Conductivity of material (W/m.K)

3.71 : Heat Capacity on Side – 01 (W.hr./m3.K)

3.71 : Heat Capacity on Side – 02 (W.hr./m3.K)

0.50 : Absorptivity on Side 01 (ratio)

0.10 : Absorptivity on Side 02 (ratio)

0.45 : SHGC on incident angle 0^0

0.42 : SHGC on incident angle 40^0

0.40 : SHGC on incident angle 50^0

0.35 : SHGC on incident angle 60^0

0.27 : SHGC on incident angle 70^0

0.14 : SHGC on incident angle 80^0

0.38 : SHGC of Hemisphere (Diffuse)

SECTION - 04

4 Thickness Material

0.03 1

0.08 4

0.15 8

0.01 2

SECTION 05

2

0.15 3

0.85 5

DEFINE NODES

9 Total No of nodes

No.	X-Coordinate	Y-Coordinate
1	0	0
2	0	3.6
3	0	7.2
4	3.6	7.2
5	7.2	7.2

* 2001 ASHRAE Fundamentals Handbook (SI) Chapter 30, Table-13.

6	7.2	3.6
7	7.2	0
8	3.6	0
9	3.6	3.6

DEFINE WALLS (max. 400 walls can be defined)[♥]

16	Node1	Node2	IR1	IR2	Ht	Section	Fens	Shed Type
1	1	2	-1[♣]	1	3	1	1	1

Start. Dist. (From Node i)	Width	Sill lvl	Lintel lvl	Section Used
1.2	1.2	0.9	2.1	3

(Similarly data will be prepared for each wall & fenestrations as given below)

2	2	3	-1	2	3	1	1	1
1.2	1.2	0.9	2.1	3				
3	3	4	-1	2	3	1	1	1
1.2	1.2	0.9	2.1	3				
4	4	5	-1	3	3	1	1	1
1.2	1.2	0.9	2.1	3				
5	6	5	3	-1	3	1	1	1
1.2	1.2	0.9	2.1	3				
6	7	6	4	-1	3	1	1	1
1.2	1.2	0.9	2.1	3				
7	8	7	4	-1	3	1	1	1
1.2	1.2	0.9	2.1	3				
8	1	8	1	-1	3	1	1	1
1.2	1.2	0.9	2.1	3				
9	2	9	2	1	3	1	1	0
1.2	1.2	0	2.1	3				
10	9	4	2	3	3	1	1	0
1.2	1.2	0	2.1	3				

[♥] though N no. of wall can be defined in the program, however, in view of certain limitations of commonly available / used computer hardware in India (particularly RAM & processor capacity), limit has been defined.

[♣] -1 represents outside ambiance (exposed to environment).

11	9	6	3	4	3	1	1	0
1.2	1.2	0	2.1	3				
12	8	9	1	4	3	1	1	0
1.2	1.2	0	2.1	3				
13	2	3	-1	5	3	1	1	0
14	3	4	-1	5	3	1	1	0
15	9	4	5	-1	3	1	1	0
16	2	9	5	-1	3	1	1	0

DEFINE SHADING DEVICES

Starting Distance From Node – I	Length of Shading Device	Lintel Lvl	Thickness	Width of Shading Device
0.9	1.8	2.1	0.3	0.6

DEFINE ROOMS

5 No. of ROOMS Defined

Ht. of Room	Heat Capacity of Room (W)
3	100
3	100
3	100
3	100
3	100

DEFINE No. OF OCCUPANTS IN EACH ROOM (HOUR WISE) Time recorded from 00.00 to 23.00 hours.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DEFINE APLLIANCESLOAD IN EACH ROOM (HOUR WISE) Time recorded from 00.00 to 23.00 hours.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DEFINE VENTILATION RATE IN EACH ROOM (HOUR WISE) Time recorded from 00.00 to 23.00 hours.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

DEFINE No. OF SLABS

4 Total No. of Slabs Defined

Slab. No.	Zone of Side 1	Zone of Side 2	Area of Slab	Section Used
1	-1	1	0	4
2	-1	5	0	4
3	-1	3	0	4
4	-1	4	0	4

DEFINE PARAPET

1	No of parapet loops
5	No of corners in parapet (parapet should be closed)
1	Ht of parapet
2 3 4 9 2	Nodes in parapet

DEFINE FLOORS

5 Total No. of Floors Defined

Floor. No.	Zone of Side 1	Area of Floor	Section Used
1	1	0	5
2	2	0	5
3	3	0	5
4	4	0	5
5	5	0	4

DEFINE PROBLEMS

12 Total No. of Problems Defined

Date	Month	Plan Rotation Angle (Start)	Increment	No. of Rotations	Initial temperature
21	1	0	15	6	30

21	2	0	15	6	30
21	3	0	15	6	30
21	4	0	15	6	30
21	5	0	15	6	30
21	6	0	15	6	30
21	7	0	15	6	30
21	8	0	15	6	30
21	9	0	15	6	30
21	10	0	15	6	30
21	11	0	15	6	30
21	12	0	15	6	30

6.4 OUTPUT DATA

Input data file is processed by the program and following four types of files known as output files are generated as a result of the simulation.

(i) **General OUTPUT File**: It comprises the input data which was processed and temperature data as generated by the program. User can verify the input data which was processed by this file.

(ii) **SHADE File**: This file stores the calculated shaded areas on different surfaces of the building during different hours of the day. Data is used by the program for further calculations. This data can be utilized by the user to judge the effectiveness of sunshade / projections (in terms of absolute area of shadow created by them on different faces during different hours of the day) on outer faces of the building.

(iii) **SOLAR File**: This File stores data of computed solar radiation which falls on different faces of the building during different hours of the day. This data is also used by the program for further calculations.

(iv) **TEMPERATURE Output File**: It is in EXCEL Format to produce the temperature curves for the outdoor temperature & indoor temperature of a room for 0 to 24 hours. This file is important because the output data of this file further will be used for the analysis of thermal performance of building.

Sample of General Output File as per recorded data is being reproduced for reference and understanding in Appendix 5. However, all the input files prepared for different units and output files thus obtained (comprising approx. 60,000 pages) during this study are available in electronic form, a CD of which is enclosed with this work (on inner side of Rear Cover).

CHAPTER 7

VALIDATION OF THE MODEL

7.0 INTRODUCTION

As per Web Dictionary _ "Validation is the process of determining the degree to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model or simulation". Use of a model or simulation is a replacement for experimentation with an actual system (existing or proposed), where experimentation with that system could be disruptive, not cost effective, or infeasible. If the model or simulation is unable to provide valid representations of the actual system, any conclusions derived from the model or simulation are likely to be erroneous and may result in poor decisions being made. Validation can be performed for all models and simulations, regardless of whether the corresponding real-world system exists in some form or will be built in the future. Validation should always be focused on the intended use. The ease or difficulty of the validation process depends on the complexity of the system being modeled. The most definitive test of a simulation's validity is establishing that its output data closely resemble the output data that would be observed from the actual system.

If a system similar to the proposed one exists, then a simulation of the existing system is developed and its output data are compared to those from the existing system itself. If the two sets of data compare "closely," then the model of the existing system is considered "valid." Greater commonality between existing and proposed systems leads to greater confidence in the simulation of the proposed system.

7.1 VALIDATION CRITERIA

There is no completely definitive approach for validating the simulation of the proposed system. If there were, then there might be no need for a simulation in the first place. If the above comparison is successful, then it has the additional benefit of providing credibility for the use of simulation. Comparing simulation and system output data for the existing system is called results validation.

In this research work, model has been developed to perform indoor temperature simulation using a limited amount of input data describing the building construction. It is expected that the model predicts the precise indoor temperatures in view of known outdoor temperature. However, validation of developed model has been carried out based on the theoretical concept as well as through experimental measurements.

7.2 THEORETICAL VALIDATION

For validation of model, based on theoretical concepts, a conceptual building (Unit 2REa, description of which is given subsequently in this chapter) was modeled using the program and results were obtained in order to analyze the effect of following parameters_

- Effect of Orientation on Indoor Temperature
- Effect of Ventilation Rate

7.2.1 EFFECT OF ORIENTATION

It is common knowledge that different amount of solar radiation is received by the building envelop in different months of the year. Further amount of solar radiation received by the building envelop will be different for the same building, if placed in different orientation. Chand & Bhargawa [15] mentioned in The Climatic Data Handbook (p-199) "*It is noted that the* ***total solar radiation received*** *by the building is* ***minimum in summer*** *and* ***maximum in winter*** *when the building is* *oriented such that its* ***longer walls face north and south directions****. Hence this orientation is the best in respect of solar heat gain by buildings.*" It can be deduced from the statement that in case of a single room building, Indoor temperature will be maximum in winters and will be minimum in summer if building is oriented such that its longer walls face north and south directions, in comparison to other orientations. Exercise was carried out for a conceptual building in order to get the results in order to analyze the effect of orientation on Indoor air temperature.

DESCRIPTION OF BUILDING

A conceptual building was modeled using the program. Geometrical description of the building (Length, Width, Coordinates of Nodes etc.) can be seen in the Plan as shown in Fig. 7.1.

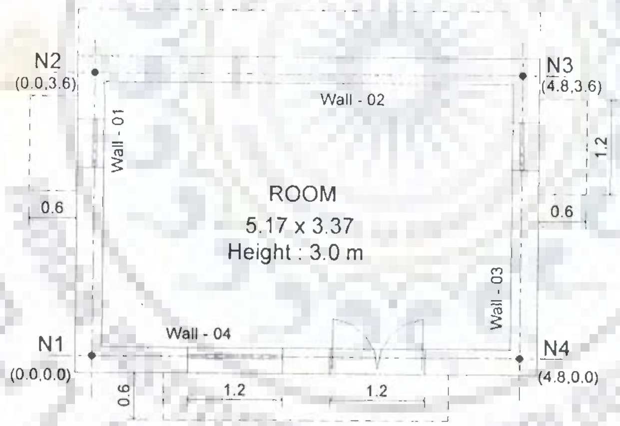


Fig. 7.1 : Plan of Conceptual Unit 2REa

Further, specifications of the building have been considered as following.

Walls : 230 mm thick Brick wall in Cement Mortar

(12 mm thick Cement Plaster on both sides).

Roof : 125 mm thick RCC Slab with 10 mm thick cement plaster on inner side.

Terracing : 80 mm Mud Phuska with 40 mm Brick Tiles on Top.

Height of Room : 3.0 m

Parapet : 1.0 m over walls.

Fenestrations: as shown (6.0 mm thick clear glass)

Sunshades: 0.6 m wide as shown in the Plan (at 2.1 m level w.r.t. FFL)

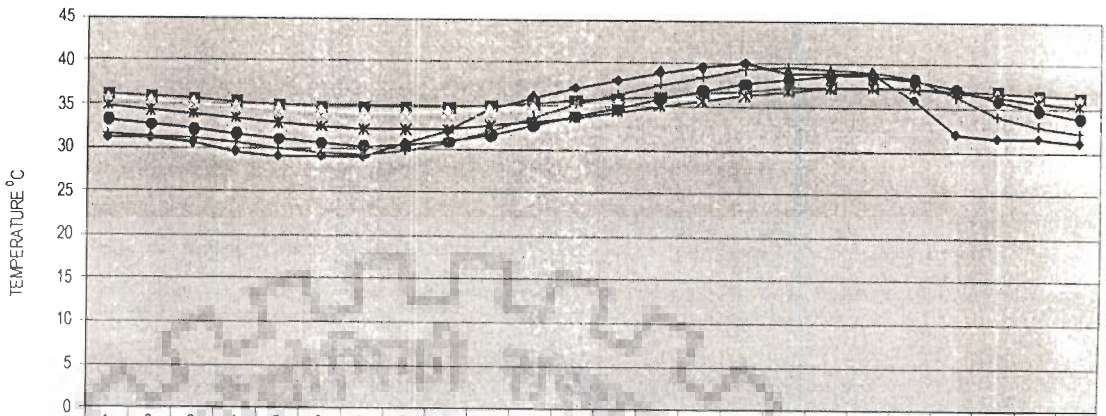
Floor : 150 mm Base Concrete over 1.0 m earth.

Air Changes : 0 ACPH

Results were obtained using the program for different orientations with respect to cardinal points, starting with PRA 0^0 with rotation increment of 6^0 and hence, for total 60 different orientations completing a full circular angle of 360^0, on hourly basis, for representative day i.e. 21 day of each month of the year. The predicted indoor temperature of each daily hour for different orientations, as obtained by the exercise, has been reproduced in Appendix 4. By analyzing the Indoor temperatures for the month of December and January, it is clearly seen that Maximum Indoor Temperature is maximum inside the building, when PRA is 0^0. For the month of April, May, June, July, August and September, Maximum Indoor Temperature during peak day hours is minimum for PRA 0^0 in comparison to other orientation angles. It can be inferred that **Results from the model are in conformity with the results of computation as discussed by Chand & Bhargava** [15].

7.2.2 EFFECT OF VENTILATION RATE

It can be theoretically envisaged that hourly Internal Temperature of the building should reach closer to the hourly Outside Temperature as ventilation rates increases. Effectiveness of the developed Model can be easily judged by taking an example of a single room. In this exercise single room unit 2REa, same as considered for previous study of effect of orientation, has been considered and results are obtained by keeping all the features unchanged with ventilation rate as only variable for a particular orientation. Unit has been modeled for Ventilation rates 0, 3, 6, 20, 60 and 150 ACPH and results have been presented in Fig. 7.2.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
2REa0	36.1	35.8	35.6	35.3	35	34.8	34.7	34.7	34.8	35	35.3	35.6	35.9	36.2	36.5	36.8	37.2	37.4	37.4	37.3	37.1	36.9	36.6	36.3
2REa3	35.6	35.4	35.1	34.8	34.5	34.2	34	34	34.2	34.4	34.7	35	35.3	35.7	36.1	36.5	36.8	37.1	37.2	37.1	36.9	36.6	36.2	35.9
2REa6	35.4	35	34.7	34.4	34	33.7	33.5	33.5	33.7	33.9	34.2	34.6	35	35.4	35.8	36.3	36.7	37	37.1	37	36.8	36.4	36	35.7
2REa20	34.7	34.2	33.8	33.3	32.8	32.4	32.1	32.1	32.2	32.6	33.1	33.7	34.3	35	35.6	36.3	36.8	37.2	37.4	37.3	36.9	36.3	35.7	35.2
2REa60	33.2	32.6	32.1	31.6	31	30.5	30.2	30.3	30.8	31.6	32.7	33.8	34.8	35.9	36.9	37.7	38.3	38.6	38.7	38.3	37.3	35.9	34.8	33.9
2REa150	31.5	31.2	31	30.5	29.9	29.4	29.3	29.7	30.6	32	33.7	35.2	36.4	37.6	38.5	39.3	39.5	39.4	39.2	38.4	36.3	34.1	32.9	32.1

DAILY HOUR

OUTSIDE 2REa0 2REa3 2REa6 2REa20 2REa60 2REa150

Fig. 7.2 : Temperature Profiles illustrating Effect of Ventilation Rate for Unit 2REa.

It can be seen clearly that hourly indoor temperature curve comes closer to the outside temperature curve as the ventilation rate increases. At Ventilation rate of 150 ACPH, internal temperature curve of room is closest to the outside temperature curve for this exercise, which was envisaged theoretically. However, it has been observed from other preliminary exercises that T_i curve comes quite close to T_{out} curve if ventilation rate of 300 ACPH is maintained in the building. This exercise clearly illustrates that Model is theoretically working well and precise results can be expected from the Model.

It can be concluded by these two exercises that the developed model is theoretically VALID, functioning well and is capable enough to predict the QUALITATIVE results. However, to determining the degree to which the developed model is accurate, an experimental study was carried out for an existing building. Details of this study are being discussed subsequently.

7.3 EXPERIMENTAL VALIDATION

A residential building (House) belonging to a middle class family has been taken into consideration for QUANTITATIVE validation purposes. House is located in Roorkee (Composite Climate Zone).

7.3.1 DESCRIPTION OF REFERENCE HOUSE

Geometrical description of the house can be judged by the Plans as given in Fig. 7.3.

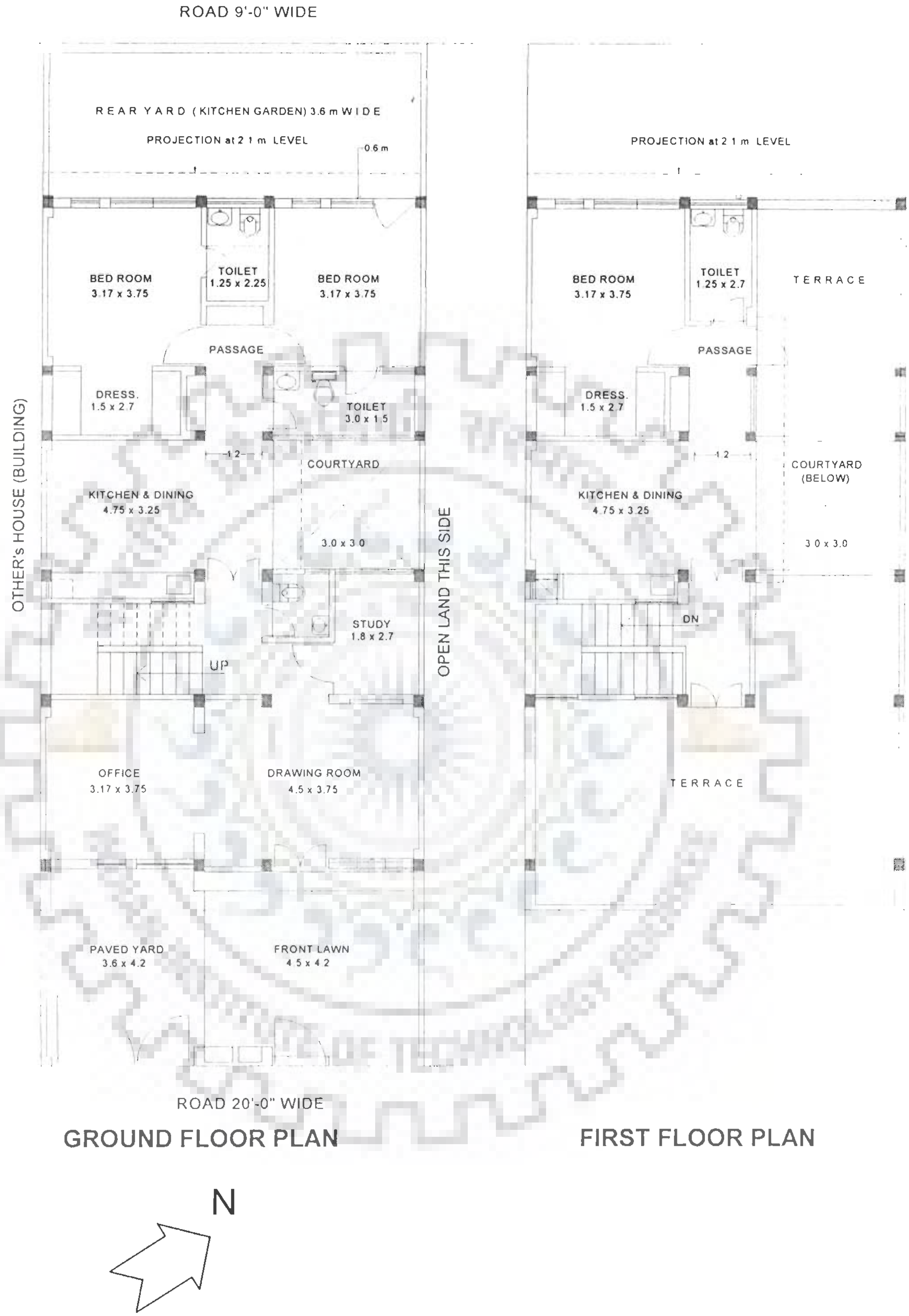
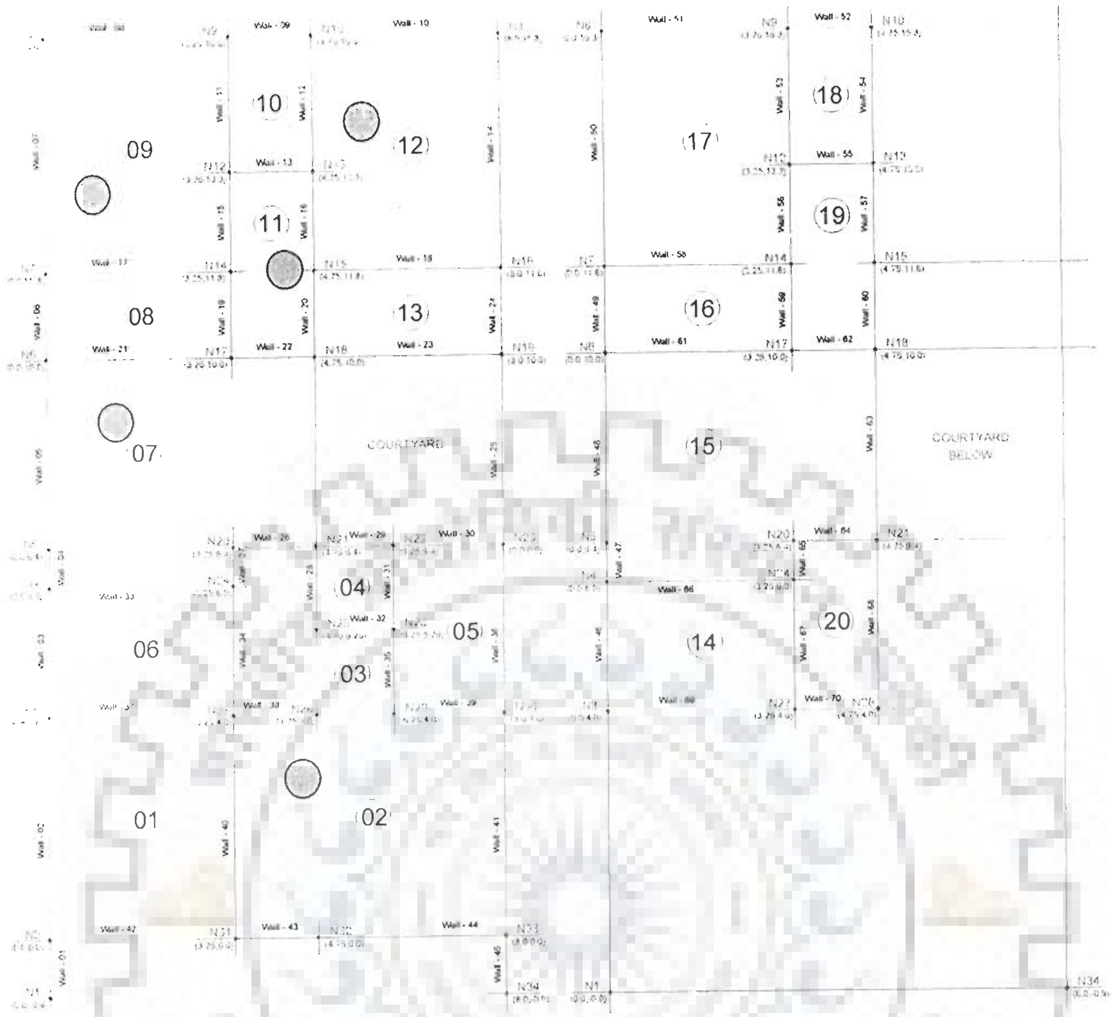


Fig. 7.3 : Ground Floor and First Floor Plan of Reference House

Building was digitized as per requirements of the Model in the following manner_



GROUND FLOOR PLAN (digitized) FIRST FLOOR PLAN (digitized)

Fig. 7.4 : Diagram of GF & FF plans illustrating nomenclature of walls & nodes.

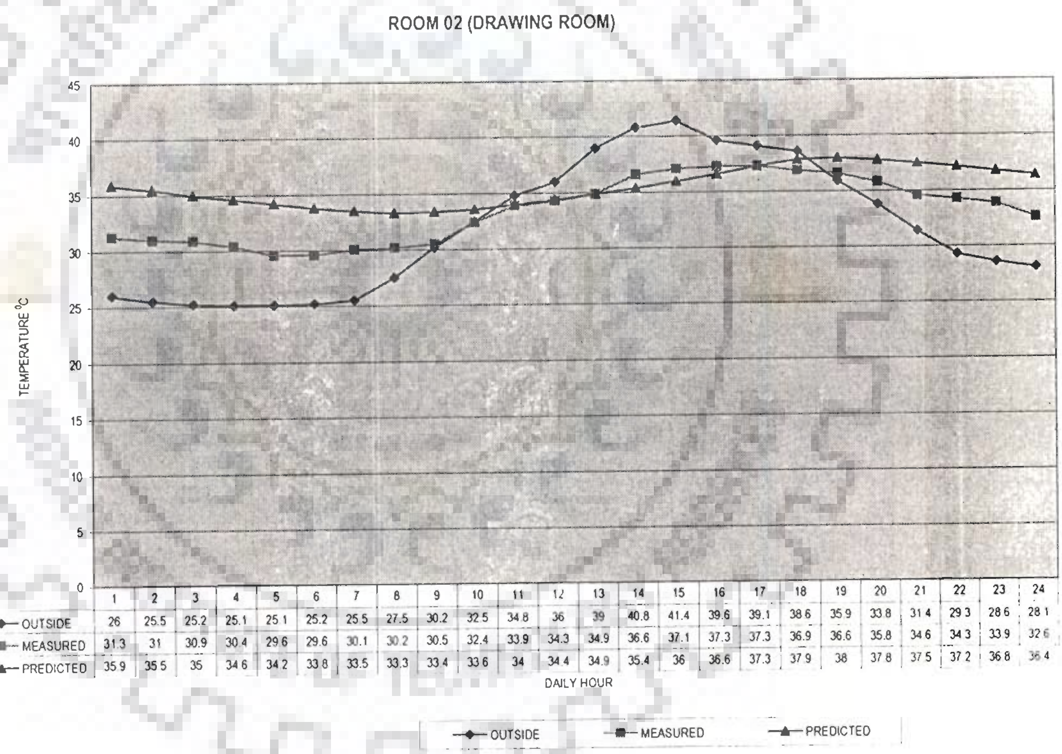
There are 20 different zones, 13 on Ground Floor and 07 on First Floor. In all, there are 34 nodes have been marked and their coordinates have been determined, which have been shown in the plans above. Total 70 walls have been defined in the input file of the model. Temperature of each hour in Room No. 02 07, 09, 11& 12 was recorded on 30. 05. 2007 round the clock. Points of Experiment are shown by filled circles in the aforesaid rooms. Results from the Model are obtained for all 20 zones/rooms, as shown in the figures. Data obtained from this exercise and as recorded by experimental measurements was compared and relevant graphs were complied for relative analysis of data.

7.3.2 INPUT DATA FOR REFERENCE HOUSE

Input data file for this exercise has been reproduced in Appendix 6.

7.3.3 OUTPUT DATA FOR REFERENCE HOUSE

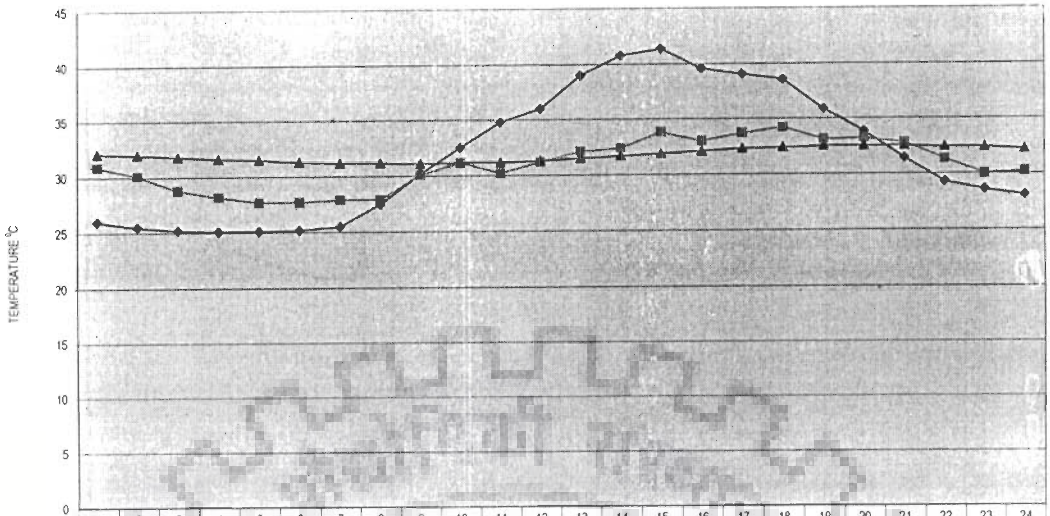
Temperature data for 20 Rooms as obtained by this exercise is available in CD enclosed with the folder Reference House. However, comparative graphs (hourly temperature curves) of outside temperature, indoor temperature as measured and indoor temperature as predicted by the model for the rooms 02, 07, 09, 11 & 12 are being produced for comparison and analysis.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	26	25.5	25.2	25.1	25.1	25.2	25.5	27.5	30.2	32.5	34.8	36	39	40.8	41.4	39.6	39.1	38.6	35.9	33.8	31.4	29.3	28.6	28.1
MEASURED	31.3	31	30.9	30.4	29.6	29.6	30.1	30.2	30.5	32.4	33.9	34.3	34.9	36.6	37.1	37.3	37.3	36.9	36.6	35.8	34.6	34.3	33.9	32.6
PREDICTED	35.9	35.5	35	34.6	34.2	33.8	33.5	33.3	33.4	33.6	34	34.4	34.9	35.4	36	36.6	37.3	37.9	38	37.8	37.5	37.2	36.8	36.4

Fig. 7.5 : Hourly Temperature Profiles of Room 02 (Drawing Room).

ROOM 07 (FAMILY LOUNGE)



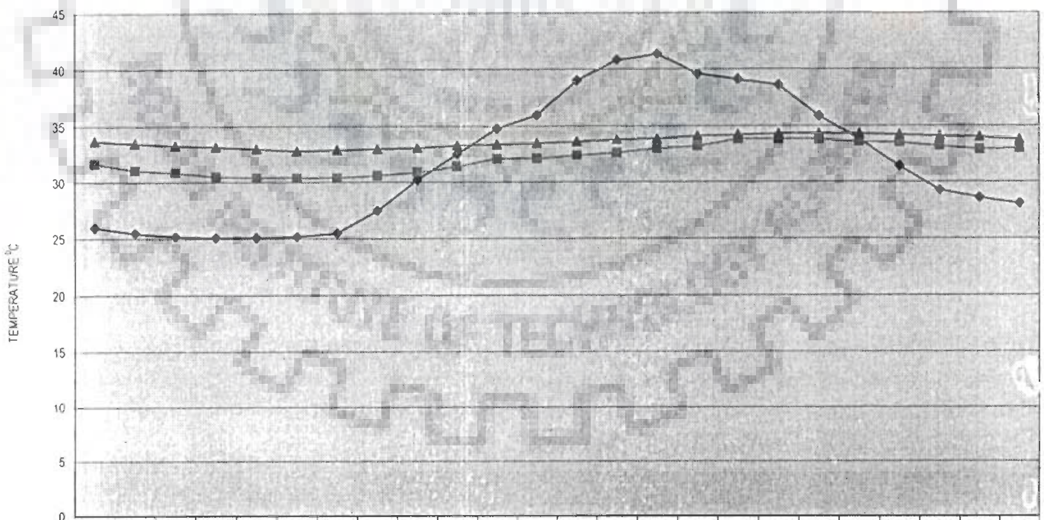
DAILY HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	26	25.5	25.2	25.1	25.1	25.2	25.5	27.5	30.2	32.5	34.8	36	39	40.8	41.4	39.6	39.1	38.6	35.9	33.8	31.4	29.3	28.6	28.1
MEASURED	30.9	30.1	28.8	28.2	27.7	27.7	27.9	27.9	30.1	31.2	30.2	31.2	32.1	32.4	33.8	33	33.7	34.2	33.1	33.2	32.8	31.3	30	30.2
PREDICTED	32.1	32	31.8	31.6	31.5	31.3	31.2	31.2	31.1	31.2	31.2	31.3	31.5	31.7	31.9	32.1	32.3	32.4	32.5	32.5	32.5	32.4	32.4	[illegible]

DAILY HOUR

OUTSIDE MEASURED PREDICTED

Fig. 7.6 : Hourly Temperature Profiles of Room 07 (Family Lounge).

ROOM 09 (MASTER BED ROOM)



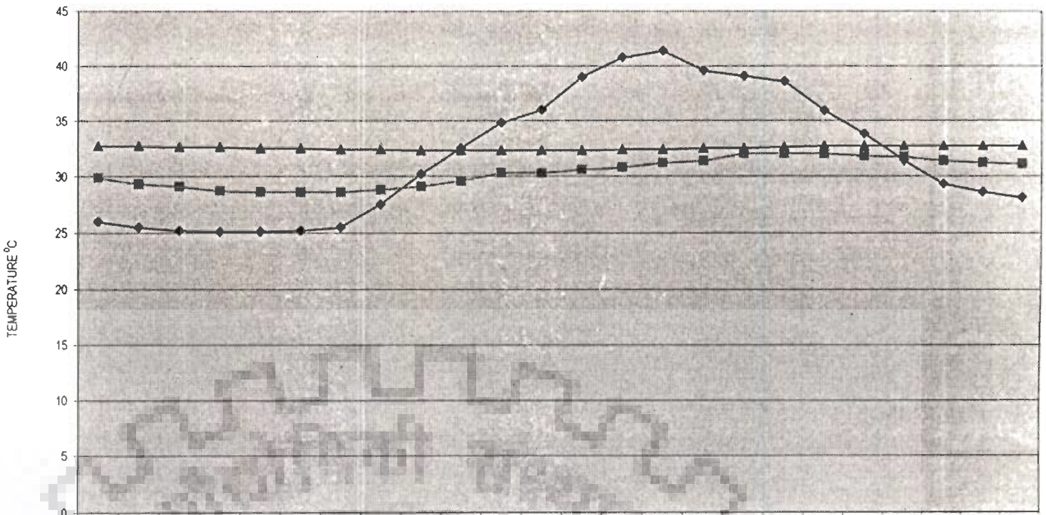
DAILY HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	26	25.5	25.2	25.1	25.1	25.2	25.5	27.5	30.2	32.5	34.8	36	39	40.8	41.4	39.6	39.1	38.6	35.9	33.8	31.4	29.3	28.6	28.1
MEASURED	31.7	31.1	30.9	30.5	30.4	30.4	30.4	30.6	30.9	31.4	32.1	32.1	32.4	32.6	33	33.2	33.8	33.8	33.8	33.6	33.5	33.2	32.9	33
PREDICTED	33.7	33.5	33.3	33.2	33	32.8	32.9	33	33.1	33.3	33.4	33.5	33.6	33.8	33.9	34.1	34.2	34.3	34.3	34.3	34.2	34.1	34	33.8

DAILY HOUR

OUTSIDE MEASURED PREDICTED

Fig. 7.7 : Hourly Temperature Profiles of Room 09 (Master Bed Room).

ROOM 11 (LOBBY)



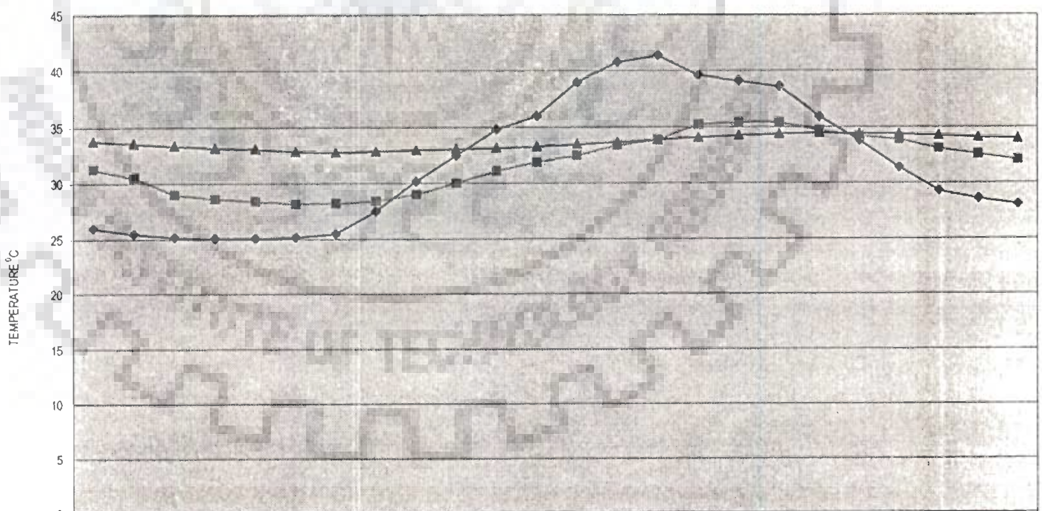
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	26	25.5	25.2	25.1	25.1	25.2	25.5	27.5	30.2	32.5	34.8	36	39	40.8	41.4	39.6	39.1	38.6	35.9	33.8	31.4	29.3	28.6	28.1
MEASURED	29.9	29.3	29.1	28.7	28.6	28.6	28.6	28.8	29.1	29.6	30.3	30.3	30.6	30.8	31.2	31.4	32	32	32	31.8	31.7	31.4	31.2	31.1
PREDICTED	32.7	32.7	32.6	32.6	32.5	32.5	32.4	32.4	32.3	32.3	32.3	32.3	32.3	32.4	32.4	32.5	32.5	32.6	32.7	32.7	32.7	32.7	32.7	32.7

DAILY HOUR

OUTSIDE — MEASURED — PREDICTED

Fig. 7.8 : Hourly Temperature Profiles of Room 11 (Circulation Lobby).

ROOM 12 (GUEST ROOM)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	26	25.5	25.2	25.1	25.1	25.2	25.5	27.5	30.2	32.5	34.8	36	39	40.8	41.4	39.6	39.1	38.6	35.9	33.8	31.4	29.3	28.6	28.1
MEASURED	31.3	30.5	29	28.6	28.4	28.2	28.2	28.4	29	30	31.1	31.9	32.5	33.4	33.9	35.2	35.4	35.4	34.7	34.2	33.9	33.1	32.6	32.1
PREDICTED	33.8	33.6	33.4	33.2	33.1	32.9	32.8	32.9	33	33.1	33.2	33.3	33.5	33.7	33.9	34.1	34.3	34.4	34.5	34.4	34.4	34.3	34.1	34

DAILY HOUR

OUTSIDE — MEASURED — PREDICTED

Fig. 7.9: Hourly Temperature Profiles of Room 12 (Guest Room).

7.4 COMPARISION OF RESULTS

It can be seen by comparing the Temperature Profiles of the day time that in all the five cases, Measured and Predicted Temperatures curves are almost parallel and very close, however, during night time a considerable fall in measured Temperature is observed. Since, it is practically impossible to maintain constant ventilation rate in the rooms round the clock (ventilation rate cannot be precisely controlled in such buildings), as has been assumed in the data while modelling (3 ACPH). Further, it is very likely that during night time ventilation rate was enhanced in the building due to increased air movement outside, and hence there is a considerable fall in the measured temperature profile. However, by suitable rectifications in the input data of ventilation rates (as per actual Ventilation rate), Temperature profiles of Measured and Predicted temperature can be found parallel and very close throughout the period. The significant fall in the measured temperature profile does not imply that the model is not working well, since the reason behind this fall is well understood and justified.

Further, two fluctuations (Measured temperature goes high) are observed in measured temperature profile for the Room No. 07 (Family Lounge) at time 15.00 and 18.00. These fluctuations are there due to use of Gas Stove for cooking at 14.15 and 17.30 in the lounge, load of which was not considered in input data. Since, developed model is based on certain assumptions and practical construction also has certain level of tolerance, difference in the results obtained from both the cases is likely. Further, building construction also may have some features like cornices, elevation offsets etc., which can not be modeled and hence their effect on thermal performance can not be incorporated. However, from the Table 7.1, it can be determined that Maximum Indoor Temperature during day time inside the room has a maximum difference of **0.90C**, which is **5.5%** of diurnal temperature range. Difference of 10 % in such results is generally acceptable in these types of simulation models. No Govt. Code or authentic literature in India is in practice which suggests the acceptable limits / tolerance for these types of simulations. ASHRAE recommends acceptable difference of 15 % to 10 % respectively for daily and monthly energy simulations.

TABLE 7.1 : Comparison of Measured and Predicted Temperatures for 05 Rooms.

	Max. Temp (^{0}C)	Max. Temp (^{0}C)
	MODEL PREDICTION	MEASUREMENTS
ROOM 02	38	37.3
ROOM 07	34.2	34.2
ROOM 09	32.7	32.0
ROOM 11	34.3	33.8
ROOM 12	34.5	35.4

It can be concluded from the above three exercises/study undertaken for validation purposes that the model is VALID and capable of predicting Thermal Performance of Buildings with in accepted tolerable limits. Further, experimental exercise (study no. 03) illustrates that Model can be used for existing buildings also in order to judge the thermal performance of existing buildings.

CHAPTER 8

EXERCISES & RESULTS

8.0 INTRODUCTION

In the previous chapters, I have discussed the need of the model, approach and concept behind development of model, criteria for validation and relevant exercises. However, this research work can not be culminated unless model is used for good purpose in order to benefit the society. To achieve this objective, some conceptual buildings are modeled using the program. Results are obtained in order to analyze the thermal performance of design parameters by considering them as variable(s). Thermal performance of conceptual unit(s) has been analyzed in view of the following aspects_

- Effect of Attic Floor
- Effect of Courtyard
- Effect of Fenestrations
- Effect of Height of Room / Building (air volume)
- Effect of Orientation
- Effect of Sunshades / Projections
- Effect of Terrace Garden
- Effect of Ventilation Rate
- Effect of Wall thickness

By analyzing the data, a set of optimum variables has been found out. Further, effect of these optimum variables on the thermal performance of building (conceptual unit) has been quantified by necessary exercises. Based on this study, inferences are derived and recommendations are made for practical purposes, which will be beneficial for the society and recommendations can be used by the general public. However, these recommendations may not be treated as final words, since research is a never ending phenomenon and always there is a scope for improvement and detailing.

8.1 EXERCISES

For Modelling purpose, three conceptual units of 01 Room, 04 Rooms and 09 Rooms have been considered for study, description of which is given in this chapter subsequently. It is worthwhile to mention here that orientation of the building has been considered as long faces of the building face North and South, because, this orientation has been found out optimum i.e. good for summer as well as for winter season.

8.1.1 EXERCISE - 01

For study purpose, a single room building (Unit name: 1RAa) has been conceptualized with clear inner dimensions as 3.37 x 3.37 m and clear height of the room as 3.0 m. Specifications of the building have been considered as following.

Walls: 230 mm thick Brick wall in Cement Mortar

(12 mm thick Cement Plaster on both sides).

Roof: 125 mm thick RCC Slab with 10 mm thick cement plaster on inner side.

Terracing : 80 mm Mud Phuska with 40 mm Brick Tiles on Top.

Height of Room: 3.0 m

Parapet: 1.0 m over walls.

Fenestrations: as shown (6.0 mm thick clear glass)

Sunshades: 0.6 m wide as shown in the Plan (at 2.1 m level w.r.t. FFL)

Floor: 150 mm Base Concrete over 1.0 m earth.

Air Changes: 0 ACPH

Preliminary unit 1RAa has no fenestration and no sunshade and is considered as reference (base) unit. By incorporating other building elements like fenestration and sunshades in the base unit, other units have been conceptualized, namely, 1RBa, 1RCa and 1RDa, geometrical description of which is given in Fig. no. 8.1 and Fig. 8.2, which are self explanatory. However, brief description of each unit is given as follows_

Unit 1RAa: A single room unit with abovementioned specifications, having no fenestrations and sunshades.

Unit 1RBa: Same as 1RAa, but comprises one door (1.2 m x 2.1 m) on North face and window (1.2 m x 1.2 m) on opposite face. Lintel level of door and window has been kept as 2.1 m with a sunshade (0.6 m wide) on the same level, which extends 0.3 m on either side of jambs.

Unit 1RCa: Same as 1RBa, but comprises two more windows on remaining faces.

Unit 1RDa: Same as 1RCa, but has a sunshade (0.6 m wide) on all the outer faces, as shown in the figure.

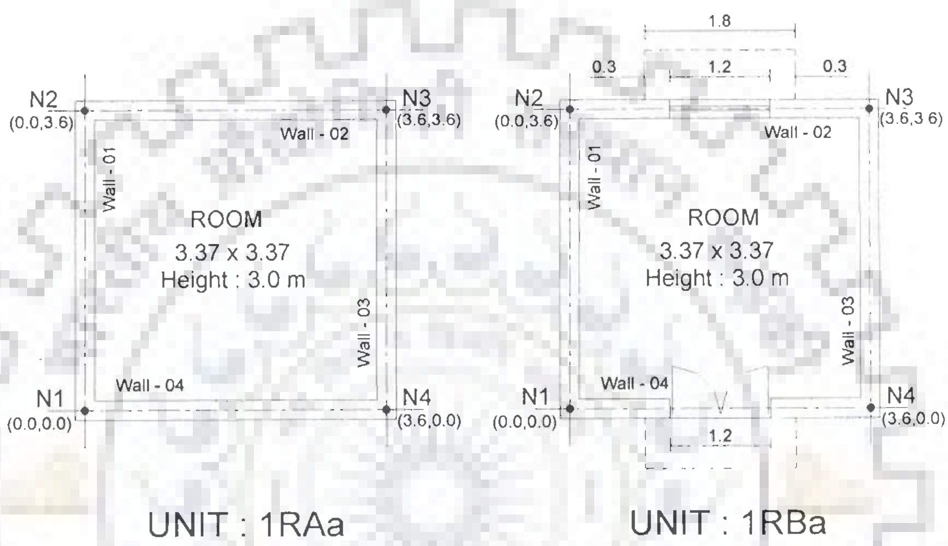


Fig. 8.1 : Plan of Unit 1RAa (left) and Unit 1RBa (right).

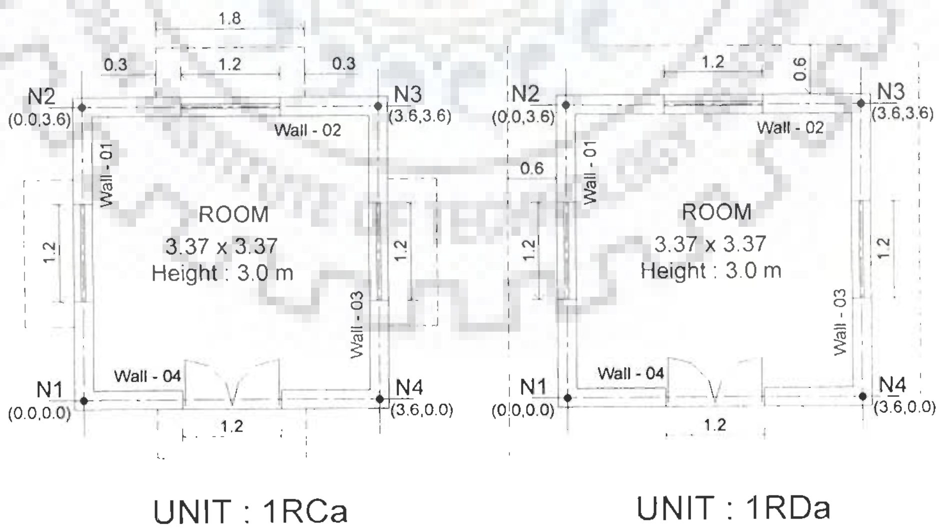
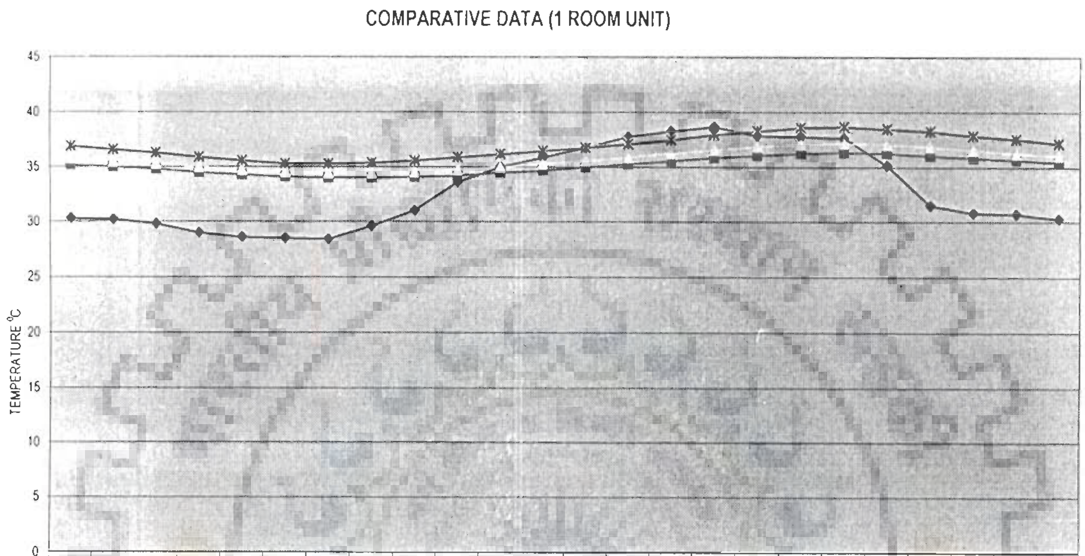


Fig. 8.2 : Plan of Unit 1RCa (left) and Unit 1RDa (right).

Units were modelled using the developed program and results were obtained for the date of May 30 for same orientation (all units facing North). Indoor temperatures in each case, thus predicted by the model, have been compared. Fig. 8.3 illustrates the comparative temperature curves and hourly predicted indoor temperatures for each unit.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	30.3	30.2	29.8	29	28.6	28.5	28.4	29.6	31	33.6	35	35.9	36.8	37.8	38.3	38.7	37.9	37.8	37.7	35.2	31.5	30.8	30.7	30.3
1RAa	35.2	35	34.8	34.5	34.3	34.1	34	34	34.1	34.2	34.5	34.7	35	35.3	35.6	35.9	36.1	36.3	36.4	36.3	36.1	35.9	35.7	35.5
1RBa	35.8	35.5	35.3	35	34.7	34.5	34.4	34.4	34.5	34.7	35	35.3	35.6	35.9	36.3	36.6	36.9	37.1	37.2	37.1	36.9	36.6	36.3	36.1
1RCa	37	36.7	36.4	36.1	35.7	35.4	35.4	35.5	35.7	36	36.3	36.6	36.9	37.3	37.7	38.1	38.5	38.8	38.9	38.7	38.4	38.1	37.7	37.4
1RDa	36.9	36.6	36.3	35.9	35.6	35.3	35.3	35.4	35.6	35.9	36.2	36.5	36.8	37.1	37.5	38	38.3	38.6	38.7	38.5	38.3	37.9	37.6	37.2

Daily Hour

OUT — 1RAa — 1RBa — 1RCa — 1RDa

Fig. 8.3 : Comparative Data & Temperature Profiles for One Room Units.

8.1.2 EXERCISE - 02

In the same manner, by incorporating some parameters (variables) in unit 1RAa, four other units have been conceptualized for exercises, brief description of which is as follow_

Unit 1RAa10: same as unit 1RAa, with the specifications as discussed in the previous exercise.

Unit 1RAa20: same as unit 1RAa10, but walls are 345 mm thick in place of 230 mm thick.

Unit 1RAa13: same as unit 1RAa10, but ventilation rate of 3 ACPH has been specified in place of 0 ACPH.

Unit 1RAa23: same as unit 1RAa20, but ventilation rate of 3 ACPH has been specified in place of 0 ACPH.

Unit 1RAa2V: same as unit 1RAa20, but ventilation rate varied for different hours of the day as mentioned hereunder for the month of June_

←-------------- DAILY HOUR (1 – 24) --------------→																							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
←-------------- VENTILATION RATE on DAILY HOUR --------------→																							
20	20	20	20	20	20	20	6	6	3	3	3	3	3	3	3	3	3	3	6	6	20	20	20

Further, ventilation rate varied for different hours of the day as mentioned hereunder for the month of January_

←-------------- DAILY HOUR (1 – 24) --------------→																							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
←-------------- VENTILATION RATE on DAILY HOUR --------------→																							
3	3	3	3	3	3	3	3	3	10	10	20	20	20	20	20	20	20	3	3	3	3	3	3

These units have been graphically represented in Fig. 8.4 and Fig. 8.5.

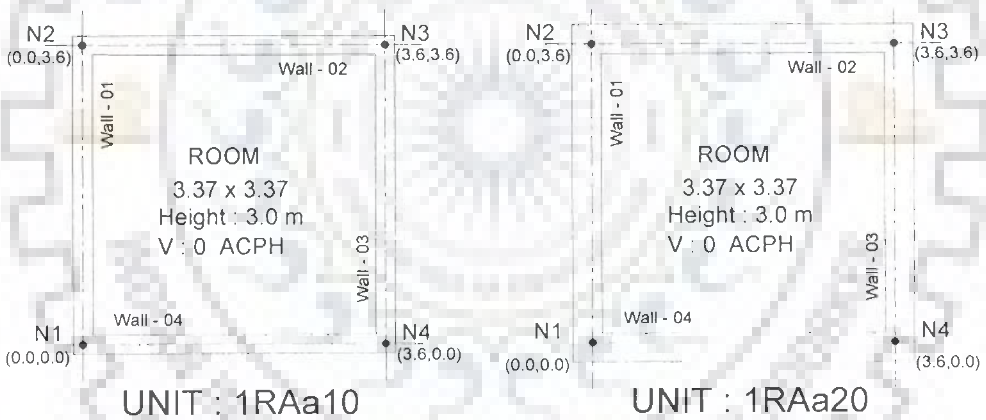


Fig. 8.4 : Plan of Unit 1RAa10 (left) and Unit 1RAa20 (right).

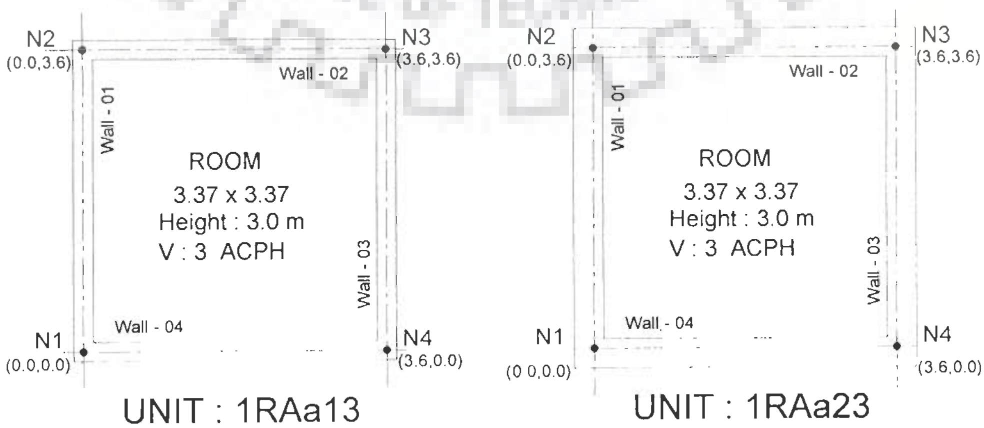
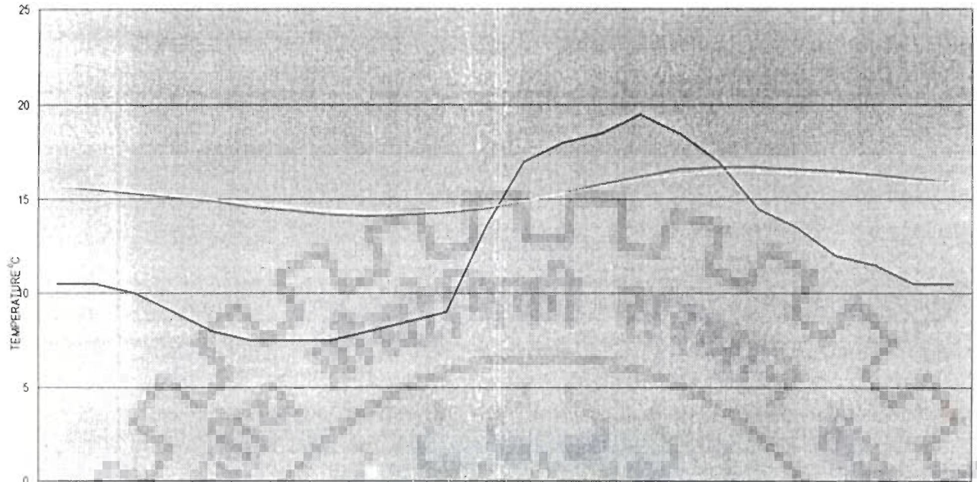


Fig. 8.5: Plan of Unit 1RAa13 (left) and Unit 1RAa23 (right).

Results were obtained for each case, for the representative day i.e. 21 of month of June & January, which are being represented in Fig. 8.6 & Fig. 8.7.

EFFECT OF WALL THICKNESS (JAN)



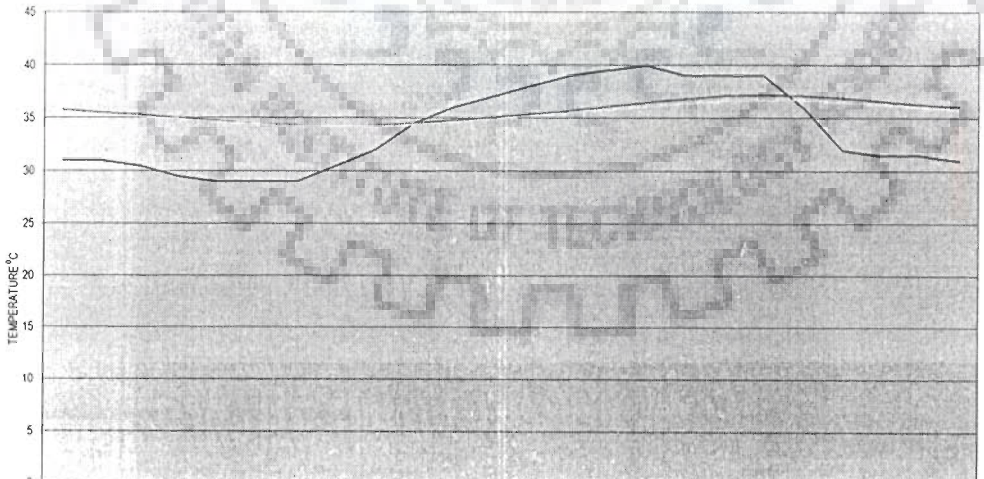
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
1RAa13	15.7	15.5	15.3	15.1	14.9	14.6	14.4	14.2	14.1	14.2	14.3	14.5	14.9	15.3	15.8	16.2	16.6	16.7	16.7	16.6	16.5	16.3	16.1	15.9
1RAa23	15.7	15.6	15.4	15.2	15	14.8	14.6	14.4	14.3	14.3	14.4	14.6	14.9	15.3	15.7	16.1	16.3	16.5	16.5	16.4	16.3	16.2	16	15.9

DAILY HOUR

OUTSIDE — 1RAa13 — 1RAa23

Fig. 8.6 : Comparative Data illustrating Effect of Wall Thickness (January)

EFFECT OF WALL THICKNESS (JUNE)



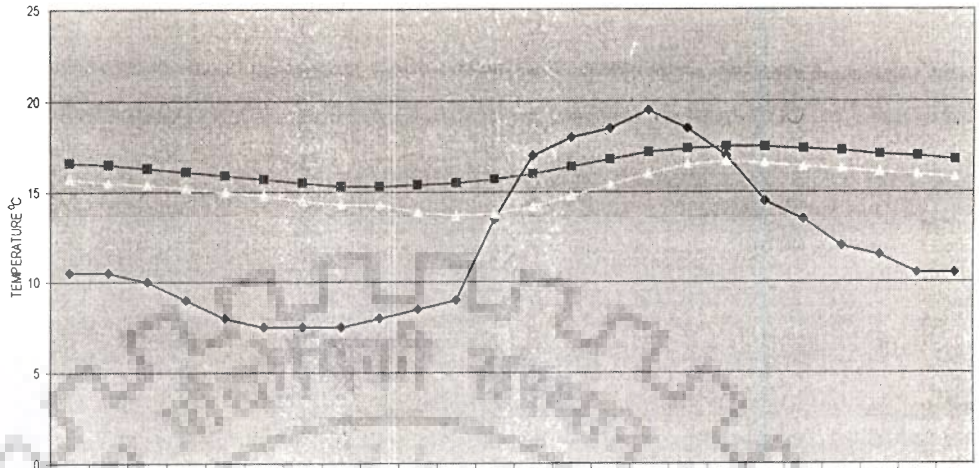
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
1RAa13	35.8	35.5	35.3	35	34.7	34.4	34.3	34.2	34.3	34.5	34.8	35.1	35.4	35.7	36.1	36.5	36.8	37.1	37.2	37.1	36.9	36.6	36.3	36.1
1RAa23	35.6	35.3	35.1	34.9	34.6	34.4	34.2	34.2	34.2	34.4	34.6	34.9	35.2	35.5	35.8	36.1	36.4	36.6	36.7	36.7	36.5	36.3	36	35.8

DAILY HOUR

OUTSIDE — 1RAa13 — 1RAa23

Fig. 8.7 : Comparative Data illustrating Effect of Wall Thickness (June)

COMPARATIVE DATA (1RAa10 & 1RAa2V)-WINTERS



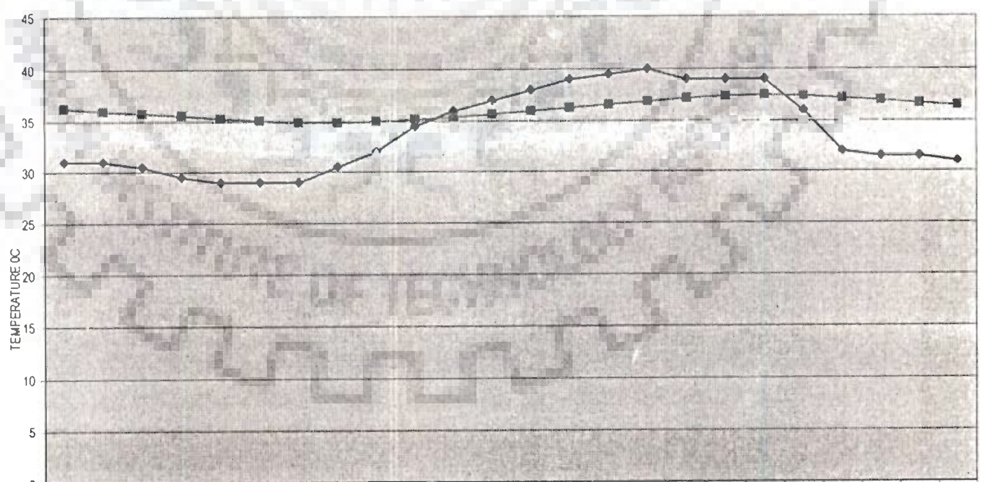
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
1RAa10	16.6	16.5	16.3	16.1	15.9	15.7	15.5	15.3	15.3	15.4	15.5	15.7	16	16.4	16.8	17.2	17.4	17.5	17.5	17.4	17.3	17.1	17	16.8
1RAa2V	15.7	15.5	15.4	15.2	15	14.8	14.5	14.3	14.3	13.9	13.7	13.8	14.2	14.8	15.4	16	16.5	16.7	16.6	16.4	16.3	16.1	16	15.8

DAILY HOUR

OUTSIDE — 1RAa10 — 1RAa2V

Fig. 8.8 : Comparative Data illustrating Effect of Ventilation Rate (January)

COMPARATIVE DATA (1RAa10 & 1RAa2V)-SUMMERS



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
1RAa10	36.3	36	35.8	35.6	35.3	35.1	34.9	34.9	35	35.2	35.4	35.7	36	36.3	36.6	36.9	37.2	37.4	37.5	37.4	37.2	37	36.7	36.5
1RAa2V	33.7	33.4	33.1	32.7	32.4	32	31.8	31.7	31.9	32.1	32.5	32.8	33.2	33.6	34	34.4	34.8	35	35.2	35.2	35.1	34.7	34.4	34

DAILY HOUR

OUTSIDE — 1RAa10 — 1RAa2V

Fig. 8.9 : Comparative Data illustrating Effect of Ventilation Rate (June)

8.1.3 **EXERCISE - 03**

For this exercises, a single room building (Unit name: 2REa) has been conceptualized with clear inner dimensions as 5.17 x 3.37 m and clear height of the room as 3.0 m. Specifications of the building have been considered as following.

Walls: 230 mm thick Brick wall in Cement Mortar

(12 mm thick Cement Plaster on both sides).

Roof: 125 mm thick RCC Slab with 10 mm thick cement plaster on inner side.

Terracing : 80 mm Mud Phuska with 40 mm Brick Tiles on Top.

Height of Room: 3.0 m

Parapet: 1.0 m over walls.

Fenestrations: as shown (6.0 mm thick clear glass)

Sunshades: 0.6 m wide as shown in the Plan (at 2.1 m level w.r.t. FFL)

Floor: 150 mm Base Concrete over 1.0 m earth.

Air Changes: 0 ACPH

Geometrical description of the unit can be understood by the self explanatory Fig. 8.10 , as given below.

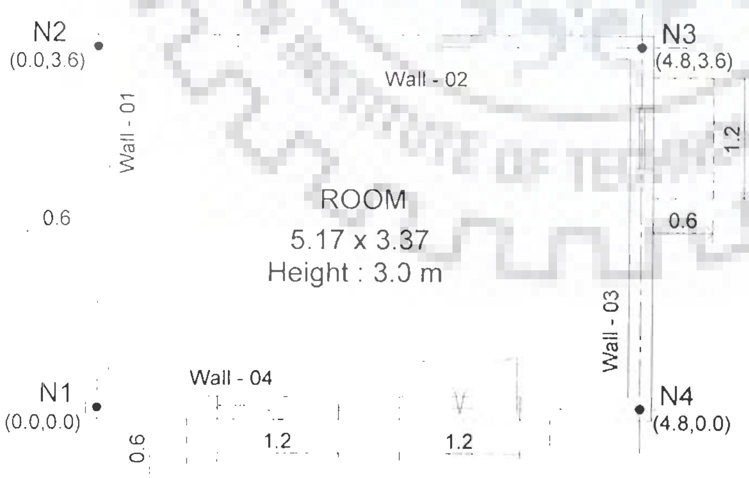


Fig. 8.10 : Plan of Unit 2REa

Different cases were considered for study by using the model, which are briefly described as hereunder_

Unit 2REa0: Same as reference Unit 2REa, with specifications as described above with ventilation rate 0 (zero) ACPH.

Unit 2REa1: Same as reference Unit 2REa0, but walls 345 mm thick instead of 230 mm thick.

Unit 2REa2: Same as reference Unit 2REa0, but south wall 345 mm thick and Height of the room 3.6 m instead of 230 mm thick.

Unit 2REa3: Same as reference Unit 2REa2, but a terrace garden on roof top (300 mm thick mud layer) and ventilation rate varied for different hours of the day as mentioned hereunder for the month of June_

←------------------ DAILY HOUR (1 – 24) ------------------→

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
←------------------ VENTILATION RATE on DAILY HOUR------------------→																							
20	20	20	20	20	20	20	6	6	3	3	3	3	3	3	3	3	3	3	6	6	20	20	20

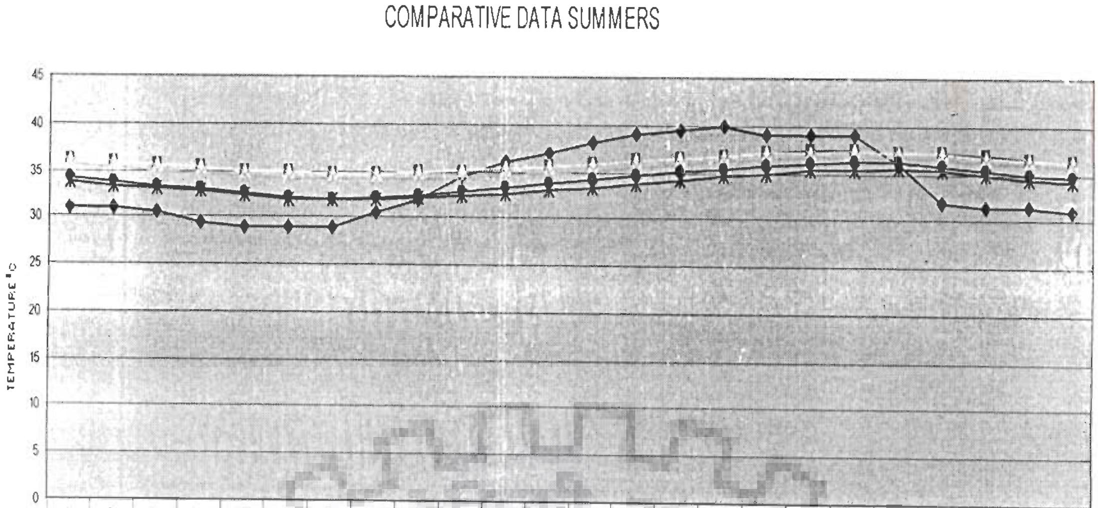
Further, ventilation rate varied for different hours of the day as mentioned hereunder for the month of January_

←------------------ DAILY HOUR (1 – 24) ------------------→

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
←------------------ VENTILATION RATE on DAILY HOUR------------------→																							
3	3	3	3	3	3	3	3	3	20	20	20	20	20	20	20	20	20	3	3	3	3	3	3

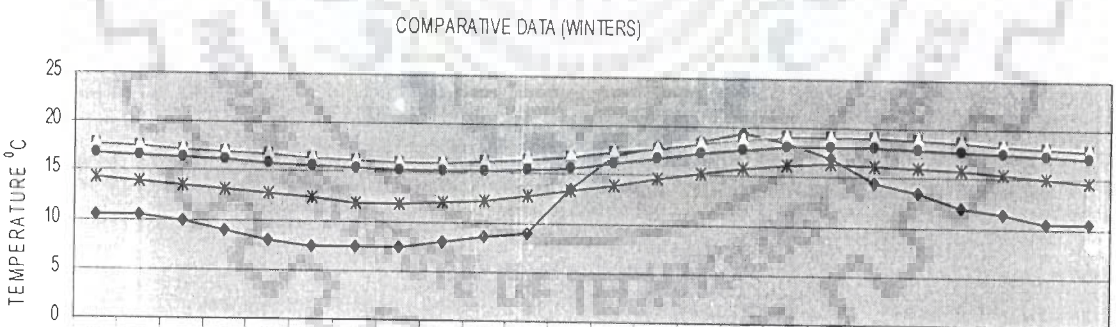
Unit 2REa4: Same as reference Unit 2REa2, but full length projections (0.6 m wide) are considered on North and South walls.

Temperature predictions for the month of June and January were obtained by using the model. Comparative data for each case for the month of June is given in Fig. 8.11.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
2REa0	36.1	35.8	35.6	35.3	35	34.8	34.7	34.7	34.8	35	35.3	35.6	35.9	36.2	36.5	36.8	37.2	37.4	37.4	37.3	37.1	36.9	36.6	36.3
2REa1	36.1	35.8	35.6	35.3	35	34.8	34.7	34.7	34.9	35.1	35.3	35.6	35.9	36.2	36.5	36.8	37.1	37.3	37.4	37.3	37.1	36.8	36.6	36.3
2REa2	35.5	35.3	35	34.7	34.5	34.2	34.1	34.1	34.2	34.3	34.6	34.9	35.2	35.5	35.8	36.2	36.5	36.7	36.8	36.7	36.6	36.3	36	35.8
2REa3	33.8	33.4	33.1	32.8	32.4	32	31.8	31.9	32.1	32.4	32.7	33	33.4	33.8	34.2	34.6	35	35.3	35.4	35.6	35.3	34.9	34.5	34.1
2REa4	34.2	33.8	33.4	33	32.6	32.2	32	32.1	32.4	32.8	33.3	33.8	34.2	34.6	35.1	35.4	35.8	36	36.2	36.2	35.9	35.4	35	34.6

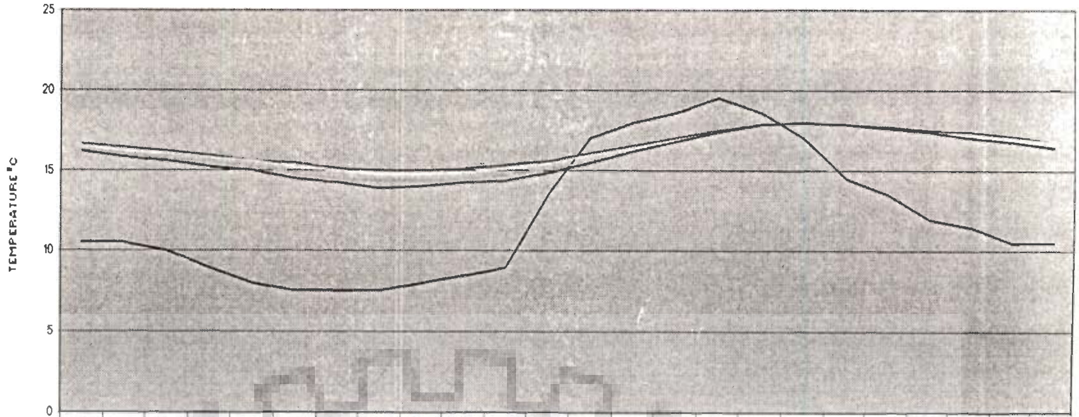
Fig. 8.11 : Comparative Data and Temperature Profiles (June) for Unit 2REa.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
2REa0	17.7	17.5	17.2	17	16.7	16.4	16.2	16	16	16.2	16.5	16.8	17.3	17.8	18.3	18.8	19.1	19.1	19	18.9	18.7	18.4	18.2	17.9
2REa1	17.9	17.7	17.4	17.2	16.9	16.6	16.4	16.2	16.2	16.4	16.7	17.1	17.5	18	18.5	18.9	19.3	19.3	19.2	19	18.8	18.6	18.4	18.1
2REa2	16.7	16.4	16.2	16	15.7	15.4	15.1	14.9	14.9	15.1	15.3	15.6	16.1	16.6	17.1	17.6	17.9	18	17.9	17.8	17.6	17.4	17.1	16.9
2REa3	14.3	13.9	13.6	13.2	12.8	12.4	11.9	11.9	12	12.3	12.7	13.3	13.9	14.6	15.2	15.8	16.2	16.4	16.3	16.1	15.8	15.5	15	14.6

Fig. 8.12 : Comparative Data and Temperature Profiles (January) for Unit 2REa.

EFFECT of HEIGHT OF ROOM (JANUARY)



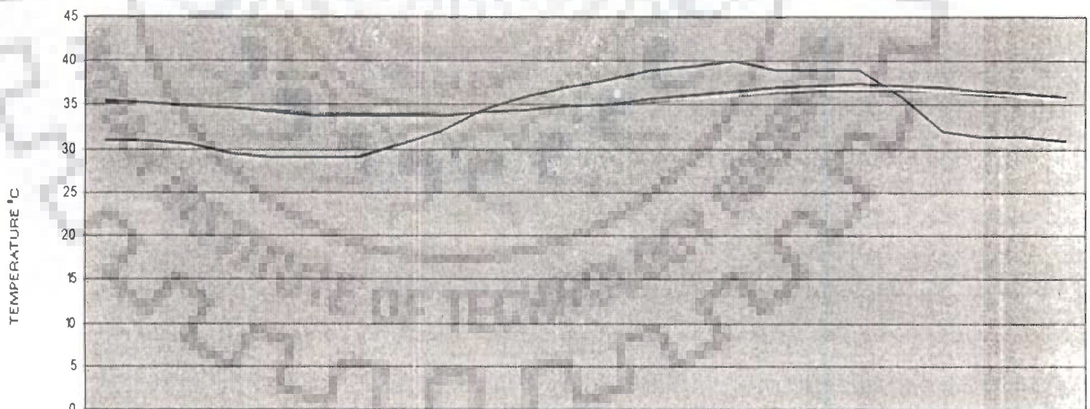
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
H-2.7	16.6	16.4	16.2	15.9	15.6	15.4	15.1	14.9	14.9	15.1	15.3	15.6	16	16.5	17	17.5	17.8	17.9	17.8	17.7	17.5	17.3	17.1	16.8
H-3.0	16.5	16.2	16	15.8	15.5	15.2	14.9	14.7	14.7	14.8	15.1	15.4	15.9	16.4	16.9	17.4	17.8	17.9	17.8	17.6	17.4	17.2	17	16.7
H-3.6	16.3	16	15.7	15.5	15.2	14.8	14.5	14.3	14.3	14.5	14.7	15.1	15.6	16.2	16.8	17.4	17.8	17.9	17.8	17.6	17.4	17.1	16.8	16.5
H-4.2	16.1	15.8	15.5	15.2	14.9	14.5	14.2	13.9	14	14.2	14.4	14.8	15.4	16.1	16.7	17.3	17.8	17.9	17.8	17.6	17.3	17	16.7	16.4

DAILY HOUR

OUTSIDE H-2.7 H-3.0 H-3.6 H-4.2

Fig. 8.13 : Comparative Data illustrating Effect of Height (January) for Unit 2REa.

EFFECT of HEIGHT OF ROOM (JUNE)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
H-2.7	35.4	35.2	34.9	34.6	34.4	34.1	34	34	34.1	34.3	34.5	34.8	35.1	35.4	35.8	36.1	36.4	36.6	36.7	36.7	36.5	36.2	35.9	35.7
H-3.0	35.5	35.2	34.9	34.6	34.3	34.1	33.9	33.9	34	34.2	34.5	34.8	35.1	35.5	35.8	36.2	36.5	36.8	36.9	36.8	36.6	36.3	36	35.7
H-3.6	35.5	35.2	34.9	34.6	34.3	34	33.8	33.9	34	34.2	34.5	34.8	35.2	35.6	36	36.4	36.8	37	37.1	37.1	36.8	36.5	36.2	35.9
H-4.2	35.6	35.3	34.9	34.6	34.2	33.9	33.7	33.8	33.9	34.2	34.5	34.9	35.2	35.7	36.1	36.6	37	37.3	37.4	37.3	37	36.7	36.3	35.9

DAILY HOUR

OUTSIDE H-2.7 H-3.0 H-3.6 H-4.2

Fig. 8.14 : Comparative Data illustrating Effect of Height (June) for Unit 2REa.

8.1.4 EXERCISE – 04

Model has been developed to analyze thermal performance of multi-room building. Exercises so far have carried out for a single room unit, in which phenomenon of thermal interactions between multi-rooms were not used by the model. A simple 04 rooms building (Unit name: 4RFF) has been conceptualized as shown in self explanatory Fig. 8.15. A room on First Floor as an attic room, over Room no. 02, has been considered for modelling in order to judge the thermal performance of attic space and its effect on the room below. Description of the unit, its specifications and input data file of this unit has been given in Chapter 03, as a sample file.

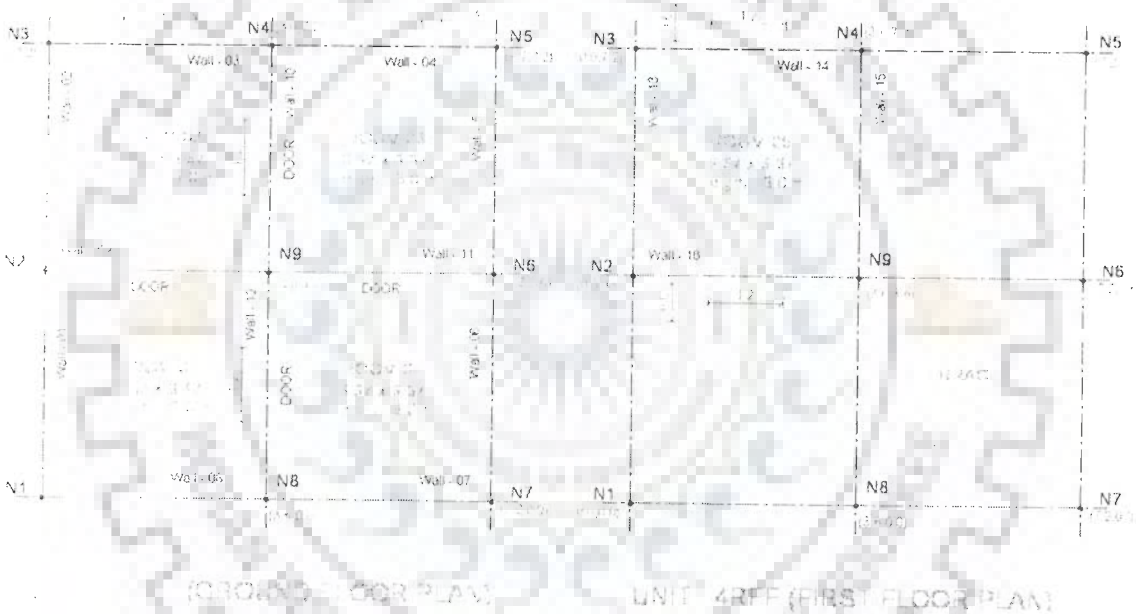
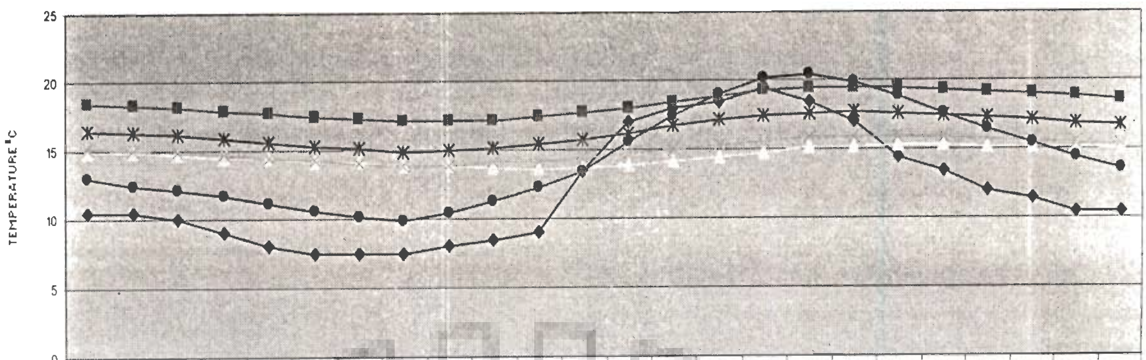


Fig. 8.15 : Ground Floor Plan & First Floor Plan of Unit 4RFF.

Results were obtained for the month of June and January. Comparative data and temperature profiles of each room for the month of January and June have been given in Fig. 8.16 and Fig. 8.17 .

COMPARATIVE TEMPERATURE DATA for DOUBLE STOREY UNIT



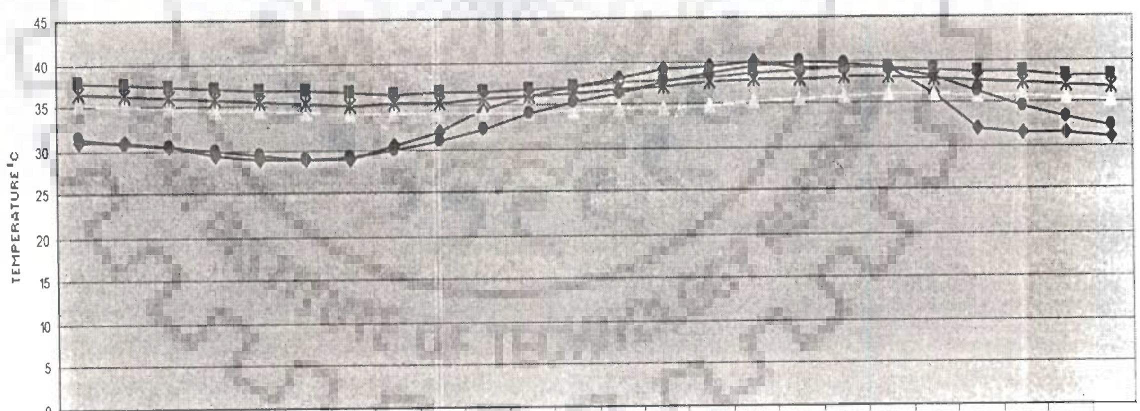
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
ROOM 01	18.4	18.3	18.1	17.9	17.7	17.5	17.3	17.1	17.1	17.2	17.4	17.7	18	18.5	18.9	19.3	19.5	19.5	19.4	19.3	19.1	19	18.8	18.6
ROOM 02	14.9	14.8	14.7	14.5	14.4	14.2	14.1	13.9	13.8	13.7	13.6	13.7	13.8	14.1	14.4	14.7	15.1	15.2	15.3	15.3	15.2	15.2	15.1	15
ROOM 03	15.1	15	14.8	14.7	14.5	14.3	14	13.9	13.9	14.1	14.2	14.4	14.7	15	15.3	15.6	15.8	15.9	15.9	15.8	15.7	15.6	15.4	15.3
ROOM 04	16.5	16.3	16.1	15.9	15.6	15.3	15.1	14.9	15	15.2	15.4	15.7	16.2	16.7	17.1	17.4	17.6	17.7	17.6	17.5	17.3	17.1	16.9	16.7
ROOM 05	13	12.5	12.2	11.7	11.2	10.6	10.1	9.9	10.4	11.3	12.3	13.5	15.6	17.4	19	20.1	20.5	19.9	18.8	17.6	16.4	15.4	14.4	13.6

DAILY HOUR

OUTSIDE — ROOM 01 — ROOM 02 — ROOM 03 — ROOM 04 — ROOM 05

Fig. 8.16 : Comparative Data illustrating (January) for Unit 4RFF.

COMPARATIVE DATA for DOUBLE STOREY UNIT (JUNE)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
ROOM 01	37.8	37.6	37.4	37.1	36.9	36.7	36.5	36.4	36.5	36.6	36.9	37.2	37.5	37.8	38.2	38.5	38.8	39	39	38.9	38.7	38.5	38.2	38
ROOM 02	35.2	35	34.8	34.6	34.4	34.2	34.1	34	34	34	34.1	34.2	34.4	34.6	34.8	35.2	35.5	35.8	36	36	35.8	35.7	35.5	35.3
ROOM 03	36.3	36	35.7	35.5	35.2	34.9	34.9	35	35.2	35.5	35.8	36.2	36.5	36.9	37.2	37.4	37.6	37.6	37.6	37.6	37.3	37.1	36.8	36.5
ROOM 04	36.6	36.3	36.1	35.8	35.5	35.2	35.1	35.2	35.4	35.7	36	36.4	36.8	37.1	37.5	37.8	37.9	38	38	37.9	37.7	37.4	37.1	36.9
ROOM 05	31.4	30.8	30.4	29.8	29.3	28.9	29.1	29.8	31	32.3	33.9	35.2	36.4	37.5	38.6	39.4	39.8	39.7	39.1	38	36.3	34.6	33.2	32.2

DAILY HOUR

OUTSIDE — ROOM 01 — ROOM 02 — ROOM 03 — ROOM 04 — ROOM 05

Fig. 8.17 : Comparative Data illustrating (June) for Unit 4RFF.

8.1.5 EXERCISE – 05

A bigger unit, consisting 09 rooms, has been conceptualized for this exercise. Basic unit is 9RAa, which contains 09 rooms, graphical description of which is given in Fig. 8.18. Other units 9RBa, 9RCa and 9RDa are based on basic reference unit 9RAa with some changes in design parameters (variables). Brief description of each unit is as follows_

Unit 9RAa: Basic reference unit, with the following specifications.

Walls: 230 mm thick Brick wall in Cement Mortar

(12 mm thick Cement Plaster on both sides).

Roof: 125 mm thick RCC Slab with 10 mm thick cement plaster on inner side.

Terracing : 80 mm Mud Phuska with 40 mm Brick Tiles on Top.

Height of Rooms: 3.0 m

Parapet: 1.0 m over walls.

Fenestrations: as shown (6.0 mm thick clear glass)

Sunshades: 0.6 m wide as shown in the Plan (at 2.1 m level w.r.t. FFL)

Floor: 150 mm Base Concrete over 1.0 m earth.

Air Changes: 0 ACPH

Unit 9RBa: Same as unit 9RAa, with the provision of doors, windows and sunshades, as shown in Fig. 8.18.

Unit 9RCa: Same as unit 9RBa, but sunshades (12. M wide) has been provided on north and south walls on entire length.

Unit 9RDa: Same as unit 9RCa, but room no. 09 (central room) has been considered as courtyard by removing the slab above. Climatic conditions as per outer ambience have been considered in the courtyard.

All the above mentioned 04 units have been graphically represented in Fig. 8.18 and Fig. 8.19, which are self explanatory.

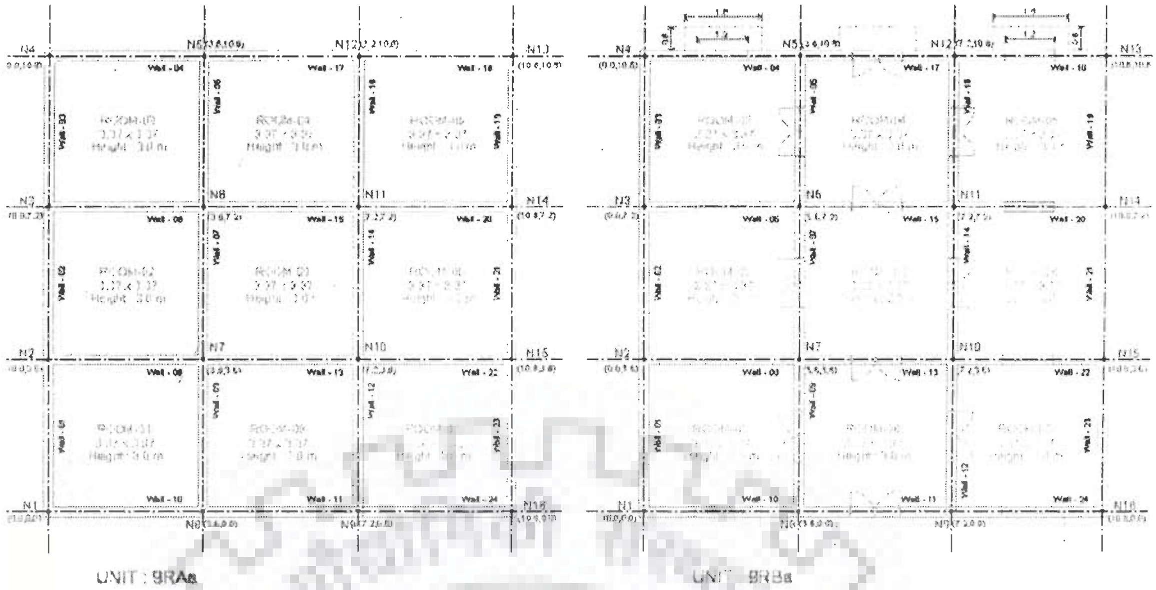


Fig. 8.18 : Plan of Unit 9RAa (left) and Unit 9RBa (right).

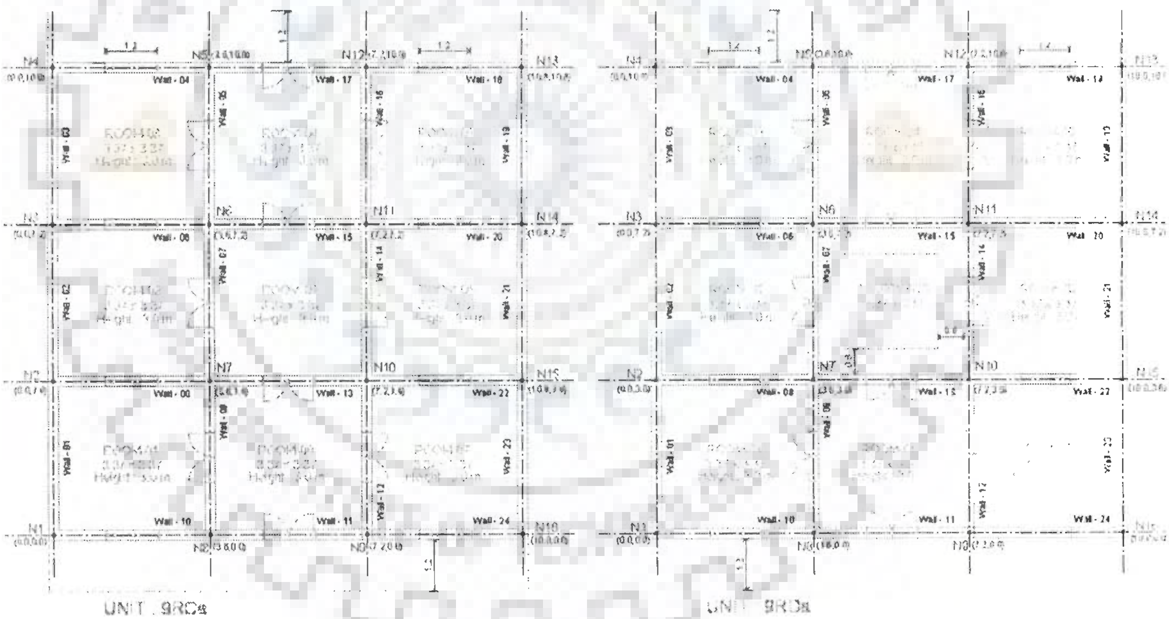
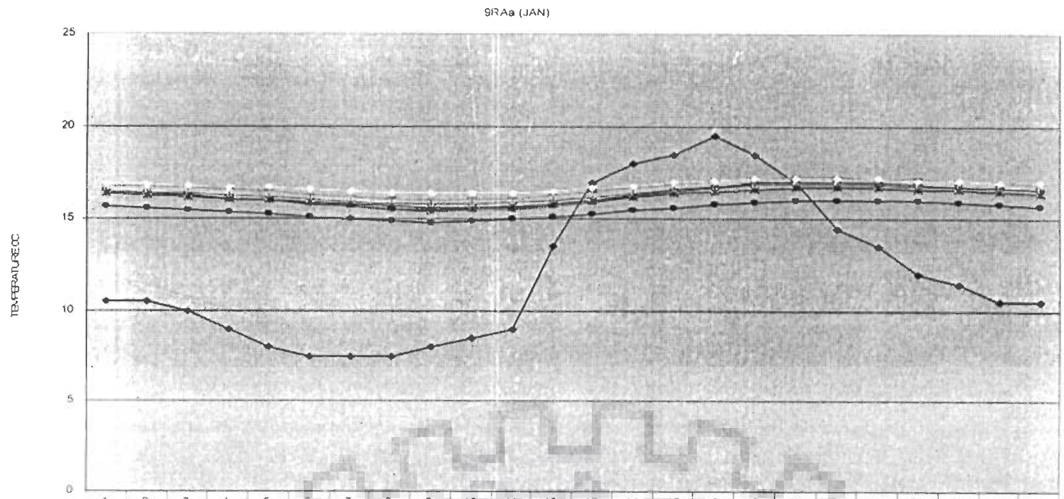


Fig. 8.19 : Plan of Unit 9RCa (left) and Unit 9RDa (right).

Results were obtained for each unit, room-wise on hourly basis, for the month of January and June, which are being presented in the following figures.

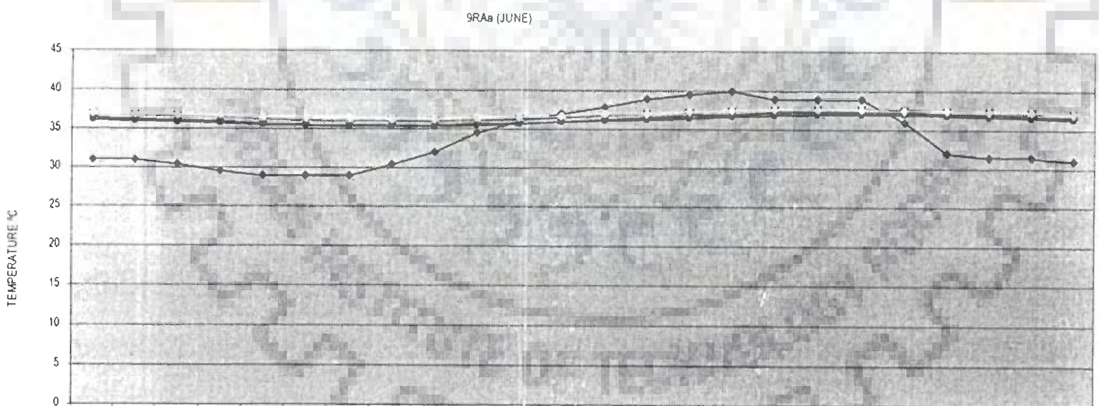


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
ROOM 01	16.5	16.4	16.3	16.1	16	15.8	15.7	15.5	15.4	15.5	15.5	15.7	16.9	16.2	16.5	16.7	16.9	17	17	17	16.9	16.8	16.7	16.6
ROOM 02	16.6	16.5	16.4	16.4	16.2	16.1	16	15.9	15.8	15.8	15.9	16	16.2	16.4	16.6	16.8	16.9	17	17	16.9	16.9	16.8	16.8	16.7
ROOM 03	16.2	16.1	16	15.9	15.7	15.6	15.4	15.3	15.2	15.2	15.2	15.4	15.6	15.9	16.2	16.4	16.6	16.7	16.7	16.6	16.6	16.5	16.4	16.3
ROOM 04	16.4	16.3	16.2	16.1	16	15.9	15.8	15.7	15.6	15.6	15.7	15.8	16	16.2	16.4	16.5	16.6	16.7	16.7	16.7	16.6	16.6	16.5	16.4
ROOM 05	15.7	15.6	15.5	15.4	15.3	15.1	15	14.9	14.8	14.9	15	15.1	15.3	15.5	15.6	15.8	15.9	16	16	16	16	15.9	15.8	15.7
ROOM 06	16.5	16.4	16.4	16.3	16.2	16.1	15.9	15.8	15.8	15.8	15.9	16	16.2	16.4	16.6	16.8	16.9	16.9	16.9	16.9	16.8	16.8	16.7	16.6
ROOM 07	16.5	16.4	16.3	16.1	16	15.8	15.7	15.5	15.5	15.6	15.6	15.8	16	16.3	16.6	16.8	17	17	17	17	16.9	16.8	16.7	16.6
ROOM 08	16.8	16.8	16.7	16.6	16.5	16.3	16.2	16.1	16	16.1	16.1	16.3	16.5	16.7	16.9	17.1	17.2	17.3	17.3	17.2	17.2	17.1	17	16.9
ROOM 09	16.9	16.9	16.8	16.7	16.7	16.6	16.5	16.4	16.4	16.4	16.4	16.5	16.7	16.8	17	17.1	17.2	17.2	17.2	17.2	17.1	17.1	17	17

DAILY HOUR

OUTSIDE ROOM 01 ROOM 02 ROOM 03 ROOM 04 ROOM 05 ROOM 06 ROOM 07 ROOM 08 ROOM 09

Fig. 8.20 : Results for the month of JANUARY for Unit 9RAa.

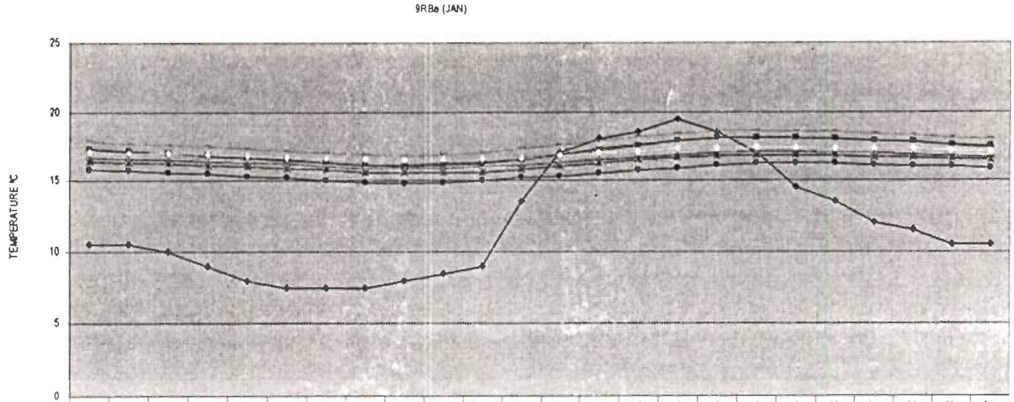


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
ROOM 01	36.5	36.3	36.1	35.9	35.7	35.6	35.4	35.4	35.4	35.6	35.8	36.1	36.3	36.5	36.7	36.9	37.2	37.3	37.3	37.3	37.1	37	36.8	36.6
ROOM 02	37	36.9	36.7	36.6	36.4	36.3	36.1	36.1	36.1	36.2	36.4	36.6	36.8	37.1	37.3	37.5	37.7	37.8	37.8	37.7	37.6	37.5	37.3	37.2
ROOM 03	36.9	36.7	36.5	36.3	36.1	35.9	35.8	35.7	35.7	35.9	36.1	36.4	36.7	37	37.3	37.5	37.7	37.8	37.8	37.8	37.6	37.4	37.3	37.1
ROOM 04	36.9	36.7	36.6	36.4	36.3	36.1	36	36	36	36.1	36.3	36.5	36.7	37	37.2	37.4	37.5	37.6	37.6	37.5	37.4	37.3	37.2	37
ROOM 05	36.2	36.1	35.9	35.7	35.6	35.4	35.3	35.3	35.3	35.4	35.7	36	36.2	36.3	36.5	36.7	36.9	37	37	37	36.9	36.7	36.6	36.4
ROOM 06	36.9	36.8	36.6	36.5	36.3	36.2	36.1	36	36.1	36.2	36.4	36.6	36.9	37.1	37.3	37.5	37.6	37.7	37.7	37.6	37.5	37.4	37.2	37.1
ROOM 07	36.5	36.3	36.2	36	35.8	35.6	35.5	35.5	35.5	35.7	35.8	36	36.3	36.6	36.9	37.1	37.3	37.4	37.4	37.3	37.2	37	36.9	36.7
ROOM 08	36.8	36.7	36.5	36.4	36.2	36.1	35.9	35.9	35.9	36	36.2	36.4	36.7	36.9	37.2	37.3	37.5	37.5	37.5	37.5	37.4	37.2	37.1	37
ROOM 09	37	36.9	36.8	36.7	36.6	36.5	36.4	36.3	36.3	36.4	36.6	36.8	37	37.1	37.3	37.5	37.6	37.6	37.6	37.5	37.5	37.4	37.3	37.1

DAILY HOUR

OUTSIDE ROOM 01 ROOM 02 ROOM 03 ROOM 04 ROOM 05 ROOM 06 ROOM 07 ROOM 08 ROOM 09

Fig. 8.21 : Results for the month of JUNE for Unit 9RAa.

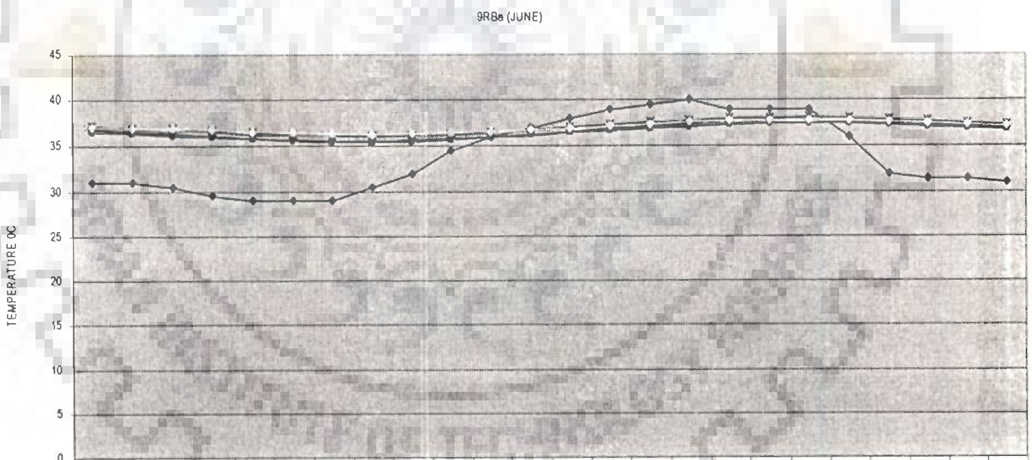


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
ROOM 01	17.3	17.2	17	16.8	16.7	16.5	16.3	16.1	16	16.1	16.2	16.5	16.8	17.2	17.5	17.9	18.1	18.1	18.1	18	17.9	17.8	17.6	17.5
ROOM 02	16.7	16.7	16.6	16.5	16.4	16.2	16.1	16	15.9	15.9	15.9	16.1	16.3	16.5	16.8	17	17.1	17.1	17.2	17.1	17.1	17	16.9	16.8
ROOM 03	16.2	16.1	16	15.9	15.7	15.6	15.4	15.2	15.1	15.1	15.2	15.4	15.6	16	16.3	16.5	16.7	16.8	16.8	16.8	16.7	16.6	16.5	16.4
ROOM 04	16.4	16.3	16.2	16.1	16	15.9	15.8	15.6	15.6	15.6	15.6	15.8	16	16.2	16.5	16.7	16.8	16.8	16.8	16.8	16.7	16.7	16.6	16.5
ROOM 05	15.8	15.7	15.6	15.5	15.3	15.2	15	14.9	14.8	14.9	15	15.2	15.3	15.5	15.7	15.9	16.1	16.2	16.2	16.2	16.1	16	16	15.9
ROOM 06	16.7	16.6	16.5	16.4	16.3	16.2	16	15.9	15.9	15.9	16	16.1	16.3	16.5	16.7	16.9	17	17.1	17.1	17	17	16.9	16.8	16.7
ROOM 07	17.3	17.1	17	16.8	16.7	16.5	16.3	16.1	16.1	16.2	16.3	16.6	16.9	17.3	17.6	17.9	18.1	18.1	18.1	18	17.9	17.8	17.6	17.4
ROOM 08	17.9	17.7	17.6	17.5	17.3	17.2	17	16.9	16.8	16.9	17	17.3	17.6	17.9	18.2	18.4	18.6	18.6	18.5	18.5	18.4	18.3	18.1	18
ROOM 09	17.1	17	17	16.9	16.8	16.7	16.6	16.5	16.5	16.5	16.5	16.6	16.8	17	17.1	17.3	17.3	17.4	17.4	17.3	17.3	17.3	17.2	17.1

DAILY HOUR

OUTSIDE, ROOM 01, ROOM 02, ROOM 03, ROOM 04, ROOM 05, ROOM 06, ROOM 07, ROOM 08, ROOM 09

Fig. 8.22 : Results for the month of JANUARY for Unit 9RBa.

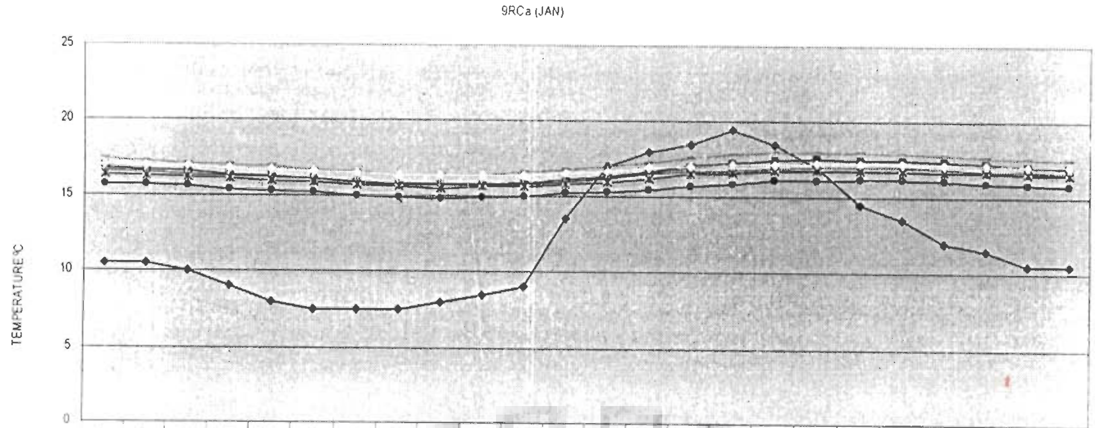


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
ROOM 01	36.7	36.5	36.3	36.1	35.9	35.7	35.5	35.5	35.6	35.7	36	36.3	36.6	36.8	37	37.3	37.5	37.7	37.7	37.6	37.5	37.3	37.1	36.9
ROOM 02	37.1	37	36.8	36.6	36.4	36.3	36.1	36.1	36.1	36.2	36.4	36.7	36.9	37.2	37.4	37.7	37.8	37.9	37.9	37.9	37.7	37.6	37.4	37.3
ROOM 03	37.2	37	36.7	36.5	36.3	36.1	35.9	35.9	35.9	36.1	36.4	36.7	37	37.4	37.7	37.9	38.1	38.2	38.3	38.2	38	37.8	37.6	37.4
ROOM 04	37.2	37	36.9	36.7	36.5	36.3	36.2	36.2	36.2	36.3	36.6	36.8	37.1	37.4	37.6	37.8	38	38	38.1	38	37.9	37.7	37.5	37.4
ROOM 05	36.6	36.4	36.2	36	35.8	35.6	35.5	35.5	35.5	35.7	36	36.3	36.5	36.7	36.9	37.1	37.4	37.5	37.5	37.5	37.3	37.1	36.9	36.8
ROOM 06	37	36.8	36.7	36.5	36.3	36.2	36.1	36	36.1	36.2	36.5	36.7	37	37.2	37.4	37.6	37.7	37.8	37.8	37.7	37.6	37.5	37.3	37.1
ROOM 07	36.8	36.6	36.4	36.2	35.9	35.7	35.6	35.6	35.7	35.9	36	36.2	36.5	36.9	37.2	37.5	37.7	37.8	37.8	37.7	37.6	37.4	37.2	37
ROOM 08	37.1	36.9	36.7	36.6	36.4	36.2	36.1	36	36.1	36.2	36.4	36.7	37	37.2	37.5	37.7	37.9	37.9	37.9	37.8	37.7	37.6	37.4	37.2
ROOM 09	37.1	37	36.9	36.8	36.6	36.5	36.4	36.3	36.4	36.5	36.6	36.8	37	37.2	37.4	37.6	37.7	37.7	37.7	37.7	37.6	37.5	37.4	37.2

DAILY HOUR

OUTSIDE, ROOM 01, ROOM 02, ROOM 03, ROOM 04, ROOM 05, ROOM 06, ROOM 07, ROOM 08, ROOM 09

Fig. 8.23 : Results for the month of JUNE for Unit 9RBa.

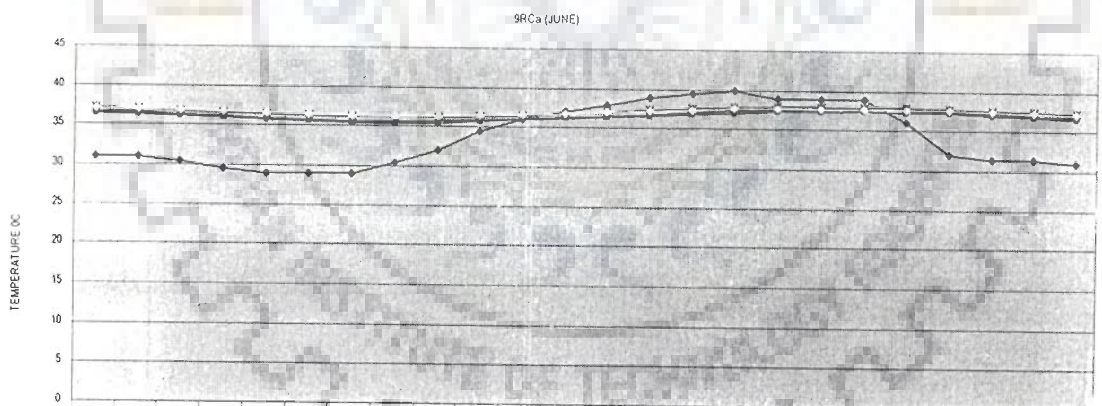


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
ROOM 01	16.9	16.7	16.6	16.4	16.3	16.1	15.9	15.7	15.7	15.7	15.8	16	16.3	16.6	16.9	17.3	17.5	17.6	17.5	17.5	17.4	17.3	17.1	17
ROOM 02	16.7	16.6	16.5	16.4	16.3	16.2	16	15.9	15.8	15.8	15.9	16	16.2	16.4	16.7	16.9	17	17.1	17.1	17	17	16.9	16.8	16.8
ROOM 03	16.2	16.1	16	15.9	15.7	15.6	15.4	15.2	15.1	15.1	15.2	15.4	15.6	16	16.3	16.5	16.7	16.8	16.8	16.7	16.7	16.6	16.5	16.3
ROOM 04	16.4	16.3	16.2	16.1	16	15.9	15.7	15.6	15.5	15.6	15.6	15.8	16	16.2	16.5	16.6	16.8	16.8	16.8	16.8	16.7	16.7	16.6	16.5
ROOM 05	15.7	15.7	15.6	15.4	15.3	15.2	15	14.9	14.8	14.9	15	15.2	15.3	15.5	15.7	15.9	16.1	16.1	16.2	16.2	16.1	16	15.9	15.8
ROOM 06	16.6	16.5	16.4	16.3	16.2	16.1	16	15.8	15.8	15.8	15.9	16	16.2	16.5	16.7	16.8	16.9	17	17	17	16.9	16.8	16.8	16.7
ROOM 07	16.8	16.7	16.6	16.4	16.3	16.1	15.9	15.8	15.7	15.8	15.9	16.1	16.4	16.7	17.1	17.3	17.5	17.6	17.5	17.5	17.4	17.3	17.1	17
ROOM 08	17.4	17.3	17.1	17	16.9	16.7	16.6	16.4	16.4	16.4	16.6	16.8	17	17.3	17.6	17.8	18	18	18	17.9	17.8	17.7	17.6	17.5
ROOM 09	17	16.9	16.9	16.8	16.7	16.6	16.5	16.4	16.4	16.4	16.4	16.5	16.7	16.9	17	17.2	17.2	17.3	17.3	17.3	17.2	17.2	17.1	17.1

DAILY HOUR

OUTSIDE — ROOM 01 — ROOM 02 — ROOM 03 — ROOM 04 — ROOM 05 — ROOM 06 — ROOM 07 — ROOM 08 — ROOM 09

Fig. 8.24 : Results for the month of JANUARY for Unit 9RCa.

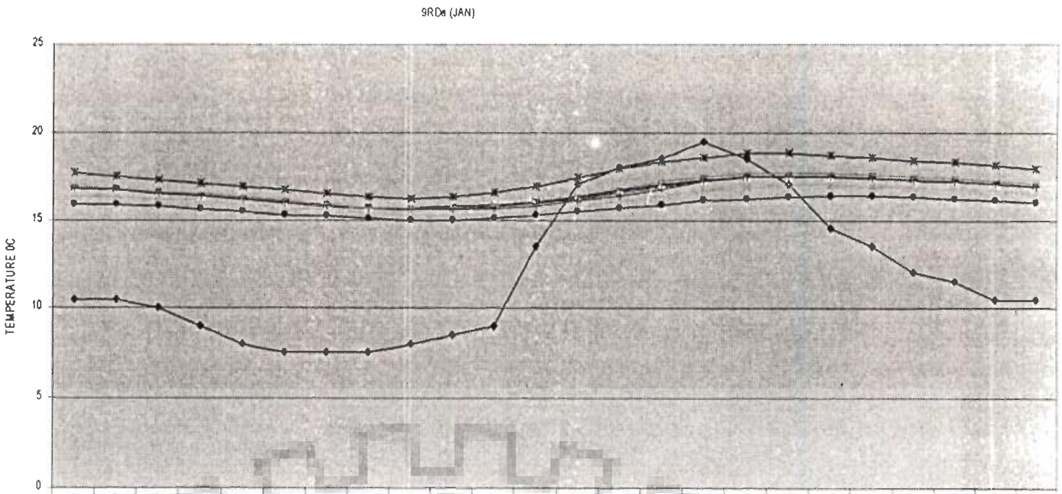


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
ROOM 01	36.7	36.5	36.3	36.1	35.9	35.7	35.5	35.5	35.5	35.7	36	36.3	36.5	36.8	37	37.3	37.5	37.6	37.7	37.6	37.5	37.3	37.1	36.9
ROOM 02	37.1	36.9	36.8	36.6	36.4	36.3	36.1	36.1	36.1	36.2	36.4	36.6	36.9	37.2	37.4	37.7	37.8	37.9	37.9	37.8	37.7	37.6	37.4	37.3
ROOM 03	37.1	36.9	36.7	36.5	36.3	36	35.9	35.8	35.9	36.1	36.3	36.6	37	37.3	37.7	37.9	38.1	38.2	38.2	38.2	38	37.8	37.6	37.3
ROOM 04	37.2	37	36.8	36.7	36.5	36.3	36.2	36.1	36.2	36.3	36.5	36.8	37.1	37.3	37.6	37.8	37.9	38	38	38	37.8	37.7	37.5	37.3
ROOM 05	36.5	36.4	36.2	36	35.8	35.6	35.5	35.4	35.5	35.7	36	36.3	36.5	36.7	36.9	37.1	37.3	37.4	37.5	37.4	37.3	37.1	36.9	36.7
ROOM 06	37	36.8	36.7	36.5	36.3	36.2	36	36	36.1	36.2	36.4	36.7	36.9	37.2	37.4	37.6	37.7	37.8	37.8	37.7	37.6	37.5	37.3	37.1
ROOM 07	36.7	36.6	36.4	36.2	35.9	35.7	35.6	35.6	35.7	35.9	36	36.2	36.5	36.8	37.2	37.5	37.6	37.7	37.7	37.7	37.5	37.3	37.1	36.9
ROOM 08	37	36.9	36.7	36.5	36.4	36.2	36	36	36	36.2	36.4	36.7	36.9	37.2	37.5	37.7	37.8	37.9	37.9	37.8	37.7	37.5	37.4	37.2
ROOM 09	37.1	37	36.9	36.8	36.6	36.5	36.4	36.[illegible]	36.4	36.5	36.6	36.8	37	37.2	37.4	37.6	37.7	37.7	37.7	37.7	37.6	37.5	37.4	37.2

DAILY HOUR

OUTSIDE — ROOM 01 — ROOM 02 — ROOM 03 — ROOM 04 — ROOM 05 — ROOM 06 — ROOM 07 — ROOM 08 — ROOM 09

Fig. 8.25 : Results for the month of JUNE for Unit 9RCa.

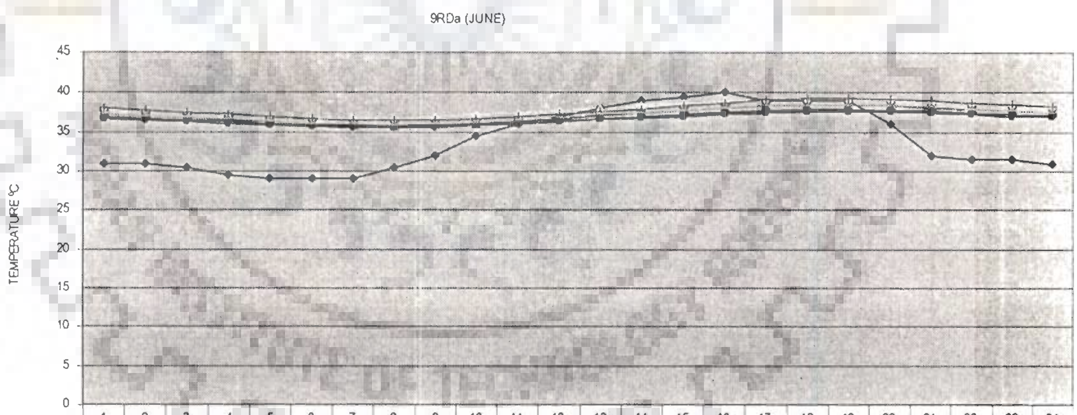


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
ROOM 01	16.8	16.7	16.5	16.4	16.2	16	15.8	15.7	15.6	15.7	15.8	16	16.2	16.6	16.9	17.2	17.4	17.5	17.5	17.4	17.3	17.2	17.1	16.9
ROOM 02	16.7	16.6	16.5	16.3	16.2	16	15.8	15.7	15.7	15.9	16	16.2	16.4	16.7	17	17.2	17.4	17.5	17.4	17.4	17.3	17.2	17	16.9
ROOM 03	16.4	16.3	16.2	16.1	15.9	15.7	15.6	15.4	15.3	15.3	15.4	15.5	15.8	16.1	16.4	16.7	16.9	17	17	16.9	16.9	16.8	16.7	16.5
ROOM 04	17.7	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.3	16.6	16.9	17.4	17.9	18.3	18.6	18.8	18.8	18.7	18.6	18.4	18.3	18.1	17.9
ROOM 05	15.9	15.9	15.8	15.6	15.5	15.3	15.2	15.1	15	15	15.1	15.3	15.5	15.7	15.9	16.1	16.2	16.3	16.4	16.4	16.3	16.2	16.1	16
ROOM 06	16.8	16.7	16.5	16.4	16.2	16	15.8	15.7	15.6	15.6	15.7	15.8	16.1	16.4	16.8	17.2	17.5	17.5	17.5	17.4	17.3	17.2	17.1	16.9
ROOM 07	16.8	16.7	16.5	16.4	16.2	16	15.8	15.7	15.7	15.8	15.9	16	16.3	16.7	17	17.3	17.5	17.5	17.5	17.4	17.3	17.2	17.1	16.9
ROOM 08	16.9	16.8	16.6	16.5	16.3	16.1	15.9	15.7	15.7	15.7	15.9	16.1	16.4	16.8	17.2	17.5	17.7	17.7	17.7	17.6	17.5	17.4	17.2	17.1

DAILY HOUR

OUTSIDE — ROOM 01 — ROOM 02 — ROOM 03 — ROOM 04 — ROOM 05 — ROOM 06 — ROOM 07 — ROOM 08

Fig. 8.26 : Results for the month of JANUARY for Unit 9RDa.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
ROOM 01	36.9	36.7	36.5	36.3	36	35.8	35.7	35.6	35.7	35.9	36.1	36.5	36.7	36.9	37.1	37.4	37.7	37.8	37.8	37.8	37.6	37.4	37.2	37.1
ROOM 02	37.8	37.6	37.4	37.1	36.9	36.6	36.6	36.7	36.9	37.2	37.5	37.8	38.1	38.4	38.7	38.9	39.1	39.1	39.1	39	38.8	38.6	38.3	38.1
ROOM 03	37.3	37.1	36.9	36.6	36.4	36.2	36	35.9	36	36.2	36.4	36.7	37.1	37.4	37.8	38	38.2	38.3	38.4	38.3	38.1	37.9	37.7	37.5
ROOM 04	37.2	37	36.8	36.5	36.3	36.1	35.9	35.9	35.9	36.1	36.4	36.7	37.1	37.5	37.8	38.1	38.3	38.4	38.4	38.3	38.1	37.9	37.7	37.4
ROOM 05	36.7	36.5	36.3	36.1	35.9	35.7	35.6	35.6	35.6	35.8	36.1	36.4	36.6	36.8	37	37.2	37.4	37.6	37.6	37.6	37.4	37.2	37	36.9
ROOM 06	38	37.7	37.5	37.2	37	36.7	36.5	36.5	36.5	36.7	37	37.3	37.6	37.9	38.3	38.7	39.1	39.3	39.3	39.2	39	38.7	38.5	38.2
ROOM 07	36.9	36.7	36.5	36.3	36.1	35.9	35.7	35.7	35.8	36	36.1	36.3	36.6	37	37.3	37.6	37.8	37.9	37.9	37.8	37.7	37.5	37.3	37.1
ROOM 08	37.3	37	36.8	36.6	36.3	36.1	36	35.9	36	36.2	36.5	36.8	37.2	37.5	37.8	38.1	38.3	38.4	38.4	38.4	38.2	37.9	37.7	37.5

DAILY HOUR

OUTSIDE — ROOM 01 — ROOM 02 — ROOM 03 — ROOM 04 — ROOM 05 — ROOM 06 — ROOM 07 — ROOM 08

Fig. 8.27 : Results for the month of JUNE for Unit 9RDa.

8.2 DATA ANALYSIS & INFERENCES

As a result of the exercises carried out for conceptual units, by using the model, huge amount of data was generated in the form of output files. As mentioned earlier, four types of output files namely, General Data File, Solar Data File, Shade File and Temperature Output Files are generated for each exercise by the program. All the input files and output files are being compiled in the electronic form, a CD of which is enclosed (available on rear inner cover) with the thesis. CD comprises folders which have been given names on the basis of exercise undertaken e.g. 1RAa, 4RFF etc. each folder contains basically five files i.e. Input Data File and 04 Output Data files. In some cases, a separate file has been created which contains comparative data in EXCEL worksheet format.

Output data thus obtained by the exercises, was analyzed basically for the month of January and June in order to judge the thermal performance of conceptual units for the winter and summer season, respectively. Effect of building elements and design parameters has been quantified for the conceptual units, which has been discussed in this chapter, subsequently.

8.2.1 Effect of Orientation on Thermal Performance of Buildings

As described in the chapter 07 (Validation of the Model), an exercise has been carried out for conceptual unit 2REa in order to judge the effect of orientation on building. Results were obtained using the program for different orientations with respect to cardinal points, starting with PRA 0^0 with rotation increment of 6^0 and hence, for total 60 different orientations completing a full circular angle of 360^0, on hourly basis, for representative day i.e. 21 day of each month of the year. The predicted indoor temperature of each daily hour for different orientations, as obtained by the exercise, has been reproduced in Appendix 4. By analyzing the Indoor temperatures for the month of December and January, it is clearly seen that Maximum Indoor Temperature is maximum inside the building, when PRA is 0^0. For the month of April, May, June, July, August and September, Maximum Indoor Temperature during peak day hours is minimum for PRA 0^0 in comparison to other orientation angles. It is interesting to note that for the month of September, building provides thermal comfort if its long axis is parallel to north-south cardinal axis, means long faces are towards East and West.

It is concluded form the exercise that indoor temperature (during peak hours) is **minimum in summer** and **maximum in winter** when the building is oriented such that its **longer walls face north and south directions**. Hence this orientation is the best for buildings in composite climate of India. However, negligible difference in indoor temperature can be seen for rotations up to 12^0 on either side of north-south axis.

8.2.2 Effect of Room Height on Thermal Performance of Buildings

Exercise no. 04, as described in chapter 08, has been carried out on conceptual unit 2REa, in this reference. Results were obtained by Height of the room keeping as variable for the height of 2.7 m, 3.0 m, 3.6 m and 4.2 m. Results reveals that height of the Room does not contribute much towards thermal performance of buildings. With higher room height, one can enjoy slightly less temperatures (0.4^0C) in summers that too from 3.00 to 13.00 with constant ventilation rate of 3 $_{ACPH}$. In winter season, more height of the rooms may lead to less temperature in rooms during cold hours. It should be noted that this result is based for a single room unit. In case of a multi room building, results may vary. However, it can be concluded form this exercise and results that clear height of the rooms should be kept somewhere between 3.0 m to 3.6 m for buildings in composite climate.

8.2.3 Effect of Wall Thickness on Thermal Performance of Buildings

In India, bricks of size 230 mm x 115 mm x 75 mm are used in building construction and hence possible wall thicknesses are 115 mm, 230mm, 345 mm and 460 mm. Several preliminary exercises were carried out in order to analyze the effect of wall thickness on thermal performance of buildings. However, results of exercise no. 02, as described in chapter 08 carried out on conceptual unit 1RAa, are available in this reference. Results were obtained for wall thickness 230 mm, 345 mm. It has been found that provision of thick walls (345 mm) lead to thermal stability of indoor thermal environment i.e. inside temperature is more stable and less effected by outdoor temperature fluctuations. In winter season, thick walls (345 mm) provide more warmth during the late night & forenoon i. e. from 01.00 to 13.00, however, one has to bear with slightly less temperature (0.5^{0}C) with thick walls from 14.00 to 23.00, which can be compensated by enhancement of ventilation rate during this time. In summer season, thick walls (345 mm) helps in reduction of indoor temperature round the clock. Maximum reduction of 0.5^{0}c is found at 18.00 & 19.00 hours for a single room unit with constant ventilation rate of 3 ACPH. However, for multi room buildings, this difference (0.5^{0}C) is supposed to enhance, which will depend on the design and specifications of building. It has also been observed from other preliminary exercises that with the provision of 460 mm thick walls, indoor temperature remains unaffected by solar radiation. Reason can be envisaged that due to the bulk thermal mass, amount of heat received by the sun in day time does not transfer to the indoor environment due to high thermal resistance and large time lag. By the time it would transfer to the indoor environment, outside temperature goes down in the evening and this heat is reradiated to the outside environment and hence, for winter season, outside wall of this thickness is useless in view of heat transfer. However, heat transfer phenomenon, takes place well in 345 mm thick walls. It can be concluded from this discussion that outer walls in buildings should be kept 345 mm thick, in order to achieve thermal comfort round the year. However, where space is scares, 230 mm thick walls can be provided.

8.2.4 Effect of Sunshade /Projections on Thermal Performance of Buildings

Effect of Sunshade / Projections can be observed by the results of exercises no. 01 and 05. Sunshades are important to achieve thermal comfort in summer only. However, over extended (projections of width more than 0.9 m) may cause thermal discomfort in winter, since it would obstruct the solar radiations up to considerable extend, which is not desired in winters. Preliminary exercises carried out in order to judge the effect of sunshades on internal room temperature for Unit 1RDa. Sunshade of width 0.3m, 0.45m, 0.6m, 0.75m and 0.9m was considered on all the outer faces of the building. It was observed that internal room temperature effects slightly (0.1^0C to 0.3^0C) in these cases. It can be inferred that increased projection on outside faces does not contribute much towards thermal performance of buildings. Though, this result seems to be non realistic and beyond expectation. In exercise no. 01, Units 1RCa and Unit 1RDa are similar in design, but unit 1RDa has extended projection (0.6 m wide) all around the room on outer face. It can be observed from Fig. 8.25 & 8.27, that there is minor difference in the results of Unit 1RCa and Unit 1RDa, which is 0.2^0C during 17 to 24 hours during summer season. It can be inferred that Sunshade and Projections provided on outer faces of the building have their contribution on thermal performance, however, in case of single room building; this effect may not be significant because all the walls of the building are exposed to outer ambience and thus indoor temperature fluctuates early and easily with the fluctuations of outside temperatures.

In exercise no. 05, Unit 9RBa and 9RCa are having similar plan, but unit 9RCa has 1.2 m wide projections on north and south faces. Effect of sunshades would appear directly on the Indoor temperature of room no. 03, 04 and 05. For the month of January, no effect is observed for both the units. However, minor difference of 0.1^{0}C has been observed on other rooms including the central room no. 09. For the month of June, a difference of 0.1^{0}C in the rooms has been observed during day time, which seems to be a minor difference.

Sunshades, no doubt, effect the thermal performance of buildings, however, no generalized statements regarding their effect on thermal performance can be given. Its quantification can be done on case to case basis by using the model.

8.2.5 Effect of Attic Space on Thermal Performance of Buildings

Exercise no. 05 based on conceptual Unit 4RFF has been carried out to judge the effect of attic space on thermal performance. A building comprises 04 rooms is conceptualized. An attic space above room no. 02 (room above roof of room no. 02) has been provided. It can be observed by the results (Fig.8.16) that for the month of January, Room no. 01 observes highest indoor temperature throughout the day in comparison to other rooms. Further, Room no. 02 observes lowest temperature throughout the day in comparison to other rooms on ground floor. It is also observed that attic room observes lowest indoor temperature in comparison to all the 05 rooms.

For the month of June, it can be observed from Fig. 8.17 that room no. 02 is highly affected by outdoor temperature fluctuations and observes max. indoor temperature 39.8^{0}C during daytime. Temperature profile of room no. 05 (attic room) is almost parallel to the outside temperature profile. It can also be inferred from Fig. 8.17 that room no. 02 observes thermally stable conditions and is coolest in comparison to other rooms. A fall of 4.8^{0}C in comparison to prevailing max. outdoor temperature is observed at 16 hours during the day. It can be inferred that attic space is beneficial for summer and temperature can be considerably reduced

In the rooms if they are provided with an attic room. However, its effect can be quantified on case to case basis.

8.2.6 Effect of Fenestrations on Thermal Performance of Buildings

Effect of fenestrations can be observed by the results of exercises no. 01 and exercise no. 05. In exercise no. 01, Unit 1RAa has been conceptualized as a single room building with no fenestrations. Unit 1RBa is a version of previous unit but has fenestrations on north and south faces. Unit 1RCa is same as unit 1RBa, but has fenestrations on remaining faces i.e. on east and west faces also. It can be observed by Fig. 8.23 that indoor temperature increases as no. of fenestrations increases in the room. Unit 1RAa, which has no fenestrations observes thermal stability in Indoor Temperature. However, temperature difference of 0.8^{0}C can be observed in the results of Unit 1RAa and Unit 1RBa for the month of May. Further, there is significant increase in indoor temperature of Unit 1RCa in comparison to Unit 1RAa which is to the order of 2.5^{0}C during day time.

Almost same observations can be seen in the results of exercise no. 05. It can be seen that fenestration play an important role on thermal performance of buildings. Indoor temperature can be controlled by judicious design of fenestrations in outer face of the building.

8.2.7 Effect of Ventilation Rate on Thermal Performance of Buildings

Exercise no. 02 (Chapter 04) has been undertaken in order to see the effect of ventilation rate on thermal performance of buildings. Unit 1RAa has been modeled for varied ventilation rates. A constant rate of ventilation in the building throughout the day is neither appropriate in summer nor in winters. In summer, outside temperature of night time is considerable low in comparison to day time outside temperature. It is advisable to increase rate of ventilation during nighttime in the buildings in order to harness the potential of cool air of night time. In the same manner, during winters, ventilation rate in the buildings should be enhanced when outside temperature is high in day time. This can be achieved by controlling of operable window areas. However, on the basis of preliminary exercises carried out for study, it has been observed that following rate of ventilation should be maintained in summer and winters.

Recommended Ventilation Rate for Summer

←------------------ DAILY HOUR (1 – 24) ------------------→

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
←------------------ VENTILATION RATE on DAILY HOUR------------------→																							
20	20	20	20	20	20	20	6	6	3	3	3	3	3	3	3	3	3	3	6	6	20	20	20

Recommended Ventilation Rate for winter

←------------------ DAILY HOUR (1 – 24) ------------------→

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
←------------------ VENTILATION RATE on DAILY HOUR------------------→																							
3	3	3	3	3	3	3	3	3	20	20	20	20	20	20	20	20	20	3	3	3	3	3	3

It is worthwhile to mention here that ventilation rate more than 30 ACPH would cause air velocity discomfort for the occupants because in this case air velocity in the room would exceed 3.0 m/s, which is the critical limit for comfortable condition. Further, ventilation rate of less than 3 ACPH in habitable rooms is not recommended by National Building Code of India.

It can be inferred from the results of exercise 02 that ventilation rate is an important parameter that drastically effect thermal performance of buildings. Recommended ventilation rate (for summer) may decrease indoor temperature by 3.0^{0}C throughout the day in summers in comparison to a constant rate of ventilation 3 ACPH. Appropriate design strategies should be adopted while designing building so that required ventilation rate for different hours of the day and night can be achieved in internal spaces.

8.3 SET OF OPTIMUM VARIABLES FOR COMPOSITE CLIMATE OF INDIA

Building Construction is an activity, which lead to creation of a fixed form. A building constructed with certain design considerations may thermally perform well in summer but may not be suitable to live in winters. A building when constructed once cannot be altered in every season in order to achieve thermal comfort.

On the basis of exercises and results, as discussed earlier, a set of optimum variables (design parameters and building elements of specific values) can be found out. If the buildings are constructed with such parameters and recommended specifications, they would thermally perform well in both the seasons. On the basis of this research study, a set of optimum variables has been recommended for the practical use which has been discussed in the chapter 9.

Orientation of Building: Longer walls face north and south directions.

Outer Walls Thickness: 345 mm thick brick wall

Inner Walls Thickness: 230 mm thick brick wall

Roof: R. C. C. Slab (125 mm thick)

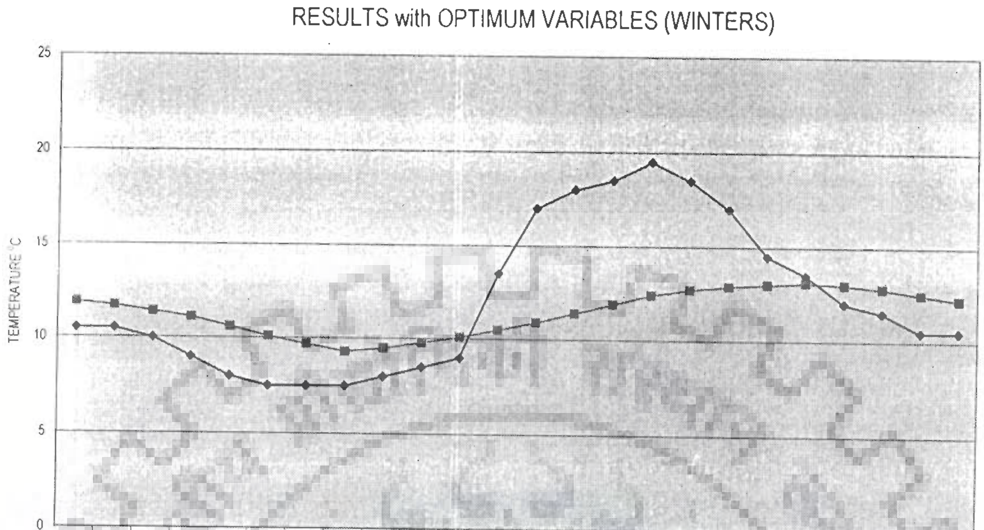
Terracing: A terrace garden on top (300 mm thick mud layer).

Fenestrations & Sunshades: As shown in Fig. 7.1, p-113.

Height of Rooms: 3.0 m.

Ventilation Rate: As recommended above in 8.2.7 for Summer & Winter.

An exercise has been carried out in order to judge the integrated effect of these optimum variables. Unit 2REa, as described earlier has been considered for the exercise with optimum variables. Results were obtained for the month of January and June by using the model. Results have been presented in Fig. 8.28 for winter season and Fig. 8.29 for summer.

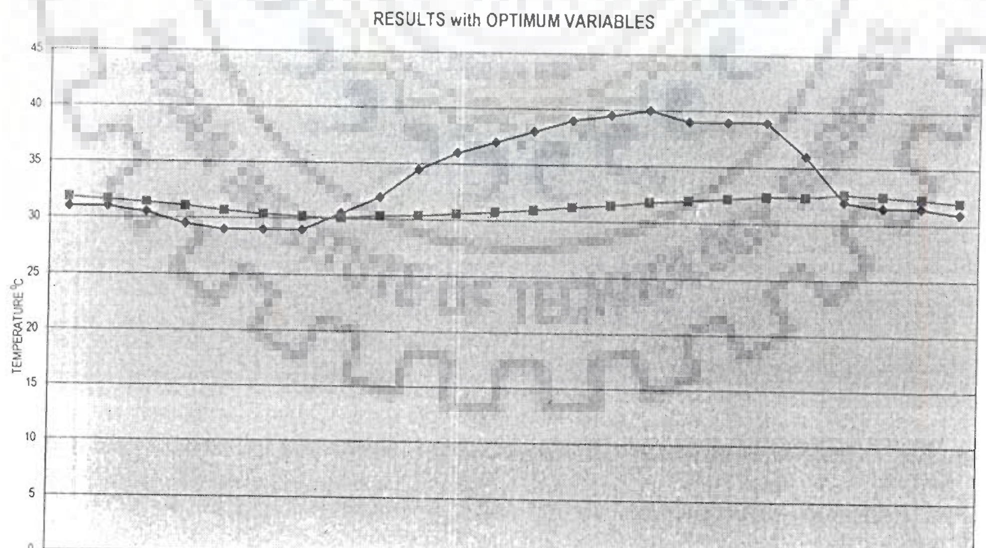


DAILY HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	10.5	10.5	10	9	8	7.5	7.5	7.5	8	8.5	9	13.5	17	18	18.5	19.5	18.5	17	14.5	13.5	12	11.5	10.5	10.5
1RE(OPT)	11.9	11.7	11.4	11.1	10.6	10.1	9.7	9.3	9.5	9.8	10.1	10.5	10.9	11.4	11.9	12.4	12.7	12.9	13	13.1	13	12.8	12.5	12.2

DAILY HOUR

OUTSIDE — 1RE(OPT)

Fig. 8.28 : Results with Optimum Variable (JANUARY) for Unit 2REa.



DAILY HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUTSIDE	31	31	30.5	29.5	29	29	29	30.5	32	34.5	36	37	38	39	39.5	40	39	39	39	36	32	31.5	31.5	31
1RE(OPT)	31.8	31.6	31.4	31.1	30.7	30.4	30.2	30.1	30.3	30.4	30.6	30.8	31	31.3	31.5	31.8	32	32.2	32.4	32.4	32.7	32.5	32.3	32

DAILY HOUR

OUTSIDE — 1RE(OPT)

Fig. 8.29 : Results with Optimum Variable (JUNE) for Unit 2REa.

CHAPTER 9

CONCLUSION & RECOMMENDATIONS

9.0 INTRODUCTION

The design of buildings is a complex process in which the architects and building designers make decisions concerning the different aspects (environmental, economy, structural, functional, safety and aesthetic) related to the building in view of occupants' comfort. The choices are narrowed from preliminary designs to final scheme through a succession of steps, which involve conceptualization, evaluation and execution of scheme. Predicting the thermal performance of buildings involves the handling of a large number of inter-related parameters. The research work characterized in this thesis is concerned with the thermal performance of the building envelop and is meant to answer specifically the architect's questions_

(a) What are the thermal design specifications such that there is minimum deviation from desired comfort conditions in view of composite climate?

(b) What would be the indoor temperature if the building is constructed with particular set of specifications and design parameters?

Computer models for the simulation of the thermal performance of buildings have been in existence for many decades. Most of them are based on the rating system and does not include solar radiation, heat gain, heat transfer and heat balance calculations, except a few like Energy Plus and TRNSYS. Although these programs consume a great deal of time and effort in computational terms, however, they still rely on designers' intuition and experience to achieve optimum solutions for a design problem. This research work presents a model, which simulates the thermal performance of the buildings taking into account the design variables (design parameters and building elements) related to the building's envelope. This research is relevant because a model has been developed with a fresh approach in the context of composite climate of India. This model involves computations starting from Solar Heat Gain to the building envelope to the Heat Balancing of different zones of buildings. Model is useful to determine the optimum design variables through which achieve the best thermal comfort conditions can be achieved in buildings.

9.1 RECOMMENDATIONS

The development and pressure to design climatically responsive, energy efficient and environment friendly buildings has created the need for the development of an appropriate model which can help the architects to make simulation an integral part of the design process. In India, most of the architects still depend on existing knowledge of climatic design, which is based on thumb rules and includes no exercises of performance evaluation.

On the basis of exercises and results, as discussed earlier, a set of optimum variables (design parameters and building elements of specific values) can be found out. If the buildings are constructed with such parameters and recommended specifications, they would thermally perform better in both the seasons (summer and winter). A set of optimum variables has been recommended for the practical use.

9.1.1 Orientation of Building

The chief aim of orientation of buildings is to provide physical and psychological comfortable living inside the building. The best orientation form climatic point of view requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. In the composite climate zone of India, Buildings should be oriented such that their longer walls face north and south directions. However, an orientation within the rotations up to 12^0 on either side of north-south axis is good.

9.1.2 Outer Walls Thickness

Conventional sizes of brick in India are 230 X115 X 75 mm and hence we can obtain wall thickness of 115 mm, 230mm, 345mm and 460 mm. It has been observed (by the exercise no. 02) that 450 mm thick brick walls are not suitable as an outer wall, since it does not allow solar heat to transfer to the indoor environment in winters. However, wall of 345 mm thickness performs well in both the seasons. 230 mm thick brick wall should be provided on north and east faces. 345 mm thick brick wall is must for south and west faces. In summer season, 345 mm thick brick wall delays the solar heat to come in (increased time lag) and occupants can enjoy thermal comfort inside the building even up to 14.00. While in winters 345 mm thick brick wall acts as a thermal mass and stores the solar heat gain of day time which is transferred to indoor environment after 18.00 hours when outside environment become very cold. And hence, occupants can enjoy more warmth even up to 24.00 hours in winter season

However, architects can explore other economic possibilities with the composite sections. Model provides flexibility for designing and use of composite sections.

9.1.3 Inner Walls Thickness

Inner walls usually act as a visual partition and defines perimeter of different spaces. A brick wall of 115 mm thick is a good solution for RCC framed structures in view of structural loads. Wherever possible 230 mm thick brick wall should be provided since it would add to thermal mass in the building. Presence of thermal mass leads to the stability of indoor building thermal environment.

9.1.4 Roof

Careful attention needs to be paid to the design of roofs. Shape of the roof itself may affect thermal performance of spaces just below to it. R. C. C. Slab (preferably 125 mm thick) is a good option for straight / flat roof. However, in case of slant roofs, AC sheet roof with a gypsum board (12 mm thick) false ceiling would be a better option since it would create an attic space in between which thermally performs well in both the seasons. Structural roof section is important for structural stability. On the contrary, for thermal stability of the indoor environment, terracing over or insulation under the roof is important. Further possibilities can be explored by modelling the building with the use of hollow blocks in roof slab.

9.1.5 Terracing

Surface of terracing over the roof should reflect the solar radiation in summers and should absorb the same in winters. Conventional roof treatments of brick tiles with cement grouting and mud phuska (75 mm thick) over bitumen layer are effective but not sufficient in composite climate. Better options should be explored with new/innovative materials. Preferably a terrace garden on building top with 300 mm (min.) thick mud layer should be provided. Use of a layer of thermal insulating material

9.1.6 Fenestrations

Fenestrations significantly contribute to solar heat gain and hence they should be designed with extra care. Preferably large openings should be provided on North and South Faces with a horizontal sunshade above. However, on east and west faces vertical slit windows (with vertical louvers) can be provided. As far as possible the area of windows on west face should be reduced. Sandwiched glass panels, Reflective glass and low-e glass can also be used on south-east face, on which solar radiation falls for a significantly prolonged time (approx. 04

hours in summers). As such no specific recommendations can be made for fenestrations since design of fenestrations depends on many factors like ventilation, functional use, view, aesthetics etc. However, it is recommended that whatever the architectural design and size of fenestration is, thermal performance of internal spaces must be evaluated before finalization of design.

9.1.7 Sunshades

The most efficient way of protecting building from direct solar radiation is to shade its windows and other apertures from direct sunlight. South facing windows can be shaded by an overhang above the glazed element. To obtain maximum benefit from sun in winter season, it is important that the overhang is properly sized and located so that the direct rays can pass through the glazing. More width of projections does not contribute much towards temperature control. Preferable projections should be provided on all the outside faces on full length of wall. A projection width of 0.6 m over a 3.0 m high wall / fenestration is good for both the seasons on all the faces. Shading of east and west faces pose a problem, however, horizontal projections and vertical louvers can be designed with the conventional method based on solar movement and shadow calculations. In summer season, preferably a screen (bamboo chick or synthetic meshes) should be provided outside the window rather than inside the window so that most of the direct radiation can be reflected before it reaches the glazing.

9.1.8 Height of Rooms

Height of the room does not contribute much towards thermal performance of buildings. A slight change in indoor temperature has been observed with variation in room height (exercise no.03). However, a height of 3.0 to 3.6 m is good for habitable purpose. However, height of the rooms should be decided in conformity with the functions of the building.

9.1.9 Ventilation Rate

Ventilation rate significantly affect the stability of thermal environment inside the building. Rate of ventilation can be controlled by the controlling of operable size of windows. It can be decreased by closing the windows and can be increased by the opening of windows and ventilators. Ventilation rate more than 30 ACPH is not recommended in buildings since it would create air velocity discomfort to the occupants.

Though it is difficult to quantify and maintain a desired rate of ventilation at any point of time in the buildings however, a constant rate of ventilation in the building throughout the day and / or night is neither appropriate in summer nor in winters. Ventilation requirements are changed drastically in summer as compared to that is comfortably accepted in winters.

Recommended Ventilation Rate for Summer

←------------------ DAILY HOUR (1 – 24) ------------------→

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

←------------------ VENTILATION RATE on DAILY HOUR------------------→

20	20	20	20	20	20	20	6	6	3	3	3	3	3	3	3	3	3	3	6	6	20	20	20

Recommended Ventilation Rate for winter

←------------------ DAILY HOUR (1 – 24) ------------------→

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

←------------------ VENTILATION RATE on DAILY HOUR------------------→

3	3	3	3	3	3	3	3	3	20	20	20	20	20	20	20	20	20	3	3	3	3	3	3

Based on this research study, in addition to the above, following recommendations are made for practical purposes.

- Architects and Building Designers should explore possibilities of designing buildings with optimized design parameters, as has been recommended in this work.

- Architects should use an appropriate simulation program, as an integral part of architectural design process, in order to analyze the performance of their design / concepts in view of thermal comfort, which will help them to achieve optimized building design and thus savings in operational energy.

9.2 SUGGESTIONS FOR FURTHER RESEARCH

Continuous demand for better buildings in terms of comfort and environmental impact has led to development of new strategies and technologies. Model provides flexibility for use of new materials since they can be easily incorporated in the model. Architects and building designers should put further efforts in order to quantify the thermal performance of design parameters and building elements in an integrated manner by experimental exercises on conceptual or constructed buildings.

Researchers [94] and [116] have studied and quantified the effect of orientation and total heat gain on the buildings with different Surface to Volume Ratio (SVR). Outer shape of the envelope is an important consideration so far as the total heat gain on building is concerned. This parameter has not been taken in this research work; however, researchers can further explore the optimized solution by considering this design parameter and make their recommendations.

Model provides flexibility to the designer for creating and use of composite sections (sections having more than one layer of different building materials). Architects and building designers can develop their own databank of sections using different building materials. Advanced modelling techniques should be developed in order to quantify the effect of minute details of the buildings that have not been considered in this research study. Emphasis in this research is on external building elements and effect of internal shading devices like curtains and

Venetian blinds can not be quantified by this model. These elements can be incorporated in the advanced modelling that can be taken up by an organization level.

9.3 CONCLUSION

A Model has been developed in order to determine Thermal Performance of Buildings in Composite Climate of India. Model has been prepared by considering Forward Approach as described by ASHRAE. Model has been formulated on the basis of computational method basically suggested by Indian Code SP: *41 (S & T) – 1987 (Handbook on Functional Requirements of Buildings)* for Heat Transmission through Building Sections. Further, in order to prepare mathematical model Heat Balance Theory has also taken into consideration. Input data preparation method has been made user (architects and building designers) friendly. Model produces clear (unambiguous) output in the form of internal room temperature (**Ti**) of different rooms on hourly basis. A Computer Program has been prepared incorporating the Model structure in order to produce output data by processing the input data. The program has been written in FORTRAN -90 by adopting Modular (structured) Approach. 24 Subroutines and 14 Functions have been formulated in order to accomplish this research. General Output File, Temperature Output File, Solar Calculation File and Shading Calculation File are generated for every simulation study by the program.

To determine the level of precision of results, an existing house in Composite Climate Zone (ROORKEE) has been selected as a reference. Actual temperature readings were recorded on hourly basis in 05 different rooms of that house as well as outdoor temperature was recorded for the same period. The same house with constructional details and specifications was used for indoor temperature simulation from the evolved computer program. Results obtained by the model were compared with the actual measurements. It was found from the experimental and theoretical exercises that model is VALID and capable of predicting Thermal Performance of Buildings within accepted tolerable limits.

Exercises were carried out for conceptual building (units) by using the model. Initially, a single room is conceptualized in order to observe thermal performance of particular layout (plan) with variations in the other variables, using the proposed model. Similarly, thermal performance of four rooms unit & nine rooms unit has also been observed. Results have been obtained by above mentioned exercises for full year; however, results of month of January & June were analyzed critically. Relevant data & graphs thus produced were analyzed in order to derive inferences form the exercises.

The quantitative & qualitative information depicted from the output is of great importance for architects and building designers in order to identify & evaluate several design decisions impacting on indoor thermal environment of a building. Model provides an opportunity for architects to formulate their ideas when design is in conceptual stage. Results can be obtained for individual building elements as well as for a combination of different elements or design parameters. Thermal performance of various building elements or design parameters can be judged in an integrated manner.

Finally, it is concluded that the models offer a valuable decision support system for designers at an early design state of buildings (that would rely on natural means of heating and cooling) for the optimization of the thermal performance to achieve optimum thermal comfort that would lead to savings in heating and cooling energy.

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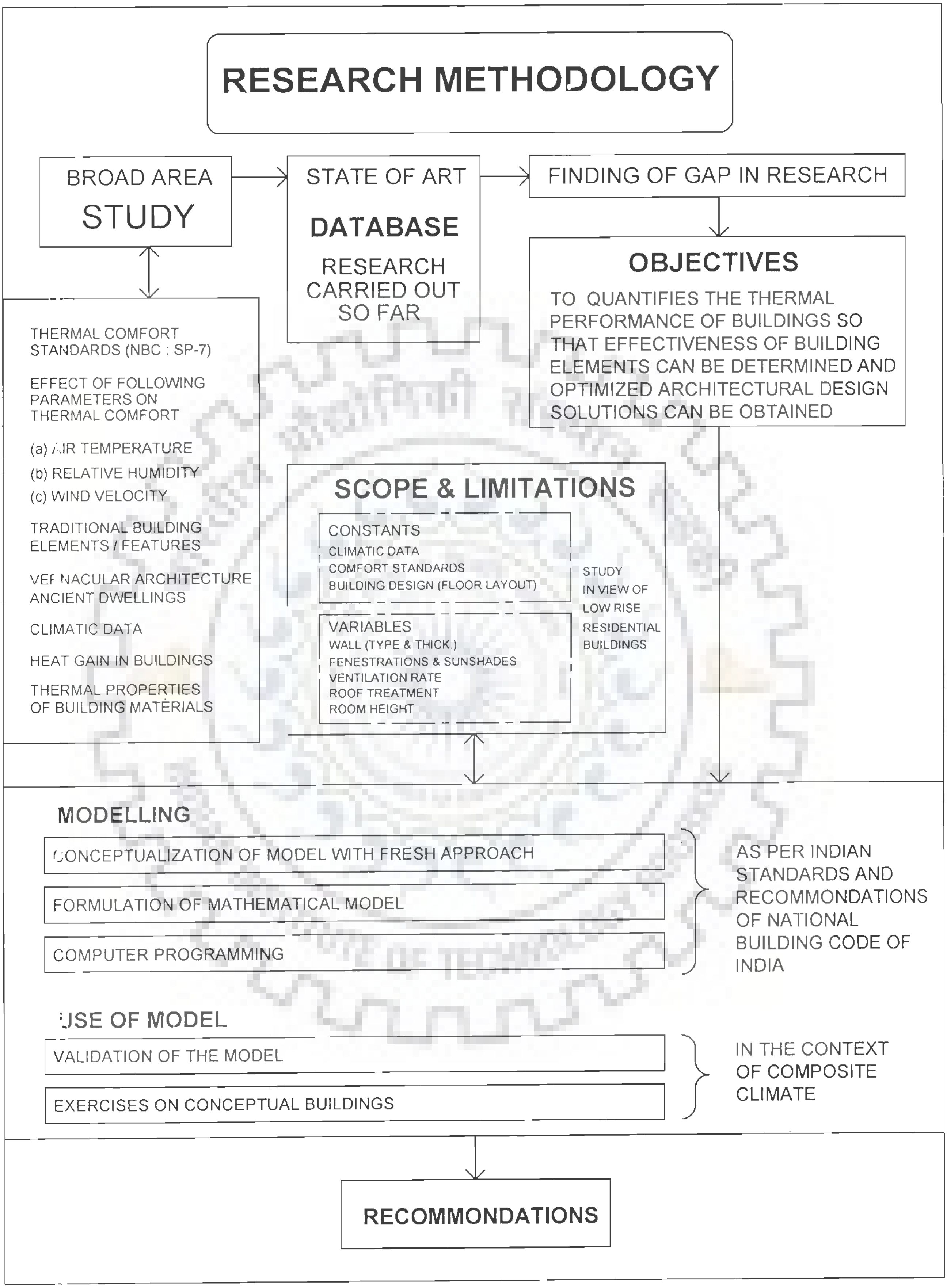
APPENDIX – 1

GRAPHICAL REPRESENTATION OF RESEARCH METHODOLOGY

(CHART)


RESEARCH METHODOLOGY
BROAD AREA STUDY
STATE OF ART
DATABASE
RESEARCH CARRIED OUT SO FAR
FINDING OF GAP IN RESEARCH
OBJECTIVES
TO QUANTIFIES THE THERMAL PERFORMANCE OF BUILDINGS SO THAT EFFECTIVENESS OF BUILDING ELEMENTS CAN BE DETERMINED AND OPTIMIZED ARCHITECTURAL DESIGN SOLUTIONS CAN BE OBTAINED
THERMAL COMFORT STANDARDS (NBC : SP-7)
EFFECT OF FOLLOWING PARAMETERS ON THERMAL COMFORT
(a) AIR TEMPERATURE
(b) RELATIVE HUMIDITY
(c) WIND VELOCITY
TRADITIONAL BUILDING ELEMENTS / FEATURES
VERNACULAR ARCHITECTURE ANCIENT DWELLINGS
CLIMATIC DATA
HEAT GAIN IN BUILDINGS
THERMAL PROPERTIES OF BUILDING MATERIALS
SCOPE & LIMITATIONS
CONSTANTS
CLIMATIC DATA
COMFORT STANDARDS
BUILDING DESIGN (FLOOR LAYOUT)
VARIABLES
WALL (TYPE & THICK.)
FENESTRATIONS & SUNSHADES
VENTILATION RATE
ROOF TREATMENT
ROOM HEIGHT
STUDY IN VIEW OF LOW RISE RESIDENTIAL BUILDINGS
MODELLING
CONCEPTUALIZATION OF MODEL WITH FRESH APPROACH
FORMULATION OF MATHEMATICAL MODEL
COMPUTER PROGRAMMING
AS PER INDIAN STANDARDS AND RECOMMONDATIONS OF NATIONAL BUILDING CODE OF INDIA
USE OF MODEL
VALIDATION OF THE MODEL
EXERCISES ON CONCEPTUAL BUILDINGS
IN THE CONTEXT OF COMPOSITE CLIMATE
RECOMMONDATIONS

APPENDIX – 2

COMPUTATION OF CONDUCTIVITY OF LELEMENTS

(METHOD)

Conductivity of elements

(A) General elements

For a n layered wall element between two thermal zones i & j, having surface air conductivities as h_i & h_j respectively, thickness of each layer as d_i, i being the layer no., specific conductivity of layer material as K_i (heat conduction coefficient), resistance of each layer per unit area can be calculation follows:

Resistance of :

(i) Air layer in zone i $= \frac{1}{h_i}$

(ii) layer 1 $= = \frac{d_1}{K_1}$

(iii) layer 2 $= \frac{d_2}{K_2}$

......layer n $= \frac{d_n}{K_n}$

Air layer in zone j $= \frac{1}{h_j}$

Total resistance of the section

$$R = \frac{1}{h_i} + \frac{d_1}{K_1} + \frac{d_2}{K_2} + \dots \frac{d_n}{K_n} + \frac{1}{h_j}$$

Conductivity of the element, $U = \frac{1}{R}$

Now, conductivity of the elements used in modeling of the building can be written by substituting the following values of h_i and h_j:

(B) For outer wall/door $h_i = h_{out}$

$h_j = h_{in}$

(C) For inner wall/door $h_i = h_{in}$

$h_j = h_{in}$

(D) For Roof $h_i = h_{floor}$

$h_j = h_{ceiling}$

(E) For Floor $h_j = h_{floor}$

$h_j = o$ {Floor is resting on earth directly}

APPENDIX – 3

DEVELOPMENT OF HEAT CAPACITY MATRIX OF ELEMENTS

(MATHEMATICAL PROCEDURE)

Heat capacity matrix of elements

(A) General element

In the model for calculation of conductivity of element, let t_i is temperate between layer i & (i+1, Conductivity of the element = U_i , initial temperature of both thermal zone = T. Now, for a temperature rise of ΔT in zone j, a thermal gradient is setup in wall causing flow of heat, q through the wall. Where,

$q = U\Delta T$

As the same heat flow passes through each layer, inter – layer temperatures can be calculated as

$$t_o = \frac{q}{h_i} + T$$

$$t_1 = \frac{qd_1}{K_1} + \frac{q}{h_i} + T$$

$$t_n = \frac{q}{h_i} + \sum_{i=1}^{n} \frac{qd_i}{K_i} + T$$

Average rise in temperature of each layer, i

$$\Delta t_i = \frac{(t_i + t_{i-1})}{2} - T$$

Or

$$\Delta t_i = \frac{1}{2}\left(\sum_{m=1}^{i} \frac{qd_m}{K_m} + \frac{q}{h_i} + T + \sum_{m=1}^{i-1} \frac{qd_m}{K_m} + \frac{q}{h_i} + T \right) - T$$

$$\Delta t_i = \frac{1}{2}\left(\sum_{m=1}^{i-1} \frac{qd_m}{K_m} + \frac{qd_i}{K_i} + \frac{2q}{h_i} + 2T + \sum_{m=1}^{i-1} \frac{qd_m}{K_m} \right) - T$$

$$\Delta t_i = \sum_{m=1}^{i-1} \frac{q_{dm}}{K_m} + \frac{1}{2}\frac{q_{di}}{K_i} + \frac{q}{h_i}$$

Or $\Delta t_i = q\left(\sum_{m=1}^{i-1} \frac{d_m}{K_m} + \frac{1}{2}\frac{d_i}{K_i} + \frac{1}{h_i}\right)$

$$= U\left(\sum_{m=1}^{i-1} \frac{d_m}{K_m} + \frac{1}{2}\frac{d_i}{K_i} + \frac{1}{h_i}\right)\Delta T$$

$$= \left(\sum_{m=1}^{i-1} \frac{d_m}{K_m} + \frac{1}{2}\frac{d_i}{K_i} + \frac{1}{h_i}\right)\frac{\Delta T}{R}$$

where $R = \frac{1}{h_i} + \frac{d_1}{K_1} + \frac{d_2}{K_2} + \ldots . \frac{d_n}{K_n} + \frac{1}{h_i}$

Now, if the specific heat of each layer is C_i and density is γ_i

heat stored in layer i

$\Delta H_i = C_i\ (\gamma_i\ d_i)\ \Delta t_i$

Hence, total heat stored in the wall for ΔT temp rise in zone i,

$$H_{jj} = \sum_{i=1}^{n} \Delta Hi$$

$$= \sum_{i=1}^{n} C_i \gamma_i d_i \Delta t_i$$

or $H_{jj} = \left[\sum_{i=1}^{n} C_i \gamma_e d_e \left(\sum_{m=1}^{i-1} \frac{d_m}{K_m} + \frac{1}{2}\frac{d_i}{K_i} + \frac{1}{h_i}\right)\right]\frac{\Delta T}{R}$

For ΔT rise on each side of the element, temperature of each element rise by ΔT, hence total heat stored in the element,

$$H = \left[\sum_{i=1}^{n} C_i \gamma_e d_e\right]\Delta T$$

Therefore, heat stored due to ΔT rise in zone i only

$H_{ii} = H - H_{jj}$

$$=\sum_{i=1}^{n} C_i\gamma_i d_i\Delta T-\frac{\Delta T}{R}\sum_{i=1}^{n}C_i\delta_i d_i\left(\sum_{m=1}^{i-1}\frac{d_m}{K_m}+\frac{1}{2}\frac{d_i}{K_i}+\frac{1}{h_i}\right)$$

$$=\left[\sum_{i=1}^{i-1} C_i\gamma_i d_i\Delta T\left(R-\left(\sum_{m=1}^{i-1}\frac{d_m}{K_m}+\frac{1}{2}\frac{d_i}{K_i}+\frac{1}{h_i}\right)\right)\right]\frac{\Delta T}{R}$$

$$=\left[\sum_{i=1}^{i-1} C_i\gamma_i d_i\left(\frac{1}{h_i}+\frac{1}{h_j}+\sum_{m=1}^{n}\frac{d_m}{K_m}-\sum_{m=1}^{i-1}\frac{d_m}{K_m}-\frac{1}{2}\frac{d_i}{K_i}+\frac{1}{h_i}\right)\right]\frac{\Delta T}{R}$$

or H_{ii} $$=\sum_{i=1}^{n} C_i\gamma_i d_i\left(\frac{1}{h_j}+\sum_{m=i+1}^{n}\frac{d_m}{K_m}+\frac{1}{2}\frac{d_i}{K_i}\right)\frac{\Delta T}{R}$$

APPENDIX – 4

HOURLY TEMPERATURE PROFILE

MONTH = 1 (JANUARY)

←------------------- DAILY HOUR (1 – 24) -------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	10.6	10.4	9.9	9	8.1	7.6	7.6	7.6	8.1	9	9.7	14	17.2	18.3	18.7	19.7	18.9	17.5	15.2	14	12.4	11.9	10.8	10.7

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR-------------------→

PRA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	18	17.7	17.4	17.2	16.9	16.5	16.2	16	16	16.3	16.6	17	17.6	18.2	18.8	19.2	**19.5**	**19.5**	19.4	19.3	19	18.8	18.5	18.2
6	17.9	17.7	17.4	17.1	16.8	16.5	16.2	16	16	16.1	16.4	16.9	17.4	18	18.6	19.1	**19.5**	**19.5**	19.4	19.2	19	18.7	18.5	18.2
12	17.9	17.6	17.4	17.1	16.8	16.5	16.2	15.9	15.9	16	16.3	16.7	17.3	17.9	18.5	19	**19.4**	**19.4**	19.3	19.1	18.9	18.7	18.4	18.1
18	17.8	17.6	17.3	17	16.7	16.4	16.1	15.9	15.8	15.9	16.2	16.6	17.1	17.8	18.4	19	19.3	**19.4**	19.3	19.1	18.9	18.6	18.4	18.1
24	17.7	17.4	17.2	16.9	16.6	16.3	16	15.8	15.7	15.8	16	16.3	16.9	17.5	18.1	18.7	19.1	**19.2**	19.1	18.9	18.7	18.5	18.2	18
30	17.6	17.3	17.1	16.8	16.5	16.2	15.9	15.7	15.6	15.6	15.8	16.2	16.7	17.3	18	18.6	19	**19.1**	19	18.8	18.6	18.4	18.1	17.9
36	17.5	17.3	17	16.7	16.5	16.2	15.9	15.6	15.5	15.5	15.7	16	16.5	17.2	17.8	18.4	**18.9**	**18.9**	18.8	18.7	18.5	18.3	18	17.8
42	17.4	17.2	16.9	16.7	16.4	16.1	15.8	15.6	15.5	15.5	15.6	15.9	16.4	17	17.7	18.3	18.7	**18.8**	18.7	18.6	18.4	18.2	17.9	17.7
48	17.3	17.1	16.9	16.6	16.3	16	15.7	15.5	15.4	15.5	15.6	15.8	16.3	16.9	17.6	18.2	18.6	**18.7**	18.6	18.5	18.3	18.1	17.8	17.6
54	17.3	17	16.8	16.6	16.3	16	15.7	15.5	15.4	15.5	15.6	15.8	16.2	16.8	17.5	18.1	**18.6**	**18.6**	**18.6**	18.4	18.2	18	17.8	17.5
60	17.2	17	16.8	16.5	16.2	15.9	15.7	15.4	15.4	15.5	15.6	15.8	16.2	16.8	17.4	18	18.5	**18.6**	18.5	18.4	18.2	18	17.7	17.5
66	17.2	17	16.7	16.5	16.2	15.9	15.6	15.4	15.4	15.5	15.6	15.8	16.2	16.7	17.3	18	18.4	**18.5**	18.4	18.3	18.1	17.9	17.7	17.4
72	17.1	16.9	16.7	16.4	16.2	15.9	15.6	15.4	15.4	15.5	15.6	15.8	16.2	16.7	17.3	17.9	18.4	**18.5**	18.4	18.2	18.1	17.9	17.6	17.4
78	17.1	16.9	16.6	16.4	16.1	15.8	15.6	15.4	15.4	15.5	15.6	15.8	16.2	16.6	17.2	17.8	18.3	**18.4**	18.3	18.2	18	17.8	17.6	17.3
84	17	16.8	16.6	16.3	16.1	15.8	15.5	15.3	15.4	15.5	15.6	15.8	16.2	16.6	17.2	17.8	18.2	**18.3**	18.2	18.1	17.9	17.7	17.5	17.3
90	17	16.7	16.5	16.3	16	15.7	15.4	15.3	15.3	15.5	15.6	15.8	16.2	16.6	17.1	17.7	18.1	**18.2**	18.1	18	17.8	17.6	17.4	17.2
96	16.9	16.7	16.4	16.2	15.9	15.7	15.4	15.2	15.3	15.4	15.6	15.8	16.2	16.6	17	17.6	18	**18.1**	18	17.9	17.8	17.6	17.3	17.1
102	16.8	16.6	16.4	16.1	15.9	15.6	15.3	15.1	15.2	15.4	15.6	15.8	16.1	16.5	17	17.5	17.9	**18**	17.9	17.8	17.7	17.5	17.3	17
108	16.7	16.5	16.3	16.1	15.8	15.5	15.3	15.1	15.1	15.3	15.5	15.8	16.1	16.5	16.9	17.4	17.8	**17.9**	17.8	17.7	17.6	17.4	17.2	16.9
114	16.6	16.4	16.2	16	15.7	15.5	15.2	15	15.1	15.3	15.5	15.7	16.1	16.5	16.9	17.3	17.7	**17.8**	17.7	17.6	17.5	17.3	17.1	16.9
120	16.6	16.4	16.1	15.9	15.7	15.4	15.1	15	15	15.2	15.4	15.7	16.1	16.5	16.9	17.2	17.6	**17.7**	17.6	17.5	17.4	17.2	17	16.8
126	16.5	16.3	16.1	15.9	15.6	15.3	15.1	14.9	15	15.2	15.4	15.7	16	16.5	16.8	17.2	17.5	**17.6**	**17.6**	17.4	17.3	17.1	16.9	16.7
132	16.5	16.3	16.1	15.8	15.6	15.3	15.1	14.9	15	15.1	15.4	15.7	16	16.5	16.8	17.2	**17.5**	**17.5**	**17.5**	17.4	17.3	17.1	16.9	16.7
138	16.5	16.3	16	15.8	15.6	15.3	15.1	14.9	15	15.1	15.4	15.7	16.1	16.5	16.9	17.2	**17.5**	**17.5**	**17.5**	17.4	17.3	17.1	16.9	16.7
144	16.5	16.3	16.1	15.8	15.6	15.3	15.1	14.9	15	15.2	15.4	15.7	16.1	16.5	16.9	17.3	17.5	**17.6**	17.5	17.4	17.3	17.1	16.9	16.7
150	16.5	16.3	16.1	15.9	15.6	15.4	15.1	14.9	15	15.2	15.4	15.7	16.1	16.6	17	17.3	**17.6**	**17.6**	**17.6**	17.5	17.3	17.1	16.9	16.7
156	16.6	16.4	16.2	15.9	15.7	15.4	15.2	15	15	15.2	15.4	15.7	16.2	16.6	17	17.4	17.6	**17.7**	**17.7**	17.6	17.4	17.2	17	16.8
162	16.6	16.4	16.2	16	15.7	15.5	15.2	15	15.1	15.3	15.5	15.8	16.2	16.6	17.1	17.5	17.7	**17.8**	17.7	17.6	17.5	17.3	17.1	16.9
168	16.7	16.5	16.3	16	15.8	15.5	15.2	15	15.1	15.3	15.5	15.8	16.2	16.7	17.1	17.5	17.8	**17.9**	17.8	17.7	17.5	17.3	17.1	16.9
174	16.7	16.5	16.3	16.1	15.8	15.5	15.3	15.1	15.1	15.3	15.5	15.8	16.2	16.7	17.1	17.6	17.8	**17.9**	**17.9**	17.7	17.6	17.4	17.2	17
180	16.8	16.5	16.3	16.1	15.8	15.6	15.3	15.1	15.1	15.2	15.5	15.8	16.2	16.6	17.1	17.6	**17.9**	**17.9**	**17.9**	17.8	17.6	17.4	17.2	17
186	16.8	16.6	16.3	16.1	15.8	15.6	15.3	15.1	15.1	15.2	15.4	15.7	16.1	16.6	17.1	17.5	**17.9**	**17.9**	**17.9**	17.8	17.6	17.4	17.2	17
192	16.8	16.5	16.3	16.1	15.8	15.6	15.3	15.1	15	15.1	15.3	15.6	16.1	16.5	17	17.5	**17.9**	**17.9**	**17.9**	17.8	17.6	17.4	17.2	17
198	16.7	16.5	16.3	16.1	15.8	15.5	15.3	15	15	15.1	15.3	15.6	16	16.5	17	17.4	17.8	**17.9**	17.8	17.7	17.6	17.4	17.2	16.9
204	16.7	16.5	16.3	16	15.8	15.5	15.2	15	14.9	15	15.2	15.5	15.9	16.4	16.9	17.4	17.7	**17.8**	**17.8**	17.7	17.5	17.3	17.1	16.9
210	16.6	16.4	16.2	16	15.7	15.5	15.2	15	14.9	15	15.1	15.4	15.8	16.3	16.8	17.3	17.7	**17.8**	17.7	17.6	17.5	17.3	17.1	16.8
216	16.6	16.4	16.2	15.9	15.7	15.4	15.2	14.9	14.9	14.9	15.1	15.3	15.7	16.2	16.7	17.2	17.6	**17.7**	**17.7**	17.6	17.4	17.2	17	16.8
222	16.6	16.4	16.2	15.9	15.7	15.4	15.1	14.9	14.9	14.9	15	15.3	15.7	16.2	16.7	17.2	17.6	**17.7**	17.6	17.5	17.4	17.2	17	16.8
228	16.6	16.4	16.1	15.9	15.7	15.4	15.1	14.9	14.9	14.9	15.1	15.3	15.7	16.2	16.7	17.2	17.6	**17.7**	17.6	17.5	17.4	17.2	17	16.8
234	16.6	16.4	16.2	15.9	15.7	15.4	15.2	15	14.9	15	15.1	15.4	15.7	16.2	16.7	17.2	17.6	**17.7**	**17.7**	17.6	17.4	17.2	17	16.8
240	16.6	16.4	16.2	16	15.7	15.4	15.2	15	15	15.1	15.2	15.4	15.8	16.3	16.8	17.3	17.7	**17.8**	17.7	17.6	17.4	17.3	17.1	16.8
246	16.7	16.5	16.2	16	15.8	15.5	15.2	15	15.1	15.2	15.3	15.6	15.9	16.4	16.9	17.4	17.7	**17.8**	**17.8**	17.7	17.5	17.3	17.1	16.9
252	16.7	16.5	16.3	16.1	15.8	15.5	15.3	15.1	15.2	15.3	15.5	15.7	16	16.5	16.9	17.4	17.8	**17.9**	17.8	17.7	17.6	17.4	17.2	16.9
258	16.8	16.6	16.4	16.1	15.9	15.6	15.3	15.1	15.3	15.4	15.6	15.8	16.2	16.6	17	17.5	17.9	**18**	17.9	17.8	17.6	17.4	17.2	17
264	16.8	16.6	16.4	16.2	15.9	15.6	15.4	15.2	15.3	15.5	15.7	16	16.3	16.7	17.1	17.6	**18**	**18**	**18**	17.9	17.7	17.5	17.3	17.1
270	16.9	16.7	16.4	16.2	15.9	15.7	15.4	15.2	15.4	15.6	15.8	16.1	16.4	16.8	17.2	17.7	18	**18.1**	18	17.9	17.8	17.6	17.3	17.1
276	16.9	16.7	16.5	16.2	16	15.7	15.4	15.3	15.4	15.7	16	16.2	16.5	16.9	17.3	17.7	18.1	**18.2**	18.1	18	17.8	17.6	17.4	17.2
282	17	16.7	16.5	16.3	16	15.7	15.4	15.3	15.4	15.7	16	16.3	16.6	17	17.4	17.8	18.1	**18.2**	18.1	18	17.8	17.6	17.4	17.2
288	17	16.8	16.5	16.3	16	15.7	15.5	15.3	15.5	15.8	16.1	16.4	16.7	17.1	17.5	17.9	**18.2**	**18.2**	18.2	18	17.9	17.7	17.4	17.2
194	17	16.8	16.6	16.3	16	15.8	15.5	15.3	15.5	15.8	16.2	16.5	16.8	17.2	17.6	17.9	18.2	**18.3**	18.2	18.1	17.9	17.7	17.5	17.2
300	17	16.8	16.6	16.3	16.1	15.8	15.5	15.3	15.5	15.8	16.2	16.5	16.9	17.3	17.6	18	**18.3**	**18.3**	18.2	18.1	17.9	17.7	17.5	17.3
306	17.1	16.8	16.6	16.4	16.1	15.8	15.5	15.4	15.5	15.8	16.2	16.6	17	17.4	17.7	18.1	18.3	**18.4**	18.3	18.1	18	17.8	17.5	17.3
312	17.1	16.9	16.7	16.4	16.1	15.9	15.6	15.4	15.6	15.9	16.3	16.7	17.1	17.5	17.9	18.2	**18.4**	**18.4**	18.3	18.2	18	17.8	17.6	17.4
318	17.2	17	16.7	16.5	16.2	15.9	15.6	15.5	15.6	15.9	16.3	16.7	17.2	17.6	18	18.3	**18.5**	**18.5**	18.4	18.3	18.1	17.9	17.7	17.4
324	17.3	17	16.8	16.5	16.3	16	15.7	15.5	15.7	16	16.4	16.8	17.3	17.7	18.1	18.4	**18.6**	**18.6**	18.5	18.4	18.2	18	17.8	17.5
330	17.4	17.1	16.9	16.6	16.4	16.1	15.8	15.6	15.7	16.1	16.4	16.9	17.4	17.9	18.3	18.6	**18.8**	**18.8**	18.7	18.5	18.3	18.1	17.9	17.6
336	17.5	17.3	17	16.8	16.5	16.2	15.9	15.7	15.8	16.1	16.5	16.9	17.4	18	18.4	18.8	18.9	**19**	18.9	18.7	18.5	18.3	18	17.8
342	17.7	17.4	17.2	16.9	16.6	16.3	16	15.8	15.9	16.2	16.6	17.1	17.6	18.1	18.6	19	**19.2**	**19.2**	19.1	18.9	18.7	18.5	18.2	17.9
348	17.8	17.5	17.3	17	16.7	16.4	16.1	15.9	16	16.2	16.6	17	17.6	18.1	18.6	19.1	**19.3**	**19.3**	19.2	19	18.8	18.6	18.3	18
354	17.9	17.6	17.3	17.1	16.8	16.5	16.2	15.9	16	16.3	16.6	17	17.6	18.1	18.7	19.1	**19.4**	**19.4**	19.3	19.1	18.9	18.7	18.4	18.1

MONTH = 2 (FEBRUARY)

←------------------- DAILY HOUR (1 – 24) -------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	12.3	11.4	11	10.5	10	9.6	9.6	9.5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR-------------------→

0	20.1	19.8	19.5	19.2	18.8	18.5	18.2	18	18	18.3	18.6	19	19.5	20	20.6	21	21.4	21.5	21.5	21.3	21.1	20.9	20.6	20.4
6	20.1	19.8	19.5	19.2	18.9	18.5	18.2	18	18	18.2	18.5	18.9	19.4	20	20.5	21	21.4	21.6	21.5	21.4	21.2	20.9	20.7	20.4
12	20.1	19.8	19.5	19.2	18.9	18.6	18.2	18	18	18.1	18.4	18.8	19.3	19.8	20.4	21	21.4	21.6	21.5	21.4	21.2	20.9	20.7	20.4
18	20.1	19.8	19.5	19.2	18.9	18.6	18.2	18	17.9	18.1	18.3	18.7	19.2	19.7	20.3	20.9	21.4	21.6	21.5	21.4	21.2	20.9	20.7	20.4
24	20.1	19.8	19.5	19.2	18.9	18.5	18.2	18	17.9	18	18.2	18.6	19.1	19.7	20.3	20.9	21.4	21.6	21.5	21.4	21.2	20.9	20.7	20.4
30	20.1	19.8	19.5	19.2	18.9	18.5	18.2	18	17.9	18	18.2	18.6	19	19.6	20.2	20.8	21.3	21.6	21.5	21.4	21.2	20.9	20.7	20.4
36	20.1	19.8	19.5	19.2	18.9	18.5	18.2	18	17.9	18	18.2	18.5	19	19.5	20.2	20.8	21.3	21.6	21.5	21.4	21.2	20.9	20.7	20.4
42	20.1	19.8	19.5	19.2	18.8	18.5	18.2	18	18	18	18.2	18.5	19	19.5	20.1	20.8	21.3	21.5	21.5	21.4	21.1	20.9	20.6	20.4
48	20.1	19.8	19.5	19.2	18.8	18.5	18.2	18	18	18.1	18.2	18.5	19	19.5	20.1	20.7	21.3	21.5	21.5	21.3	21.1	20.9	20.6	20.4
54	20.1	19.8	19.5	19.1	18.8	18.5	18.2	18	18	18.1	18.3	18.6	19	19.5	20.1	20.7	21.3	21.5	21.5	21.3	21.1	20.9	20.6	20.3
60	20	19.8	19.4	19.1	18.8	18.5	18.2	18	18	18.1	18.3	18.6	19	19.5	20.1	20.7	21.3	21.5	21.5	21.3	21.1	20.9	20.6	20.3
66	20	19.7	19.4	19.1	18.8	18.5	18.2	18	18.1	18.2	18.3	18.6	19	19.5	20.1	20.7	21.2	21.5	21.4	21.3	21.1	20.9	20.6	20.3
72	20	19.7	19.4	19.1	18.8	18.5	18.2	18	18.1	18.2	18.4	18.6	19	19.5	20	20.7	21.2	21.5	21.4	21.3	21.1	20.8	20.6	20.3
78	20.1	19.8	19.5	19.1	18.8	18.5	18.2	18.1	18.1	18.3	18.4	18.7	19.1	19.6	20.1	20.7	21.3	21.5	21.5	21.3	21.1	20.9	20.6	20.3
84	20	19.7	19.4	19.1	18.7	18.4	18.1	18	18.1	18.2	18.4	18.7	19	19.5	20	20.6	21.1	21.4	21.3	21.2	21	20.8	20.5	20.2
90	19.9	19.6	19.3	19	18.7	18.4	18.1	17.9	18	18.2	18.4	18.7	19	19.4	19.9	20.5	21.1	21.3	21.3	21.2	21	20.7	20.5	20.2
96	19.8	19.6	19.3	19	18.6	18.3	18	17.9	18	18.2	18.4	18.7	19	19.4	19.9	20.4	21	21.2	21.2	21.1	20.9	20.6	20.4	20.1
102	19.8	19.5	19.2	18.9	18.6	18.3	18	17.8	17.9	18.1	18.3	18.6	19	19.4	19.8	20.3	20.9	21.1	21.1	21	20.8	20.5	20.3	20
108	19.7	19.4	19.1	18.8	18.5	18.2	17.9	17.8	17.8	18	18.3	18.6	18.9	19.3	19.7	20.2	20.7	21	21	20.8	20.7	20.4	20.2	19.9
114	19.6	19.3	19	18.7	18.4	18.1	17.8	17.7	17.8	18	18.2	18.5	18.9	19.3	19.7	20.1	20.6	20.8	20.8	20.7	20.5	20.3	20.1	19.8
120	19.5	19.2	18.9	18.6	18.3	18	17.7	17.6	17.7	17.9	18.1	18.4	18.8	19.2	19.6	20	20.5	20.7	20.7	20.6	20.4	20.2	20	19.7
126	19.4	19.1	18.8	18.5	18.2	17.9	17.7	17.5	17.6	17.8	18.1	18.4	18.8	19.2	19.6	20	20.4	20.6	20.6	20.5	20.3	20.1	19.9	19.6
132	19.3	19	18.7	18.5	18.2	17.9	17.6	17.5	17.6	17.8	18	18.3	18.7	19.1	19.5	19.9	20.3	20.5	20.5	20.4	20.2	20	19.8	19.5
138	19.2	18.9	18.7	18.4	18.1	17.8	17.5	17.4	17.5	17.7	18	18.3	18.7	19.1	19.5	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.7	19.5
144	19.2	18.9	18.6	18.3	18.1	17.8	17.5	17.4	17.5	17.7	17.9	18.3	18.7	19.1	19.5	19.8	20.1	20.3	20.3	20.2	20.1	19.9	19.6	19.4
150	19.1	18.9	18.6	18.3	18	17.7	17.5	17.3	17.4	17.6	17.9	18.2	18.6	19	19.4	19.8	20.1	20.3	20.3	20.2	20	19.8	19.6	19.4
156	19.1	18.9	18.6	18.3	18	17.7	17.5	17.3	17.4	17.6	17.9	18.2	18.6	19	19.4	19.8	20.1	20.3	20.3	20.2	20	19.8	19.6	19.4
162	19.1	18.9	18.6	18.3	18	17.7	17.5	17.3	17.4	17.6	17.9	18.2	18.6	19	19.4	19.8	20.1	20.3	20.3	20.2	20	19.8	19.6	19.4
168	19.1	18.9	18.6	18.3	18	17.8	17.5	17.3	17.4	17.6	17.8	18.2	18.5	19	19.4	19.8	20.1	20.3	20.3	20.2	20	19.8	19.6	19.4
174	19.2	18.9	18.6	18.3	18.1	17.8	17.5	17.3	17.4	17.5	17.8	18.1	18.5	19	19.4	19.8	20.2	20.3	20.3	20.2	20.1	19.9	19.6	19.4
180	19.2	18.9	18.6	18.4	18.1	17.8	17.5	17.3	17.3	17.5	17.7	18.1	18.5	18.9	19.4	19.8	20.2	20.3	20.3	20.2	20.1	19.9	19.7	19.4
186	19.2	18.9	18.7	18.4	18.1	17.8	17.5	17.3	17.3	17.5	17.7	18	18.4	18.9	19.4	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.7	19.4
192	19.2	18.9	18.7	18.4	18.1	17.8	17.5	17.3	17.3	17.4	17.7	18	18.4	18.8	19.3	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.7	19.4
198	19.2	18.9	18.7	18.4	18.1	17.8	17.5	17.3	17.3	17.4	17.6	18	18.4	18.8	19.3	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.7	19.5
204	19.2	19	18.7	18.4	18.1	17.8	17.5	17.3	17.3	17.4	17.6	17.9	18.3	18.8	19.3	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.7	19.5
210	19.2	19	18.7	18.4	18.1	17.8	17.6	17.4	17.3	17.4	17.6	17.9	18.3	18.8	19.3	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.7	19.5
216	19.3	19	18.7	18.4	18.1	17.9	17.6	17.4	17.4	17.5	17.7	18	18.4	18.8	19.3	19.8	20.2	20.4	20.4	20.4	20.2	20	19.8	19.5
222	19.3	19	18.8	18.5	18.2	17.9	17.6	17.4	17.4	17.5	17.7	18	18.4	18.9	19.3	19.8	20.3	20.5	20.5	20.4	20.2	20	19.8	19.5
228	19.3	19.1	18.8	18.5	18.2	17.9	17.6	17.5	17.5	17.6	17.8	18.1	18.5	18.9	19.4	19.9	20.3	20.6	20.5	20.5	20.3	20.1	19.8	19.6
234	19.4	19.1	18.9	18.6	18.3	18	17.7	17.6	17.6	17.7	17.9	18.2	18.6	19	19.5	20	20.4	20.6	20.6	20.5	20.4	20.1	19.9	19.7
240	19.5	19.2	18.9	18.6	18.3	18	17.7	17.6	17.7	17.9	18.1	18.3	18.7	19.1	19.6	20.1	20.5	20.7	20.7	20.6	20.4	20.2	20	19.7
246	19.5	19.3	19	18.7	18.4	18.1	17.8	17.7	17.8	18	18.2	18.5	18.8	19.3	19.7	20.2	20.6	20.8	20.8	20.7	20.5	20.3	20.1	19.8
252	19.6	19.3	19.1	18.8	18.5	18.2	17.9	17.8	17.9	18.1	18.4	18.6	19	19.4	19.8	20.3	20.7	20.9	20.9	20.8	20.6	20.4	20.1	19.9
258	19.8	19.5	19.2	18.9	18.6	18.3	18	17.9	18	18.3	18.5	18.8	19.2	19.6	20	20.5	20.9	21.1	21.1	21	20.8	20.5	20.3	20
264	19.8	19.5	19.2	18.9	18.6	18.3	18	17.9	18.1	18.4	18.6	18.9	19.2	19.6	20	20.5	20.9	21.1	21.1	21	20.8	20.5	20.3	20
270	19.8	19.5	19.2	18.9	18.6	18.3	18	17.9	18.1	18.4	18.7	19	19.3	19.7	20.1	20.6	21	21.2	21.1	21	20.8	20.6	20.3	20.1
276	19.8	19.5	19.2	18.9	18.6	18.3	18	17.9	18.1	18.5	18.8	19.1	19.4	19.8	20.2	20.6	21	21.2	21.2	21.1	20.9	20.6	20.4	20.1
282	19.9	19.6	19.3	19	18.7	18.3	18	18	18.2	18.5	18.8	19.2	19.5	19.9	20.2	20.7	21	21.2	21.2	21.1	20.9	20.7	20.4	20.1
288	19.9	19.6	19.3	19	18.7	18.3	18	18	18.2	18.5	18.9	19.2	19.5	19.9	20.3	20.7	21.1	21.2	21.2	21.1	20.9	20.7	20.4	20.1
294	19.9	19.6	19.3	19	18.7	18.3	18	18	18.2	18.5	18.9	19.2	19.6	20	20.3	20.7	21.1	21.2	21.2	21.1	20.9	20.7	20.4	20.1
300	19.8	19.6	19.3	19	18.7	18.3	18	17.9	18.2	18.5	18.9	19.3	19.6	20	20.4	20.7	21.1	21.2	21.2	21.1	20.9	20.6	20.4	20.1
306	19.9	19.6	19.3	19	18.7	18.3	18	18	18.2	18.5	18.9	19.3	19.7	20.1	20.4	20.8	21.1	21.2	21.2	21.1	20.9	20.7	20.4	20.1
312	19.8	19.6	19.3	19	18.6	18.3	18	17.9	18.1	18.5	18.9	19.3	19.7	20.1	20.4	20.8	21.1	21.2	21.2	21.1	20.9	20.6	20.4	20.1
318	19.8	19.5	19.3	18.9	18.6	18.3	18	17.9	18.1	18.5	18.9	19.3	19.7	20.1	20.5	20.8	21.1	21.2	21.2	21.1	20.9	20.6	20.4	20.1
324	19.8	19.6	19.3	19	18.6	18.3	18	17.9	18.1	18.5	18.9	19.3	19.7	20.2	20.5	20.8	21.1	21.2	21.2	21.1	20.9	20.6	20.4	20.1
330	19.9	19.6	19.3	19	18.7	18.3	18	17.9	18.1	18.5	18.9	19.3	19.8	20.2	20.6	20.9	21.1	21.3	21.2	21.1	20.9	20.7	20.4	20.1
336	19.9	19.6	19.3	19	18.7	18.4	18.1	17.9	18.1	18.4	18.8	19.3	19.7	20.2	20.6	20.9	21.2	21.3	21.2	21.1	20.9	20.7	20.4	20.2
342	19.9	19.6	19.3	19	18.7	18.4	18.1	18	18.1	18.4	18.8	19.2	19.7	20.2	20.6	21	21.3	21.3	21.3	21.2	21	20.7	20.5	20.2
348	20	19.7	19.4	19.1	18.8	18.4	18.1	18	18.1	18.4	18.8	19.2	19.7	20.2	20.6	21	21.3	21.4	21.4	21.2	21	20.8	20.5	20.3
354	20	19.7	19.4	19.1	18.8	18.5	18.2	18	18.1	18.3	18.7	19.1	19.6	20.1	20.6	21	21.4	21.5	21.4	21.3	21.1	20.9	20.6	20.3

MONTH = 3 (MARCH)

←------------------- DAILY HOUR (1 – 24) -------------------→

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR-------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	18.7	18.1	18	17.4	16.8	16.9	16.7	16.2	17.7	21.2	23.9	26.4	27.6	27.8	29.2	30.1	30.5	29.6	28.1	21.5	20.5	20.1	19.6	19.2
0	25.9	25.6	25.3	25	24.7	24.4	24.1	24	24	24.2	24.6	25	25.4	25.9	26.3	26.8	27.2	**27.4**	**27.4**	27.3	27	26.7	26.5	26.2
6	25.9	25.7	25.4	25.1	24.8	24.4	24.2	24	24	24.2	24.5	24.9	25.3	25.8	26.3	26.8	27.2	27.4	**27.5**	27.3	27.1	26.8	26.5	26.2
12	26	25.7	25.4	25.1	24.8	24.5	24.2	24.1	24.1	24.2	24.5	24.9	25.3	25.8	26.3	26.8	27.3	27.5	**27.6**	27.4	27.2	26.9	26.6	26.3
18	26.1	25.8	25.5	25.2	24.9	24.6	24.3	24.2	24.2	24.3	24.6	25	25.4	25.9	26.4	26.9	27.4	**27.7**	**27.7**	27.6	27.3	27	26.7	26.4
24	26.3	26	25.7	25.3	25	24.7	24.4	24.3	24.3	24.4	24.7	25	25.5	25.9	26.5	27.1	27.6	**27.9**	**27.9**	27.7	27.5	27.2	26.9	26.6
30	26.4	26.1	25.8	25.5	25.1	24.8	24.5	24.4	24.4	24.5	24.8	25.1	25.5	26	26.6	27.2	27.7	**28**	**28**	27.9	27.6	27.3	27	26.7
36	26.5	26.2	25.9	25.6	25.2	24.9	24.6	24.5	24.5	24.6	24.9	25.2	25.6	26.1	26.7	27.3	27.8	**28.2**	**28.2**	28	27.7	27.4	27.1	26.8
42	26.6	26.3	25.9	25.6	25.3	25	24.7	24.6	24.6	24.7	25	25.3	25.7	26.2	26.7	27.4	27.9	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
48	26.7	26.3	26	25.7	25.4	25	24.8	24.7	24.7	24.8	25.1	25.4	25.8	26.2	26.8	27.4	28	**28.4**	**28.4**	28.2	27.9	27.6	27.3	27
54	26.7	26.4	26.1	25.7	25.4	25.1	24.8	24.7	24.8	24.9	25.1	25.5	25.8	26.3	26.8	27.5	28.1	**28.4**	**28.4**	28.3	28	27.7	27.3	27
60	26.7	26.4	26.1	25.8	25.4	25.1	24.8	24.8	24.8	25	25.2	25.5	25.9	26.3	26.9	27.5	28.1	**28.5**	**28.5**	28.3	28	27.7	27.4	27.1
66	26.8	26.4	26.1	25.8	25.4	25.1	24.8	24.8	24.9	25	25.2	25.6	25.9	26.4	26.9	27.5	28.1	**28.5**	**28.5**	28.3	28	27.7	27.4	27.1
72	26.8	26.4	26.1	25.8	25.4	25.1	24.8	24.8	24.9	25	25.3	25.6	26	26.4	26.9	27.5	28.1	**28.5**	**28.5**	28.3	28	27.7	27.4	27.1
78	26.8	26.4	26.1	25.8	25.4	25.1	24.8	24.8	24.9	25	25.3	25.6	26	26.4	26.9	27.5	28.1	**28.5**	**28.5**	28.3	28	27.7	27.4	27.1
84	26.7	26.4	26.1	25.8	25.4	25.1	24.8	24.8	24.9	25	25.3	25.6	26	26.4	26.9	27.5	28.1	**28.5**	**28.5**	28.3	28	27.7	27.4	27.1
90	26.7	26.4	26.1	25.7	25.4	25.1	24.8	24.8	24.9	25	25.3	25.6	26	26.4	26.9	27.5	28.1	**28.4**	**28.4**	28.3	28	27.7	27.4	27
96	26.7	26.3	26	25.7	25.4	25	24.8	24.7	24.8	25	25.2	25.6	25.9	26.3	26.8	27.4	28	**28.4**	**28.4**	28.2	27.9	27.6	27.3	27
102	26.6	26.3	26	25.6	25.3	25	24.7	24.7	24.8	24.9	25.2	25.5	25.9	26.3	26.7	27.3	27.9	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
108	26.5	26.2	25.9	25.6	25.2	24.9	24.6	24.6	24.7	24.9	25.2	25.5	25.9	26.2	26.7	27.2	27.8	**28.2**	**28.2**	28	27.7	27.4	27.1	26.8
114	26.4	26.1	25.8	25.5	25.2	24.8	24.6	24.6	24.6	24.8	25.1	25.4	25.8	26.2	26.6	27.1	27.7	**28.1**	**28.1**	27.9	27.6	27.3	27	26.7
120	26.3	26	25.7	25.4	25.1	24.8	24.5	24.5	24.6	24.8	25	25.4	25.7	26.1	26.5	27	27.6	27.9	**28**	27.8	27.5	27.2	26.9	26.6
126	26.2	25.9	25.6	25.3	25	24.7	24.4	24.4	24.5	24.7	25	25.3	25.7	26.1	26.5	26.9	27.4	**27.8**	**27.8**	27.7	27.4	27.1	26.8	26.5
132	26.1	25.8	25.5	25.2	24.9	24.6	24.3	24.3	24.4	24.6	24.9	25.2	25.6	26	26.4	26.8	27.3	27.6	**27.7**	27.5	27.3	27	26.7	26.4
138	26	25.7	25.4	25.1	24.8	24.5	24.2	24.2	24.3	24.5	24.8	25.1	25.5	25.9	26.3	26.7	27.2	**27.5**	**27.5**	27.4	27.1	26.9	26.6	26.3
144	25.9	25.6	25.3	25	24.7	24.4	24.1	24.1	24.2	24.4	24.7	25	25.4	25.8	26.2	26.6	27	27.3	**27.4**	27.2	27	26.7	26.4	26.2
150	25.8	25.5	25.2	24.9	24.6	24.3	24	24	24.1	24.3	24.6	24.9	25.3	25.7	26.1	26.5	26.9	**27.2**	**27.2**	27.1	26.9	26.6	26.3	26
156	25.7	25.4	25.1	24.8	24.5	24.2	24	23.9	24	24.2	24.5	24.8	25.2	25.6	26	26.4	26.8	27	**27.1**	27	26.7	26.5	26.2	25.9
162	25.6	25.3	25	24.7	24.4	24.1	23.9	23.8	23.9	24.1	24.4	24.7	25.1	25.5	25.9	26.3	26.7	26.9	**27**	26.9	26.6	26.4	26.1	25.8
168	25.5	25.2	24.9	24.7	24.4	24.1	23.8	23.7	23.8	24	24.3	24.6	25	25.4	25.8	26.3	26.6	26.8	**26.9**	26.8	26.5	26.3	26	25.8
174	25.5	25.2	24.9	24.6	24.3	24.1	23.8	23.7	23.7	23.9	24.2	24.5	24.9	25.3	25.8	26.2	26.6	26.8	**26.9**	26.7	26.5	26.3	26	25.7
180	25.5	25.2	24.9	24.6	24.3	24.1	23.8	23.7	23.7	23.9	24.2	24.5	24.9	25.3	25.7	26.2	26.6	**26.8**	**26.8**	26.7	26.5	26.3	26	25.7
186	25.5	25.2	24.9	24.7	24.4	24.1	23.8	23.7	23.7	23.9	24.1	24.5	24.9	25.3	25.7	26.2	26.6	26.8	**26.9**	26.8	26.5	26.3	26	25.8
192	25.5	25.3	25	24.7	24.4	24.1	23.9	23.7	23.7	23.9	24.2	24.5	24.9	25.3	25.8	26.2	26.6	26.9	**27**	26.8	26.6	26.3	26.1	25.8
198	25.6	25.3	25.1	24.8	24.5	24.2	23.9	23.8	23.8	23.9	24.2	24.6	25	25.4	25.8	26.3	26.7	27	27	26.9	26.7	26.4	26.2	25.9
204	25.7	25.4	25.1	24.8	24.6	24.3	24	23.9	23.9	24	24.3	24.7	25.1	25.5	25.9	26.4	26.8	27.1	**27.2**	27	26.8	26.5	26.3	26
210	25.8	25.5	25.2	24.9	24.6	24.3	24.1	24	24	24.2	24.4	24.8	25.2	25.6	26	26.5	27	27.2	**27.3**	27.2	26.9	26.6	26.4	26.1
216	25.9	25.6	25.3	25	24.7	24.4	24.2	24.1	24.2	24.3	24.6	24.9	25.3	25.7	26.1	26.6	27.1	**27.4**	**27.4**	27.3	27	26.8	26.5	26.2
222	26	25.7	25.4	25.1	24.8	24.5	24.3	24.2	24.3	24.5	24.7	25	25.4	25.8	26.3	26.7	27.2	27.5	**27.6**	27.4	27.2	26.9	26.6	26.3
228	26.1	25.8	25.5	25.2	24.9	24.6	24.3	24.3	24.4	24.6	24.9	25.2	25.6	26	26.4	26.9	27.3	**27.7**	**27.7**	27.5	27.3	27	26.7	26.4
234	26.2	25.9	25.6	25.3	25	24.7	24.4	24.4	24.6	24.7	25	25.3	25.7	26.1	26.5	27	27.5	**27.8**	**27.8**	27.6	27.4	27.1	26.8	26.5
240	26.3	26	25.7	25.4	25	24.7	24.5	24.5	24.7	24.9	25.1	25.5	25.8	26.2	26.6	27.1	27.6	**27.9**	**27.9**	27.7	27.5	27.2	26.9	26.6
246	26.4	26	25.7	25.4	25.1	24.8	24.5	24.6	24.8	25	25.3	25.6	26	26.3	26.7	27.2	27.7	**28**	**28**	27.8	27.6	27.3	27	26.7
252	26.4	26.1	25.8	25.5	25.2	24.8	24.6	24.6	24.9	25.1	25.4	25.7	26.1	26.4	26.8	27.3	27.8	**28.1**	**28.1**	27.9	27.6	27.3	27	26.7
258	26.5	26.2	25.8	25.5	25.2	24.9	24.6	24.7	24.9	25.2	25.5	25.8	26.2	26.5	26.9	27.4	27.8	**28.1**	**28.1**	28	27.7	27.4	27.1	26.8
264	26.5	26.2	25.9	25.6	25.2	24.9	24.7	24.7	25	25.3	25.6	25.9	26.2	26.6	27	27.5	27.9	**28.2**	**28.2**	28.1	27.8	27.5	27.2	26.8
270	26.6	26.3	25.9	25.6	25.3	25	24.7	24.8	25	25.3	25.6	25.9	26.3	26.7	27.1	27.5	28	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
276	26.6	26.3	26	25.6	25.3	25	24.7	24.8	25	25.4	25.7	26	26.4	26.7	27.1	27.6	28	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
282	26.6	26.3	26	25.6	25.3	25	24.7	24.8	25	25.4	25.7	26	26.4	26.7	27.1	27.6	28	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
288	26.6	26.3	26	25.6	25.3	25	24.7	24.8	25	25.4	25.7	26	26.4	26.8	27.1	27.6	28	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
294	26.6	26.3	25.9	25.6	25.3	25	24.7	24.8	25	25.4	25.7	26	26.4	26.8	27.1	27.6	28	**28.3**	**28.3**	28.1	27.8	27.5	27.2	26.9
300	26.6	26.2	25.9	25.6	25.3	24.9	24.7	24.7	25	25.3	25.7	26	26.4	26.8	27.1	27.5	28	**28.2**	**28.2**	28.1	27.8	27.5	27.2	26.9
306	26.5	26.2	25.9	25.6	25.2	24.9	24.7	24.7	25	25.3	25.7	26	26.4	26.7	27.1	27.5	27.9	**28.2**	**28.2**	28	27.7	27.4	27.1	26.8
312	26.5	26.1	25.8	25.5	25.2	24.9	24.6	24.7	24.9	25.2	25.6	26	26.3	26.7	27.1	27.5	27.8	**28.1**	**28.1**	28	27.7	27.4	27.1	26.8
318	26.4	26.1	25.8	25.4	25.1	24.8	24.6	24.6	24.8	25.2	25.5	25.9	26.3	26.6	27	27.4	27.8	**28**	**28**	27.9	27.6	27.3	27	26.7
324	26.3	26	25.7	25.4	25.1	24.7	24.5	24.5	24.7	25.1	25.4	25.8	26.2	26.6	26.9	27.3	27.7	**27.9**	**27.9**	27.8	27.5	27.2	26.9	26.6
330	26.2	25.9	25.6	25.3	25	24.7	24.4	24.4	24.6	24.9	25.3	25.7	26.1	26.5	26.8	27.2	27.6	**27.8**	**27.8**	27.7	27.4	27.1	26.8	26.5
336	26.1	25.8	25.5	25.2	24.9	24.6	24.3	24.3	24.5	24.8	25.1	25.5	25.9	26.3	26.7	27.1	27.4	27.6	**27.7**	27.5	27.3	27	26.7	26.4
342	26	25.7	25.4	25.1	24.8	24.5	24.2	24.2	24.3	24.6	25	25.4	25.8	26.2	26.6	27	27.3	**27.5**	**27.5**	27.4	27.1	26.9	26.6	26.3
348	25.9	25.6	25.3	25	24.7	24.4	24.2	24.1	24.2	24.4	24.8	25.2	25.6	26	26.5	26.9	27.2	**27.4**	**27.4**	27.3	27.1	26.8	26.5	26.2
354	25.9	25.6	25.3	25	24.7	24.4	24.1	24	24.1	24.3	24.7	25.1	25.5	25.9	26.4	26.8	27.2	**27.4**	**27.4**	27.3	27	26.7	26.5	26.2

MONTH = 4 (APRIL)

←------------------ DAILY HOUR (1 – 24) ------------------→

⇓PRA (Plan Rotation Angle) ←------------------ INDOOR TEMPERATURE on DAILY HOUR------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	24	23.2	22.6	21.7	20.9	21.2	20.5	20.2	21.8	26.9	30	32.4	34.3	35.3	36.4	36.7	36.7	36.2	34.6	31.2	28.4	28.3	27.9	26.1
0	31.5	31.1	30.8	30.4	30.1	29.7	29.4	29.3	29.3	29.4	29.7	30	30.4	30.9	31.4	31.8	32.2	32.5	**32.6**	32.5	32.4	32.2	32	31.8
6	31.5	31.2	30.8	30.5	30.1	29.7	29.5	29.3	29.3	29.4	29.7	30	30.4	30.9	31.4	31.9	32.3	32.5	**32.6**	**32.6**	32.4	32.2	32	31.8
12	31.6	31.2	30.9	30.5	30.1	29.8	29.5	29.4	29.4	29.5	29.8	30.1	30.5	30.9	31.4	31.9	32.3	32.6	**32.7**	32.6	32.5	32.3	32.1	31.8
18	31.7	31.3	31	30.6	30.2	29.9	29.6	29.5	29.5	29.6	29.9	30.2	30.6	31	31.5	32.1	32.5	**32.8**	**32.8**	**32.8**	32.6	32.4	32.2	32
24	31.8	31.5	31.1	30.8	30.4	30	29.8	29.6	29.6	29.7	30	30.3	30.7	31.2	31.7	32.2	32.7	**33**	**33**	**33**	32.8	32.6	32.4	32.1
30	32	31.6	31.3	30.9	30.5	30.1	29.9	29.8	29.8	29.9	30.1	30.5	30.9	31.3	31.8	32.4	32.8	**33.2**	**33.2**	**33.2**	33	32.8	32.5	32.3
36	32.1	31.8	31.4	31	30.6	30.3	30	29.9	29.9	30	30.3	30.6	31	31.4	32	32.5	33	33.4	**33.5**	33.4	33.2	33	32.7	32.5
42	32.3	31.9	31.6	31.2	30.8	30.4	30.2	30.1	30.1	30.2	30.4	30.7	31.1	31.6	32.1	32.7	33.2	**33.6**	**33.6**	**33.6**	33.4	33.1	32.9	32.6
48	32.4	32.1	31.7	31.3	30.9	30.5	30.3	30.2	30.2	30.3	30.5	30.9	31.2	31.7	32.2	32.8	33.4	33.7	**33.8**	33.7	33.5	33.3	33	32.8
54	32.5	32.2	31.8	31.4	31	30.6	30.3	30.3	30.3	30.4	30.6	30.9	31.3	31.7	32.3	32.9	33.5	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
60	32.6	32.2	31.8	31.5	31	30.6	30.4	30.4	30.4	30.5	30.7	31	31.4	31.8	32.3	33	33.6	**34**	**34**	33.9	33.7	33.5	33.2	32.9
66	32.7	32.3	31.9	31.5	31.1	30.7	30.4	30.4	30.4	30.5	30.7	31.1	31.4	31.9	32.4	33	33.6	34	**34.1**	34	33.8	33.5	33.3	33
72	32.7	32.3	31.9	31.5	31.1	30.7	30.5	30.4	30.4	30.5	30.8	31.1	31.5	31.9	32.4	33	33.6	**34.1**	**34.1**	34	33.8	33.6	33.3	33
78	32.7	32.3	31.9	31.5	31.1	30.7	30.5	30.4	30.4	30.5	30.8	31.1	31.5	31.9	32.4	33	33.6	**34.1**	**34.1**	34	33.8	33.6	33.3	33
84	32.7	32.3	31.9	31.5	31.1	30.7	30.5	30.4	30.4	30.5	30.7	31.1	31.5	31.9	32.4	33	33.6	34	**34.1**	34	33.8	33.5	33.3	33
90	32.7	32.3	31.9	31.5	31.1	30.7	30.4	30.4	30.4	30.5	30.7	31	31.4	31.9	32.4	33	33.6	34	**34.1**	34	33.8	33.5	33.3	33
96	32.6	32.3	31.9	31.5	31.1	30.7	30.4	30.4	30.4	30.5	30.7	31	31.4	31.8	32.3	33	33.6	34	**34.1**	34	33.8	33.5	33.3	33
102	32.6	32.2	31.9	31.5	31	30.6	30.4	30.4	30.4	30.5	30.7	31	31.4	31.8	32.3	32.9	33.5	34	**34.1**	34	33.7	33.5	33.2	33
108	32.6	32.2	31.8	31.4	31	30.6	30.4	30.3	30.4	30.5	30.7	31	31.4	31.8	32.3	32.9	33.5	33.9	**34**	33.9	33.7	33.5	33.2	32.9
114	32.5	32.2	31.8	31.4	31	30.6	30.3	30.3	30.3	30.4	30.6	30.9	31.3	31.8	32.2	32.8	33.4	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
120	32.5	32.1	31.7	31.3	30.9	30.5	30.3	30.2	30.3	30.4	30.6	30.9	31.3	31.7	32.2	32.7	33.3	33.8	**33.9**	33.8	33.6	33.3	33.1	32.8
126	32.4	32	31.6	31.2	30.8	30.4	30.2	30.2	30.2	30.3	30.5	30.8	31.2	31.6	32.1	32.7	33.2	33.6	**33.7**	33.7	33.5	33.2	33	32.7
132	32.3	31.9	31.5	31.1	30.7	30.4	30.1	30	30.1	30.2	30.4	30.7	31.1	31.6	32	32.5	33.1	33.5	**33.6**	33.5	33.3	33.1	32.9	32.6
138	32.1	31.8	31.4	31	30.6	30.3	30	29.9	29.9	30.1	30.3	30.6	31	31.4	31.9	32.4	32.9	33.3	**33.4**	**33.4**	33.2	32.9	32.[illegible]	32.5
144	32	31.6	31.3	30.9	30.5	30.1	29.9	29.8	29.8	29.9	30.2	30.5	30.9	31.3	31.8	32.3	32.8	33.2	**33.3**	33.2	33	32.8	32.6	32.3
150	31.9	31.5	31.2	30.8	30.4	30	29.8	29.7	29.7	29.8	30	30.4	30.7	31.2	31.7	32.1	32.6	33	**33.1**	33	32.8	32.6	32.4	32.2
156	31.7	31.4	31	30.7	30.3	29.9	29.7	29.5	29.5	29.7	29.9	30.2	30.6	31.1	31.6	32	32.5	32.8	**32.9**	32.9	32.7	32.5	32.3	32
162	31.6	31.3	30.9	30.6	30.2	29.8	29.6	29.4	29.4	29.5	29.8	30.1	30.5	31	31.5	31.9	32.3	32.7	**32.8**	32.7	32.6	32.4	32.1	31.9
168	31.5	31.2	30.8	30.5	30.1	29.7	29.5	29.3	29.3	29.4	29.7	30	30.4	30.9	31.4	31.8	32.2	32.5	**32.6**	32.6	32.4	32.2	32	31.8
174	31.5	31.1	30.8	30.4	30.1	29.7	29.4	29.3	29.3	29.4	29.7	30	30.4	30.9	31.3	31.8	32.2	32.5	**32.6**	32.5	32.4	32.2	32	31.7
180	31.4	31.1	30.8	30.4	30	29.7	29.4	29.3	29.2	29.4	29.6	30	30.4	30.8	31.3	31.8	32.2	32.4	**32.5**	**32.5**	32.3	32.1	31.9	31.7
186	31.4	31.1	30.8	30.4	30.1	29.7	29.4	29.3	29.3	29.4	29.7	30	30.4	30.9	31.3	31.8	32.2	32.5	**32.6**	32.5	32.4	32.2	32	31.7
192	31.5	31.2	30.8	30.5	30.1	29.7	29.5	29.4	29.3	29.5	29.7	30.1	30.5	30.9	31.4	31.9	32.3	32.5	**32.6**	32.6	32.4	32.2	32	31.8
198	31.6	31.2	30.9	30.5	30.2	29.8	29.6	29.5	29.5	29.6	29.8	30.2	30.6	31	31.5	32	32.4	32.6	**32.7**	32.7	32.5	32.3	32.1	31.9
204	31.7	31.3	31	30.6	30.3	29.9	29.7	29.6	29.6	29.7	30	30.3	30.7	31.1	31.6	32.1	32.5	32.8	**32.9**	32.8	32.6	32.4	32.2	32
210	31.8	31.5	31.1	30.7	30.4	30	29.8	29.7	29.7	29.9	30.1	30.5	30.9	31.3	31.7	32.2	32.6	32.9	**33**	32.9	32.8	32.6	32.3	32.1
216	31.9	31.6	31.2	30.8	30.5	30.1	29.9	29.9	29.9	30	30.3	30.6	31	31.4	31.9	32.3	32.8	33.1	**33.2**	33.1	32.9	32.7	32.5	32.2
222	32	31.7	31.3	31	30.6	30.2	30	30	30.1	30.2	30.4	30.8	31.2	31.6	32	32.5	32.9	**33.3**	**33.3**	**33.3**	33.1	32.8	32.6	32.4
228	32.2	31.8	31.4	31.1	30.7	30.3	30.1	30.1	30.2	30.3	30.6	30.9	31.3	31.7	32.1	32.6	33.1	33.4	**33.5**	33.4	33.2	33	32.[illegible]	32.5
234	32.3	31.9	31.5	31.1	30.7	30.4	30.2	30.2	30.3	30.5	30.7	31	31.4	31.8	32.2	32.7	33.2	**33.5**	**33.6**	33.5	33.3	33.1	32.8	32.6
240	32.3	32	31.6	31.2	30.8	30.4	30.2	30.3	30.4	30.6	30.8	31.2	31.5	31.9	32.3	32.8	33.3	33.6	**33.7**	33.6	33.4	33.2	32.9	32.7
246	32.4	32	31.7	31.3	30.9	30.5	30.3	30.4	30.5	30.7	30.9	31.2	31.6	32	32.4	32.9	33.4	33.7	**33.8**	33.7	33.5	33.2	33	32.7
252	32.4	32.1	31.7	31.3	30.9	30.5	30.3	30.4	30.6	30.7	31	31.3	31.7	32.1	32.5	33	33.4	**33.8**	**33.8**	33.7	33.5	33.3	33	32.8
258	32.5	32.1	31.7	31.3	30.9	30.5	30.3	30.4	30.6	30.8	31	31.3	31.7	32.1	32.5	33	33.5	33.8	**33.9**	33.8	33.6	33.3	33.1	32.8
264	32.5	32.1	31.7	31.3	30.9	30.5	30.4	30.4	30.6	30.8	31.1	31.4	31.7	32.1	32.6	33	33.5	33.8	**33.9**	33.8	33.6	33.3	33.1	32.8
270	32.5	32.1	31.7	31.4	30.9	30.5	30.4	30.4	30.6	30.8	31.1	31.4	31.8	32.2	32.6	33.1	33.5	33.8	**33.9**	33.8	33.6	33.4	33.1	32.8
276	32.5	32.1	31.8	31.4	31	30.6	30.4	30.4	30.6	30.8	31.1	31.4	31.8	32.2	32.6	33.1	33.5	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.8
282	32.5	32.2	31.8	31.4	31	30.6	30.4	30.5	30.6	30.8	31.1	31.4	31.8	32.2	32.6	33.1	33.5	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
288	32.5	32.2	31.8	31.4	31	30.6	30.4	30.5	30.6	30.8	31.1	31.4	31.8	32.2	32.6	33.1	33.5	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
294	32.5	32.1	31.8	31.4	31	30.6	30.4	30.4	30.6	30.8	31.1	31.4	31.8	32.2	32.6	33.1	33.5	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.8
300	32.5	32.1	31.7	31.3	30.9	30.5	30.3	30.4	30.5	30.8	31	31.3	31.7	32.1	32.5	33	33.5	33.8	**33.9**	33.8	33.6	33.3	33.1	32.8
306	32.4	32	31.7	31.3	30.9	30.5	30.3	30.3	30.5	30.7	31	31.3	31.6	32	32.5	32.9	33.4	33.7	**33.8**	33.7	33.5	33.2	33	32.7
312	32.3	31.9	31.6	31.2	30.8	30.4	30.2	30.2	30.3	30.6	30.8	31.1	31.5	31.9	32.4	32.8	33.3	33.6	**33.7**	33.6	33.4	33.1	32.9	32.6
318	32.2	31.8	31.5	31.1	30.7	30.3	30.1	30.1	30.2	30.4	30.7	31	31.4	31.8	32.2	32.7	33.1	33.4	**33.5**	33.4	33.2	33	32.8	32.5
324	32.1	31.7	31.3	31	30.6	30.2	30	29.9	30	30.2	30.5	30.8	31.2	31.6	32.1	32.5	32.9	**33.3**	**33.3**	**33.3**	33.1	32.9	32.6	32.4
330	31.9	31.6	31.2	30.8	30.5	30.1	29.8	29.8	29.8	30	30.3	30.6	31	31.5	31.9	32.4	32.8	33.1	**33.2**	33.1	32.9	32.7	32.5	32.2
336	31.8	31.4	31.1	30.7	30.3	30	29.7	29.6	29.7	29.8	30.1	30.4	30.8	31.3	31.7	32.2	32.6	32.9	**33**	32.9	32.8	32.5	32.3	32.1
342	31.7	31.3	31	30.6	30.2	29.9	29.6	29.5	29.5	29.7	29.9	30.3	30.7	31.1	31.6	32	32.4	32.7	**32.8**	**32.8**	32.6	32.4	32.2	32
348	31.5	31.2	30.9	30.5	30.1	29.8	29.5	29.4	29.4	29.5	29.8	30.1	30.5	31	31.5	31.9	32.3	32.6	**32.7**	32.6	32.5	32.3	32.1	31.8
354	31.5	31.2	30.8	30.5	30.1	29.7	29.5	29.3	29.3	29.4	29.7	30.1	30.5	30.9	31.4	31.9	32.2	32.5	**32.6**	**32.6**	32.4	32.2	32	31.8

MONTH = 5 (MAY)

←------------------- DAILY HOUR (1 – 24) -------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	27	27	26.1	25.5	25.4	25	25.4	26.1	28	31.3	32.8	34.6	36	37	38.3	38	37.8	37.4	35.8	31.2	28.8	28.3	28.3	27.4

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR-------------------→

PRA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	33.7	33.4	33.1	32.8	32.4	32.1	32	32	32.1	32.3	32.6	32.9	33.3	33.7	34.2	34.6	34.9	**35.2**	**35.2**	35.1	34.8	34.6	34.3	34
6	33.7	33.4	33.1	32.8	32.4	32.2	32	32	32.1	32.3	32.6	33	33.3	33.7	34.2	34.6	34.9	**35.2**	**35.2**	35.1	34.8	34.6	34.3	34
12	33.7	33.4	33.1	32.8	32.5	32.2	32	32.1	32.2	32.4	32.7	33	33.4	33.8	34.2	34.6	35	35.2	**35.3**	35.1	34.9	34.6	34.3	34
18	33.7	33.4	33.1	32.8	32.5	32.2	32.1	32.1	32.2	32.4	32.7	33.1	33.4	33.8	34.3	34.7	35.1	**35.3**	**35.3**	35.2	34.9	34.6	34.4	34.1
24	33.8	33.5	33.2	32.9	32.6	32.3	32.2	32.2	32.3	32.5	32.8	33.2	33.5	33.9	34.3	34.8	35.2	**35.4**	**35.4**	35.3	35	34.7	34.4	34.1
30	33.9	33.6	33.3	33	32.7	32.4	32.3	32.3	32.4	32.6	32.9	33.3	33.6	34	34.4	34.9	35.3	35.5	**35.6**	35.4	35.2	34.9	34.6	34.3
36	34.1	33.8	33.4	33.1	32.8	32.5	32.4	32.4	32.6	32.8	33	33.4	33.7	34.1	34.5	35	35.4	**35.7**	**35.7**	35.6	35.3	35	34.7	34.4
42	34.2	33.9	33.6	33.2	32.9	32.6	32.5	32.6	32.7	32.9	33.2	33.5	33.8	34.2	34.6	35.1	35.6	**35.9**	**35.9**	35.8	35.5	35.2	34.8	34.5
48	34.3	34	33.7	33.4	33	32.7	32.6	32.7	32.8	33	33.3	33.6	33.9	34.3	34.7	35.2	35.7	36	**36.1**	35.9	35.6	35.3	35	34.7
54	34.5	34.1	33.8	33.5	33.1	32.8	32.7	32.8	32.9	33.1	33.4	33.7	34	34.4	34.8	35.3	35.8	36.2	**36.3**	36.1	35.8	35.5	35.1	34.8
60	34.6	34.2	33.9	33.6	33.2	32.9	32.8	32.9	33	33.2	33.4	33.8	34.1	34.4	34.9	35.4	36	36.3	**36.4**	36.2	35.9	35.6	35.3	34.9
66	34.6	34.3	34	33.6	33.3	33	32.9	32.9	33.1	33.2	33.5	33.8	34.1	34.5	34.9	35.5	36	36.4	**36.5**	36.3	36	35.7	35.3	35
72	34.7	34.3	34	33.7	33.3	33	32.9	32.9	33.1	33.3	33.5	33.8	34.1	34.5	35	35.5	36.1	36.4	**36.5**	36.3	36	35.7	35.4	35
78	34.7	34.4	34	33.7	33.3	33	32.9	32.9	33.1	33.3	33.5	33.8	34.1	34.5	35	35.5	36.1	**36.5**	**36.5**	36.4	36.1	35.7	35.4	35.1
84	34.7	34.4	34	33.7	33.3	33	32.9	33	33.1	33.3	33.5	33.8	34.1	34.5	35	35.5	36.1	36.5	**36.6**	36.4	36.1	35.7	35.4	35.1
90	34.7	34.4	34	33.7	33.3	33	32.9	33	33.1	33.3	33.5	33.8	34.1	34.5	35	35.5	36.1	36.5	**36.6**	36.4	36.1	35.7	35.4	35.1
96	34.7	34.4	34	33.7	33.3	33	32.9	33	33.1	33.3	33.5	33.8	34.1	34.5	35	35.5	36.1	36.5	**36.6**	36.4	36.1	35.7	35.4	35.1
102	34.7	34.4	34	33.7	33.3	33	32.9	33	33.1	33.3	33.5	33.8	34.1	34.5	35	35.5	36.1	**36.5**	**36.5**	36.4	36.1	35.7	35.4	35.1
108	34.7	34.4	34	33.7	33.3	33	32.9	32.9	33.1	33.3	33.5	33.8	34.1	34.5	34.9	35.5	36	**36.5**	**36.5**	36.4	36.1	35.7	35.4	35
114	34.7	34.3	34	33.6	33.3	33	32.9	32.9	33	33.2	33.5	33.7	34.1	34.5	34.9	35.5	36	36.4	**36.5**	36.3	36	35.7	35.4	35
120	34.6	34.3	34	33.6	33.2	32.9	32.8	32.9	33	33.2	33.4	33.7	34	34.4	34.9	35.4	35.9	**36.4**	**36.4**	36.3	36	35.6	35.3	35
126	34.6	34.2	33.9	33.5	33.2	32.9	32.7	32.8	32.9	33.1	33.3	33.6	34	34.4	34.8	35.3	35.8	36.3	**36.4**	36.2	35.9	35.6	35.2	34.9
132	34.5	34.1	33.8	33.4	33.1	32.8	32.7	32.7	32.8	33	33.2	33.5	33.9	34.3	34.7	35.2	35.7	36.1	**36.2**	36.1	35.8	35.4	35.1	34.8
138	34.4	34	33.7	33.4	33	32.7	32.6	32.6	32.7	32.9	33.1	33.4	33.8	34.2	34.6	35.1	35.6	36	**36.1**	35.9	35.6	35.3	35	34.7
144	34.2	33.9	33.6	33.3	32.9	32.6	32.5	32.5	32.6	32.8	33	33.3	33.7	34.1	34.5	35	35.5	35.9	**36**	35.8	35.5	35.2	34.9	34.6
150	34.1	33.8	33.5	33.2	32.8	32.5	32.4	32.3	32.4	32.6	32.9	33.2	33.6	34	34.4	34.9	35.3	35.7	**35.8**	35.7	35.4	35.1	34.8	34.5
156	34	33.7	33.4	33.1	32.7	32.4	32.2	32.2	32.3	32.5	32.8	33.1	33.5	33.9	34.3	34.8	35.2	35.6	**35.7**	35.5	35.2	34.9	34.6	34.3
162	33.9	33.6	33.3	33	32.6	32.3	32.2	32.1	32.2	32.4	32.7	33	33.4	33.8	34.3	34.7	35.1	35.4	**35.5**	35.4	35.1	34.8	34.5	34.2
168	33.8	33.5	33.2	32.9	32.6	32.3	32.1	32.1	32.2	32.4	32.7	33	33.4	33.8	34.2	34.6	35	35.3	**35.4**	35.3	35	34.7	34.4	34.1
174	33.7	33.4	33.1	32.8	32.5	32.2	32	32	32.1	32.3	32.6	33	33.3	33.7	34.2	34.6	35	35.2	**35.3**	35.2	34.9	34.6	34.3	34
180	33.7	33.4	33.1	32.8	32.5	32.2	32	32	32.1	32.3	32.6	33	33.3	33.7	34.2	34.6	34.9	35.2	**35.3**	35.1	34.9	34.6	34.3	34
186	33.7	33.4	33.1	32.8	32.5	32.2	32.1	32.1	32.2	32.4	32.7	33	33.4	33.8	34.2	34.6	35	35.2	**35.3**	35.1	34.9	34.6	34.3	34
192	33.7	33.4	33.1	32.8	32.5	32.2	32.1	32.2	32.3	32.5	32.8	33.1	33.5	33.9	34.3	34.7	35	**35.3**	**35.3**	35.2	34.9	34.6	34.3	34
198	33.8	33.5	33.2	32.9	32.6	32.3	32.2	32.3	32.4	32.6	32.9	33.2	33.6	33.9	34.4	34.8	35.1	**35.4**	**35.4**	35.3	35	34.7	34.4	34.1
204	33.9	33.6	33.3	32.9	32.6	32.3	32.3	32.4	32.5	32.7	33	33.3	33.7	34.1	34.5	34.9	35.2	**35.5**	**35.5**	35.4	35.1	34.8	34.5	34.2
210	34	33.7	33.4	33	32.7	32.4	32.4	32.5	32.7	32.9	33.1	33.5	33.8	34.2	34.6	35	35.4	**35.6**	**35.6**	35.5	35.2	34.9	34.6	34.3
216	34.1	33.8	33.5	33.1	32.8	32.5	32.5	32.6	32.8	33	33.3	33.6	33.9	34.3	34.7	35.1	35.5	35.7	**35.8**	35.6	35.3	35	34.7	34.4
222	34.2	33.9	33.5	33.2	32.9	32.6	32.6	32.7	32.9	33.1	33.4	33.7	34.1	34.4	34.8	35.2	35.6	35.8	**35.9**	35.7	35.5	35.1	34.8	34.5
228	34.3	34	33.6	33.3	33	32.7	32.7	32.8	33.1	33.3	33.5	33.8	34.2	34.5	34.9	35.3	35.7	**36**	**36**	35.9	35.6	35.3	34.9	34.6
234	34.4	34.1	33.7	33.4	33	32.8	32.7	32.9	33.2	33.4	33.7	33.9	34.3	34.6	35	35.4	35.8	**36.1**	**36.1**	36	35.7	35.4	35	34.7
240	34.5	34.1	33.8	33.5	33.1	32.8	32.8	33	33.2	33.5	33.7	34	34.4	34.7	35.1	35.5	35.9	**36.2**	**36.2**	36.1	35.8	35.4	35.1	34.8
246	34.5	34.2	33.8	33.5	33.2	32.9	32.8	33	33.3	33.6	33.8	34.1	34.4	34.7	35.1	35.6	36	**36.3**	**36.3**	36.1	35.8	35.5	35.2	34.9
252	34.5	34.2	33.9	33.5	33.2	32.9	32.9	33	33.3	33.6	33.8	34.1	34.4	34.8	35.1	35.6	36	**36.3**	**36.3**	36.2	35.9	35.5	35.2	34.9
258	34.6	34.2	33.9	33.5	33.2	32.9	32.9	33	33.3	33.6	33.8	34.1	34.5	34.8	35.2	35.6	36	**36.3**	**36.3**	36.2	35.9	35.5	35.2	34.9
264	34.6	34.2	33.9	33.5	33.2	32.9	32.9	33.1	33.3	33.6	33.8	34.1	34.5	34.8	35.2	35.6	36	36.3	**36.4**	36.2	35.9	35.6	35.2	34.9
270	34.6	34.2	33.9	33.5	33.2	32.9	32.9	33.1	33.3	33.6	33.8	34.1	34.5	34.8	35.2	35.6	36	36.3	**36.4**	36.2	35.9	35.6	35.2	34.9
276	34.6	34.2	33.9	33.5	33.2	32.9	32.9	33.1	33.3	33.6	33.8	34.1	34.4	34.8	35.2	35.6	36	36.3	**36.4**	36.2	35.9	35.5	35.2	34.9
282	34.5	34.2	33.9	33.5	33.2	32.9	32.9	33	33.3	33.6	33.8	34.1	34.4	34.8	35.2	35.6	36	**36.3**	**36.3**	36.2	35.9	35.5	35.2	34.9
288	34.5	34.2	33.9	33.5	33.2	32.9	32.8	33	33.3	33.6	33.8	34.1	34.4	34.8	35.2	35.6	36	**36.3**	**36.3**	36.2	35.9	35.5	35.2	34.9
294	34.5	34.2	33.9	33.5	33.2	32.9	32.8	33	33.2	33.5	33.8	34	34.4	34.7	35.1	35.5	36	**36.3**	**36.3**	36.1	35.9	35.5	35.2	34.9
300	34.5	34.2	33.8	33.5	33.1	32.8	32.8	32.9	33.2	33.4	33.7	34	34.3	34.7	35.1	35.5	35.9	36.2	**36.3**	36.1	35.8	35.5	35.1	34.8
306	34.4	34.1	33.7	33.4	33.1	32.8	32.7	32.8	33	33.3	33.6	33.8	34.2	34.5	34.9	35.4	35.8	36.1	**36.2**	36	35.7	35.4	35.1	34.7
312	34.3	34	33.7	33.3	33	32.7	32.6	32.7	32.9	33.1	33.4	33.7	34	34.4	34.8	35.2	35.6	**36**	**36**	35.9	35.6	35.3	35	34.6
318	34.2	33.9	33.5	33.2	32.9	32.6	32.5	32.5	32.7	33	33.2	33.5	33.9	34.3	34.7	35.1	35.5	35.8	**35.9**	35.7	35.5	35.1	34.8	34.5
324	34.1	33.8	33.4	33.1	32.8	32.5	32.3	32.4	32.6	32.8	33.1	33.4	33.7	34.1	34.5	35	35.3	**35.7**	**35.7**	35.6	35.3	35	34.7	34.4
330	34	33.7	33.3	33	32.7	32.4	32.2	32.3	32.4	32.6	32.9	33.2	33.6	34	34.4	34.8	35.2	35.5	**35.6**	35.5	35.2	34.9	34.6	34.3
336	33.9	33.6	33.3	32.9	32.6	32.3	32.1	32.1	32.3	32.5	32.8	33.1	33.5	33.9	34.3	34.7	35.1	35.4	**35.5**	35.3	35.1	34.8	34.5	34.2
342	33.8	33.5	33.2	32.9	32.5	32.2	32.1	32.1	32.2	32.4	32.7	33	33.4	33.8	34.2	34.6	35	35.3	**35.4**	35.2	35	34.7	34.4	34.1
348	33.7	33.4	33.1	32.8	32.5	32.2	32	32	32.1	32.3	32.6	33	33.3	33.7	34.2	34.6	35	35.2	**35.3**	35.2	34.9	34.6	34.3	34
354	33.7	33.4	33.1	32.8	32.5	32.2	32	32	32.1	32.3	32.6	32.9	33.3	33.7	34.2	34.6	34.9	35.2	**35.3**	35.1	34.9	34.6	34.3	34

MONTH = 6 (JUNE)

←------------------- DAILY HOUR (1 – 24) ------------------→

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	30.3	30.2	29.8	29	28.6	28.5	28.4	29.6	31	33.6	35	35.9	36.8	37.8	38.3	38.7	37.9	37.8	37.7	35.2	31.5	30.8	30.7	30.3
0	35.9	35.6	35.3	35.1	34.8	34.5	34.4	34.4	34.6	34.8	35.1	35.4	35.7	36	36.4	36.8	37.1	**37.3**	**37.3**	37.2	37	36.7	36.4	36.2
6	35.9	35.6	35.3	35.1	34.8	34.5	34.4	34.5	34.6	34.8	35.1	35.4	35.7	36.1	36.4	36.8	37.1	**37.3**	**37.3**	37.2	37	36.7	36.4	36.2
12	35.9	35.6	35.4	35.1	34.8	34.5	34.5	34.5	34.6	34.8	35.1	35.4	35.7	36.1	36.5	36.8	37.1	**37.3**	**37.3**	37.2	37	36.7	36.4	36.2
18	35.9	35.7	35.4	35.1	34.8	34.6	34.5	34 5	34.7	34.9	35.2	35.5	35.8	36.1	36.5	36.9	37.2	37.3	**37.4**	37.3	37	36.8	36.5	36.2
24	36	35.7	35.4	35.2	34.9	34.6	34.6	34.6	34.8	35	35.3	35.6	35.9	36.2	36.6	36.9	37.2	**37.4**	**37.4**	37.3	37.1	36.8	36.5	36.3
30	36.1	35.8	35.5	35.2	34.9	34.7	34.6	34.7	34.9	35.1	35.3	35.6	35.9	36.3	36.6	37	37.3	37.5	**37.6**	37.4	37.2	36.9	36.6	36.4
36	36.2	35.9	35.6	35.3	35	34.8	34.7	34.8	35	35.2	35.4	35.7	36	36.4	36.7	37.1	37.4	**37.7**	**37.7**	37.6	37.4	37.1	36.8	36.5
42	36.3	36	35.7	35.4	35.1	34.9	34.8	34.9	35.1	35.3	35.5	35.8	36.1	36.4	36.8	37.2	37.6	37.8	**37.9**	37.7	37.5	37.2	36.9	36.6
48	36.4	36.1	35.9	35.6	35.3	35	34.9	35	35.2	35.4	35.6	35.9	36.2	36.5	36.9	37.3	37.7	**38**	**38**	37.9	37.7	37.3	37	36.7
54	36.7	36.4	36.1	35.8	35.4	35.2	35.1	35.2	35.4	35.6	35.8	36.1	36.5	36.8	37.1	37.6	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
60	36.7	36.4	36.1	35.8	35.4	35.2	35.1	35.2	35.4	35.6	35.8	36.1	36.4	36.7	37	37.5	37.9	38.2	**38.3**	38.2	37.9	37.6	37.3	37
66	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.3	35.4	35.6	35.8	36.1	36.4	36.7	37.1	37.5	38	38.3	**38.4**	38.3	38	37.7	37.4	37.1
72	36.8	36.5	36.2	35.9	35.6	35.3	35.2	35.3	35.4	35.6	35.9	36.1	36.4	36.7	37.1	37.6	38	38.4	**38.5**	38.3	38.1	37.7	37.4	37.1
78	36.8	36.5	36.2	35.9	35.6	35.3	35.2	35.3	35.5	35.6	35.9	36.1	36.4	36.7	37.1	37.6	38.1	38.4	**38.5**	38.4	38.1	37.8	37.5	37.1
84	36.8	36.5	36.2	35.9	35.6	35.3	35.2	35.3	35.5	35.7	35.9	36.1	36.4	36.7	37.1	37.6	38.1	38.4	**38.5**	38.4	38.1	37.8	37.5	37.1
90	36.8	36.5	36.2	35.9	35.6	35.3	35.3	35.3	35.5	35.7	35.9	36.2	36.4	36.7	37.1	37.6	38.1	38.4	**38.5**	38.4	38.1	37.8	37.5	37.2
96	36.8	36.5	36.2	35.9	35.6	35.3	35.3	35.3	35.5	35.7	35.9	36.2	36.4	36.7	37.1	37.6	38.1	38.4	**38.5**	38.4	38.1	37.8	37.5	37.2
102	36.8	36.5	36.2	35.9	35.6	35.3	35.3	35.3	35.5	35.7	35.9	36.2	36.4	36.8	37.1	37.6	38.1	38.4	**38.5**	38.4	38.1	37.8	37.5	37.2
108	36.8	36.5	36.2	35.9	35.6	35.3	35.2	35.3	35.5	35.7	35.9	36.1	36.4	36.7	37.1	37.6	38.1	38.4	**38.5**	38.4	38.1	37.8	37.5	37.2
114	36.8	36.5	36.2	35.9	35.6	35.3	35.2	35.3	35.4	35.6	35.9	36.1	36.4	36.7	37.1	37.6	38	38.4	**38.5**	38.4	38.1	37.8	37.5	37.1
120	36.8	36.5	36.2	35.9	35.6	35.3	35.2	35.2	35.4	35.6	35.8	36.1	36.4	36.7	37	37.5	38	38.4	**38.5**	38.3	38.1	37.7	37.4	37.1
126	36.7	36.4	36.1	35.8	35.5	35.2	35.1	35.2	35.3	35.5	35.7	36	36.3	36.6	37	37.4	37.9	38.3	**38.4**	38.2	38	37.7	37.4	37
132	36.6	36.3	36	35.7	35.4	35.1	35	35.1	35.2	35.4	35.6	35.9	36.2	36.5	36.9	37.3	37.8	38.2	**38.3**	38.1	37.9	37.6	37.3	36.9
138	36.5	36.3	36	35.7	35.4	35.1	34.9	35	35.1	35.3	35.5	35.8	36.1	36.5	36.8	37.2	37.7	38	**38.2**	38	37.8	37.5	37.2	36.9
144	36.4	36.2	35.9	35.6	35.3	35	34.9	34.9	35	35.2	35.5	35.7	36	36.4	36.7	37.1	37.6	37.9	**38**	37.9	37.7	37.4	37.1	36.7
150	36.3	36.1	35.8	35.5	35.2	34.9	34.8	34.8	34.9	35.1	35.4	35.6	36	36.3	36.7	37	37.5	37.8	**37.9**	37.8	37.5	37.2	36.9	36.6
156	36.2	36	35.7	35.4	35.1	34.8	34.7	34.7	34.8	35	35.3	35.6	35.9	36.2	36.6	37	37.3	37.7	**37.8**	37.6	37.4	37.1	36.8	36.5
162	36.2	36	35.7	35.4	35.1	34.8	34.7	34.7	34.8	35	35.3	35.6	35.9	36.3	36.7	37	37.4	37.7	**37.8**	37.7	37.4	37.1	36.8	36.5
168	36	35.8	35.5	35.2	34.9	34.7	34.5	34.5	34.6	34.9	35.1	35.4	35.8	36.1	36.5	36.8	37.2	37.4	**37.5**	37.4	37.2	36.9	36.6	36.3
174	36	35.7	35.4	35.2	34.9	34.6	34.5	34.5	34.6	34.8	35.1	35.4	35.7	36.1	36.5	36.8	37.1	**37.4**	**37.4**	37.3	37.1	36.8	36.5	36.3
180	35.9	35.7	35.4	35.1	34.8	34.6	34.5	34.5	34.6	34.8	35.1	35.4	35.8	36.1	36.5	36.8	37.1	37.3	**37.4**	37.3	37.1	36.8	36.5	36.2
186	35.9	35.7	35.4	35.1	34.8	34.6	34.5	34.6	34.7	34.9	35.2	35.5	35.8	36.1	36.5	36.9	37.2	37.3	**37.4**	37.3	37.1	36.8	36.5	36.2
192	36	35.7	35.4	35.1	34.9	34.6	34.6	34.6	34.8	35	35.3	35.6	35.9	36.2	36.6	36.9	37.2	**37.4**	**37.4**	37.3	37.1	36.8	36.5	36.2
198	36	35.7	35.5	35.2	34.9	34.7	34.6	34.7	34.9	35.1	35.4	35.7	36	36.3	36.7	37	37.3	**37.5**	**37.5**	37.4	37.2	36.9	36.6	36.3
204	36.1	35.8	35.5	35.3	35	34.7	34.7	34.8	35	35.2	35.5	35.8	36.1	36.4	36.8	37.1	37.4	**37.6**	**37.6**	37.5	37.3	37	36.7	36.4
210	36.2	35.9	35.6	35.3	35	34.8	34.8	35	35.1	35.4	35.6	35.9	36.2	36.5	36.9	37.2	37.5	**37.7**	**37.7**	37.6	37.4	37.1	36.8	36.5
216	36.3	36	35.7	35.4	35.1	34.9	34.9	35.1	35.3	35.5	35.8	36	36.3	36.6	37	37.3	37.6	**37.8**	**37.8**	37.7	37.5	37.2	36.9	36.6
222	36.4	36.1	35.8	35.5	35.2	34.9	35	35.2	35.4	35.6	35.9	36.2	36.4	36.7	37.1	37.4	37.7	**37.9**	**37.9**	37.8	37.6	37.3	37	36.7
228	36.5	36.2	35.9	35.6	35.3	35	35	35.2	35.5	35.7	36	36.3	36.5	36.8	37.2	37.5	37.8	38	**38.1**	37.9	37.7	37.4	37.1	36.8
234	36.6	36.3	36.1	35.7	35.4	35.2	35.2	35.4	35.7	35.9	36.2	36.5	36.8	37.1	37.4	37.7	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
240	36.6	36.3	36	35.7	35.4	35.1	35.2	35.4	35.7	35.9	36.2	36.4	36.7	37	37.3	37.6	38	**38.2**	**38.2**	38.1	37.9	37.5	37.2	36.9
246	36.7	36.4	36.1	35.8	35.4	35.2	35.2	35.4	35.7	36	36.2	36.5	36.7	37	37.3	37.7	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
252	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.4	35.7	36	36.2	36.5	36.8	37	37.3	37.7	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
258	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.4	35.7	36	36.2	36.5	36.8	37	37.3	37.7	38	38.3	**38.4**	38.2	38	37.6	37.3	37
264	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.4	35.7	36	36.2	36.5	36.8	37	37.3	37.7	38	38.3	**38.4**	38.2	38	37.6	37.3	37
270	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.4	35.7	36	36.2	36.5	36.8	37	37.3	37.7	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
276	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.4	35.7	36	36.2	36.5	36.7	37	37.3	37.7	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
282	36.7	36.4	36.1	35.8	35.5	35.2	35.2	35.4	35.7	36	36.2	36.4	36.7	37	37.3	37.7	38	**38.3**	**38.3**	38.2	37.9	37.6	37.3	37
288	36.7	36.4	36.1	35.8	35.4	35.2	35.2	35.4	35.6	35.9	36.2	36.4	36.7	37	37.3	37.7	38	38.2	**38.3**	38.2	37.9	37.6	37.3	37
294	36.6	36.3	36	35.7	35.4	35.2	35.1	35.3	35.6	35.9	36.1	36.3	36.6	36.9	37.3	37.6	38	38.2	**38.3**	38.1	37.9	37.6	37.3	36.9
300	36.6	36.3	36	35.7	35.4	35.1	35.1	35.2	35.5	35.8	36	36.2	36.5	36.8	37.2	37.5	37.9	38.1	**38.2**	38.1	37.8	37.5	37.2	36.9
306	36.5	36.2	35.9	35.6	35.3	35	35	35.1	35.4	35.6	35.9	36.1	36.4	36.7	37.1	37.4	37.8	38	**38.1**	38	37.7	37.4	37.1	36.8
312	36.4	36.1	35.8	35.5	35.2	35	34.9	35	35.2	35.5	35.7	36	36.3	36.6	36.9	37.3	37.6	37.9	**38**	37.9	37.6	37.3	37	36.7
318	36.3	36	35.7	35.5	35.2	34.9	34.8	34.9	35.1	35.3	35.5	35.8	36.1	36.5	36.8	37.2	37.5	37.8	**37.9**	37.7	37.5	37.2	36.9	36.6
324	36.2	35.9	35.7	35.4	35.1	34.8	34.7	34.7	34.9	35.1	35.4	35.7	36	36.3	36.7	37	37.4	**37.7**	**37.7**	37.6	37.4	37.1	36.8	36.5
330	36.1	35.8	35.6	35.3	35	34.7	34.6	34.6	34.8	35	35.3	35.6	35.9	36.2	36.6	36.9	37.3	37.5	**37.6**	37.5	37.3	37	36.7	36.4
336	36	35.8	35.5	35.2	34.9	34.7	34.5	34.5	34.7	34.9	35.2	35.5	35.8	36.1	36.5	36.9	37.2	37.4	**37.5**	37.4	37.2	36.9	36.6	36.3
342	36.1	35.8	35.5	35.2	35	34.7	34.5	34.5	34.7	34.9	35.2	35.5	35.8	36.2	36.6	37	37.3	37.5	**37.6**	37.5	37.2	36.9	36.7	36.4
348	35.9	35.7	35.4	35.1	34.8	34.6	34.4	34.4	34.6	34.8	35.1	35.4	35.7	36	36.4	36.8	37.1	37.3	**37.4**	37.3	37.1	36.8	36.5	36.2
354	35.9	35.6	35.4	35.1	34.8	34.6	34.4	34.4	34.6	34.8	35.1	35.4	35.7	36.1	36.4	36.8	37.1	37.3	**37.4**	37.2	37	36.8	36.5	36.2

MONTH = 7 (JULY)

←------------------- DAILY HOUR (1 – 24) -------------------→

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR-------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T OUT >	27.6	27.1	27.1	27	26.9	26.5	26.1	26.1	27	30	30.7	31.2	32	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
0	32.6	32.4	32.2	31.9	31.7	31.5	31.4	31.4	31.5	31.7	32	32.2	32.5	32.8	33.2	33.5	33.7	**33.9**	**33.9**	33.7	33.6	33.4	33.1	32.9
6	32.6	32.4	32.1	31.9	31.7	31.5	31.4	31.4	31.5	31.7	32	32.3	32.5	32.8	33.2	33.5	33.7	**33.9**	**33.9**	33.7	33.6	33.4	33.1	32.9
12	32.7	32.4	32.2	31.9	31.7	31.5	31.4	31.5	31.6	31.8	32	32.3	32.6	32.9	33.2	33.5	33.8	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
18	32.7	32.5	32.2	32	31.8	31.5	31.5	31.5	31.6	31.8	32.1	32.4	32.6	32.9	33.3	33.6	33.8	**34**	**34**	33.8	33.7	33.4	33.2	32.9
24	32.8	32.5	32.3	32.1	31.8	31.6	31.5	31.6	31.7	31.9	32.2	32.5	32.7	33	33.3	33.7	33.9	**34.1**	**34.1**	33.9	33.8	33.5	33.3	33
30	32.9	32.6	32.4	32.1	31.9	31.7	31.6	31.7	31.8	32	32.3	32.5	32.8	33.1	33.4	33.7	34	**34.2**	**34.2**	34	33.9	33.6	33.4	33.1
36	33	32.7	32.5	32.3	32	31.8	31.7	31.8	31.9	32.1	32.4	32.7	32.9	33.2	33.5	33.8	34.2	**34.4**	34.3	34.2	34	33.8	33.5	33.3
42	33.1	32.9	32.6	32.4	32.1	31.9	31.8	31.9	32.1	32.3	32.5	32.8	33	33.3	33.6	34	34.3	**34.5**	**34.5**	34.4	34.2	33.9	33.7	33.4
48	33.3	33	32.7	32.5	32.2	32	32	32	32.2	32.4	32.6	32.9	33.1	33.4	33.7	34.1	34.4	**34.7**	**34.7**	34.5	34.3	34.1	33.8	33.5
54	33.4	33.1	32.9	32.6	32.4	32.1	32.1	32.1	32.3	32.5	32.7	33	33.2	33.5	33.8	34.2	34.6	**34.8**	**34.8**	34.7	34.5	34.2	33.9	33.7
60	33.5	33.2	32.9	32.7	32.4	32.2	32.1	32.2	32.4	32.6	32.8	33	33.3	33.5	33.9	34.3	34.7	**35**	**35**	34.8	34.6	34.3	34.1	33.8
66	33.6	33.3	33	32.7	32.5	32.2	32.2	32.3	32.4	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.7	35	**35.1**	34.9	34.7	34.4	34.1	33.8
72	33.6	33.3	33	32.8	32.5	32.3	32.2	32.3	32.4	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.8	**35.1**	**35.1**	34.9	34.7	34.5	34.2	33.9
78	33.6	33.3	33.1	32.8	32.5	32.3	32.2	32.3	32.4	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.8	**35.1**	**35.1**	35	34.7	34.5	34.2	33.9
84	33.7	33.4	33.1	32.9	32.6	32.4	32.3	32.4	32.5	32.7	32.9	33.1	33.4	33.6	34	34.4	34.9	**35.2**	**35.2**	35.1	34.8	34.6	34.3	34
90	33.6	33.3	33.1	32.8	32.5	32.3	32.2	32.3	32.5	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.8	**35.1**	**35.1**	35	34.7	34.5	34.2	33.9
96	33.6	33.3	33.1	32.8	32.5	32.3	32.2	32.3	32.5	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.8	**35.1**	**35.1**	35	34.7	34.5	34.2	33.9
102	33.6	33.3	33.1	32.8	32.5	32.3	32.2	32.3	32.5	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.8	**35.1**	**35.1**	35	34.7	34.5	34.2	33.9
108	33.6	33.3	33.1	32.8	32.5	32.3	32.2	32.3	32.4	32.6	32.8	33.1	33.3	33.6	33.9	34.3	34.8	**35.1**	**35.1**	35	34.7	34.5	34.2	33.9
114	33.6	33.3	33	32.8	32.5	32.3	32.2	32.3	32.4	32.6	32.8	33	33.3	33.6	33.9	34.3	34.7	**35.1**	**35.1**	34.9	34.7	34.4	34.2	33.9
120	33.5	33.3	33	32.7	32.5	32.2	32.1	32.2	32.4	32.5	32.8	33	33.2	33.5	33.8	34.2	34.7	**35**	**35**	34.9	34.7	34.4	34.1	33.8
126	33.5	33.2	32.9	32.7	32.4	32.2	32.1	32.1	32.3	32.5	32.7	32.9	33.2	33.4	33.7	34.1	34.6	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
132	33.4	33.1	32.8	32.6	32.3	32.1	32	32	32.2	32.4	32.6	32.8	33.1	33.4	33.7	34	34.5	**34.8**	**34.8**	34.7	34.5	34.2	33.9	33.7
138	33.3	33	32.8	32.5	32.3	32	31.9	31.9	32.1	32.2	32.5	32.7	33	33.3	33.6	33.9	34.3	34.6	**34.7**	34.5	34.3	34.1	33.8	33.5
144	33.2	32.9	32.7	32.4	32.2	31.9	31.8	31.8	31.9	32.1	32.4	32.6	32.9	33.2	33.5	33.8	34.2	34.5	**34.6**	34.4	34.2	34	33.7	33.4
150	33.1	32.8	32.6	32.3	32.1	31.8	31.7	31.7	31.8	32	32.3	32.5	32.8	33.1	33.4	33.7	34.1	**34.4**	**34.4**	34.3	34.1	33.8	33.6	33.3
156	33	32.7	32.5	32.2	32	31.7	31.6	31.6	31.7	31.9	32.2	32.4	32.7	33	33.3	33.7	34	34.2	**34.3**	34.1	34	33.7	33.5	33.2
162	32.9	32.7	32.4	32.2	32	31.7	31.6	31.6	31.7	31.9	32.2	32.4	32.7	33	33.4	33.7	34	34.2	**34.3**	34.1	33.9	33.7	33.5	33.2
168	32.8	32.5	32.3	32	31.8	31.6	31.5	31.5	31.6	31.8	32	32.3	32.6	32.9	33.2	33.5	33.8	**34**	**34**	33.9	33.7	33.5	33.3	33
174	32.7	32.4	32.2	32	31.8	31.5	31.4	31.4	31.5	31.7	32	32.3	32.5	32.8	33.2	33.5	33.7	**33.9**	**33.9**	33.8	33.6	33.4	33.2	32.9
180	32.7	32.4	32.2	31.9	31.7	31.5	31.4	31.4	31.5	31.7	32	32.3	32.5	32.9	33.2	33.5	33.7	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
186	32.7	32.4	32.2	31.9	31.7	31.5	31.4	31.5	31.6	31.8	32	32.3	32.6	32.9	33.2	33.5	33.8	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9
192	32.7	32.5	32.2	32	31.8	31.5	31.5	31.6	31.7	31.9	32.1	32.4	32.7	33	33.3	33.6	33.8	**34**	**34**	33.8	33.7	33.4	33.2	32.9
198	32.8	32.5	32.3	32	31.8	31.6	31.5	31.6	31.8	32	32.2	32.5	32.8	33.1	33.4	33.7	33.9	**34.1**	34	33.9	33.7	33.5	33.2	33
204	32.8	32.6	32.3	32.1	31.9	31.7	31.6	31.8	31.9	32.1	32.4	32.6	32.9	33.2	33.5	33.8	34	**34.2**	34.1	34	33.8	33.6	33.3	33.1
210	32.9	32.7	32.4	32.2	32	31.7	31.7	31.9	32	32.2	32.5	32.8	33	33.3	33.6	33.9	34.1	**34.3**	**34.3**	34.1	33.9	33.7	33.4	33.2
216	33	32.8	32.5	32.3	32	31.8	31.8	32	32.2	32.4	32.6	32.9	33.1	33.4	33.7	34	34.2	**34.4**	**34.4**	34.2	34	33.8	33.5	33.3
222	33.1	32.9	32.6	32.4	32.1	31.9	31.9	32.1	32.3	32.5	32.8	33	33.2	33.5	33.8	34.1	34.4	**34.5**	**34.5**	34.4	34.2	33.9	33.6	33.4
228	33.2	33	32.7	32.4	32.2	32	32	32.2	32.4	32.6	32.9	33.1	33.4	33.6	33.9	34.2	34.5	**34.6**	**34.6**	34.5	34.3	34	33.8	33.5
234	33.3	33	32.8	32.5	32.3	32	32	32.3	32.5	32.8	33	33.2	33.5	33.7	34	34.3	34.6	**34.8**	**34.7**	34.6	34.4	34.1	33.9	33.6
240	33.4	33.1	32.8	32.6	32.3	32.1	32.1	32.3	32.6	32.8	33.1	33.3	33.5	33.8	34	34.3	34.6	**34.8**	**34.8**	34.7	34.5	34.2	33.9	33.7
246	33.4	33.2	32.9	32.6	32.4	32.1	32.1	32.4	32.6	32.9	33.1	33.4	33.6	33.8	34.1	34.4	34.7	**34.9**	**34.9**	34.7	34.5	34.3	34	33.7
252	33.5	33.2	32.9	32.7	32.4	32.2	32.2	32.4	32.7	32.9	33.2	33.4	33.6	33.9	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
258	33.5	33.2	32.9	32.7	32.4	32.2	32.2	32.4	32.7	32.9	33.2	33.4	33.6	33.9	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
264	33.5	33.2	32.9	32.7	32.4	32.2	32.2	32.4	32.7	32.9	33.2	33.4	33.6	33.9	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
270	33.5	33.2	32.9	32.7	32.4	32.2	32.2	32.4	32.7	32.9	33.2	33.4	33.6	33.9	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
276	33.5	33.2	32.9	32.7	32.4	32.2	32.2	32.4	32.7	32.9	33.2	33.4	33.6	33.9	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
282	33.5	33.2	32.9	32.7	32.4	32.2	32.2	32.4	32.6	32.9	33.2	33.4	33.6	33.9	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
288	33.5	33.2	32.9	32.7	32.4	32.2	32.1	32.3	32.6	32.9	33.1	33.3	33.6	33.8	34.1	34.4	34.7	**34.9**	**34.9**	34.8	34.6	34.3	34	33.7
294	33.4	33.2	32.9	32.6	32.4	32.2	32.1	32.3	32.6	32.9	33.1	33.3	33.5	33.8	34.1	34.4	34.7	**34.9**	**34.9**	34.7	34.5	34.3	34	33.7
300	33.4	33.1	32.9	32.6	32.4	32.1	32.1	32.2	32.5	32.8	33	33.2	33.5	33.7	34	34.3	34.6	**34.8**	**34.8**	34.7	34.5	34.2	33.9	33.7
306	33.3	33.1	32.8	32.5	32.3	32.1	32	32.2	32.4	32.6	32.9	33.1	33.3	33.6	33.9	34.2	34.5	34.7	**34.8**	34.6	34.4	34.1	33.9	33.6
312	33.2	33	32.7	32.5	32.2	32	31.9	32	32.2	32.5	32.7	33	33.2	33.5	33.8	34.1	34.4	**34.6**	**34.6**	34.5	34.3	34	33.8	33.5
318	33.1	32.9	32.6	32.4	32.1	31.9	31.8	31.9	32.1	32.3	32.6	32.8	33.1	33.4	33.7	34	34.3	**34.5**	**34.5**	34.3	34.2	33.9	33.6	33.4
324	33	32.8	32.5	32.3	32	31.8	31.7	31.8	31.9	32.2	32.4	32.6	32.9	33.2	33.5	33.8	34.1	**34.3**	**34.3**	34.2	34	33.8	33.5	33.3
330	32.9	32.7	32.4	32.2	31.9	31.7	31.6	31.6	31.8	32	32.3	32.5	32.8	33.1	33.4	33.7	34	**34.2**	**34.2**	34.1	33.9	33.7	33.4	33.2
336	32.8	32.6	32.3	32.1	31.9	31.6	31.5	31.5	31.7	31.9	32.1	32.4	32.7	33	33.3	33.6	33.9	**34.1**	**34.1**	34	33.8	33.6	33.3	33.1
342	32.8	32.6	32.3	32.1	31.9	31.6	31.5	31.5	31.6	31.8	32.1	32.4	32.6	33	33.4	33.7	33.9	**34.1**	**34.1**	34	33.8	33.6	33.3	33.1
348	32.7	32.4	32.2	32	31.7	31.5	31.4	31.4	31.5	31.7	32	32.3	32.5	32.9	33.2	33.5	33.8	**33.9**	**33.9**	33.8	33.6	33.4	33.2	32.9
354	32.7	32.4	32.2	31.9	31.7	31.5	31.4	31.4	31.5	31.7	32	32.3	32.5	32.8	33.2	33.5	33.7	**33.9**	**33.9**	33.8	33.6	33.4	33.1	32.9

MONTH = 8 (AUGUST)

←------------------- DAILY HOUR (1 – 24) ------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	28	27.5	27.5	27.1	26.6	26.5	26.4	26.4	26.9	29.7	29.7	30.4	32.1	32.7	33.2	33.6	33.4	32.5	31.8	30.6	30.1	29.5	29	28.5

⇓PRA (Plan Rotation Angle) ←------------------- INDOOR TEMPERATURE on DAILY HOUR------------------→

PRA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	32.3	32.1	31.8	31.6	31.4	31.2	31	31	31.1	31.3	31.6	31.8	32.1	32.4	32.7	33.1	33.3	**33.4**	33.3	33.2	33	32.9	32.7	32.5
6	32.3	32.1	31.9	31.7	31.4	31.2	31.1	31.1	31.2	31.4	31.6	31.9	32.1	32.4	32.8	33.1	33.3	**33.4**	**33.4**	33.2	33.1	32.9	32.7	32.5
12	32.4	32.1	31.9	31.7	31.5	31.3	31.1	31.1	31.2	31.4	31.7	31.9	32.2	32.5	32.8	33.1	33.4	**33.5**	33.4	33.3	33.1	33	32.8	32.6
18	32.5	32.2	32	31.8	31.6	31.3	31.2	31.2	31.3	31.5	31.8	32	32.3	32.6	32.9	33.3	33.5	**33.7**	33.6	33.4	33.3	33.1	32.9	32.7
24	32.6	32.4	32.2	31.9	31.7	31.5	31.3	31.4	31.5	31.7	31.9	32.1	32.4	32.7	33	33.4	33.7	**33.8**	33.8	33.6	33.4	33.2	33	32.8
30	32.8	32.5	32.3	32.1	31.8	31.6	31.5	31.5	31.6	31.8	32	32.3	32.5	32.8	33.2	33.5	33.9	**34**	**34**	33.8	33.6	33.4	33.2	33
36	32.9	32.7	32.4	32.2	32	31.7	31.6	31.6	31.8	31.9	32.2	32.4	32.6	32.9	33.3	33.7	34	**34.2**	**34.2**	34	33.8	33.6	33.4	33.1
42	33.1	32.8	32.6	32.3	32.1	31.8	31.7	31.8	31.9	32.1	32.3	32.5	32.8	33	33.4	33.8	34.2	**34.4**	34.3	34.2	34	33.7	33.5	33.3
48	33.2	32.9	32.7	32.4	32.2	31.9	31.8	31.9	32	32.2	32.4	32.6	32.9	33.1	33.5	33.9	34.3	**34.6**	34.5	34.3	34.1	33.9	33.7	33.4
54	33.3	33	32.8	32.5	32.3	32	31.9	32	32.1	32.3	32.5	32.7	32.9	33.2	33.6	34	34.4	**34.7**	34.6	34.4	34.2	34	33.8	33.5
60	33.4	33.1	32.8	32.6	32.3	32.1	31.9	32	32.2	32.3	32.5	32.8	33	33.3	33.7	34.1	34.5	**34.8**	34.7	34.5	34.3	34.1	33.8	33.6
66	33.4	33.1	32.9	32.6	32.4	32.1	32	32.1	32.2	32.4	32.6	32.8	33.1	33.3	33.7	34.1	34.6	**34.8**	34.8	34.6	34.4	34.1	33.9	33.6
72	33.4	33.2	32.9	32.6	32.4	32.1	32	32.1	32.2	32.4	32.6	32.8	33.1	33.3	33.7	34.2	34.6	**34.9**	34.8	34.6	34.4	34.2	33.9	33.7
78	33.4	33.2	32.9	32.6	32.4	32.1	32	32.1	32.2	32.4	32.6	32.8	33.1	33.4	33.7	34.2	34.6	**34.9**	34.8	34.6	34.4	34.2	33.9	33.7
84	33.4	33.2	32.9	32.6	32.4	32.1	32	32.1	32.2	32.4	32.6	32.8	33.1	33.3	33.7	34.2	34.6	**34.8**	**34.8**	34.6	34.4	34.2	33.9	33.7
90	33.4	33.1	32.9	32.6	32.4	32.1	32	32	32.2	32.4	32.6	32.8	33	33.3	33.7	34.1	34.6	**34.8**	**34.8**	34.6	34.4	34.1	33.9	33.6
96	33.4	33.1	32.9	32.6	32.3	32.1	32	32	32.2	32.4	32.6	32.8	33	33.3	33.7	34.1	34.5	**34.8**	**34.7**	34.6	34.3	34.1	33.9	33.6
102	33.4	33.1	32.8	32.6	32.3	32.1	32	32	32.2	32.4	32.6	32.8	33	33.3	33.6	34.1	34.5	**34.8**	34.7	34.5	34.3	34.1	33.9	33.6
108	33.3	33.1	32.8	32.6	32.3	32	31.9	32	32.2	32.3	32.5	32.7	33	33.3	33.6	34	34.5	**34.7**	**34.7**	34.5	34.3	34.1	33.8	33.6
114	33.3	33	32.8	32.5	32.3	32	31.9	32	32.1	32.3	32.5	32.7	33	33.2	33.6	34	34.4	**34.7**	34.6	34.4	34.2	34	33.8	33.5
120	33.2	33	32.7	32.5	32.2	31.9	31.8	31.9	32.1	32.3	32.5	32.6	32.9	33.2	33.5	33.9	34.3	**34.6**	34.5	34.3	34.1	33.9	33.7	33.5
126	33.1	32.9	32.6	32.4	32.1	31.9	31.8	31.8	32	32.2	32.4	32.6	32.8	33.1	33.4	33.8	34.2	**34.5**	34.4	34.2	34	33.8	33.6	33.4
132	33	32.8	32.5	32.3	32	31.8	31.7	31.7	31.9	32.1	32.3	32.5	32.7	33	33.3	33.7	34.1	**34.3**	**34.3**	34.1	33.9	33.7	33.5	33.3
138	32.9	32.7	32.4	32.2	31.9	31.7	31.6	31.6	31.8	32	32.2	32.4	32.6	32.9	33.2	33.6	33.9	**34.2**	34.1	34	33.8	33.6	33.4	33.1
144	32.8	32.5	32.3	32.1	31.8	31.6	31.5	31.5	31.6	31.8	32.1	32.3	32.5	32.8	33.1	33.5	33.8	**34**	**34**	33.8	33.6	33.4	33.2	33
150	32.6	32.4	32.2	32	31.7	31.5	31.4	31.4	31.5	31.7	31.9	32.1	32.4	32.7	33	33.3	33.6	**33.8**	**33.8**	33.7	33.5	33.3	33.1	32.9
156	32.5	32.3	32.1	31.8	31.6	31.4	31.2	31.3	31.4	31.6	31.8	32	32.3	32.6	32.9	33.2	33.5	**33.7**	33.6	33.5	33.3	33.1	32.9	32.7
162	32.4	32.2	32	31.8	31.5	31.3	31.2	31.2	31.3	31.5	31.7	31.9	32.2	32.5	32.8	33.1	33.4	**33.5**	**33.5**	33.4	33.2	33	32.8	32.6
168	32.4	32.2	31.9	31.7	31.5	31.3	31.1	31.1	31.2	31.4	31.7	31.9	32.2	32.5	32.8	33.1	33.4	**33.5**	**33.5**	33.3	33.1	33	32.8	32.6
174	32.3	32	31.8	31.6	31.4	31.2	31	31	31.1	31.3	31.6	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.3	33.2	33	32.9	32.7	32.5
180	32.2	32	31.8	31.6	31.4	31.2	31	31	31.1	31.3	31.6	31.8	32.1	32.4	32.7	33	33.2	**33.3**	**33.3**	33.2	33	32.8	32.6	32.4
186	32.3	32	31.8	31.6	31.4	31.2	31	31	31.1	31.3	31.6	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.3	33.2	33	32.8	32.7	32.5
192	32.3	32.1	31.9	31.7	31.4	31.2	31.1	31.1	31.2	31.4	31.7	31.9	32.2	32.5	32.8	33.1	33.3	**33.4**	**33.4**	33.2	33.1	32.9	32.7	32.5
198	32.4	32.2	31.9	31.7	31.5	31.3	31.2	31.2	31.3	31.5	31.8	32	32.3	32.5	32.9	33.2	33.4	**33.5**	**33.5**	33.3	33.2	33	32.8	32.6
204	32.5	32.3	32	31.8	31.6	31.4	31.3	31.3	31.4	31.6	31.9	32.1	32.4	32.6	33	33.3	33.5	**33.7**	33.6	33.4	33.3	33.1	32.9	32.7
210	32.6	32.4	32.1	31.9	31.7	31.4	31.3	31.4	31.6	31.8	32	32.3	32.5	32.8	33.1	33.4	33.7	**33.8**	33.7	33.6	33.4	33.2	33	32.8
216	32.7	32.5	32.2	32	31.8	31.5	31.5	31.6	31.7	31.9	32.2	32.4	32.6	32.9	33.2	33.5	33.8	**33.9**	**33.9**	33.7	33.5	33.3	33.1	32.9
222	32.8	32.6	32.3	32.1	31.9	31.6	31.6	31.7	31.9	32.1	32.3	32.5	32.8	33	33.3	33.7	33.9	**34.1**	34	33.9	33.7	33.5	33.3	33.1
228	32.9	32.7	32.4	32.2	32	31.7	31.6	31.8	32	32.2	32.5	32.7	32.9	33.2	33.5	33.8	34.1	**34.2**	**34.2**	34	33.8	33.6	33.4	33.2
234	33	32.8	32.5	32.3	32	31.8	31.7	31.9	32.1	32.4	32.6	32.8	33	33.3	33.6	33.9	34.2	**34.4**	34.3	34.1	33.9	33.7	33.5	33.3
240	33.1	32.8	32.6	32.4	32.1	31.9	31.8	32	32.2	32.5	32.7	32.9	33.1	33.4	33.7	34	34.3	**34.5**	34.4	34.2	34	33.8	33.6	33.3
246	33.2	32.9	32.7	32.4	32.2	31.9	31.8	32	32.3	32.5	32.8	33	33.2	33.5	33.7	34	34.4	**34.5**	**34.5**	34.3	34.1	33.9	33.6	33.4
252	33.2	32.9	32.7	32.4	32.2	31.9	31.9	32.1	32.3	32.6	32.8	33	33.3	33.5	33.8	34.1	34.4	**34.6**	34.5	34.3	34.1	33.9	33.7	33.4
258	33.2	33	32.7	32.5	32.2	32	31.9	32.1	32.4	32.6	32.9	33.1	33.3	33.6	33.8	34.1	34.4	**34.6**	34.5	34.4	34.1	33.9	33.7	33.5
264	33.2	33	32.7	32.5	32.2	32	31.9	32.1	32.4	32.7	32.9	33.1	33.3	33.6	33.9	34.2	34.5	**34.6**	**34.6**	34.4	34.2	33.9	33.7	33.5
270	33.2	33	32.7	32.5	32.2	32	31.9	32.1	32.4	32.7	32.9	33.1	33.4	33.6	33.9	34.2	34.5	**34.6**	**34.6**	34.4	34.2	34	33.7	33.5
276	33.3	33	32.7	32.5	32.2	32	31.9	32.1	32.4	32.7	32.9	33.1	33.4	33.6	33.9	34.2	34.5	**34.7**	34.6	34.4	34.2	34	33.7	33.5
282	33.3	33	32.8	32.5	32.3	32	31.9	32.1	32.4	32.7	32.9	33.1	33.4	33.6	33.9	34.2	34.5	**34.7**	34.6	34.4	34.2	34	33.8	33.5
288	33.3	33	32.8	32.5	32.3	32	31.9	32.1	32.4	32.7	32.9	33.1	33.4	33.6	33.9	34.2	34.5	**34.7**	34.6	34.4	34.2	34	33.8	33.5
294	33.3	33	32.7	32.5	32.2	32	31.9	32.1	32.4	32.7	32.9	33.1	33.4	33.6	33.9	34.2	34.5	**34.7**	34.6	34.4	34.2	34	33.7	33.5
300	33.2	33	32.7	32.5	32.2	32	31.9	32	32.3	32.6	32.9	33.1	33.3	33.6	33.9	34.1	34.4	**34.6**	34.5	34.3	34.1	33.9	33.7	33.5
306	33.2	32.9	32.7	32.4	32.2	31.9	31.8	32	32.3	32.6	32.8	33	33.2	33.5	33.8	34.1	34.4	**34.5**	**34.5**	34.3	34.1	33.9	33.6	33.4
312	33.1	32.8	32.6	32.3	32.1	31.8	31.7	31.9	32.1	32.4	32.7	32.9	33.1	33.4	33.7	34	34.2	**34.4**	34.3	34.2	34	33.8	33.5	33.3
318	33	32.7	32.5	32.2	32	31.7	31.6	31.8	32	32.3	32.5	32.7	33	33.3	33.6	33.8	34.1	**34.3**	34.2	34	33.8	33.6	33.4	33.2
324	32.9	32.7	32.4	32.2	32	31.7	31.6	31.7	31.9	32.2	32.4	32.7	33	33.2	33.5	33.8	34.1	**34.2**	34.2	34	33.8	33.6	33.4	33.2
330	32.7	32.5	32.2	32	31.8	31.5	31.4	31.5	31.7	31.9	32.2	32.4	32.6	32.9	33.3	33.5	33.8	**33.9**	**33.9**	33.7	33.5	33.3	33.1	32.9
336	32.6	32.3	32.1	31.9	31.7	31.4	31.3	31.3	31.5	31.8	32	32.2	32.5	32.8	33.1	33.4	33.6	**33.8**	33.7	33.6	33.4	33.2	33	32.8
342	32.5	32.2	32	31.8	31.6	31.3	31.2	31.2	31.4	31.6	31.8	32.1	32.3	32.6	32.9	33.2	33.5	**33.6**	**33.6**	33.4	33.2	33.1	32.9	32.7
348	32.4	32.2	32	31.7	31.5	31.3	31.1	31.2	31.3	31.5	31.7	32	32.2	32.5	32.9	33.2	33.4	**33.6**	33.5	33.4	33.2	33	32.8	32.6
354	32.3	32.1	31.9	31.7	31.4	31.2	31.1	31.1	31.2	31.4	31.6	31.9	32.1	32.4	32.8	33.1	33.3	**33.4**	**33.4**	33.2	33.1	32.9	32.7	32.5

MONTH = 9 (SEPTEMBER)

←------------------ DAILY HOUR (1 – 24) ------------------→

⇓PRA (Plan Rotation Angle) ←------------------ INDOOR TEMPERATURE on DAILY HOUR------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	26.5	26	26	25.8	25.3	24.9	24.5	24.4	25	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
0	31.3	31.1	30.9	30.7	30.4	30.2	30	30	30.1	30.3	30.5	30.9	31.2	31.6	32	32.3	32.5	**32.6**	32.5	32.4	32.2	32	31.8	31.6
6	31.4	31.1	30.9	30.7	30.5	30.2	30	30	30	30.2	30.5	30.8	31.1	31.5	31.9	32.3	32.5	**32.6**	32.5	32.4	32.2	32	31.8	31.6
12	31.5	31.2	31	30.8	30.5	30.3	30.1	30	30.1	30.2	30.5	30.8	31.1	31.5	32	32.4	32.6	**32.7**	32.6	32.5	32.3	32.1	31.9	31.7
18	31.6	31.3	31.1	30.8	30.6	30.4	30.2	30.1	30.2	30.3	30.5	30.8	31.2	31.6	32	32.4	32.8	**32.9**	32.8	32.6	32.4	32.2	32	31.8
24	31.7	31.4	31.2	30.9	30.7	30.5	30.3	30.2	30.3	30.4	30.6	30.9	31.2	31.6	32.1	32.6	32.9	**33**	32.9	32.8	32.6	32.4	32.1	31.9
30	31.8	31.5	31.3	31.1	30.8	30.6	30.4	30.3	30.4	30.5	30.7	31	31.3	31.7	32.2	32.7	33	**33.2**	33.1	32.9	32.7	32.5	32.3	32
36	31.9	31.6	31.4	31.1	30.9	30.6	30.4	30.4	30.5	30.6	30.8	31.1	31.4	31.8	32.3	32.8	33.2	**33.3**	33.2	33	32.8	32.6	32.4	32.1
42	32	31.7	31.5	31.2	31	30.7	30.5	30.5	30.6	30.7	30.9	31.2	31.5	31.9	32.4	32.9	33.3	**33.4**	33.3	33.1	32.9	32.7	32.5	32.2
48	32	31.8	31.5	31.3	31	30.8	30.6	30.6	30.6	30.8	31	31.2	31.5	31.9	32.4	32.9	33.3	**33.5**	33.4	33.2	33	32.8	32.5	32.3
54	32.1	31.8	31.5	31.3	31	30.8	30.6	30.6	30.7	30.8	31	31.3	31.6	32	32.5	33	33.4	**33.5**	33.4	33.2	33	32.8	32.6	32.3
60	32.1	31.8	31.6	31.3	31.1	30.8	30.6	30.7	30.7	30.9	31.1	31.3	31.6	32	32.5	33	33.4	**33.6**	33.5	33.3	33.1	32.8	32.6	32.3
66	32.1	31.8	31.6	31.3	31.1	30.8	30.6	30.7	30.8	30.9	31.1	31.4	31.7	32	32.5	33	33.4	**33.6**	33.5	33.3	33.1	32.9	32.6	32.4
72	32.1	31.9	31.6	31.4	31.1	30.8	30.7	30.7	30.8	31	31.2	31.4	31.7	32.1	32.5	33	33.5	**33.6**	33.5	33.3	33.1	32.9	32.6	32.4
78	32.1	31.9	31.6	31.3	31.1	30.8	30.6	30.7	30.8	31	31.2	31.4	31.7	32.1	32.5	33	33.4	**33.6**	33.5	33.3	33.1	32.9	32.6	32.4
84	32.1	31.8	31.6	31.3	31.1	30.8	30.6	30.7	30.8	31	31.2	31.4	31.7	32.1	32.5	33	33.4	**33.6**	33.5	33.3	33.1	32.9	32.6	32.4
90	32.1	31.8	31.6	31.3	31	30.8	30.6	30.7	30.8	31	31.2	31.4	31.7	32	32.5	33	33.4	**33.5**	33.4	33.3	33.1	32.8	32.6	32.3
96	32	31.8	31.5	31.3	31	30.8	30.6	30.6	30.8	30.9	31.1	31.4	31.7	32	32.4	32.9	33.3	**33.5**	33.4	33.2	33	32.8	32.5	32.3
102	32	31.7	31.5	31.2	31	30.7	30.5	30.6	30.7	30.9	31.1	31.3	31.6	32	32.3	32.8	33.2	**33.4**	33.3	33.1	32.9	32.7	32.5	32.2
108	31.9	31.6	31.4	31.1	30.9	30.6	30.5	30.5	30.7	30.8	31	31.3	31.6	31.9	32.3	32.7	33.1	**33.3**	33.2	33	32.8	32.6	32.4	32.1
114	31.8	31.6	31.3	31.1	30.8	30.6	30.4	30.5	30.6	30.8	31	31.2	31.5	31.9	32.2	32.6	33	**33.2**	33.1	32.9	32.7	32.5	32.3	32.1
120	31.7	31.5	31.2	31	30.8	30.5	30.3	30.4	30.5	30.7	30.9	31.2	31.5	31.8	32.1	32.5	32.9	**33.1**	33	32.8	32.6	32.4	32.2	32
126	31.6	31.4	31.1	30.9	30.7	30.4	30.3	30.3	30.5	30.7	30.9	31.1	31.4	31.7	32.1	32.4	32.8	**32.9**	**32.9**	32.7	32.5	32.3	32.1	31.9
132	31.5	31.3	31	30.8	30.6	30.3	30.2	30.2	30.4	30.6	30.8	31.1	31.4	31.7	32	32.3	32.7	**32.8**	32.7	32.6	32.4	32.2	32	31.8
138	31.4	31.2	30.9	30.7	30.5	30.3	30.1	30.2	30.3	30.5	30.7	31	31.3	31.6	31.9	32.2	32.5	**32.7**	32.6	32.4	32.3	32.1	31.9	31.6
144	31.3	31.1	30.8	30.6	30.4	30.2	30	30.1	30.2	30.4	30.6	30.9	31.2	31.5	31.8	32.1	32.4	**32.5**	32.4	32.3	32.1	32	31.7	31.5
150	31.2	31	30.7	30.5	30.3	30.1	29.9	30	30.1	30.3	30.5	30.8	31.1	31.4	31.7	32	32.3	**32.4**	32.3	32.2	32	31.8	31.6	31.4
156	31.1	30.9	30.7	30.4	30.2	30	29.8	29.9	30	30.2	30.4	30.7	31	31.3	31.6	31.9	**32.2**	**32.2**	**32.2**	32.1	31.9	31.7	31.5	31.3
162	31	30.8	30.6	30.4	30.2	29.9	29.8	29.8	29.9	30.1	30.3	30.6	30.9	31.2	31.6	31.8	**32.1**	**32.1**	**32.1**	32	31.8	31.6	31.4	31.2
168	31	30.8	30.5	30.3	30.1	29.9	29.7	29.7	29.8	30	30.2	30.5	30.8	31.1	31.5	31.8	32	**32.1**	32	31.9	31.8	31.6	31.4	31.2
174	30.9	30.7	30.5	30.3	30.1	29.9	29.7	29.7	29.8	29.9	30.2	30.4	30.7	31.1	31.4	31.7	**32**	**32**	**32**	31.9	31.7	31.5	31.3	31.1
180	30.9	30.7	30.5	30.3	30.1	29.9	29.7	29.6	29.7	29.9	30.1	30.4	30.7	31	31.4	31.7	31.9	**32**	**32**	31.9	31.7	31.5	31.3	31.1
186	31	30.7	30.5	30.3	30.1	29.9	29.7	29.7	29.7	29.9	30.1	30.4	30.7	31	31.4	31.7	32	**32.1**	32	31.9	31.7	31.6	31.4	31.2
192	31	30.8	30.6	30.4	30.1	29.9	29.7	29.7	29.8	29.9	30.1	30.4	30.7	31.1	31.4	31.8	32	**32.1**	**32.1**	31.9	31.8	31.6	31.4	31.2
198	31.1	30.9	30.6	30.4	30.2	30	29.8	29.8	29.8	30	30.2	30.5	30.8	31.1	31.5	31.8	32.1	**32.2**	32.1	32	31.9	31.7	31.5	31.3
204	31.2	30.9	30.7	30.5	30.3	30	29.9	29.8	29.9	30	30.3	30.6	30.8	31.2	31.6	31.9	32.2	**32.3**	32.2	32.1	32	31.8	31.6	31.4
210	31.2	31	30.8	30.6	30.3	30.1	30	30	30	30.2	30.4	30.7	31	31.3	31.7	32	32.3	**32.4**	**32.4**	32.2	32.1	31.9	31.7	31.5
216	31.3	31.1	30.9	30.7	30.4	30.2	30	30.1	30.1	30.3	30.5	30.8	31.1	31.4	31.8	32.1	32.4	**32.6**	32.5	32.4	32.2	32	31.8	31.6
222	31.4	31.2	31	30.7	30.5	30.3	30.1	30.2	30.3	30.4	30.6	30.9	31.2	31.5	31.9	32.3	32.6	**32.7**	32.6	32.5	32.3	32.1	31.9	31.7
228	31.5	31.3	31.1	30.8	30.6	30.3	30.2	30.3	30.4	30.6	30.8	31	31.3	31.6	32	32.4	32.7	**32.8**	32.7	32.6	32.4	32.2	32	31.8
234	31.6	31.4	31.1	30.9	30.7	30.4	30.3	30.4	30.5	30.7	30.9	31.2	31.5	31.8	32.1	32.5	32.8	**32.9**	32.8	32.7	32.5	32.3	32.1	31.8
240	31.7	31.4	31.2	31	30.7	30.5	30.3	30.5	30.6	30.8	31	31.3	31.6	31.9	32.2	32.6	32.9	**33**	32.9	32.8	32.6	32.4	32.2	31.9
246	31.7	31.5	31.3	31	30.8	30.5	30.4	30.5	30.7	30.9	31.2	31.4	31.7	32	32.3	32.7	33	**33.1**	33	32.9	32.7	32.5	32.2	32
252	31.8	31.6	31.3	31.1	30.8	30.6	30.4	30.6	30.8	31	31.3	31.5	31.8	32.1	32.4	32.8	33.1	**33.2**	33.1	32.9	32.7	32.5	32.3	32
258	31.9	31.6	31.4	31.1	30.9	30.6	30.5	30.6	30.9	31.1	31.4	31.6	31.9	32.2	32.5	32.9	33.2	**33.3**	33.2	33	32.8	32.6	32.3	32.1
264	31.9	31.7	31.4	31.2	30.9	30.7	30.5	30.7	30.9	31.2	31.4	31.7	32	32.3	32.6	32.9	33.2	**33.3**	33.2	33.1	32.9	32.6	32.4	32.2
270	32	31.7	31.4	31.2	30.9	30.7	30.6	30.7	31	31.3	31.5	31.7	32	32.3	32.6	33	33.3	**33.4**	33.3	33.1	32.9	32.7	32.4	32.2
276	32	31.7	31.5	31.2	31	30.7	30.6	30.7	31	31.3	31.5	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.3	33.1	32.9	32.7	32.5	32.2
282	32	31.7	31.5	31.2	31	30.7	30.6	30.7	31	31.3	31.6	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.3	33.1	32.9	32.7	32.5	32.2
288	32	31.7	31.5	31.2	31	30.7	30.6	30.7	31	31.3	31.6	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.3	33.1	32.9	32.7	32.5	32.2
294	32	31.7	31.4	31.2	30.9	30.7	30.6	30.7	31	31.3	31.6	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.2	33.1	32.9	32.7	32.4	32.2
300	31.9	31.7	31.4	31.2	30.9	30.7	30.5	30.7	31	31.3	31.6	31.8	32.1	32.4	32.7	33	33.3	**33.4**	33.3	33.1	32.9	32.7	32.5	32.2
306	31.9	31.6	31.4	31.1	30.9	30.6	30.5	30.7	30.9	31.3	31.5	31.8	32.1	32.4	32.7	33	33.2	**33.3**	33.2	33	32.8	32.6	32.4	32.1
312	31.8	31.6	31.3	31.1	30.9	30.6	30.5	30.6	30.9	31.2	31.5	31.8	32.1	32.3	32.6	32.9	**33.2**	**33.2**	33.1	33	32.8	32.6	32.3	32.1
318	31.8	31.5	31.3	31	30.8	30.6	30.4	30.5	30.8	31.1	31.4	31.7	32	32.3	32.6	32.8	33.1	**33.2**	33.1	32.9	32.7	32.5	32.3	32
324	31.7	31.5	31.2	31	30.7	30.5	30.3	30.5	30.7	31	31.3	31.6	31.9	32.2	32.5	32.8	33	**33.1**	33	32.8	32.6	32.4	32.2	31.9
330	31.6	31.4	31.1	30.9	30.7	30.4	30.3	30.4	30.6	30.9	31.2	31.5	31.8	32.1	32.4	32.7	**32.9**	**32.9**	32.8	32.7	32.5	32.3	32.1	31.9
336	31.5	31.3	31	30.8	30.6	30.3	30.2	30.2	30.5	30.8	31.1	31.4	31.7	32	32.3	32.6	32.7	**32.8**	32.7	32.6	32.4	32.2	32	31.8
342	31.4	31.2	31	30.7	30.5	30.3	30.1	30.1	30.3	30.6	30.9	31.2	31.5	31.9	32.2	32.4	32.6	**32.7**	32.6	32.5	32.3	32.1	31.9	31.7
348	31.4	31.1	30.9	30.7	30.4	30.2	30	30	30.2	30.4	30.8	31.1	31.4	31.7	32.1	32.4	32.5	**32.6**	32.5	32.4	32.2	32	31.8	31.6
354	31.3	31.1	30.9	30.6	30.4	30.2	30	30	30.1	30.3	30.6	30.9	31.3	31.6	32	32.3	32.5	**32.6**	32.5	32.3	32.2	32	31.8	31.6

MONTH = 10 (OCTOBER)

←------------------ DAILY HOUR (1 – 24) ------------------→

←------------------ INDOOR TEMPERATURE on DAILY HOUR------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T OUT >	19	18.5	18.4	17.5	17	17	16.9	16.4	17.3	19.8	21.2	23.4	26	27.1	27.4	27.4	26.8	25.2	23.3	21.8	20.7	19.8	19.3	19.1
⇓PRA (Plan Rotation Angle)																								
0	25.3	25.1	24.8	24.5	24.3	24	23.7	23.7	23.8	24	24.4	24.8	25.3	25.8	26.3	26.7	26.9	26.9	26.7	26.6	26.3	26.1	25.8	25.6
6	25.3	25.1	24.8	24.6	24.3	24	23.7	23.7	23.7	24	24.3	24.7	25.2	25.7	26.3	26.7	26.9	26.9	26.8	26.6	26.4	26.1	25.9	25.6
12	25.4	25.1	24.8	24.6	24.3	24	23.8	23.6	23.7	23.9	24.2	24.6	25.1	25.6	26.2	26.7	26.9	26.9	26.8	26.6	26.4	26.1	25.9	25.6
18	25.3	25.1	24.8	24.6	24.3	24	23.7	23.6	23.6	23.8	24.1	24.5	25	25.6	26.1	26.6	26.9	26.9	26.8	26.6	26.4	26.1	25.9	25.6
24	25.3	25.1	24.8	24.5	24.3	24	23.7	23.6	23.6	23.8	24	24.4	24.9	25.5	26.1	26.6	26.9	26.9	26.8	26.6	26.4	26.1	25.9	25.6
30	25.4	25.1	24.8	24.6	24.3	24	23.8	23.6	23.6	23.8	24	24.4	24.8	25.5	26.1	26.6	27	26.9	26.8	26.6	26.4	26.2	25.9	25.6
36	25.3	25	24.8	24.5	24.2	24	23.7	23.6	23.6	23.7	23.9	24.3	24.8	25.3	26	26.5	26.9	26.9	26.7	26.5	26.3	26.1	25.8	25.6
42	25.3	25	24.8	24.5	24.2	23.9	23.7	23.6	23.6	23.7	23.9	24.3	24.7	25.3	25.9	26.5	26.8	26.8	26.7	26.5	26.3	26.1	25.8	25.5
48	25.3	25	24.8	24.5	24.2	23.9	23.7	23.6	23.6	23.7	24	24.3	24.7	25.3	25.9	26.5	26.8	26.8	26.7	26.5	26.3	26.1	25.8	25.5
54	25.3	25	24.7	24.5	24.2	23.9	23.7	23.6	23.7	23.8	24	24.3	24.7	25.3	25.9	26.4	26.8	26.8	26.7	26.5	26.3	26	25.8	25.5
60	25.2	25	24.7	24.5	24.2	23.9	23.7	23.6	23.7	23.8	24	24.3	24.7	25.2	25.9	26.4	26.8	26.8	26.7	26.5	26.3	26	25.8	25.5
66	25.2	25	24.7	24.5	24.2	23.9	23.7	23.6	23.7	23.8	24	24.3	24.7	25.2	25.8	26.4	26.8	26.8	26.6	26.5	26.3	26	25.7	25.5
72	25.2	25	24.7	24.4	24.2	23.9	23.7	23.6	23.7	23.9	24.1	24.3	24.7	25.2	25.8	26.4	26.7	26.7	26.6	26.4	26.2	26	25.7	25.5
78	25.2	24.9	24.7	24.4	24.1	23.9	23.6	23.6	23.7	23.9	24.1	24.3	24.7	25.2	25.8	26.3	26.7	26.7	26.6	26.4	26.2	26	25.7	25.4
84	25.2	24.9	24.7	24.4	24.1	23.8	23.6	23.6	23.7	23.9	24.1	24.4	24.7	25.2	25.7	26.3	26.7	26.7	26.5	26.4	26.2	25.9	25.7	25.4
90	25.1	24.9	24.6	24.3	24.1	23.8	23.6	23.6	23.7	23.9	24.1	24.4	24.7	25.1	25.7	26.2	26.6	26.6	26.5	26.3	26.1	25.9	25.6	25.4
96	25	24.8	24.5	24.3	24	23.8	23.5	23.5	23.7	23.9	24.1	24.3	24.7	25.1	25.6	26.1	26.5	26.5	26.4	26.2	26	25.8	25.5	25.3
102	25	24.7	24.5	24.2	24	23.7	23.5	23.5	23.6	23.8	24	24.3	24.6	25	25.5	26	26.4	26.4	26.3	26.1	25.9	25.7	25.5	25.2
108	24.9	24.6	24.4	24.1	23.9	23.6	23.4	23.4	23.5	23.7	24	24.3	24.6	25	25.4	25.9	26.3	26.3	26.2	26	25.8	25.6	25.4	25.1
114	24.8	24.5	24.3	24.1	23.8	23.5	23.3	23.3	23.5	23.7	23.9	24.2	24.5	24.9	25.4	25.8	26.1	26.2	26.1	25.9	25.7	25.5	25.3	25
120	24.7	24.4	24.2	24	23.7	23.5	23.2	23.3	23.4	23.6	23.9	24.1	24.5	24.9	25.3	25.7	26	26	25.9	25.8	25.6	25.4	25.1	24.9
126	24.6	24.4	24.1	23.9	23.6	23.4	23.2	23.2	23.3	23.5	23.8	24.1	24.5	24.8	25.2	25.6	25.9	25.9	25.8	25.7	25.5	25.3	25.1	24.8
132	24.5	24.3	24.1	23.8	23.6	23.3	23.1	23.1	23.3	23.5	23.8	24.1	24.4	24.8	25.2	25.5	25.8	25.8	25.7	25.6	25.4	25.2	25	24.7
138	24.5	24.2	24	23.8	23.5	23.3	23.1	23.1	23.2	23.5	23.7	24	24.4	24.8	25.1	25.5	25.7	25.7	25.7	25.5	25.3	25.1	24.9	24.7
144	24.4	24.2	24	23.7	23.5	23.2	23	23.1	23.2	23.4	23.7	24	24.4	24.8	25.1	25.4	25.7	25.7	25.6	25.5	25.3	25.1	24.9	24.6
150	24.4	24.2	23.9	23.7	23.5	23.2	23	23	23.2	23.4	23.7	24	24.3	24.8	25.1	25.4	25.6	25.6	25.6	25.4	25.3	25.1	24.8	24.6
156	24.4	24.2	23.9	23.7	23.5	23.2	23	23	23.2	23.4	23.7	24	24.3	24.7	25.1	25.4	25.6	25.6	25.6	25.4	25.3	25.1	24.8	24.6
162	24.4	24.2	24	23.7	23.5	23.2	23	23	23.1	23.4	23.6	23.9	24.3	24.7	25.1	25.5	25.6	25.7	25.6	25.4	25.3	25.1	24.8	24.6
168	24.4	24.2	24	23.7	23.5	23.2	23	23	23.1	23.3	23.6	23.9	24.3	24.7	25.1	25.5	25.7	25.7	25.6	25.5	25.3	25.1	24.9	24.6
174	24.4	24.2	24	23.8	23.5	23.3	23	23	23.1	23.3	23.6	23.9	24.3	24.7	25.1	25.5	25.7	25.7	25.6	25.5	25.3	25.1	24.9	24.7
180	24.5	24.2	24	23.8	23.5	23.3	23.1	23	23.1	23.3	23.5	23.8	24.2	24.7	25.1	25.5	25.7	25.7	25.6	25.5	25.3	25.1	24.9	24.7
186	24.5	24.2	24	23.8	23.5	23.3	23.1	23	23	23.2	23.5	23.8	24.2	24.6	25.1	25.5	25.7	25.7	25.7	25.5	25.4	25.1	24.9	24.7
192	24.5	24.3	24	23.8	23.5	23.3	23.1	23	23	23.2	23.4	23.8	24.2	24.6	25.1	25.5	25.7	25.8	25.7	25.5	25.4	25.2	24.9	24.7
198	24.5	24.3	24	23.8	23.5	23.3	23.1	23	23	23.2	23.4	23.7	24.1	24.6	25	25.5	25.7	25.8	25.7	25.5	25.4	25.2	24.9	24.7
204	24.5	24.3	24	23.8	23.6	23.3	23.1	23	23	23.1	23.4	23.7	24.1	24.5	25	25.5	25.8	25.8	25.7	25.6	25.4	25.2	24.9	24.7
210	24.5	24.3	24	23.8	23.6	23.3	23.1	23	23	23.1	23.4	23.7	24.1	24.5	25	25.5	25.8	25.8	25.7	25.6	25.4	25.2	24.9	24.7
216	24.5	24.3	24.1	23.8	23.6	23.3	23.1	23	23	23.2	23.4	23.7	24.1	24.6	25	25.5	25.8	25.8	25.7	25.6	25.4	25.2	25	24.7
222	24.5	24.3	24.1	23.9	23.6	23.3	23.1	23.1	23.1	23.2	23.5	23.8	24.1	24.6	25.1	25.5	25.8	25.9	25.8	25.6	25.4	25.2	25	24.8
228	24.6	24.4	24.1	23.9	23.6	23.4	23.2	23.1	23.2	23.3	23.5	23.8	24.2	24.7	25.1	25.6	25.9	25.9	25.8	25.7	25.5	25.3	25	24.8
234	24.6	24.4	24.2	23.9	23.7	23.4	23.2	23.2	23.3	23.4	23.6	23.9	24.3	24.7	25.2	25.6	25.9	26	25.9	25.7	25.5	25.3	25.1	24.9
240	24.7	24.5	24.2	24	23.7	23.5	23.3	23.3	23.4	23.6	23.8	24	24.4	24.8	25.3	25.7	26	26.1	26	25.8	25.6	25.4	25.2	24.9
246	24.8	24.5	24.3	24	23.8	23.5	23.3	23.4	23.5	23.7	23.9	24.2	24.5	24.9	25.4	25.8	26.1	26.1	26	25.9	25.7	25.5	25.2	25
252	24.8	24.6	24.4	24.1	23.8	23.6	23.4	23.4	23.6	23.8	24	24.3	24.6	25.1	25.5	25.9	26.2	26.2	26.1	26	25.8	25.6	25.3	25.1
258	24.9	24.7	24.4	24.2	23.9	23.6	23.4	23.5	23.7	23.9	24.2	24.4	24.8	25.2	25.6	26	26.3	26.3	26.2	26.1	25.9	25.6	25.4	25.1
264	25	24.7	24.5	24.2	24	23.7	23.5	23.6	23.8	24	24.3	24.5	24.9	25.3	25.7	26.1	26.4	26.4	26.3	26.1	25.9	25.7	25.5	25.2
270	25	24.8	24.5	24.3	24	23.7	23.5	23.6	23.8	24.1	24.4	24.6	25	25.3	25.8	26.2	26.5	26.5	26.4	26.2	26	25.7	25.5	25.2
276	25	24.8	24.5	24.3	24	23.7	23.5	23.6	23.9	24.2	24.5	24.7	25	25.4	25.8	26.2	26.5	26.5	26.4	26.2	26	25.8	25.5	25.3
282	25.1	24.8	24.6	24.3	24	23.8	23.5	23.6	23.9	24.2	24.5	24.8	25.1	25.5	25.9	26.3	26.5	26.5	26.4	26.2	26	25.8	25.6	25.3
288	25.1	24.8	24.6	24.3	24	23.8	23.6	23.6	23.9	24.3	24.6	24.9	25.2	25.5	25.9	26.3	26.5	26.5	26.4	26.3	26	25.8	25.6	25.3
294	25.1	24.8	24.6	24.3	24	23.8	23.6	23.6	23.9	24.3	24.6	24.9	25.2	25.6	25.9	26.3	26.5	26.5	26.4	26.3	26	25.8	25.6	25.3
300	25.1	24.8	24.6	24.3	24	23.8	23.5	23.6	23.9	24.3	24.6	24.9	25.3	25.6	26	26.3	26.5	26.5	26.4	26.2	26	25.8	25.6	25.3
306	25.1	24.8	24.6	24.3	24	23.8	23.5	23.6	23.9	24.3	24.6	25	25.3	25.7	26	26.3	26.5	26.5	26.4	26.2	26	25.8	25.6	25.3
312	25.1	24.8	24.6	24.3	24	23.8	23.5	23.6	23.9	24.3	24.6	25	25.4	25.7	26	26.3	26.5	26.5	26.4	26.2	26	25.8	25.6	25.3
318	25.1	24.8	24.6	24.3	24	23.8	23.5	23.6	23.9	24.3	24.7	25	25.4	25.8	26.1	26.4	26.5	26.5	26.4	26.3	26	25.8	25.6	25.3
324	25.1	24.8	24.6	24.3	24	23.8	23.6	23.6	23.9	24.3	24.6	25	25.4	25.8	26.1	26.4	26.6	26.5	26.4	26.3	26.1	25.8	25.6	25.3
330	25.1	24.8	24.6	24.3	24.1	23.8	23.6	23.6	23.9	24.3	24.6	25	25.4	25.8	26.2	26.5	26.6	26.6	26.5	26.3	26.1	25.8	25.6	25.3
336	25.1	24.9	24.6	24.4	24.1	23.8	23.6	23.6	23.9	24.2	24.6	25	25.5	25.9	26.2	26.5	26.7	26.6	26.5	26.3	26.1	25.9	25.6	25.4
342	25.2	24.9	24.7	24.4	24.1	23.9	23.6	23.7	23.9	24.2	24.6	25	25.5	25.9	26.3	26.6	26.7	26.7	26.6	26.4	26.2	25.9	25.7	25.4
348	25.3	25	24.8	24.5	24.2	24	23.7	23.7	23.9	24.2	24.6	25.1	25.5	26	26.4	26.7	26.9	26.8	26.7	26.5	26.3	26.1	25.8	25.5
354	25.3	25	24.8	24.5	24.2	23.9	23.7	23.7	23.8	24.1	24.5	24.9	25.4	25.9	26.3	26.7	26.9	26.8	26.7	26.5	26.3	26.1	25.8	25.5

MONTH = 11 (NOVEMBER)

←------------------- DAILY HOUR (1 – 24) -------------------→

←------------------- INDOOR TEMPERATURE on DAILY HOUR-------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	12.7	12.2	11.7	11.2	10.6	10.5	10	9.5	9.9	12.4	15.6	20.4	23.3	24.5	26	**26.1**	25.2	21.6	18.2	16.6	15.2	14.6	13.7	13.2
⇓PRA (Plan Rotation Angle)																								
0	21.2	20.8	20.5	20.2	19.9	19.5	19.2	19	19.1	19.3	19.7	20.2	20.8	21.5	22.2	22.7	23	23	22.8	22.6	22.4	22.1	21.8	21.5
6	21.2	20.8	20.5	20.2	19.9	19.5	19.2	19	19	19.2	19.6	20.1	20.7	21.4	22.1	22.7	23	23	22.8	22.6	22.4	22.1	21.8	21.5
12	21.1	20.8	20.5	20.2	19.8	19.5	19.2	18.9	18.9	19.1	19.4	19.9	20.6	21.3	22	22.6	22.9	22.9	22.8	22.6	22.3	22	21.7	21.4
18	21	20.7	20.4	20.1	19.8	19.4	19.1	18.9	18.8	18.9	19.2	19.8	20.4	21.1	21.8	22.4	22.8	22.8	22.7	22.5	22.2	21.9	21.7	21.3
24	20.9	20.6	20.3	20	19.7	19.3	19	18.8	18.7	18.8	19.1	19.6	20.2	20.9	21.7	22.3	22.6	22.7	22.5	22.3	22.1	21.8	21.5	21.2
30	20.8	20.5	20.2	19.9	19.6	19.3	18.9	18.7	18.6	18.7	18.9	19.4	20	20.8	21.5	22.1	22.5	22.5	22.4	22.2	22	21.7	21.4	21.1
36	20.7	20.4	20.1	19.8	19.5	19.2	18.9	18.6	18.5	18.6	18.8	19.2	19.9	20.6	21.3	22	22.4	22.4	22.3	22.1	21.9	21.6	21.3	21
42	20.7	20.4	20.1	19.7	19.4	19.1	18.8	18.6	18.5	18.5	18.7	19.1	19.7	20.5	21.2	21.9	22.3	22.3	22.2	22	21.8	21.5	21.2	21
48	20.6	20.3	20	19.7	19.4	19.1	18.7	18.5	18.4	18.4	18.6	19	19.6	20.3	21.1	21.8	22.2	22.2	22.1	21.9	21.7	21.4	21.2	20.9
54	20.5	20.2	19.9	19.6	19.3	19	18.7	18.5	18.4	18.4	18.6	19	19.5	20.3	21	21.7	22.1	22.1	22	21.8	21.6	21.4	21.1	20.8
60	20.5	20.2	19.9	19.6	19.3	19	18.7	18.5	18.4	18.4	18.6	18.9	19.5	20.2	20.9	21.6	22	22	22	21.8	21.6	21.3	21	20.8
66	20.4	20.1	19.8	19.5	19.2	18.9	18.6	18.4	18.4	18.5	18.6	18.9	19.4	20.1	20.9	21.5	21.9	22	21.9	21.7	21.5	21.3	21	20.7
72	20.4	20.1	19.8	19.5	19.2	18.9	18.6	18.4	18.4	18.5	18.6	18.9	19.4	20.1	20.8	21.5	21.9	21.9	21.8	21.7	21.4	21.2	20.9	20.7
78	20.3	20	19.8	19.5	19.2	18.8	18.5	18.4	18.4	18.5	18.6	18.9	19.4	20	20.7	21.4	21.8	21.9	21.8	21.6	21.4	21.1	20.9	20.6
84	20.3	20	19.7	19.4	19.1	18.8	18.5	18.3	18.4	18.5	18.6	18.9	19.4	20	20.6	21.3	21.7	21.8	21.7	21.5	21.3	21.1	20.8	20.6
90	20.2	19.9	19.6	19.3	19	18.7	18.4	18.3	18.3	18.4	18.6	18.9	19.4	19.9	20.6	21.2	21.6	21.7	21.6	21.4	21.2	21	20.7	20.5
96	20.1	19.9	19.6	19.3	19	18.7	18.4	18.2	18.3	18.4	18.6	18.9	19.4	19.9	20.5	21.1	21.5	21.6	21.5	21.4	21.2	20.9	20.7	20.4
102	20.1	19.8	19.5	19.2	18.9	18.6	18.3	18.2	18.2	18.4	18.6	18.9	19.4	19.9	20.4	21	21.4	21.5	21.4	21.3	21.1	20.8	20.6	20.3
108	20	19.7	19.4	19.1	18.9	18.6	18.3	18.1	18.2	18.3	18.6	18.9	19.3	19.8	20.4	20.9	21.3	21.4	21.3	21.2	21	20.7	20.5	20.2
114	19.9	19.6	19.4	19.1	18.8	18.5	18.2	18.1	18.1	18.3	18.5	18.9	19.3	19.8	20.3	20.8	21.2	21.3	21.2	21.1	20.9	20.7	20.4	20.2
120	19.8	19.6	19.3	19	18.7	18.4	18.2	18	18.1	18.2	18.5	18.9	19.3	19.8	20.3	20.8	21.1	21.2	21.1	21	20.8	20.6	20.3	20.1
126	19.8	19.5	19.2	19	18.7	18.4	18.1	18	18	18.2	18.5	18.8	19.3	19.8	20.3	20.7	21	21.1	21.1	20.9	20.7	20.5	20.3	20
132	19.8	19.5	19.2	18.9	18.7	18.4	18.1	18	18	18.2	18.5	18.8	19.3	19.8	20.3	20.7	21	21.1	21	20.9	20.7	20.5	20.3	20
138	19.7	19.5	19.2	18.9	18.7	18.4	18.1	18	18	18.2	18.5	18.8	19.3	19.8	20.3	20.7	21	21.1	21	20.9	20.7	20.5	20.3	20
144	19.8	19.5	19.2	19	18.7	18.4	18.1	18	18	18.2	18.5	18.9	19.4	19.9	20.3	20.8	21	21.1	21	20.9	20.7	20.5	20.3	20
150	19.8	19.6	19.3	19	18.7	18.4	18.1	18	18.1	18.2	18.5	18.9	19.4	19.9	20.4	20.8	21.1	21.2	21.1	21	20.8	20.6	20.3	20.1
156	19.9	19.6	19.3	19.1	18.8	18.5	18.2	18	18.1	18.3	18.5	18.9	19.4	20	20.5	20.9	21.2	21.2	21.2	21	20.8	20.6	20.4	20.1
162	19.9	19.7	19.4	19.1	18.8	18.5	18.2	18.1	18.1	18.3	18.6	19	19.5	20	20.5	21	21.2	21.3	21.3	21.1	20.9	20.7	20.5	20.2
168	20	19.7	19.4	19.2	18.9	18.6	18.3	18.1	18.2	18.3	18.6	19	19.5	20	20.6	21	21.3	21.4	21.3	21.2	21	20.7	20.5	20.2
174	20	19.8	19.5	19.2	18.9	18.6	18.3	18.1	18.2	18.3	18.6	19	19.5	20	20.6	21.1	21.4	21.4	21.4	21.2	21	20.8	20.5	20.3
180	20	19.8	19.5	19.2	18.9	18.6	18.3	18.1	18.1	18.3	18.5	18.9	19.4	20	20.6	21.1	21.4	21.5	21.4	21.2	21	20.8	20.6	20.3
186	20	19.8	19.5	19.2	18.9	18.6	18.3	18.1	18.1	18.2	18.5	18.9	19.4	20	20.6	21.1	21.4	21.5	21.4	21.2	21	20.8	20.6	20.3
192	20	19.8	19.5	19.2	18.9	18.6	18.3	18.1	18.1	18.2	18.4	18.8	19.3	19.9	20.5	21.1	21.4	21.5	21.4	21.2	21	20.8	20.6	20.3
198	20	19.7	19.5	19.2	18.9	18.6	18.3	18.1	18	18.1	18.4	18.8	19.3	19.8	20.4	21	21.3	21.4	21.3	21.2	21	20.8	20.5	20.3
204	20	19.7	19.4	19.1	18.8	18.5	18.3	18	18	18	18.3	18.7	19.2	19.8	20.4	20.9	21.3	21.4	21.3	21.1	20.9	20.7	20.5	20.2
210	19.9	19.6	19.4	19.1	18.8	18.5	18.2	18	17.9	18	18.2	18.6	19.1	19.7	20.3	20.9	21.2	21.3	21.2	21.1	20.9	20.7	20.4	20.2
216	19.9	19.6	19.3	19.1	18.8	18.5	18.2	18	17.9	17.9	18.1	18.5	19	19.6	20.2	20.8	21.2	21.2	21.2	21	20.8	20.6	20.4	20.1
222	19.9	19.6	19.3	19	18.7	18.5	18.2	18	17.9	17.9	18.1	18.5	19	19.6	20.2	20.8	21.1	21.2	21.2	21	20.8	20.6	20.4	20.1
228	19.8	19.6	19.3	19	18.7	18.4	18.2	18	17.9	17.9	18.1	18.5	19	19.6	20.2	20.8	21.1	21.2	21.1	21	20.8	20.6	20.4	20.1
234	19.9	19.6	19.3	19	18.7	18.5	18.2	18	18	18	18.2	18.5	19	19.6	20.2	20.8	21.1	21.2	21.2	21	20.8	20.6	20.4	20.1
240	19.9	19.6	19.3	19.1	18.8	18.5	18.2	18	18	18.1	18.3	18.6	19.1	19.7	20.3	20.8	21.2	21.3	21.2	21.1	20.9	20.6	20.4	20.2
246	19.9	19.7	19.4	19.1	18.8	18.5	18.2	18.1	18.1	18.2	18.4	18.7	19.2	19.7	20.3	20.9	21.3	21.3	21.3	21.1	20.9	20.7	20.5	20.2
252	20	19.7	19.4	19.2	18.9	18.6	18.3	18.2	18.2	18.3	18.5	18.8	19.3	19.8	20.4	21	21.3	21.4	21.3	21.2	21	20.8	20.5	20.3
258	20	19.8	19.5	19.2	18.9	18.6	18.3	18.2	18.3	18.4	18.6	18.9	19.4	19.9	20.5	21	21.4	21.5	21.4	21.2	21	20.8	20.6	20.3
264	20.1	19.8	19.5	19.2	18.9	18.6	18.4	18.2	18.4	18.6	18.8	19.1	19.5	20	20.6	21.1	21.5	21.5	21.5	21.3	21.1	20.9	20.6	20.4
270	20.1	19.9	19.6	19.3	19	18.7	18.4	18.3	18.4	18.6	18.9	19.2	19.6	20.1	20.6	21.2	21.5	21.6	21.5	21.4	21.1	20.9	20.7	20.4
276	20.2	19.9	19.6	19.3	19	18.7	18.4	18.3	18.5	18.7	19	19.3	19.7	20.2	20.7	21.2	21.6	21.6	21.6	21.4	21.2	21	20.7	20.4
282	20.2	19.9	19.6	19.3	19	18.7	18.4	18.4	18.5	18.8	19.1	19.4	19.8	20.3	20.8	21.3	21.6	21.7	21.6	21.4	21.2	21	20.7	20.5
288	20.2	20	19.7	19.4	19.1	18.8	18.5	18.4	18.6	18.8	19.2	19.5	19.9	20.4	20.9	21.4	21.7	21.7	21.6	21.5	21.3	21	20.8	20.5
294	20.3	20	19.7	19.4	19.1	18.8	18.5	18.4	18.6	18.9	19.2	19.6	20	20.5	21	21.4	21.7	21.8	21.7	21.5	21.3	21.1	20.8	20.5
300	20.3	20	19.7	19.4	19.1	18.8	18.5	18.4	18.6	18.9	19.3	19.7	20.1	20.6	21	21.5	21.7	21.8	21.7	21.5	21.3	21.1	20.8	20.6
306	20.3	20	19.8	19.5	19.1	18.8	18.5	18.4	18.6	18.9	19.3	19.8	20.2	20.7	21.1	21.5	21.8	21.8	21.8	21.6	21.4	21.1	20.9	20.6
312	20.4	20.1	19.8	19.5	19.2	18.9	18.6	18.5	18.6	19	19.4	19.8	20.3	20.8	21.2	21.6	21.9	21.9	21.8	21.7	21.4	21.2	20.9	20.7
318	20.4	20.2	19.9	19.6	19.2	18.9	18.6	18.5	18.7	19	19.4	19.9	20.4	20.9	21.4	21.7	22	22	21.9	21.7	21.5	21.3	21	20.7
324	20.5	20.2	19.9	19.6	19.3	19	18.7	18.6	18.8	19.1	19.5	20	20.5	21	21.5	21.9	22.1	22.1	22	21.8	21.6	21.4	21.1	20.8
330	20.6	20.4	20	19.7	19.4	19.1	18.8	18.7	18.8	19.1	19.5	20.1	20.6	21.2	21.7	22	22.2	22.3	22.2	22	21.8	21.5	21.2	20.9
336	20.8	20.5	20.2	19.9	19.5	19.2	18.9	18.8	18.9	19.2	19.6	20.1	20.7	21.3	21.8	22.2	22.4	22.4	22.3	22.1	21.9	21.6	21.4	21.1
342	20.9	20.6	20.3	20	19.6	19.3	19	18.9	19	19.3	19.7	20.2	20.8	21.4	22	22.4	22.6	22.6	22.5	22.3	22.1	21.8	21.5	21.2
348	21	20.7	20.4	20.1	19.7	19.4	19.1	18.9	19	19.3	19.7	20.2	20.9	21.5	22.1	22.5	22.8	22.8	22.7	22.4	22.2	21.9	21.6	21.3
354	21.1	20.8	20.5	20.2	19.8	19.5	19.2	19	19.1	19.3	19.7	20.2	20.9	21.5	22.1	22.6	22.9	22.9	22.8	22.6	22.3	22	21.7	21.4

MONTH = 12 (DECEMBER)

←------------------- DAILY HOUR (1 – 24) ------------------→

⇓PRA (Plan Rotation Angle) ←------------------ INDOOR TEMPERATURE on DAILY HOUR------------------→

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T_{OUT} >	11.3	10.9	10.4	9.8	8.8	8.3	7.9	7.5	7.6	9.7	13	17.1	19.8	20	21.3	21.9	21.3	19.4	16.5	14.7	13.6	12.7	12.1	11.7
0	19.1	18.8	18.5	18.2	17.9	17.6	17.3	17	17	17.2	17.6	18.1	18.7	19.4	20	20.5	20.7	20.7	20.6	20.4	20.2	19.9	19.7	19.4
6	19.1	18.8	18.5	18.2	17.9	17.6	17.3	17	17	17.2	17.5	18	18.7	19.3	19.9	20.4	20.7	20.7	20.6	20.4	20.2	19.9	19.7	19.4
12	19.1	18.8	18.5	18.2	17.9	17.6	17.3	17	16.9	17.1	17.4	17.9	18.6	19.2	19.9	20.4	20.7	20.7	20.6	20.4	20.2	19.9	19.6	19.4
18	19	18.7	18.4	18.1	17.8	17.5	17.2	16.9	16.8	16.9	17.2	17.7	18.3	19	19.6	20.2	20.5	20.5	20.4	20.2	20	19.8	19.5	19.2
24	18.9	18.6	18.3	18	17.7	17.4	17.1	16.8	16.7	16.7	17	17.5	18.1	18.8	19.4	20	20.4	20.4	20.3	20.1	19.9	19.6	19.4	19.1
30	18.7	18.5	18.2	17.9	17.6	17.3	17	16.7	16.6	16.6	16.8	17.3	17.9	18.6	19.2	19.8	20.2	20.2	20.1	20	19.7	19.5	19.3	19
36	18.6	18.3	18.1	17.8	17.5	17.2	16.9	16.6	16.5	16.5	16.7	17.1	17.7	18.4	19.1	19.7	20	20	20	19.8	19.6	19.4	19.1	18.9
42	18.5	18.2	18	17.7	17.4	17.1	16.8	16.5	16.4	16.4	16.6	17	17.5	18.2	18.9	19.5	19.9	19.9	19.8	19.7	19.5	19.3	19	18.8
48	18.4	18.2	17.9	17.6	17.3	17	16.7	16.5	16.3	16.3	16.5	16.8	17.4	18.1	18.8	19.4	19.7	19.8	19.7	19.6	19.4	19.1	18.9	18.7
54	18.3	18.1	17.8	17.6	17.3	17	16.7	16.4	16.3	16.3	16.4	16.8	17.3	18	18.6	19.3	19.6	19.7	19.6	19.5	19.3	19.1	18.8	18.6
60	18.3	18	17.8	17.5	17.2	16.9	16.6	16.4	16.3	16.3	16.4	16.7	17.2	17.9	18.5	19.2	19.6	19.6	19.5	19.4	19.2	19	18.8	18.5
66	18.2	18	17.7	17.4	17.2	16.9	16.6	16.3	16.3	16.3	16.4	16.7	17.2	17.8	18.5	19.1	19.5	19.5	19.5	19.3	19.1	18.9	18.7	18.5
72	18.1	17.9	17.6	17.4	17.1	16.8	16.5	16.3	16.2	16.3	16.4	16.7	17.2	17.7	18.4	19	19.4	19.4	19.4	19.2	19.1	18.9	18.6	18.4
78	18.1	17.8	17.6	17.3	17.1	16.8	16.5	16.2	16.2	16.3	16.4	16.7	17.1	17.7	18.3	18.9	19.3	19.3	19.3	19.2	19	18.8	18.6	18.3
84	18	17.8	17.5	17.3	17	16.7	16.4	16.2	16.2	16.3	16.4	16.7	17.1	17.6	18.2	18.8	19.2	19.3	19.2	19.1	18.9	18.7	18.5	18.2
90	17.9	17.7	17.5	17.2	16.9	16.7	16.4	16.1	16.2	16.3	16.4	16.7	17.1	17.6	18.1	18.7	19.1	19.2	19.1	19	18.8	18.6	18.4	18.2
96	17.9	17.6	17.4	17.1	16.9	16.6	16.3	16.1	16.1	16.2	16.4	16.7	17.1	17.6	18.1	18.6	19	19.1	19	18.9	18.7	18.5	18.3	18.1
102	17.8	17.6	17.3	17.1	16.8	16.5	16.2	16	16.1	16.2	16.4	16.7	17.1	17.5	18	18.5	18.9	19	18.9	18.8	18.6	18.5	18.2	18
108	17.7	17.5	17.3	17	16.8	16.5	16.2	16	16	16.2	16.4	16.7	17.1	17.5	18	18.5	18.8	18.9	18.8	18.7	18.6	18.4	18.2	17.9
114	17.7	17.4	17.2	17	16.7	16.4	16.1	15.9	16	16.1	16.4	16.7	17.1	17.5	18	18.4	18.7	18.8	18.8	18.6	18.5	18.3	18.1	17.9
120	17.6	17.4	17.1	16.9	16.6	16.4	16.1	15.9	15.9	16.1	16.3	16.7	17.1	17.5	17.9	18.3	18.6	18.7	18.7	18.6	18.4	18.2	18	17.8
126	17.6	17.3	17.1	16.9	16.6	16.3	16.1	15.9	15.9	16	16.3	16.7	17.1	17.5	17.9	18.3	18.6	18.7	18.6	18.5	18.4	18.2	18	17.8
132	17.6	17.3	17.1	16.9	16.6	16.3	16.1	15.9	15.9	16	16.3	16.7	17.1	17.6	18	18.3	18.6	18.6	18.6	18.5	18.4	18.2	18	17.8
138	17.6	17.4	17.1	16.9	16.6	16.3	16.1	15.9	15.9	16	16.3	16.7	17.2	17.6	18	18.4	18.6	18.7	18.6	18.5	18.4	18.2	18	17.8
144	17.6	17.4	17.2	16.9	16.7	16.4	16.1	15.9	15.9	16.1	16.3	16.7	17.2	17.7	18.1	18.4	18.7	18.7	18.7	18.6	18.4	18.3	18	17.8
150	17.7	17.5	17.2	17	16.7	16.4	16.2	16	16	16.1	16.4	16.8	17.3	17.7	18.2	18.5	18.7	18.8	18.8	18.7	18.5	18.3	18.1	17.9
156	17.8	17.5	17.3	17	16.8	16.5	16.2	16	16	16.2	16.4	16.8	17.3	17.8	18.2	18.6	18.8	18.9	18.9	18.8	18.6	18.4	18.2	18
162	17.8	17.6	17.3	17.1	16.8	16.6	16.3	16.1	16.1	16.2	16.5	16.9	17.3	17.8	18.3	18.7	18.9	19	19	18.8	18.7	18.5	18.3	18
168	17.9	17.6	17.4	17.2	16.9	16.6	16.3	16.1	16.1	16.2	16.5	16.9	17.4	17.9	18.3	18.8	19	19.1	19	18.9	18.7	18.5	18.3	18.1
174	17.9	17.7	17.4	17.2	16.9	16.6	16.3	16.1	16.1	16.2	16.5	16.9	17.4	17.9	18.4	18.8	19.1	19.1	19.1	19	18.8	18.6	18.4	18.1
180	17.9	17.7	17.5	17.2	16.9	16.7	16.4	16.1	16.1	16.2	16.5	16.9	17.3	17.9	18.4	18.8	19.1	19.2	19.1	19	18.8	18.6	18.4	18.2
186	17.9	17.7	17.5	17.2	16.9	16.6	16.4	16.1	16.1	16.2	16.4	16.8	17.3	17.8	18.3	18.8	19.1	19.2	19.1	19	18.8	18.6	18.4	18.2
192	17.9	17.7	17.4	17.2	16.9	16.6	16.3	16.1	16	16.1	16.4	16.8	17.2	17.8	18.3	18.8	19.1	19.1	19.1	19	18.8	18.6	18.4	18.1
198	17.9	17.6	17.4	17.2	16.9	16.6	16.3	16.1	16	16.1	16.3	16.7	17.2	17.7	18.2	18.7	19	19.1	19	18.9	18.7	18.6	18.3	18.1
204	17.8	17.6	17.4	17.1	16.8	16.6	16.3	16	15.9	16	16.2	16.6	17.1	17.6	18.1	18.6	18.9	19	19	18.9	18.7	18.5	18.3	18.1
210	17.8	17.5	17.3	17.1	16.8	16.5	16.2	16	15.9	15.9	16.1	16.5	17	17.5	18	18.5	18.9	18.9	18.9	18.8	18.6	18.4	18.2	18
216	17.7	17.5	17.3	17	16.7	16.5	16.2	15.9	15.8	15.8	16	16.4	16.9	17.4	17.9	18.5	18.8	18.9	18.8	18.7	18.6	18.4	18.2	17.9
222	17.7	17.4	17.2	17	16.7	16.4	16.1	15.9	15.8	15.8	16	16.3	16.8	17.4	17.9	18.4	18.7	18.8	18.8	18.7	18.5	18.3	18.1	17.9
228	17.6	17.4	17.2	16.9	16.7	16.4	16.1	15.9	15.8	15.8	16	16.3	16.8	17.3	17.9	18.4	18.7	18.8	18.7	18.6	18.5	18.3	18.1	17.9
234	17.7	17.4	17.2	17	16.7	16.4	16.1	15.9	15.8	15.8	16	16.3	16.8	17.3	17.9	18.4	18.7	18.8	18.7	18.6	18.5	18.3	18.1	17.9
240	17.7	17.4	17.2	17	16.7	16.4	16.1	15.9	15.9	15.9	16.1	16.4	16.8	17.3	17.9	18.4	18.7	18.8	18.8	18.7	18.5	18.3	18.1	17.9
246	17.7	17.5	17.2	17	16.7	16.5	16.2	16	16	16	16.2	16.5	16.9	17.4	17.9	18.4	18.8	18.8	18.8	18.7	18.5	18.4	18.1	17.9
252	17.7	17.5	17.3	17	16.8	16.5	16.2	16	16	16.1	16.3	16.6	17	17.5	18	18.5	18.8	18.9	18.9	18.8	18.6	18.4	18.2	18
258	17.8	17.6	17.3	17.1	16.8	16.5	16.2	16	16.1	16.2	16.4	16.7	17.1	17.6	18.1	18.6	18.9	19	18.9	18.8	18.6	18.4	18.2	18
264	17.8	17.6	17.4	17.1	16.8	16.6	16.3	16.1	16.2	16.3	16.5	16.8	17.2	17.7	18.1	18.6	19	19	19	18.9	18.7	18.5	18.3	18.1
270	17.9	17.6	17.4	17.2	16.9	16.6	16.3	16.1	16.2	16.4	16.7	17	17.3	17.8	18.2	18.7	19	19.1	19	18.9	18.7	18.6	18.3	18.1
276	17.9	17.7	17.4	17.2	16.9	16.6	16.3	16.2	16.3	16.5	16.8	17.1	17.5	17.9	18.3	18.8	19.1	19.1	19.1	19	18.8	18.6	18.4	18.2
282	18	17.7	17.5	17.2	17	16.7	16.4	16.2	16.3	16.6	16.9	17.2	17.6	18	18.4	18.8	19.1	19.2	19.1	19	18.8	18.6	18.4	18.2
288	18	17.8	17.5	17.3	17	16.7	16.4	16.2	16.3	16.6	17	17.3	17.7	18.1	18.5	18.9	19.2	19.2	19.2	19.1	18.9	18.7	18.5	18.2
294	18	17.8	17.6	17.3	17	16.7	16.4	16.3	16.4	16.7	17	17.4	17.8	18.2	18.6	19	19.2	19.3	19.2	19.1	18.9	18.7	18.5	18.3
300	18.1	17.8	17.6	17.3	17.1	16.8	16.5	16.3	16.4	16.7	17.1	17.5	17.9	18.3	18.7	19.1	19.3	19.3	19.3	19.2	19	18.8	18.6	18.3
306	18.1	17.9	17.6	17.4	17.1	16.8	16.5	16.3	16.4	16.7	17.1	17.6	18	18.5	18.8	19.2	19.4	19.4	19.4	19.2	19	18.8	18.6	18.4
312	18.2	18	17.7	17.4	17.2	16.9	16.6	16.4	16.5	16.8	17.2	17.7	18.2	18.6	19	19.3	19.5	19.5	19.5	19.3	19.1	18.9	18.7	18.5
318	18.3	18	17.8	17.5	17.2	16.9	16.6	16.4	16.6	16.8	17.3	17.8	18.3	18.7	19.1	19.4	19.6	19.6	19.6	19.4	19.2	19	18.8	18.5
324	18.4	18.2	17.9	17.6	17.3	17	16.7	16.5	16.6	16.9	17.3	17.8	18.4	18.9	19.3	19.6	19.8	19.8	19.7	19.6	19.4	19.2	18.9	18.7
330	18.6	18.3	18	17.8	17.5	17.2	16.8	16.6	16.7	17	17.4	17.9	18.5	19	19.5	19.8	20	20	19.9	19.7	19.5	19.3	19.1	18.8
336	18.7	18.4	18.2	17.9	17.6	17.3	17	16.7	16.8	17.1	17.5	18	18.6	19.2	19.6	20	20.2	20.2	20.1	19.9	19.7	19.5	19.2	19
342	18.9	18.6	18.3	18	17.7	17.4	17.1	16.8	16.9	17.2	17.6	18.1	18.7	19.3	19.8	20.2	20.4	20.4	20.3	20.1	19.9	19.6	19.4	19.1
348	19	18.7	18.4	18.1	17.8	17.5	17.2	16.9	17	17.2	17.6	18.2	18.8	19.4	19.9	20.3	20.5	20.5	20.4	20.3	20	19.8	19.5	19.3
354	19.1	18.8	18.5	18.2	17.9	17.6	17.2	17	17	17.3	17.7	18.2	18.8	19.4	20	20.4	20.7	20.7	20.6	20.4	20.1	19.9	19.6	19.3

APPENDIX – 5

GENERAL OUTPUT FILE OF UNIT 4RFF0

(EXERCISE- 4)

GENERAL OUTPUT FILE of the Reference Unit 4RFF0

as generated by the programme

is being reproduced as hereunder_

Unit : 4RFF

ROORKEE

ROORKEE

LATITUDE = 29.850 LONGITUDE = 77.880 STANDARD LONGITUDE = 82.500

REPRESENTATIVE DAY = 15

OUTSIDE TEMPERATURE DATA

MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	10.5	10.5	10.0	9.0	8.0	7.5	7.5	7.5	8.0	8.5	9.0	13.5	17.0	18.0	18.5	19.5	18.5	17.0	14.5	13.5	12.0	11.5	10.5	10.5	10.5
2	11.0	10.0	9.5	9.0	8.5	8.0	8.0	8.0	8.5	11.0	12.5	16.0	18.0	19.5	19.5	20.5	20.5	19.5	18.0	16.0	14.0	13.5	12.0	11.5	11.0
3	17.5	17.0	17.0	16.5	16.0	16.0	16.0	15.5	17.0	20.0	22.5	25.0	26.0	26.0	27.5	28.5	29.0	28.0	26.5	19.0	18.5	18.0	17.5	17.5	17.5
4	23.5	22.5	22.0	21.0	20.0	20.5	19.5	19.0	20.5	26.0	29.5	32.0	34.0	35.0	36.0	36.5	36.5	36.0	34.5	31.5	28.5	28.5	28.0	26.0	23.5
5	26.0	26.0	25.0	24.5	24.5	24.0	24.5	25.0	27.0	30.5	32.0	34.0	35.5	36.5	38.0	37.5	37.5	37.0	35.0	30.0	28.0	27.5	27 5	26.5	26.0
6	31.0	31.0	30.5	29.5	29.0	29.0	29.0	30.5	32.0	34.5	36.0	37.0	38.0	39.0	39.5	40.0	39.0	39.0	39.0	36.0	32.0	31.5	31.5	31.0	31.0
7	27.5	27.0	27.0	27.0	27.0	26.5	26.0	26.0	27.0	30.0	31.0	31.5	32.0	33.0	33.5	33.5	33.5	33.0	32.5	32.0	29.5	28.0	27.5	27.5	27.5
8	28.0	27.5	27.5	27.0	26.5	26.5	26.5	26.5	27.0	30.0	29.5	30.0	32.0	32.5	33.0	33.5	33.0	32.0	31.5	30.5	30.0	29.5	29.0	28.5	28.0
9	28.0	27.5	27.5	27.5	27.0	26.5	26.0	26.0	26.5	28.5	30.5	32.0	32.5	33.5	34.0	34.0	35.0	34.5	33.0	31.0	30.5	29.5	29.0	28.5	28.0
10	20.5	20.0	20.0	19.0	18.5	18.5	18.5	18.0	19.0	21.5	22.5	24.0	26.5	27.5	27.5	27.5	27.0	26.0	24.5	23.0	22.0	21.0	20.5	20.5	20.5
11	13.0	12.5	12.0	11.5	11.0	11.0	10.5	10.0	10.5	13.0	16.0	21.0	24.0	25.5	27.0	27.0	26.0	22.0	18.5	17.0	15.5	15.0	14.0	13.5	13.0
12	11.5	11.0	10.5	10.0	9.0	8.5	8.0	7.5	7.5	10.0	14.0	18.0	20.5	20.5	22.0	22.5	22.0	20.0	17.0	15.0	14.0	13.0	12.5	12.0	11.5

TEMPERATURE OF EARTH

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
TEMP	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0

HEAT LOAD PER OCCUPENT

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
LOAD	40.	40.	40.	40.	40.	60.	60.	60.	60.	90.	90.	90.	90.	90.	90.	90.	90.	90.	60.	60.	60.	40.	40.	40.

NO OF MATERIALS = 8

H VALUES :

INSIDE-VERTICAL = 8.29

INSIDE-CEILING = 6.13

INSIDE-FLOOR = 6.25

OUTSIDE = 17.30

MAT	SP. HEAT	CONDUCT	S.ABSOR
1	445.00	0.81	0.80
2	411.00	0.72	0.45
3	590.00	1.74	0.65

4	396.00	0.52	0.45
5	522.00	1.74	0.45
6	312.00	0.17	0.25
7	574.00	0.81	0.79
8	560.00	1.58	0.65

Rg = 0.20

SECTION = 1

LAYER	THICK	RESIST	HC	R1	R2	T-GRAD	HC1	HC2
1	0.01	0.01	4.11	0.00	0.01	0.02	4.02	0.09
2	0.23	0.28	102.35	0.01	0.30	0.50	51.17	51.17
3	0.01	0.01	4.11	0.30	0.31	0.98	0.09	4.02

SECTION = 2

LAYER	THICK	RESIST	HC	R1	R2	T-GRAD	HC1	HC2
1	0.01	0.01	4.11	0.00	0.01	0.02	4.04	0.07
2	0.23	0.28	102.35	0.01	0.30	0.41	60.62	41.73
3	0.01	0.01	4.11	0.30	0.31	0.80	0.83	3.28
4	0.01	0.07	3.74	0.31	0.38	0.91	0.35	3.40

SECTION = 4

LAYER	THICK	RESIST	HC	R1	R2	T-GRAD	HC1	HC2
1	0.03	0.04	13.35	0.00	0.04	0.06	12.53	0.82
2	0.08	0.15	31.68	0.04	0.19	0.38	19.63	12.05
3	0.15	0.09	84.00	0.19	0.29	0.80	17.20	66.80
4	0.01	0.01	4.11	0.29	0.30	0.98	0.10	4.01

SECTION = 5

LAYER	THICK	RESIST	HC	R1	R2	T-GRAD	HC1	HC2
1	0.15	0.09	88.50	0.00	0.09	0.08	81.86	6.64
2	0.85	0.49	443.70	0.09	0.57	0.57	188.57	255.13

SECTION DATA

COND	HC-1	HC-2	ABSR1	ABSR2	SHGC00	SHGC40	SHGC50	SHGC60	SHGC70	SHGC80	SHGCHM
1.81	55.29	55.28	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.60	65.84	48.48	0.45	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.18	3.71	3.71	0.50	0.10	0.45	0.42	0.40	0.35	0.27	0.14	0.38
1.85	49.45	83.69	0.90	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.23	270.43	261.77	0.65	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CORNER	X	Y
1	0.00	0.00
2	0.00	3.60
3	0.00	7.20

4	3.60	7.20
5	7.20	7.20
6	7.20	3.60
7	7.20	0.00
8	3.60	0.00
9	3.60	3.60

NO OF WALLS = 16

IWAL	INOD	JNOD	IROM	JROM	HT	PROP	FENS	SHAD	WIDTH	HT:F-S	HT:S-L	PROP
1	1	2	-1	1	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
2	2	3	-1	2	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
3	3	4	-1	2	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
4	4	5	-1	3	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
5	6	5	3	-1	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
6	7	6	4	-1	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
7	8	7	4	-1	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
8	1	8	1	-1	3.00	1	1	1	1.20	1.20	0.90	2.10 3.
9	2	9	2	1	3.00	1	0	1	1.20	1.20	0.00	2.10 3.
10	9	4	2	3	3.00	1	0	1	1.20	1.20	0.00	2.10 3.
11	9	6	3	4	3.00	1	0	1	1.20	1.20	0.00	2.10 3.
12	8	9	1	4	3.00	1	0	1	1.20	1.20	0.00	2.10 3.
13	2	3	-1	5	3.00	1	0	0				
14	3	4	-1	5	3.00	1	0	0				
15	9	4	5	-1	3.00	1	0	0				
16	2	9	5	-1	3.00	1	0	0				

NO OF SHADS = 1

NO.	START	LENGTH	HEIGHT	THICK	PROJ
1	0.90	1.80	2.10	0.30	0.60

NO OF ROOMS = 5

NO. OF OCCUPANTS IN THE ROOM

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPLIANCE HEAT LOAD

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

2	0.	0.	0.	0.	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

AIR CHANGES IN THE ROOM

R\T->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

INDEX 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ROOM	AREA	HEIGHT	G.H.C.	NODES ->			
1	12.96	3.00	100.00	1	2	9	8
2	12.96	3.00	100.00	2	3	4	9
3	12.96	3.00	100.00	4	5	6	9
4	12.96	3.00	100.00	6	7	8	9
5	12.96	3.00	100.00	2	3	4	9

NO OF SLABS = 4

SLAB	RM1	RM2	PROP	AREA	COND	HC-1	HC-2
1	-1	1	4	12.96	20.81	641.	1085.
2	-1	5	4	12.96	20.81	641.	1085.
3	-1	3	4	12.96	20.81	641.	1085.
4	-1	4	4	12.96	20.81	641.	1085.

NO OF PARAPET LOOPS = 1

NODES IN EACH LOOP = 5

HEIGHT OF PARAPET = 1.00

COORDINATES OF PARAPET LOOP -

NODE	X	Y
1	0.00	3.60
1	0.00	7.20
1	3 60	7.20
1	3.60	3.60
1	0.00	3 60

DATA FOR OUTER ELEMENTS

ELEM	ROOM	PROP	COND	AREA	HCR	ABSR	WAZI	TILT	GR
1	1	3	3.97	2.52	3.71	0.50	90.00	90.00	0.20
2	1	1	2.04	8.28	55.28	0.45	90.00	90.00	0.20
3	2	3	3.97	2.52	3.71	0.50	90.00	90.00	0.20
4	2	1	2.04	8.28	55.28	0.45	90.00	90.00	0.20
5	2	3	3.97	2.52	3.71	0 50	180.00	90.00	0.20
6	2	1	2.04	8.28	55.28	0.45	180.00	90.00	0.20
7	3	3	3.97	2.52	3.71	0.50	180.00	90.00	0.20
8	3	1	2.04	8.28	55.28	0.45	180.00	90.00	0.20
9	3	3	3.97	2.52	3.71	0.10	-90.00	90.00	0.20
10	3	1	2.04	8.28	55.29	0.45	-90.00	90.00	0.20
11	4	3	3.97	2.52	3.71	0.10	-90.00	90.00	0.20
12	4	1	2.04	8.28	55.29	0.45	-90.00	90.00	0.20
13	4	3	3.97	2.52	3.71	0.10	0.00	90.00	0.20
14	4	1	2.04	8.28	55.29	0.45	0.00	90.00	0.20
15	1	3	3.97	2.52	3.71	0.10	0.00	90.00	0.20
16	1	1	2.04	8.28	55.29	0.45	0.00	90.00	0.20
17	5	1	2.04	10.80	55.28	0.45	90.00	90.00	0.20
18	5	1	2.04	10.80	55.28	0.45	180.00	90.00	0.20
19	5	1	2.04	10.80	55.29	0.45	90.00	90.00	0.20
20	5	1	2.04	10.80	55.29	0.45	0.00	90.00	0.20
21	1	4	2.16	12.96	83.69	0.80	0.00	0.00	0.20
22	5	4	2.16	12.96	83.69	0.80	0.00	0.00	0.20
23	3	4	2.16	12.96	83.69	0.80	0.00	0.00	0.20
24	4	4	2.16	12.96	83.69	0.80	0.00	0.00	0.20

NO OF FLOOR = 5

FLOOR	ROOM	PROP	AREA	COND	HC
1	1	5	12.96	17.64	3505.
2	2	5	12.96	17.64	3505.
3	3	5	12.96	17.64	3505.
4	4	5	12.96	17.64	3505.
5	5	4	12.96	28.19	641.

U (CONDUCTIVITY) MATRIX

-45.97	22.99	0.00	22.99
-45.97	22.99	0.00	0.00
-45.97	22.99	0.00	0.00
-45.97	0.00	0.00	0.00
0.00	0.00	0.00	0.00

(HC-U.dT) MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577.96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760.14	0.00	0.00	0.00

TOTAL NO OF PROBLEMS = 12

PROBLEM = 1

DAY = 21 MONTH = 1

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577.96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760.14	0.00	0.00	0.00

MONTH = 1 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	7.6	19 7	12.4	10.6	10.4	9.9	9.0	8.1	7.6	7.6	7.6	8.1	9.0	9.7	14.0	17.2	18.3	18.7	19.7	18.9	17.5	15.2	14.0	12.4	11.9	10.8	10.7
1	18.1	20.5	19.3	19.5	19.3	19.1	18.9	18.7	18.5	18.3	18.1	18.1	18.2	18.4	18.7	19.1	19.5	19.9	20.3	20.5	20.5	20.4	20.3	20.2	20.0	19.8	19.6
2	16.5	17.4	17.0	17.2	17.1	17.0	16.9	16.9	16.8	16.7	16.6	16.5	16.5	16.5	16.5	16.6	16.7	16.9	17.1	17.3	17.4	17.4	17.4	17.4	17.3	17.3	17.2
3	16.6	18.1	17.4	17.5	17.4	17.2	17.1	17.0	16.8	16.7	16.6	16.6	16.8	17.0	17.2	17.4	17.6	17.8	18.0	18.0	18.1	18.0	18.0	17.9	17.8	17.7	17.6
4	18.1	20.5	19.4	19.4	19.2	19.1	18.9	18.7	18.5	18.3	18.1	18.2	18.5	18.8	19.1	19.4	19.8	20.1	20.4	20.5	20.5	20.4	20 2	20.1	19.9	19.8	19.6
5	11.5	21.4	16.0	14.9	14.4	13.9	13.3	12.8	12.2	11.7	11.5	12.0	12.9	14.0	15.2	16.9	18.4	19.8	20.9	21.4	20.9	20.1	19.2	18.2	17.3	16.4	15.6

MONTH = 1 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	7.6	19.7	12.4	10.6	10.4	9.9	9.0	8.1	7.6	7.6	7.6	8.1	9.0	9.7	14.0	17.2	18.3	18.7	19.7	18.9	17.5	15.2	14.0	12.4	11.9	10.8	10.7
1	17.8	20.2	19.0	19.2	19.0	18.8	18.6	18.4	18.2	18.0	17.9	17.8	17.8	18.0	18.3	18.7	19.1	19.5	19.9	20.2	20.2	20.1	20.0	19.8	19.7	19.5	19.3
2	16.2	17.0	16.7	16.8	16.8	16.7	16.7	16.6	16.5	16.4	16.3	16.3	16.2	16.2	16.2	16.3	16.4	16.6	16.8	17.0	17.0	17.0	17.0	17.0	17.0	16.9	16.9
3	16 8	18.4	17.7	17.7	17.6	17.5	17.4	17.2	17.0	16.9	16.8	16.9	17.1	17.3	17.5	17.8	18.0	18.2	18.3	18.4	18.4	18.4	18.3	18.2	18.1	18.0	17.9
4	18 3	20 7	19.6	19.6	19.4	19.2	19.0	18.8	18.6	18.4	18.3	18.4	18.6	18.9	19.2	19.6	20.0	20.3	20.6	20.7	20.7	20.6	20.5	20.3	20.1	20.0	19.8
5	11.5	21.2	15.9	14.9	14.4	13.8	13.3	12.8	12.2	11.7	11.5	11.9	12.8	13.9	15.2	16.8	18.3	19.6	20.7	21.2	20.8	20.0	19.1	18.2	17.3	16.4	15.6

MONTH = 1 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	7 6	19.7	12.4	10.6	10.4	9.9	9.0	8.1	7.6	7.6	7.6	8.1	9.0	9.7	14.0	17.2	18.3	18.7	19.7	18.9	17.5	15.2	14.0	12.4	11.9	10.8	10.7
1	17.4	19.7	18.6	18.8	18.6	18.4	18.3	18.1	17.9	17.7	17.5	17.4	17.5	17.6	17.8	18.2	18.6	19.0	19.4	19.7	19.7	19.6	19.5	19.4	19.2	19.1	18.9
2	16.0	16.7	16.4	16.6	16.5	16.5	16.4	16.3	16.2	16.2	16.1	16.0	16.0	16.0	16.0	16.1	16.2	16.3	16.5	16.6	16.7	16.7	16.7	16.7	16.7	16.6	16.6

3 17.0 18.7 18.0 18.0 17.8 17.7 17.6 17.4 17.2 17.1 17.0 17.1 17.3 17.5 17.8 18.1 18.3 18.5 18.7 18.7 18.7 18.7 18.6 18.5 18.4 18.2 18.1

4 18.3 20.8 19.6 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.4 18.6 18.8 19.2 19.6 20.0 20.3 20.6 20.8 20.8 20.7 20.5 20.4 20.2 20.0 19.8

5 11.5 21.0 15.9 14.9 14.3 13.8 13.3 12.8 12.2 11.7 11.5 11.8 12.6 13.7 15.1 16.7 18.3 19.5 20.5 21.0 20.7 19.9 19.0 18.1 17.2 16.3 15.5

MONTH = 1 DAY = 21 PLAN ROTATION = 45.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 7.6 19.7 12.4 10.6 10.4 9.9 9.0 8.1 7.6 7.6 7.6 8.1 9.0 9.7 14.0 17.2 18.3 18.7 19.7 18.9 17.5 15.2 14.0 12.4 11.9 10.8 10.7

1 17.1 19.3 18.2 18.4 18.3 18.1 18.0 17.8 17.6 17.4 17.3 17.2 17.1 17.2 17.5 17.8 18.2 18.6 19.0 19.2 19.3 19.2 19.1 19.0 18.9 18.7 18.6

2 15.9 16.6 16.3 16.4 16.4 16.3 16.3 16.2 16.1 16.0 16.0 15.9 15.9 15.9 15.9 16.0 16.1 16.2 16.4 16.5 16.5 16.6 16.6 16.6 16.5 16.5 16.5

3 17.2 19.1 18.2 18.2 18.1 18.0 17.8 17.6 17.5 17.3 17.2 17.3 17.5 17.7 18.0 18.4 18.6 18.9 19.0 19.1 19.0 19.0 18.9 18.8 18.7 18.5 18.4

4 18.3 20.8 19.6 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.4 18.5 18.8 19.1 19.5 19.9 20.3 20.6 20.8 20.8 20.7 20.6 20.4 20.2 20.0 19.9

5 11.5 20.9 15.8 14.9 14.3 13.8 13.3 12.7 12.2 11.7 11.5 11.9 12.6 13.6 14.9 16.6 18.3 19.6 20.5 20.9 20.6 19.8 19.0 18.0 17.1 16.3 15.5

MONTH = 1 DAY = 21 PLAN ROTATION = 60.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 7.6 19.7 12.4 10.6 10.4 9.9 9.0 8.1 7.6 7.6 7.6 8.1 9.0 9.7 14.0 17.2 18.3 18.7 19.7 18.9 17.5 15.2 14.0 12.4 11.9 10.8 10.7

1 16.9 18.9 18.0 18.2 18.0 17.9 17.7 17.6 17.4 17.2 17.1 16.9 16.9 17.0 17.2 17.5 17.9 18.3 18.6 18.9 18.9 18.9 18.8 18.7 18.6 18.4 18.3

2 16.1 16.7 16.4 16.5 16.5 16.4 16.4 16.3 16.2 16.1 16.1 16.1 16.1 16.1 16.1 16.2 16.3 16.4 16.5 16.6 16.6 16.7 16.7 16.7 16.6 16.6 16.6

3 17.5 19.5 18.6 18.6 18.4 18.3 18.1 17.9 17.8 17.6 17.5 17.6 17.8 18.1 18.4 18.7 19.0 19.3 19.4 19.5 19.5 19.4 19.3 19.2 19.0 18.9 18.7

4 18.3 20.8 19.6 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.3 18.5 18.7 19.1 19.5 19.9 20.3 20.6 20.8 20.8 20.7 20.6 20.4 20.2 20.1 19.9

5 11.5 21.0 15.8 14.9 14.3 13.8 13.3 12.8 12.2 11.7 11.5 12.0 12.8 13.7 14.9 16.6 18.3 19.7 20.6 21.0 20.6 19.8 19.0 18.1 17.2 16.3 15.5

MONTH = 1 DAY = 21 PLAN ROTATION = 75.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 7.6 19.7 12.4 10.6 10.4 9.9 9.0 8.1 7.6 7.6 7.6 8.1 9.0 9.7 14.0 17.2 18.3 18.7 19.7 18.9 17.5 15.2 14.0 12.4 11.9 10.8 10.7

1 16.7 18.6 17.7 17.9 17.8 17.6 17.5 17.3 17.2 17.0 16.9 16.8 16.7 16.8 17.0 17.2 17.6 18.0 18.3 18.6 18.6 18.6 18.5 18.4 18.3 18.2 18.0

2 16.3 17.0 16.7 16.8 16.7 16.7 16.6 16.5 16.4 16.3 16.3 16.3 16.4 16.4 16.5 16.5 16.6 16.7 16.8 16.9 16.9 17.0 17.0 16.9 16.9 16.9 16.8

3 17.8 20.0 19.0 19.0 18.8 18.7 18.5 18.3 18.1 17.9 17.8 17.9 18.2 18.4 18.8 19.1 19.5 19.8 19.9 20.0 20.0 19.9 19.8 19.6 19.5 19.3 19.2

4 18.3 20.8 19.6 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.3 18.4 18.7 19.0 19.4 19.8 20.2 20.6 20.8 20.8 20.7 20.5 20.4 20.2 20.0 19.9

5 11.5 21.2 15.9 14.9 14.3 13.8 13.3 12.8 12.2 11.7 11.5 12.0 12.9 13.9 15.0 16.6 18.3 19.7 20.8 21.2 20.8 20.0 19.1 18.2 17.2 16.4 15.6

PROBLEM = 2

DAY = 21 MONTH = 2

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96 -11.49 0.00 -11.49

4576.88 -11.49 0.00 0.00

4577.96 -11.49 0.00 0.00

4577.96 0.00 0.00 0.00

760.14 0.00 0.00 0.00

MONTH = 2 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	22.2	14.9	12.3	11.4	11.0	10.5	10.0	9.6	9.6	9.5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7
1	20.7	23.4	22.1	22.3	22.1	21.8	21.6	21.4	21.2	20.9	20.8	20.7	20.8	21.1	21.4	21.8	22.2	22.6	23.0	23.3	23.4	23.3	23.2	23.1	22.9	22.7	22.5
2	19.2	20.3	19.7	20.0	19.9	19.8	19.7	19.6	19.5	19.4	19.3	19.2	19.2	19.2	19.2	19.3	19.4	19.6	19.9	20.1	20.3	20.3	20.3	20.2	20.2	20.1	20.0
3	19.5	21.3	20.5	20.6	20.4	20.2	20.1	19.9	19.7	19.5	19.5	19.6	19.8	20.0	20.3	20.6	20.8	21.0	21.2	21.3	21.3	21.3	21.2	21.1	21.0	20.9	20.7
4	20.8	23.4	22.2	22.2	22.0	21.8	21.6	21.4	21.2	20.9	20.8	21.0	21.2	21.6	21.9	22.3	22.7	23.0	23.2	23.4	23.3	23.3	23.2	23.0	22.8	22.6	22.4
5	13 5	24.2	18.5	17.3	16.6	15.8	15.2	14.6	14.0	13.5	13.5	14.1	15.2	16.6	18.1	19.6	21.1	22.5	23.6	24.2	24.1	23.3	22.4	21.2	20.1	19.1	18.2

MONTH = 2 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	22 2	14.9	12.3	11.4	11.0	10.5	10.0	9.6	9.6	9 5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7
1	20 5	23.1	21.8	22.0	21.8	21.6	21.4	21.2	21.0	20.8	20.6	20.5	20.5	20.7	21.0	21.4	21.8	22.3	22.7	23.0	23.1	23.1	23.0	22.8	22.6	22.4	22.2
2	18.9	20.0	19.5	19.7	19.6	19.5	19.4	19.3	19.2	19.1	19.0	19.0	18.9	19.0	19.0	19.1	19.2	19.3	19.5	19.8	19.9	20.0	20.0	19.9	19.9	19.8	19.8
3	19.7	21.6	20.8	20.8	20.6	20.5	20.3	20.1	19.9	19.7	19.7	19.8	20.0	20.3	20.6	20.9	21.1	21.4	21.5	21.6	21.6	21.6	21.5	21.4	21.3	21.1	21.0
4	21.0	23.6	22.4	22.4	22.2	22.0	21.8	21.6	21.3	21.1	21.0	21.1	21.3	21.6	22.0	22.4	22.8	23.1	23.4	23.6	23.6	23.5	23.4	23.2	23.0	22.9	22.6
5	13 4	24 2	18.5	17.3	16.6	15.8	15.2	14.6	14.0	13.5	13.4	14.0	15.1	16.4	18.0	19.6	21.0	22.4	23.5	24.2	24.1	23.3	22.4	21.2	20.2	19.1	18.2

MONTH = 2 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	22 2	14.9	12.3	11.4	11.0	10.5	10.0	9.6	9.6	9.5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7
1	20.2	22 8	21 5	21.8	21.6	21.4	21.2	20.9	20.7	20.5	20.3	20.2	20.3	20.4	20.7	21.1	21.5	21.9	22.3	22.7	22.8	22.7	22.6	22.5	22.3	22.1	21.9
2	18.7	19.6	19.2	19.4	19.3	19.3	19.2	19.1	19.0	18.9	18.8	18.8	18.7	18.8	18.8	18.9	19.0	19.1	19.3	19.5	19.6	19.6	19.6	19.6	19.6	19.5	19.5
3	19 8	21.9	21.0	21.0	20.8	20.7	20.5	20.3	20.1	19.9	19.8	20.0	20.2	20.5	20.8	21.1	21.4	21.6	21.8	21.9	21.9	21.8	21.8	21.6	21.5	21.3	21.2
4	21.1	23.8	22.5	22.6	22.3	22.1	21.9	21.7	21.4	21.2	21.1	21.2	21.4	21.7	22.0	22.4	22.8	23.2	23.5	23.7	23.8	23.7	23.5	23.4	23.2	23.0	22.8
5	13.5	24.1	18.4	17.3	16.5	15.8	15.2	14.6	14.0	13.5	13.5	13.9	14.9	16.3	17.9	19.5	21.0	22.3	23.3	24.1	24.0	23.3	22.3	21.2	20.1	19.1	18.1

MONTH = 2 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	22.2	14.9	12.3	11.4	11.0	10.5	10.0	9.6	9.6	9.5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7
1	20.0	22.5	21.2	21.5	21.3	21.1	20.9	20.7	20.5	20.3	20.1	20.0	20.0	20.2	20.4	20.8	21.2	21.6	22.0	22.3	22.5	22.4	22.3	22.2	22.0	21.8	21.7
2	18 7	19.5	19.1	19.3	19.2	19.1	19.1	19.0	18.9	18.8	18.7	18.7	18.7	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.5	19.5	19.4	19.4	19.3
3	20.0	22 2	21.2	21.3	21.1	20.9	20.7	20.5	20.3	20.1	20.0	20.2	20.4	20.8	21.1	21.4	21.7	21.9	22.1	22.2	22.2	22.1	22.0	21.9	21.8	21.6	21.4
4	21 1	23.8	22.5	22.6	22.4	22.2	21.9	21.7	21.5	21.2	21.1	21.2	21.4	21.7	22.0	22.4	22.8	23.2	23.5	23.8	23.8	23.7	23.6	23.4	23.2	23.0	22.8
5	13 5	23.9	18.4	17.3	16.5	15.8	15.1	14.5	14.0	13.5	13.5	14.1	15.0	16.3	17.8	19.5	21.1	22.3	23.3	23.9	23.8	23.1	22.2	21.1	20.1	19.0	18.1

MONTH = 2 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	22.2	14.9	12.3	11.4	11.0	10.5	10.0	9.6	9.6	9.5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7
1	19.8	22.1	21.0	21.2	21.1	20.9	20.7	20.5	20.3	20.1	19.9	19.8	19.8	19.9	20.2	20.5	20.9	21.3	21.7	22.0	22.1	22.1	22.0	21.9	21.7	21.6	21.4
2	18.8	19.6	19.2	19.3	19.3	19.2	19.1	19.0	18.9	18.8	18.8	18.8	18.9	18.9	19.0	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.6	19.5	19.5	19.5	19.4
3	20.3	22.5	21.5	21.5	21.3	21.2	21.0	20.7	20.5	20.3	20.3	20.4	20.7	21.0	21.4	21.7	22.0	22.3	22.5	22.5	22.5	22.5	22.4	22.2	22.1	21.9	21.7
4	21.1	23.8	22.5	22.6	22.4	22.2	21.9	21.7	21.5	21.2	21.1	21.1	21.3	21.6	21.9	22.3	22.7	23.1	23.5	23.7	23.8	23.7	23.6	23.4	23.2	23.0	22.8
5	13.5	23.9	18.4	17.3	16.5	15.8	15.1	14.5	14.0	13.5	13.5	14.2	15.2	16.4	17.9	19.5	21.1	22.4	23.4	23.9	23.8	23.1	22.2	21.1	20.0	19.0	18.1

MONTH = 2 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	22.2	14.9	12.3	11.4	11.0	10.5	10.0	9.6	9.6	9.5	10.2	12.8	14.5	17.8	19.6	20.8	21.1	22.1	22.2	21.2	19.7	16.6	14.9	14.4	13.1	12.7
1	19.6	21.9	20.8	21.0	20.8	20.7	20.5	20.3	20.1	19.9	19.7	19.6	19.6	19.8	20.0	20.3	20.6	21.0	21.4	21.7	21.9	21.8	21.7	21.6	21.5	21.3	21.2
2	19.0	19.8	19.5	19.6	19.5	19.4	19.3	19.2	19.1	19.0	19.0	19.1	19.2	19.2	19.3	19.4	19.5	19.6	19.6	19.7	19.8	19.8	19.8	19.8	19.8	19.7	19.6
3	20.5	22.9	21.8	21.8	21.6	21.4	21.2	21.0	20.8	20.6	20.5	20.7	21.0	21.3	21.6	22.0	22.3	22.6	22.8	22.9	22.9	22.8	22.7	22.6	22.4	22.2	22.0
4	21.0	23.7	22.4	22.5	22.3	22.1	21.9	21.6	21.4	21.2	21.0	21.0	21.2	21.4	21.8	22.1	22.6	23.0	23.4	23.6	23.7	23.6	23.5	23.3	23.1	22.9	22.7
5	13.5	24.1	18.5	17.3	16.5	15.8	15.2	14.5	14.0	13.5	13.5	14.2	15.3	16.6	18.0	19.6	21.1	22.5	23.5	24.1	23.9	23.2	22.3	21.1	20.1	19.1	18.1

PROBLEM = 3

DAY = 21 MONTH = 3

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577.96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760.14	0.00	0.00	0.00

MONTH = 3 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	16.2	30.5	22.2	18.7	18.1	18.0	17.4	16.8	16.9	16.7	16.2	17.7	21.2	23.9	26.4	27.6	27.8	29.2	30.1	30.5	29.6	28.1	21.5	20.5	20.1	19.6	19.2
1	27.1	29.9	28.4	28.6	28.4	28.1	27.9	27.7	27.5	27.2	27.1	27.1	27.2	27.4	27.8	28.2	28.6	29.0	29.4	29.7	29.9	29.8	29.7	29.5	29.3	29.0	28.8
2	25.5	26.8	26.1	26.4	26.3	26.1	26.0	25.9	25.8	25.7	25.6	25.5	25.5	25.5	25.6	25.7	25.8	26.0	26.3	26.6	26.8	26.8	26.8	26.7	26.6	26.5	26.5
3	26.2	28.4	27.4	27.4	27.2	27.0	26.8	26.6	26.4	26.2	26.3	26.4	26.7	27.0	27.3	27.6	27.9	28.1	28.3	28.3	28.4	28.3	28.2	28.1	27.9	27.7	27.6
4	27.3	29.8	28.6	28.6	28.4	28.2	27.9	27.7	27.5	27.3	27.3	27.4	27.7	28.0	28.4	28.8	29.1	29.4	29.7	29.8	29.8	29.8	29.6	29.4	29.2	29.0	28.8
5	19.4	30.9	24.7	23.0	22.2	21.5	20.8	20.2	19.7	19.4	19.6	20 3	21.6	23.1	24.8	26.3	27.8	29.1	30.2	30.9	30.9	30.3	29.0	27.5	26.1	24.9	23.9

MONTH = 3 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OUT 16 2 30.5 22.2 18.7 18.1 18.0 17.4 16 8 16.9 16.7 16.2 17 7 21.2 23 9 26.4 27.6 27.8 29.2 30.1 30.5 29.6 28.1 21.5 20.5 20.1 19.6 19.2

1 26 9 29.8 28.3 28.5 28.3 28.1 27.8 27.6 27.4 27.2 27.0 26.9 27.0 27.3 27 6 28.0 28.4 28.8 29.2 29.6 29.8 29.7 29.6 29.4 29.2 28.9 28.7

2 25.4 26 6 25.9 26.2 26.1 26.0 25.9 25.8 25.6 25.5 25.4 25.4 25.4 25.4 25.5 25.6 25.7 25.8 26.1 26.3 26.5 26.6 26.6 26.5 26.4 26.3 26.3

3 26 4 28.6 27.6 27.6 27.4 27.2 27.0 26.8 26.6 26.4 26.4 26.6 26.9 27.2 27.5 27.8 28.1 28.3 28.5 28.6 28.6 28.6 28.5 28.3 28.1 27.9 27.8

4 27.4 30.1 28.8 28.8 28.6 28.4 28.1 27.9 27.7 27.5 27.4 27.6 27.8 28.2 28.5 28.9 29.3 29.6 29.9 30.1 30.1 30.0 29.9 29.7 29.5 29.3 29.0

5 19.4 31.0 24.7 23.0 22.2 21.5 20.9 20.2 19.7 19.4 19.6 20.2 21.4 23.0 24.7 26.3 27.7 29.0 30.1 31.0 31.0 30.4 29.1 27.5 26.2 25.0 23.9

MONTH = 3 DAY = 21 PLAN ROTATION = 30.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 16.2 30.5 22.2 18.7 18.1 18.0 17.4 16.8 16.9 16.7 16.2 17.7 21.2 23.9 26.4 27.6 27.8 29.2 30.1 30.5 29.6 28.1 21.5 20.5 20.1 19.6 19.2

1 26 9 29.7 28.2 28.4 28.2 28.0 27.8 27.5 27.3 27.1 26.9 26.9 26.9 27.1 27.4 27.8 28.2 28.6 29.1 29.4 29.7 29.6 29.5 29.3 29.1 28.9 28.6

2 25.3 26.4 25.8 26.0 25.9 25.8 25.7 25.6 25.5 25.4 25.4 25.3 25.3 25.4 25.4 25.5 25.6 25.8 26.0 26.2 26.4 26.4 26.4 26.3 26.3 26.2 26.1

3 26.6 28 9 27.8 27.8 27.6 27.4 27.2 27.0 26.8 26.6 26.6 26.8 27.1 27.4 27.7 28.1 28.4 28.6 28.8 28.9 28.9 28.8 28.7 28.6 28.4 28.2 28.0

4 27.6 30 4 29 0 29.0 28.8 28.6 28.3 28.1 27.8 27.6 27.6 27.7 28.0 28.3 28.6 29.0 29.4 29.7 30.1 30 3 30.4 30.3 30.2 29.9 29.7 29.5 29.3

5 19.4 31 1 24.7 23.0 22.2 21.5 20.9 20 3 19.7 19.4 19.7 20.3 21.4 22.9 24.6 26.3 27.6 28.9 30.1 30.9 31.1 30.4 29.1 27.6 26.2 25.0 23.9

MONTH = 3 DAY = 21 PLAN ROTATION = 45.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 16 2 30.5 22.2 18.7 18.1 18.0 17.4 16.8 16.9 16.7 16.2 17.7 21.2 23.9 26.4 27.6 27.8 29.2 30.1 30.5 29.6 28.1 21.5 20.5 20.1 19.6 19.2

1 26.7 29.5 28.1 28.3 28.1 27.8 27.6 27.4 27.2 27.0 26.8 26.7 26.8 27.0 27.3 27.6 28.0 28.4 28.9 29.2 29.5 29.4 29.3 29.1 28.9 28.7 28.5

2 25.4 26.3 25.8 25.9 25.9 25.8 25.7 25.6 25.4 25.4 25.4 25.4 25.4 25.4 25.5 25.6 25.7 25.8 25.9 26.1 26.3 26.3 26.3 26.2 26.2 26.1 26.0

3 26.8 29.1 28.1 28.0 27.8 27.6 27.4 27.2 26.9 26.8 26.8 27.0 27.3 27.6 28.0 28.3 28.6 28.8 29.0 29.1 29.1 29.1 29.0 28.8 28.6 28.4 28.2

4 27.7 30 5 29.1 29.1 28.9 28.7 28.4 28.2 27.9 27.7 27.7 27.8 28.0 28.3 28.6 29.0 29.4 29.8 30.1 30.4 30.5 30.4 30.3 30.1 29.8 29.6 29.4

5 19.4 31.0 24.7 23.0 22.2 21.5 20.8 20.2 19.7 19.4 19.7 20.5 21.6 23.1 24.7 26.3 27.7 28.9 30.0 30.8 31.0 30.3 29.1 27.5 26.1 24.9 23.9

MONTH = 3 DAY = 21 PLAN ROTATION = 60.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 16.2 30.5 22.2 18.7 18.1 18.0 17.4 16.8 16.9 16.7 16.2 17.7 21.2 23.9 26.4 27.6 27.8 29.2 30.1 30.5 29.6 28.1 21.5 20.5 20.1 19.6 19.2

1 26.5 29.2 27.8 28.1 27.8 27.6 27.4 27.2 27.0 26.8 26.6 26.5 26.6 26.8 27.1 27.4 27.8 28.2 28.6 29.0 29.2 29.2 29.0 28.8 28.7 28.5 28.3

2 25.4 26.3 25.8 25.9 25.8 25.8 25.7 25.5 25.4 25.4 25.4 25.5 25.5 25.6 25.6 25.7 25.8 25.9 26.0 26.2 26.3 26.3 26.3 26.2 26.2 26.1 26.0

3 26.9 29.3 28.2 28.2 27.9 27.7 27.5 27.3 27.1 26.9 27.0 27.2 27.4 27.8 28.1 28.5 28.8 29.0 29.2 29.3 29.3 29.3 29.2 29.0 28.8 28.6 28.4

4 27.6 30.4 29.0 29.1 28.9 28.6 28.4 28.1 27.9 27.7 27.6 27.7 27.8 28.1 28.5 28.9 29.3 29.6 30.0 30.3 30.4 30.4 30.2 30.0 29.8 29.6 29.3

5 19.4 30.9 24.7 23.0 22.2 21.5 20.8 20.2 19.7 19.4 19.7 20.5 21.7 23.2 24.7 26.4 27.8 29.0 30.0 30.7 30.9 30.2 29.0 27.4 26.1 24.9 23.9

MONTH = 3 DAY = 21 PLAN ROTATION = 75.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 16.2 30.5 22.2 18.7 18.1 18.0 17.4 16.8 16.9 16.7 16.2 17.7 21.2 23.9 26.4 27.6 27.8 29.2 30.1 30.5 29.6 28.1 21.5 20.5 20.1 19.6 19.2

1 26 3 28.9 27.6 27.8 27.6 27.4 27.2 27.0 26.8 26.6 26.4 26.3 26.4 26.6 26.8 27.2 27.6 28.0 28.4 28.7 28.9 28.9 28.8 28.6 28.4 28.2 28.0

2 25 4 26.4 26.0 26.0 25 9 25.8 25.7 25.6 25.5 25.4 25.5 25.6 25.7 25.7 25.8 25.9 26.0 26.1 26.2 26.3 26.4 26.4 26.4 26.3 26.3 26.2 26.1

3	27.0	29.5	28.3	28.3	28.1	27.8	27.6	27.4	27.2	27.0	27.0	27.2	27.5	27.8	28.2	28.6	28.9	29.2	29.4	29.5	29.5	29.4	29.3	29.1	28.9	28.7	28.5
4	27.4	30.3	28.8	28.9	28.7	28.5	28.2	28.0	27.8	27.5	27.4	27.4	27.6	27.9	28.2	28.6	29.0	29.4	29.8	30.1	30.3	30.2	30.0	29.8	29.6	29.4	29.2
5	19.4	30.8	24.7	23.0	22.2	21.4	20.8	20.2	19.7	19.4	19.7	20.5	21.7	23.2	24.7	26.3	27.8	29.0	30.1	30.7	30.8	30.1	28.9	27.4	26.0	24.9	23.9

PROBLEM = 4

DAY = 21 MONTH = 4

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577.96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760.14	0.00	0.00	0.00

MONTH = 4 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	20.2	36.7	28.2	24.0	23.2	22.6	21.7	20.9	21.2	20.5	20.2	21.8	26.9	30.0	32.4	34.3	35.3	36.4	36.7	36.7	36.2	34.6	31.2	28.4	28.3	27.9	26.1
1	32.3	35.2	33.8	34.1	33.8	33.6	33.3	33.0	32.8	32.5	32.4	32.3	32.5	32.7	33.0	33.4	33.8	34.2	34.6	35.0	35.2	35.1	35.0	34.9	34.7	34.5	34.3
2	30.8	32.3	31.6	31.9	31.8	31.6	31.5	31.3	31.2	31.1	31.0	30.9	30.8	30.9	30.9	31.0	31.2	31.4	31.7	32.0	32.2	32.3	32.3	32.2	32.1	32.1	32.0
3	32.0	34.2	33.2	33.3	33.1	32.8	32.6	32.3	32.1	32.0	32.0	32.2	32.4	32.7	33.0	33.3	33.6	33.9	34.1	34.2	34.2	34.2	34.1	34.0	33.8	33.7	33.5
4	32.7	35.1	34.0	34.1	33.8	33.6	33.3	33.1	32.8	32.7	32.7	32.8	33.1	33.4	33.7	34.1	34.4	34.7	35.0	35.1	35.1	35.1	35.0	34.9	34.7	34.5	34.3
5	24.0	36.2	29.9	29.0	27.9	26.9	25.9	25.0	24.3	24.0	24.1	24.7	25.9	27.6	29.3	30.9	32.6	34.1	35.3	36.0	36.2	35.7	34.7	33.4	32.2	31.2	30.1

MONTH = 4 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	20.2	36.7	28.2	24.0	23.2	22.6	21.7	20.9	21.2	20.5	20.2	21.8	26.9	30.0	32.4	34.3	35.3	36.4	36.7	36.7	36.2	34.6	31.2	28.4	28.3	27.9	26.1
1	32.3	35.2	33.8	34.1	33.8	33.6	33.3	33.0	32.8	32.5	32.4	32.3	32.4	32.6	33.0	33.3	33.7	34.2	34.6	34.9	35.2	35.1	35.0	34.9	34.7	34.5	34.3
2	30.9	32.2	31.6	31.9	31.7	31.6	31.5	31.3	31.2	31.1	31.0	30.9	30.9	30.9	31.0	31.1	31.2	31.4	31.7	31.9	32.2	32.2	32.2	32.2	32.1	32.0	32.0
3	32.1	34.4	33.4	33.4	33.2	33.0	32.7	32.5	32.2	32.1	32.2	32.3	32.6	32.9	33.2	33.5	33.8	34.1	34.3	34.4	34.4	34.4	34.3	34.1	34.0	33.8	33.6
4	32.8	35.3	34.1	34.2	34.0	33.7	33.5	33.2	32.9	32.8	32.8	32.9	33.1	33.4	33.8	34.1	34.5	34.8	35.1	35.3	35.3	35.3	35.2	35.0	34.8	34.7	34.5
5	24.0	36.4	29.9	29.1	27.9	26.9	26.0	25.1	24.3	24.0	24.3	24.9	25.9	27.5	29.3	30.9	32.5	34.1	35.4	36.2	36.4	35.8	34.8	33.5	32.3	31.2	30.2

MONTH = 4 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	20.2	36.7	28.2	24.0	23.2	22.6	21.7	20.9	21.2	20.5	20.2	21.8	26.9	30.0	32.4	34.3	35.3	36.4	36.7	36.7	36.2	34.6	31.2	28.4	28.3	27.9	26.1
1	32.3	35.2	33.8	34.1	33.9	33.6	33.3	33.1	32.8	32.6	32.4	32.3	32.4	32.6	32.9	33.3	33.7	34.1	34.6	34.9	35.2	35.2	35.1	34.9	34.7	34.5	34.3
2	31.0	32.2	31.6	31.9	31.7	31.6	31.5	31.3	31.2	31.1	31.1	31.0	31.0	31.0	31.1	31.2	31.3	31.5	31.7	32.0	32.2	32.2	32.2	32.2	32.1	32.0	32.0
3	32.3	34.6	33.6	33.6	33.4	33.1	32.9	32.6	32.4	32.3	32.4	32.5	32.8	33.1	33.4	33.7	34.0	34.3	34.5	34.6	34.6	34.6	34.5	34.3	34.2	34.0	33.8
4	32.9	35.5	34.3	34.4	34.2	33.9	33.7	33.4	33.1	32.9	32.9	33.0	33.2	33.5	33.9	34.2	34.6	34.9	35.2	35.5	35.5	35.5	35.4	35.2	35.0	34.9	34.7
5	24.1	36.5	30.0	29.1	28.0	26.9	26.0	25.1	24.3	24.1	24.4	25.0	26.1	27.6	29.3	31.0	32.6	34.1	35.4	36.3	36.5	35.9	34.9	33.6	32.4	31.3	30.2

MONTH = 4 DAY = 21 PLAN ROTATION = 45 0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 20.2 36.7 28.2 24.0 23.2 22.6 21.7 20.9 21.2 20.5 20.2 21.8 26.9 30.0 32.4 34.3 35.3 36.4 36.7 36.7 36.2 34.6 31.2 28.4 28.3 27.9 26.1

1 32.3 35.1 33.7 34.1 33.8 33.6 33.3 33.0 32.8 32.5 32.4 32.3 32.3 32.6 32.9 33.2 33.6 34.1 34.5 34.9 35.1 35.1 35.0 34.9 34.7 34.5 34.3

2 31.1 32.2 31.6 31.8 31.7 31.6 31.5 31.3 31.2 31.1 31.1 31.1 31.1 31.2 31.2 31.3 31.4 31.6 31.8 32.0 32.1 32.2 32.2 32.2 32.1 32.0 31.9

3 32.4 34.8 33.7 33.8 33.5 33.3 33.0 32.8 32.5 32.4 32.5 32.7 32.9 33.2 33.5 33.9 34.2 34.4 34.6 34.8 34.8 34.7 34.6 34.5 34.3 34.2 34.0

4 33.0 35.7 34.4 34.6 34.3 34.0 33.8 33.5 33.2 33.0 33.0 33.0 33.2 33.5 33.8 34.2 34.6 35.0 35.3 35.6 35.7 35.6 35.5 35.4 35.2 35.0 34.8

5 24.1 36.5 30.0 29.1 28.0 26.9 26.0 25.1 24.3 24.1 24.4 25.1 26.2 27.7 29.4 31.0 32.6 34.1 35.4 36.3 36.5 36.0 35.0 33.6 32.4 31.3 30.3

MONTH = 4 DAY = 21 PLAN ROTATION = 60.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 20.2 36.7 28.2 24.0 23.2 22.6 21.7 20.9 21.2 20.5 20.2 21.8 26.9 30.0 32.4 34.3 35.3 36.4 36.7 36.7 36.2 34.6 31.2 28.4 28.3 27.9 26.1

1 32.1 35.0 33.6 33.9 33.7 33.4 33.2 32.9 32.7 32.4 32.2 32.1 32.2 32.4 32.7 33.1 33.5 33.9 34.3 34.7 35.0 35.0 34.9 34.7 34.5 34.4 34.2

2 31.1 32 1 31.6 31.8 31.7 31.5 31.4 31.3 31.1 31.1 31.1 31.1 31.2 31.2 31.3 31.4 31.5 31.6 31.8 31.9 32.1 32.1 32.1 32.1 32.0 31.9 31.9

3 32.4 34.9 33.8 33.8 33.6 33.3 33.1 32.8 32.5 32.4 32.5 32.7 32.9 33.2 33.6 33.9 34.2 34.5 34.7 34.8 34.9 34.8 34.7 34.6 34.4 34.2 34.0

4 32.9 35 7 34.3 34.5 34.3 34.0 33.7 33.5 33.2 33.0 32.9 32.9 33.1 33.3 33.7 34.0 34.4 34.8 35.2 35.5 35.7 35.6 35.5 35.3 35.2 35.0 34.8

5 24.1 36.4 30 0 29.1 28.0 26.9 26.0 25.1 24.3 24.1 24.4 25.0 26.2 27.8 29.3 31.0 32.6 34.0 35.3 36.2 36.4 35.9 34.9 33.6 32.3 31.3 30.2

MONTH = 4 DAY = 21 PLAN ROTATION = 75.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 20 2 36.7 28.2 24.0 23.2 22.6 21.7 20.9 21.2 20.5 20.2 21.8 26.9 30.0 32.4 34.3 35.3 36.4 36.7 36.7 36.2 34.6 31.2 28.4 28.3 27.9 26.1

1 32.0 34.7 33.4 33.7 33.5 33.3 33.0 32.7 32.5 32.2 32.1 32.0 32.0 32.2 32.5 32.9 33.3 33.7 34.1 34.5 34.7 34.7 34.6 34.5 34.3 34.1 34.0

2 31.0 32.0 31.5 31.7 31.6 31.4 31.3 31.2 31.0 31.0 31.1 31.1 31.2 31.3 31.3 31.4 31.5 31.6 31.8 31.9 32.0 32.0 32.0 32.0 31.9 31.9 31.8

3 32.4 34.9 33.8 33.8 33.6 33.3 33.1 32.8 32.6 32.4 32.5 32.6 32.9 33.2 33.5 33.9 34.2 34.5 34.7 34.8 34.9 34.8 34.7 34.6 34.4 34.2 34.0

4 32.7 35.5 34.1 34.4 34.2 33.9 33.6 33.4 33.1 32.9 32.7 32.7 32.8 33.1 33.4 33.8 34.2 34.6 35.0 35.3 35.5 35.5 35.4 35.2 35.0 34.9 34.7

5 24.0 36.3 29.9 29.1 27.9 26.9 26.0 25.1 24.3 24.0 24.2 24.9 26.1 27.7 29.3 31.0 32.6 34.0 35.2 36.0 36.3 35.7 34.8 33.5 32.2 31.2 30.2

PROBLEM = 5

DAY = 21 MONTH = 5

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96 -11.49 0.00 -11.49

4576.88 -11.49 0.00 0.00

4577.96 -11 49 0.00 0.00

4577.96 0.00 0.00 0.00

760.14 0.00 0.00 0.00

MONTH = 5 DAY = 21 PLAN ROTATION = 0.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT	25.0	38.3	30.8	27.0	27.0	26.1	25.5	25.4	25.0	25.4	26.1	28.0	31.3	32.8	34.6	36.0	37.0	38.3	38.0	37.8	37.4	35.8	31.2	28.8	28.3	28.3	27.4
1	34.7	37.5	36.1	36.2	36.0	35.7	35.5	35.2	35.0	34.8	34.7	34.8	34.9	35.2	35.5	35.8	36.2	36.6	37.0	37.3	37.5	37.5	37.3	37.1	36.9	36.7	36.4
2	33.4	34.7	34.0	34.2	34.1	33.9	33.8	33.7	33.5	33.5	33.4	33.4	33.4	33.4	33.5	33.6	33.7	33.9	34.2	34.4	34.7	34.7	34.7	34.6	34.5	34.4	34.3
3	34.6	36.9	35.8	35.7	35.5	35.3	35.0	34.8	34.6	34.6	34.7	34.9	35.2	35.5	35.8	36.1	36.4	36.6	36.8	36.9	36.9	36.9	36.8	36.6	36.4	36.1	35.9
4	35.0	37.5	36.3	36.2	36.0	35.8	35.5	35.3	35.1	35.0	35.1	35.3	35.6	35.9	36.2	36.5	36.9	37.2	37.4	37.5	37.5	37.5	37.3	37.1	36.9	36.7	36.5
5	26.8	38.1	32.1	30.1	29.3	28.5	27.8	27.2	26.8	26.9	27.5	28.4	29.7	31.1	32.5	33.8	35.1	36.4	37.4	38.0	38.1	37.5	36.3	34.8	33.3	32.1	31.0

MONTH = 5 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	25.0	38.3	30.8	27.0	27.0	26.1	25.5	25.4	25.0	25.4	26.1	28.0	31.3	32.8	34.6	36.0	37.0	38.3	38.0	37.8	37.4	35.8	31.2	28.8	28.3	28.3	27.4
1	34.7	37.5	36.1	36.2	36.0	35.7	35.5	35.3	35.0	34.8	34.7	34.8	34.9	35.2	35.5	35.8	36.2	36.6	37.0	37.3	37.5	37.5	37.3	37.1	36.9	36.7	36.5
2	33.5	34.8	34.1	34.2	34.1	34.0	33.9	33.7	33.6	33.5	33.5	33.5	33.5	33.5	33.6	33.7	33.8	34.0	34.2	34.5	34.7	34.8	34.8	34.7	34.6	34.5	34.3
3	34.6	37.0	35.9	35.8	35.5	35.3	35.1	34.9	34.6	34.6	34.8	35.0	35.3	35.6	35.9	36.2	36.5	36.7	36.9	37.0	37.0	36.9	36.8	36.6	36.4	36.2	36.0
4	35.1	37.6	36.4	36.3	36.1	35.8	35.6	35.3	35.1	35.1	35.1	35.3	35.6	35.9	36.2	36.5	36.9	37.2	37.4	37.6	37.6	37.5	37.4	37.2	37.0	36.7	36.5
5	26.8	38.2	32.1	30.1	29.3	28.5	27.8	27.2	26.8	26.9	27.6	28.6	29.8	31.2	32.5	33.8	35.1	36.4	37.5	38.1	38.2	37.5	36.3	34.8	33.3	32.1	31.0

MONTH = 5 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	25.0	38.3	30.8	27.0	27.0	26.1	25.5	25.4	25.0	25.4	26.1	28.0	31.3	32.8	34.6	36.0	37.0	38.3	38.0	37.8	37.4	35.8	31.2	28.8	28.3	28.3	27.4
1	34.8	37.5	36.1	36.3	36.0	35.8	35.5	35.3	35.1	34.9	34.8	34.8	34.9	35.2	35.5	35.8	36.2	36.6	37.0	37.3	37.5	37.5	37.4	37.2	37.0	36.7	36.5
2	33.7	34.9	34.2	34.3	34.2	34.1	33.9	33.8	33.7	33.7	33.7	33.7	33.7	33.8	33.8	33.9	34.0	34.2	34.4	34.6	34.8	34.9	34.9	34.8	34.7	34.6	34.4
3	34.8	37.1	36.0	35.9	35.7	35.4	35.2	35.0	34.8	34.8	34.9	35.2	35.4	35.7	36.0	36.4	36.6	36.9	37.1	37.1	37.1	37.1	36.9	36.7	36.5	36.3	36.1
4	35.1	37.7	36.4	36.4	36.2	35.9	35.7	35.4	35.2	35.1	35.2	35.3	35.6	35.9	36.2	36.5	36.9	37.2	37.4	37.6	37.7	37.6	37.5	37.3	37.1	36.8	36.6
5	26.8	38.4	32.2	30.1	29.3	28.6	27.9	27.3	26.8	27.0	27.7	28.7	30.0	31.3	32.6	33.9	35.2	36.5	37.6	38.3	38.4	37.7	36.5	34.9	33.4	32.2	31.1

MONTH = 5 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	25.0	38.3	30.8	27.0	27.0	26.1	25.5	25.4	25.0	25.4	26.1	28.0	31.3	32.8	34.6	36.0	37.0	38.3	38.0	37.8	37.4	35.8	31.2	28.8	28.3	28.3	27.4
1	34.8	37.6	36.1	36.3	36.0	35.8	35.6	35.3	35.1	34.9	34.8	34.8	34.9	35.1	35.4	35.8	36.1	36.5	36.9	37.3	37.5	37.6	37.4	37.2	37.0	36.7	36.5
2	33.7	34.9	34.2	34.3	34.2	34.1	34.0	33.8	33.7	33.7	33.8	33.8	33.9	33.9	34.0	34.1	34.2	34.3	34.5	34.7	34.8	34.9	34.9	34.8	34.7	34.6	34.5
3	34.8	37.2	36.1	36.0	35.7	35.5	35.3	35.0	34.8	34.8	35.0	35.2	35.5	35.8	36.1	36.4	36.7	37.0	37.1	37.2	37.2	37.2	37.0	36.8	36.6	36.4	36.2
4	35.1	37.8	36.4	36.5	36.2	36.0	35.7	35.5	35.3	35.1	35.1	35.3	35.5	35.8	36.1	36.4	36.8	37.1	37.4	37.7	37.8	37.7	37.6	37.4	37.2	36.9	36.7
5	26.8	38.5	32.2	30.2	29.3	28.6	27.9	27.3	26.8	27.0	27.7	28.7	30.0	31.4	32.6	33.9	35.2	36.5	37.6	38.3	38.5	37.8	36.6	35.0	33.5	32.2	31.1

MONTH = 5 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	25.0	38.3	30.8	27.0	27.0	26.1	25.5	25.4	25.0	25.4	26.1	28.0	31.3	32.8	34.6	36.0	37.0	38.3	38.0	37.8	37.4	35.8	31.2	28.8	28.3	28.3	27.4
1	34.7	37.5	36.0	36.2	36.0	35.7	35.5	35.3	35.0	34.8	34.7	34.7	34.8	35.0	35.3	35.7	36.1	36.4	36.8	37.2	37.5	37.5	37.3	37.1	36.9	36.7	36.4
2	33.6	34.8	34.2	34.2	34.1	34.0	33.9	33.7	33.6	33.6	33.7	33.8	33.9	33.9	34.0	34.1	34.2	34.3	34.4	34.6	34.7	34.8	34.8	34.7	34.6	34.5	34.4

3 34.8 37.3 36.1 36.0 35.7 35.5 35.3 35.0 34.8 34.8 34.9 35.2 35.4 35.8 36.1 36.4 36.7 36.9 37.1 37.2 37.3 37.2 37.1 36.9 36.6 36.4 36.2

4 35.1 37 8 36.4 36.5 36.3 36.0 35.8 35.5 35.3 35.1 35.1 35.2 35.4 35.6 36.0 36.3 36.7 37.0 37.4 37.6 37.8 37.8 37.6 37.4 37.2 37.0 36.7

5 26.8 38.4 32.2 30.2 29.3 28.6 27.9 27.3 26.8 26.9 27.6 28.6 29.9 31.3 32.6 33.8 35.1 36.4 37.5 38.3 38.4 37.8 36.5 35.0 33.5 32.2 31.1

MONTH = 5 DAY = 21 PLAN ROTATION = 75 0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 25.0 38.3 30 8 27.0 27.0 26.1 25.5 25.4 25.0 25.4 26.1 28.0 31.3 32 8 34.6 36.0 37.0 38.3 38.0 37.8 37.4 35.8 31.2 28.8 28.3 28.3 27.4

1 34.6 37.3 35.9 36.1 35.9 35.6 35.4 35.1 34.9 34.7 34.6 34.6 34.7 34.9 35.2 35.5 35.9 36.3 36.7 37.1 37.3 37.3 37.2 37.0 36.8 36.5 36.3

2 33 5 34.6 34.1 34.1 34.0 33.8 33.7 33.6 33.5 33.5 33.6 33.7 33.8 33.9 34.0 34.0 34.1 34.2 34.3 34.5 34.6 34.6 34.6 34.5 34.4 34.3 34.2

3 34.8 37 3 36.1 36.0 35.7 35.5 35.3 35.0 34.8 34.8 34.9 35.1 35.4 35.7 36.0 36.3 36.6 36.9 37.1 37.2 37.3 37.2 37.0 36.8 36.6 36.4 36.2

4 35.0 37.8 36.4 36.5 36.2 36.0 35.8 35.5 35.3 35.1 35.0 35.1 35.2 35.5 35.8 36.2 36.5 36.9 37.3 37.6 37.8 37.7 37.6 37.4 37.2 36.9 36.7

5 26.8 38.3 32.1 30.1 29.3 28.6 27.9 27.2 26.8 26.8 27.4 28.4 29.8 31.2 32.5 33.7 35.0 36.3 37.4 38.1 38.3 37.7 36.4 34.9 33.4 32.1 31.1

PROBLEM = 6

DAY = 21 MONTH = 6

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577 96 -11.49 0.00 -11.49

4576.88 -11.49 0.00 0.00

4577.96 -11 49 0.00 0.00

4577.96 0 00 0.00 0.00

760.14 0.00 0.00 0.00

MONTH = 6 DAY = 21 PLAN ROTATION = 0.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 28.4 38 7 33.1 30.3 30.2 29.8 29.0 28.6 28.5 28.4 29.6 31.0 33.6 35.0 35.9 36.8 37.8 38.3 38.7 37.9 37.8 37.7 35.2 31.5 30.8 30.7 30.3

1 36.9 39.5 38.2 38.3 38.0 37.8 37.6 37.4 37.2 37.0 36.9 37.0 37.1 37.4 37.7 38.0 38.3 38.7 39.0 39.3 39.5 39.5 39.3 39.1 38.9 38.7 38.5

2 35.6 36.9 36.2 36.3 36.2 36.1 36.0 35.9 35.7 35.7 35.6 35.6 35.6 35.7 35.7 35.8 35.9 36.1 36.3 36.5 36.8 36.9 36.8 36.8 36.7 36.5 36.4

3 36 9 39.1 38.1 37.9 37.7 37.5 37.3 37.1 36.9 36.9 37.0 37.3 37.5 37.8 38.1 38.4 38.7 38.9 39.0 39.1 39.1 39.1 38.9 38.8 38.6 38.3 38.1

4 37.2 39 6 38 5 38.3 38 1 37.9 37.7 37.5 37.3 37.2 37.3 37.6 37.8 38 1 38.4 38.7 39.0 39.3 39.5 39.6 39.6 39.5 39.4 39.2 39.0 38.8 38.5

5 29 4 39.3 34 2 32.2 31.5 30.9 30.4 29.8 29.4 29.6 30.2 31.2 32.4 33.7 34.8 35.9 36.9 37.9 38.7 39.3 39.3 38.8 37.8 36.6 35.2 34.0 33.0

MONTH = 6 DAY = 21 PLAN ROTATION = 15.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 28.4 38.7 33.1 30.3 30.2 29.8 29.0 28.6 28.5 28.4 29.6 31.0 33.6 35.0 35.9 36.8 37.8 38.3 38.7 37.9 37.8 37.7 35.2 31.5 30.8 30.7 30.3

1 36.9 39.5 38.2 38.3 38.1 37.9 37.6 37.4 37.2 37.0 36.9 37.0 37.1 37.4 37.7 38.0 38.3 38.7 39.0 39.3 39.5 39.5 39.4 39.2 39.0 38.7 38.5

2 35.8 36.9 36.3 36.4 36.3 36.2 36.1 35.9 35.8 35.8 35.8 35.8 35.8 35.8 35.9 36.0 36.1 36.2 36.4 36.7 36.9 36.9 36.9 36.8 36.7 36.6 36.5

3 36.9 39.1 38.1 37.9 37.7 37.5 37.3 37.1 36.9 36.9 37.1 37.3 37.6 37.9 38.2 38.5 38.7 38.9 39.1 39.1 39.1 39.0 38.9 38.8 38.5 38.3 38.1

4 37.2 39.6 38.5 38.3 38.1 37.9 37.7 37.5 37.3 37.2 37.3 37.5 37.8 38.1 38.4 38.7 39.0 39.2 39.4 39.6 39.6 39.5 39.4 39.2 39.0 38.8 38.6

5	29.4	39.4	34.2	32.2	31.5	30.9	30.4	29.8	29.4	29.6	30.4	31.4	32.6	33.8	34.9	35.9	37.0	38.0	38.9	39.4	39.3	38.8	37.8	36.5	35.2	34.0	33.0

MONTH = 6 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	28.4	38.7	33.1	30.3	30.2	29.8	29.0	28.6	28.5	28.4	29.6	31.0	33.6	35.0	35.9	36.8	37.8	38.3	38.7	37.9	37.8	37.7	35.2	31.5	30.8	30.7	30.3
1	37.0	39.6	38.2	38.3	38.1	37.9	37.7	37.5	37.2	37.1	37.0	37.0	37.1	37.4	37.6	38.0	38.3	38.7	39.0	39.3	39.5	39.6	39.4	39.2	39.0	38.8	38.6
2	35.9	37.1	36.4	36.5	36.4	36.3	36.2	36.0	35.9	35.9	35.9	36.0	36.0	36.1	36.1	36.2	36.3	36.4	36.6	36.8	37.0	37.1	37.0	36.9	36.8	36.7	36.6
3	37.0	39.2	38.2	38.0	37.8	37.6	37.4	37.2	37.0	37.0	37.2	37.4	37.7	38.0	38.3	38.6	38.8	39.0	39.2	39.2	39.2	39.1	39.0	38.8	38.6	38.4	38.2
4	37.2	39.6	38.5	38.4	38.2	38.0	37.7	37.5	37.3	37.2	37.3	37.5	37.7	38.0	38.3	38.6	38.9	39.2	39.4	39.6	39.6	39.6	39.4	39.3	39.0	38.8	38.6
5	29.5	39.5	34.3	32.3	31.6	31.0	30.4	29.8	29.5	29.7	30.4	31.5	32.7	33.9	35.0	36.0	37.0	38.1	39.0	39.5	39.5	39.0	38.0	36.7	35.3	34.1	33.1

MONTH = 6 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	28.4	38.7	33.1	30.3	30.2	29.8	29.0	28.6	28.5	28.4	29.6	31.0	33.6	35.0	35.9	36.8	37.8	38.3	38.7	37.9	37.8	37.7	35.2	31.5	30.8	30.7	30.3
1	37.0	39.6	38.2	38.4	38.1	37.9	37.7	37.5	37.3	37.1	37.0	37.0	37.1	37.3	37.6	37.9	38.3	38.6	39.0	39.3	39.6	39.6	39.4	39.3	39.0	38.8	38.6
2	35.9	37.1	36.5	36.5	36.4	36.3	36.2	36.0	35.9	35.9	36.0	36.1	36.1	36.2	36.3	36.3	36.4	36.5	36.7	36.8	37.0	37.1	37.0	37.0	36.9	36.7	36.6
3	37.0	39.3	38.2	38.0	37.8	37.6	37.4	37.2	37.0	37.0	37.2	37.4	37.7	38.0	38.3	38.6	38.8	39.1	39.2	39.3	39.3	39.2	39.1	38.9	38.7	38.5	38.3
4	37.2	39.7	38.5	38.4	38.2	38.0	37.8	37.6	37.4	37.2	37.3	37.4	37.6	37.9	38.2	38.5	38.8	39.1	39.4	39.6	39.7	39.6	39.5	39.3	39.1	38.9	38.7
5	29.5	39.7	34.3	32.3	31.6	31.0	30.4	29.9	29.5	29.6	30.4	31.4	32.7	33.9	35.0	36.0	37.0	38.1	39.0	39.6	39.7	39.1	38.1	36.8	35.4	34.2	33.1

MONTH = 6 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	28.4	38.7	33.1	30.3	30.2	29.8	29.0	28.6	28.5	28.4	29.6	31.0	33.6	35.0	35.9	36.8	37.8	38.3	38.7	37.9	37.8	37.7	35.2	31.5	30.8	30.7	30.3
1	36.9	39.5	38.2	38.3	38.1	37.9	37.7	37.4	37.2	37.0	36.9	36.9	37.1	37.3	37.6	37.9	38.2	38.6	38.9	39.3	39.5	39.5	39.4	39.2	39.0	38.8	38.6
2	35.9	37.0	36.4	36.4	36.3	36.2	36.1	36.0	35.9	35.9	36.0	36.1	36.2	36.2	36.3	36.3	36.4	36.5	36.6	36.8	36.9	37.0	36.9	36.9	36.8	36.6	36.5
3	37.0	39.3	38.2	38.1	37.8	37.6	37.4	37.2	37.0	37.0	37.1	37.4	37.7	38.0	38.3	38.5	38.8	39.0	39.2	39.3	39.3	39.2	39.1	38.9	38.7	38.5	38.3
4	37.2	39.7	38.5	38.5	38.3	38.1	37.8	37.6	37.4	37.2	37.2	37.3	37.5	37.8	38.1	38.4	38.7	39.0	39.3	39.6	39.7	39.7	39.6	39.4	39.2	38.9	38.7
5	29.5	39.6	34.3	32.3	31.6	31.0	30.4	29.9	29.5	29.6	30.3	31.3	32.5	33.8	34.9	35.9	36.9	38.0	38.9	39.5	39.6	39.1	38.1	36.8	35.4	34.2	33.1

MONTH = 6 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	28.4	38.7	33.1	30.3	30.2	29.8	29.0	28.6	28.5	28.4	29.6	31.0	33.6	35.0	35.9	36.8	37.8	38.3	38.7	37.9	37.8	37.7	35.2	31.5	30.8	30.7	30.3
1	36.9	39.4	38.1	38.2	38.0	37.8	37.6	37.4	37.1	37.0	36.9	36.9	37.0	37.2	37.5	37.8	38.1	38.5	38.8	39.2	39.4	39.4	39.3	39.1	38.9	38.7	38.5
2	35.7	36.8	36.3	36.3	36.1	36.0	35.9	35.8	35.7	35.7	35.8	36.0	36.1	36.2	36.2	36.3	36.4	36.4	36.5	36.6	36.7	36.8	36.7	36.7	36.6	36.5	36.4
3	37.0	39.3	38.2	38.1	37.8	37.6	37.4	37.2	37.0	37.0	37.1	37.3	37.6	37.9	38.2	38.5	38.8	39.0	39.2	39.3	39.3	39.2	39.1	38.9	38.7	38.5	38.3
4	37.2	39.7	38.5	38.5	38.3	38.1	37.9	37.6	37.4	37.3	37.2	37.3	37.4	37.7	38.0	38.3	38.6	39.0	39.3	39.6	39.7	39.7	39.6	39.4	39.2	39.0	38.7
5	29.4	39.5	34.2	32.3	31.6	31.0	30.4	29.8	29.4	29.5	30.2	31.1	32.4	33.7	34.8	35.8	36.9	37.9	38.8	39.4	39.5	39.0	38.0	36.7	35.3	34.1	33.1

PROBLEM = 7

DAY = 21 MONTH = 7

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577 96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760 14	0.00	0.00	0.00

MONTH = 7 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.1	33.5	29.5	27.6	27.1	27.1	27.0	26.9	26.5	26.1	26.1	27.0	30.0	30.7	31.2	32.0	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
1	34.0	36.4	35.2	35.2	35.0	34.8	34.6	34.4	34.3	34.1	34.0	34.1	34.2	34.4	34.7	35.0	35.3	35.7	36.0	36.2	36.4	36.4	36.2	36.1	35.9	35.7	35.4
2	32 7	33.8	33.2	33.4	33.3	33.2	33.1	33.0	32.9	32.8	32.7	32.7	32.7	32.8	32.8	32.9	33.0	33.1	33.3	33.5	33.8	33.8	33.8	33.7	33.6	33.5	33.5
3	33.9	35 9	35.0	34.8	34.6	34.4	34.2	34.0	33.9	33.9	34.0	34.2	34.5	34.7	35.0	35.3	35.5	35.7	35.9	35.9	35.9	35.8	35.7	35.5	35.4	35.2	35.0
4	34.3	36.5	35.4	35.3	35.1	34.9	34.7	34.5	34.3	34.3	34.4	34.6	34.8	35.1	35.4	35.7	36.0	36.2	36.4	36.5	36.5	36.4	36.2	36.1	35.9	35.7	35.5
5	27.3	35.7	31.2	29.5	28.9	28.4	27.9	27.6	27.3	27.4	27.9	28.7	29.8	31.0	32.0	32.9	33.8	34.6	35.3	35.7	35.7	35.0	34.1	33.1	32.1	31.1	30.2

MONTH = 7 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.1	33.5	29.5	27.6	27.1	27.1	27.0	26.9	26.5	26.1	26.1	27.0	30.0	30.7	31.2	32.0	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
1	34 0	36.4	35 2	35.3	35.1	34.9	34.7	34.5	34.3	34.1	34.0	34.1	34.2	34 4	34.7	35.0	35.3	35.6	36.0	36.2	36.4	36.4	36.2	36.1	35.9	35.7	35.5
2	32.8	33.9	33.3	33.4	33.3	33.2	33.1	33.0	32.9	32.9	32.8	32.8	32.9	32.9	32.9	33.0	33.1	33.2	33.4	33.6	33.8	33.9	33.8	33.8	33.7	33.6	33.5
3	33 9	36.0	35.0	34.8	34.6	34.4	34.3	34.1	33.9	33.9	34.1	34.3	34.5	34.8	35.1	35.4	35.6	35.8	35.9	36.0	36.0	35.8	35.7	35.6	35.4	35.2	35.0
4	34.3	36.5	35.5	35.3	35.1	34.9	34.7	34.6	34.4	34.3	34.4	34.6	34.8	35.1	35.4	35.7	36.0	36.2	36.4	36.5	36.5	36.4	36.3	36.1	35.9	35.7	35.5
5	27.3	35.9	31.3	29.5	28.9	28.4	27.9	27.6	27.3	27.4	28.0	28.9	29.9	31.0	32.0	32.9	33.8	34.7	35.4	35.9	35.7	35.1	34.1	33.1	32.1	31.1	30.2

MONTH = 7 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.1	33.5	29.5	27.6	27.1	27.1	27.0	26.9	26.5	26.1	26.1	27.0	30.0	30.7	31.2	32.0	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
1	34.1	36.5	35.2	35.3	35.1	34.9	34.7	34.5	34.3	34.2	34.1	34.1	34.2	34.4	34.7	35.0	35.3	35.6	36.0	36.3	36.5	36.4	36.3	36.1	35.9	35.7	35.5
2	33.0	34.0	33 4	33.5	33.4	33.3	33.2	33.1	33.0	33.0	33.0	33.0	33.1	33.1	33.1	33.2	33.3	33.4	33.6	33.8	33.9	34.0	33.9	33.9	33.8	33.7	33.6
3	34.0	36.1	35.1	34.9	34.7	34.6	34.4	34.2	34.0	34.0	34.2	34.4	34.7	35.0	35.3	35.5	35.8	36.0	36.1	36.1	36.1	36.0	35.9	35.7	35.5	35.3	35.1
4	34.4	36.6	35.5	35.4	35.2	35.0	34.8	34.6	34.4	34.4	34.4	34.6	34.8	35.1	35.4	35.7	35.9	36.2	36.4	36.6	36.6	36.5	36.4	36.2	36.0	35.8	35.6
5	27,3	36.0	31.4	29.6	29.0	28.4	28.0	27.6	27.3	27.5	28.1	29.0	30.1	31 2	32.1	33.0	33.9	34.8	35.6	36.0	36.0	35.3	34.3	33.3	32.2	31.2	30.3

MONTH = 7 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.1	33.5	29.5	27.6	27.1	27.1	27.0	26.9	26.5	26.1	26.1	27.0	30.0	30.7	31.2	32.0	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
1	34.1	36.5	35.2	35.3	35.1	34.9	34.7	34.5	34.3	34.2	34.1	34.1	34.2	34.4	34.6	34.9	35.3	35.6	35.9	36.2	36.5	36.4	36.3	36.1	35.9	35.7	35.5

2	33.0	34.0	33.5	33.5	33.4	33.3	33.2	33.1	33.0	33.0	33.1	33.1	33.2	33.2	33.3	33.3	33.4	33.5	33.6	33.8	33.9	34.0	33.9	33.9	33.8	33.7	33.6
3	34.1	36.2	35.2	35.0	34.8	34.6	34.4	34.3	34.1	34.1	34.2	34.5	34.7	35.0	35.3	35.6	35.8	36.0	36.2	36.2	36.2	36.1	35.9	35.8	35.6	35.4	35.2
4	34.4	36.7	35.5	35.5	35.3	35.1	34.9	34.7	34.5	34.4	34.4	34.5	34.7	35.0	35.3	35.6	35.9	36.2	36.4	36.6	36.7	36.6	36.5	36.3	36.1	35.9	35.7
5	27.3	36.1	31.4	29.6	29.0	28.4	28.0	27.6	27.3	27.4	28.1	29.0	30.1	31.2	32.1	33.0	33.8	34.8	35.6	36.1	36.1	35.4	34.4	33.3	32.2	31.2	30.4

MONTH = 7 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.1	33.5	29.5	27.6	27.1	27.1	27.0	26.9	26.5	26.1	26.1	27.0	30.0	30.7	31.2	32.0	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
1	34.0	36.4	35.1	35.3	35.1	34.9	34.7	34.5	34.3	34.1	34.0	34.0	34.1	34.3	34.6	34.9	35.2	35.5	35.8	36.2	36.4	36.4	36.2	36.1	35.9	35.7	35.5
2	32.9	33.9	33.4	33.4	33.3	33.2	33.1	33.0	32.9	32.9	33.0	33.1	33.2	33.3	33.3	33.4	33.4	33.5	33.6	33.7	33.8	33.9	33.8	33.8	33.7	33.6	33.5
3	34.1	36.2	35.2	35.0	34.8	34.6	34.5	34.3	34.1	34.1	34.2	34.4	34.7	35.0	35.3	35.6	35.8	36.0	36.2	36.2	36.2	36.1	36.0	35.8	35.6	35.4	35.2
4	34.4	36.7	35.5	35.5	35.3	35.1	34.9	34.7	34.5	34.4	34.4	34.4	34.6	34.9	35.2	35.5	35.8	36.1	36.4	36.6	36.7	36.6	36.5	36.3	36.1	35.9	35.7
5	27.3	36.0	31.4	29.6	29.0	28.4	28.0	27.6	27.3	27.4	28.0	28.9	30.0	31.2	32.1	32.9	33.8	34.7	35.4	36.0	36.0	35.3	34.3	33.3	32.2	31.2	30.3

MONTH = 7 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.1	33.5	29.5	27.6	27.1	27.1	27.0	26.9	26.5	26.1	26.1	27.0	30.0	30.7	31.2	32.0	32.9	33.4	33.5	33.4	32.8	32.3	31.7	29.6	28.3	27.8	27.7
1	33.9	36.2	35.0	35.1	34.9	34.7	34.5	34.4	34.2	34.0	33.9	33.9	34.0	34.2	34.4	34.7	35.1	35.4	35.7	36.0	36.2	36.2	36.1	35.9	35.7	35.5	35.3
2	32.8	33.7	33.3	33.2	33.2	33.1	33.0	32.9	32.8	32.8	32.9	33.0	33.1	33.2	33.3	33.3	33.4	33.5	33.5	33.6	33.7	33.7	33.7	33.6	33.5	33.4	33.3
3	34.0	36.2	35.2	35.0	34.8	34.6	34.4	34.3	34.1	34.0	34.2	34.4	34.6	34.9	35.2	35.5	35.8	36.0	36.1	36.2	36.2	36.1	36.0	35.8	35.6	35.4	35.2
4	34.3	36.7	35.5	35.5	35.3	35.1	34.9	34.7	34.5	34.4	34.3	34.3	34.5	34.8	35.0	35.3	35.6	36.0	36.3	36.5	36.7	36.6	36.5	36.3	36.1	35.9	35.7
5	27.3	35.8	31.3	29.6	29.0	28.4	28.0	27.6	27.3	27.3	27.9	28.7	29.8	31.0	32.0	32.8	33.7	34.6	35.3	35.8	35.8	35.2	34.2	33.2	32.2	31.2	30.3

PROBLEM = 8

DAY = 21 MONTH = 8

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577.96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760.14	0.00	0.00	0.00

MONTH = 8 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.4	33.6	29.6	28.0	27.5	27.5	27.1	26.6	26.5	26.4	26.4	26.9	29.7	29.7	30.4	32.1	32.7	33.2	33.6	33.4	32.5	31.8	30.6	30.1	29.5	29.0	28.5
1	33.6	36.0	34.8	34.8	34.7	34.5	34.3	34.1	33.9	33.7	33.6	33.7	33.8	34.1	34.3	34.6	35.0	35.3	35.6	35.9	36.0	35.9	35.7	35.6	35.4	35.2	35.0
2	32.1	33.1	32.6	32.7	32.6	32.6	32.5	32.4	32.3	32.2	32.1	32.1	32.1	32.1	32.2	32.2	32.3	32.5	32.7	32.9	33.1	33.1	33.1	33.0	33.0	32.9	32.8
3	33.2	35.1	34.2	34.1	33.9	33.8	33.6	33.4	33.2	33.2	33.3	33.5	33.8	34.0	34.3	34.6	34.8	35.0	35.1	35.1	35.1	35.0	34.8	34.7	34.6	34.4	34.3
4	33.8	36.0	35.0	34.9	34.7	34.5	34.3	34.1	33.9	33.8	33.9	34.1	34.4	34.7	35.0	35.3	35.6	35.8	36.0	36.0	36.0	35.9	35.7	35.6	35.4	35.2	35.1

5 27.1 35.4 31 0 29.5 28.9 28.4 28.0 27.6 27.2 27.1 27.6 28.4 29.5 30 6 31.6 32.5 33.5 34.4 35.1 35.4 35.1 34.3 33.4 32.4 31.6 30.9 30.2

MONTH = 8 DAY = 21 PLAN ROTATION = 15.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 26.4 33.6 29.6 28.0 27.5 27.5 27.1 26.6 26.5 26.4 26.4 26.9 29.7 29.7 30.4 32.1 32.7 33.2 33.6 33.4 32.5 31.8 30.6 30.1 29.5 29.0 28.5

1 33.6 36.0 34.8 34.9 34.7 34.5 34.3 34.1 33.9 33.7 33.6 33.7 33.8 34.0 34.3 34.6 34.9 35.2 35.6 35.8 36.0 35.9 35.7 35.6 35.4 35.2 35.0

2 32.1 33.1 32.6 32.7 32.6 32.5 32.4 32.3 32.2 32.2 32.2 32.1 32.1 32.2 32.2 32.3 32.4 32.5 32.7 32.9 33.1 33.1 33.0 33.0 32.9 32.9 32.8

3 33.3 35.3 34.4 34.2 34.1 33.9 33.7 33.5 33.4 33.3 33.4 33.6 33.9 34.2 34.5 34.7 35.0 35.2 35.3 35.3 35.2 35.1 35.0 34.9 34.7 34.6 34.4

4 34.0 36.2 35.1 35.0 34.8 34.6 34.4 34.3 34.1 34.0 34.0 34.2 34.5 34.8 35.1 35.3 35.6 35.9 36.1 36.2 36.2 36.0 35.9 35.7 35.6 35.4 35.2

5 27.2 35 5 31.0 29.6 29.0 28.5 28.0 27.6 27.2 27.2 27 7 28.5 29.5 30.6 31.6 32.5 33.5 34.4 35.2 35.5 35.3 34.5 33.5 32.5 31.7 30.9 30.2

MONTH = 8 DAY = 21 PLAN ROTATION = 30.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 26.4 33.6 29.6 28.0 27.5 27.5 27.1 26.6 26.5 26.4 26.4 26.9 29.7 29.7 30.4 32.1 32.7 33.2 33.6 33.4 32.5 31.8 30.6 30.1 29.5 29.0 28.5

1 33.6 36.0 34.8 34.9 34.7 34.5 34.3 34.1 33.9 33.7 33.6 33.7 33.8 34.0 34.2 34.5 34.9 35.2 35.5 35.8 36.0 35.9 35.8 35.6 35.4 35.2 35.1

2 32.2 33.1 32.6 32.7 32.6 32.5 32.4 32.4 32.3 32.2 32.2 32.2 32.3 32.3 32.3 32.4 32.5 32.6 32.7 32.9 33.1 33.1 33.0 33.0 32.9 32.9 32.8

3 33.5 35 5 34.6 34.4 34.2 34.0 33.9 33.7 33.5 33.5 33.6 33.8 34.1 34.4 34.7 34.9 35.2 35.4 35.5 35.5 35.5 35.3 35.2 35.1 34.9 34.7 34.6

4 34.1 36.4 35.3 35.2 35.0 34.8 34.6 34.4 34.2 34.1 34.2 34.3 34.6 34.8 35.1 35.4 35.7 36.0 36.2 36.4 36.4 36.2 36.1 35.9 35.8 35.6 35.4

5 27 2 35 6 31.1 29.6 29.0 28.5 28.0 27.6 27.2 27.2 27.8 28.6 29.6 30.7 31.6 32.5 33.5 34.4 35.2 35.6 35.4 34.6 33.6 32.6 31.8 31.0 30.3

MONTH = 8 DAY = 21 PLAN ROTATION = 45.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 26.4 33.6 29.6 28.0 27.5 27.5 27.1 26.6 26.5 26 4 26.4 26.9 29.7 29.7 30.4 32.1 32.7 33.2 33.6 33.4 32.5 31.8 30.6 30.1 29.5 29.0 28.5

1 33 6 35.9 34.7 34.8 34.7 34.5 34.3 34.1 33.9 33.7 33.6 33.6 33.7 33.9 34.2 34.5 34.8 35.1 35.5 35.8 35.9 35.9 35.7 35.6 35.4 35.2 35.0

2 32.2 33.1 32.6 32.7 32.6 32.5 32.4 32.3 32.2 32.2 32.3 32.3 32.4 32.4 32.4 32.5 32.6 32.7 32.8 32.9 33.1 33.1 33.0 33.0 32.9 32.8 32.8

3 33.6 35.7 34.7 34.5 34.4 34.2 34.0 33.8 33.6 33.6 33.7 34.0 34.2 34.5 34.8 35.1 35.3 35.5 35.6 35.7 35.6 35.5 35.4 35.2 35.0 34.9 34.7

4 34.2 36 5 35.3 35.3 35.1 34.9 34.7 34.5 34.3 34.2 34.2 34.3 34.6 34.8 35.1 35.4 35.7 36.0 36.3 36.4 36.5 36.4 36.2 36.1 35.9 35.7 35.5

5 27.2 35.8 31.2 29.7 29.0 28.5 28.1 27.6 27.2 27.2 27.8 28.7 29.8 30.8 31.7 32.6 33.9 34.7 35.4 35.8 35.7 34.8 33.7 32.7 31.9 31.1 30.3

MONTH = 8 DAY = 21 PLAN ROTATION = 60.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 26 4 33 6 29.6 28.0 27.5 27.5 27.1 26.6 26.5 26.4 26.4 26.9 29.7 29.7 30.4 32.1 32.7 33.2 33.6 33.4 32.5 31.8 30.6 30.1 29.5 29.0 28.5

1 33.5 35.8 34.6 34.7 34.5 34.3 34.2 34.0 33.8 33.6 33.5 33.5 33.6 33.8 34.0 34.3 34.6 35.0 35.3 35.6 35.8 35.7 35.6 35.4 35.2 35.1 34.9

2 32 2 33 0 32.6 32.6 32.5 32.4 32.4 32.3 32.2 32.2 32.3 32.3 32.4 32.5 32.5 32.6 32.6 32.7 32.8 32.9 33.0 33.0 32.9 32.9 32.8 32.8 32.7

3 33.6 35.7 34.7 34.6 34.4 34.2 34.0 33.9 33.7 33.6 33.7 34.0 34.3 34.5 34.8 35.1 35.4 35.6 35.7 35.7 35.7 35.6 35.4 35.3 35.1 34.9 34.8

4 34 1 36 5 35.3 35.3 35.1 34.9 34.7 34.5 34.3 34.1 34.1 34.2 34.4 34.7 34.9 35.2 35.6 35.9 36.2 36.4 36.5 36.4 36.2 36.0 35.9 35.7 35.5

5 27.2 35.5 31 1 29.6 29.0 28.5 28.0 27.6 27.2 27.2 27.7 28.6 29.7 30.8 31.7 32.6 33.5 34.3 35.1 35.5 35.4 34.6 33.5 32.6 31.7 31.0 30.2

MONTH = 8 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	26.4	33.6	29.6	28.0	27.5	27.5	27.1	26.6	26.5	26.4	26.4	26.9	29.7	29.7	30.4	32.1	32.7	33.2	33.6	33.4	32.5	31.8	30.6	30.1	29.5	29.0	28.5
1	33.3	35.5	34.4	34.5	34.3	34.2	34.0	33.8	33.6	33.4	33.3	33.3	33.4	33.6	33.8	34.1	34.4	34.8	35.1	35.4	35.5	35.5	35.3	35.2	35.0	34.9	34.7
2	32.1	32.9	32.5	32.5	32.5	32.4	32.3	32.2	32.1	32.1	32.2	32.3	32.4	32.5	32.6	32.6	32.7	32.7	32.8	32.9	32.9	32.9	32.9	32.8	32.7	32.7	32.6
3	33.6	35.8	34.7	34.6	34.4	34.2	34.1	33.9	33.7	33.6	33.7	33.9	34.2	34.5	34.8	35.1	35.3	35.5	35.7	35.8	35.7	35.6	35.4	35.3	35.1	35.0	34.8
4	34.0	36.3	35.1	35.2	35.0	34.8	34.6	34.4	34.2	34.0	34.0	34.0	34.2	34.4	34.7	35.0	35.3	35.7	36.0	36.2	36.3	36.2	36.1	35.9	35.7	35.6	35.4
5	27.1	35.4	31.0	29.6	29.0	28.4	28.0	27.6	27.2	27.1	27.6	28.5	29.6	30.7	31.6	32.5	33.5	34.3	35.0	35.4	35.2	34.4	33.4	32.5	31.6	30.9	30.2

PROBLEM = 9

DAY = 21 MONTH = 9

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96	-11.49	0.00	-11.49
4576.88	-11.49	0.00	0.00
4577.96	-11.49	0.00	0.00
4577.96	0.00	0.00	0.00
760.14	0.00	0.00	0.00

MONTH = 9 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	24.4	33.4	28.4	26.5	26.0	26.0	25.8	25.3	24.9	24.5	24.4	25.0	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
1	32.4	34.8	33.6	33.6	33.4	33.2	33.0	32.8	32.6	32.5	32.4	32.4	32.6	32.8	33.1	33.4	33.8	34.2	34.5	34.7	34.8	34.6	34.5	34.3	34.2	34.0	33.8
2	30.6	31.7	31.1	31.3	31.2	31.1	31.0	31.0	30.9	30.8	30.7	30.7	30.6	30.7	30.7	30.8	30.9	31.1	31.3	31.5	31.7	31.6	31.6	31.6	31.5	31.4	31.4
3	31.6	33.4	32.6	32.5	32.3	32.1	32.0	31.8	31.7	31.6	31.7	31.8	32.1	32.3	32.6	32.9	33.1	33.3	33.3	33.4	33.3	33.2	33.1	33.0	32.9	32.8	32.6
4	32.6	34.8	33.8	33.6	33.5	33.3	33.1	32.9	32.7	32.6	32.7	32.9	33.1	33.4	33.7	34.1	34.4	34.6	34.8	34.8	34.7	34.6	34.5	34.3	34.2	34.0	33.8
5	25.8	34.6	29.9	28.4	27.8	27.3	26.8	26.4	26.0	25.8	26.2	27.0	28.0	29.2	30.4	31.5	32.6	33.6	34.3	34.6	34.2	33.4	32.5	31.5	30.6	29.8	29.1

MONTH = 9 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	24.4	33.4	28.4	26.5	26.0	26.0	25.8	25.3	24.9	24.5	24.4	25.0	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
1	32.3	34.6	33.4	33.5	33.3	33.1	33.0	32.8	32.6	32.4	32.3	32.3	32.4	32.6	32.9	33.3	33.6	34.0	34.3	34.6	34.6	34.5	34.4	34.2	34.1	33.9	33.7
2	30.5	31.4	31.0	31.1	31.0	31.0	30.9	30.8	30.7	30.6	30.6	30.5	30.5	30.5	30.6	30.7	30.8	30.9	31.1	31.3	31.4	31.4	31.4	31.4	31.3	31.2	31.2
3	31.7	33.6	32.8	32.6	32.5	32.3	32.2	32.0	31.8	31.7	31.8	32.0	32.3	32.6	32.8	33.1	33.3	33.5	33.6	33.6	33.6	33.5	33.4	33.2	33.1	33.0	32.8
4	32.7	35.0	33.9	33.8	33.6	33.5	33.3	33.1	32.9	32.7	32.8	33.0	33.2	33.5	33.8	34.2	34.5	34.8	35.0	35.0	35.0	34.9	34.7	34.6	34.4	34.2	34.0
5	25.8	34.6	29.9	28.4	27.8	27.3	26.8	26.4	26.0	25.8	26.1	26.8	27.8	29.1	30.3	31.4	32.5	33.6	34.3	34.6	34.3	33.5	32.5	31.6	30.7	29.8	29.1

MONTH = 9 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	24.4	33.4	28.4	26.5	26.0	26.0	25.8	25.3	24.9	24.5	24.4	25.0	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
1	32.2	34.5	33.3	33.4	33.2	33.1	32.9	32.7	32.5	32.3	32 2	32.2	32.3	32.5	32.8	33.1	33.5	33.8	34.2	34.5	34.5	34.4	34.3	34.1	34.0	33.8	33.6

2	30.5	31.3	30.8	31.0	30.9	30.8	30.8	30.7	30.6	30.5	30.5	30.5	30.5	30.5	30.6	30.6	30.7	30.8	31.0	31.2	31.3	31.3	31.3	31.2	31.2	31.1	31.0
3	31 9	33.9	33.0	32.8	32.7	32.5	32.3	32.2	32.0	31.9	32.0	32.2	32.5	32.8	33.1	33.3	33.6	33.7	33.8	33.9	33.8	33.7	33.6	33.5	33.3	33.2	33.0
4	32 9	35.3	34.1	34.0	33.8	33.6	33.4	33.2	33.0	32.9	32.9	33.1	33.3	33.6	33.9	34.3	34.6	34.9	35.1	35.3	35.2	35.1	35.0	34.8	34.6	34.4	34.2
5	25.9	34.6	29.9	28.4	27.8	27.3	26.8	26.4	26.0	25.9	26.3	26.9	27.9	29.0	30.3	31.5	32.5	33.5	34.2	34.6	34.3	33.5	32.5	31.6	30.7	29.8	29.1

MONTH = 9 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	24.4	33.4	28.4	26.5	26.0	26.0	25.8	25.3	24.9	24.5	24.4	25.0	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
1	32 1	34.3	33.2	33.3	33.1	32.9	32.7	32.6	32.4	32.2	32.1	32.1	32 1	32.3	32.6	32.9	33.3	33.7	34.0	34.3	34.3	34.2	34.1	34.0	33.8	33.6	33.5
2	30.5	31.2	30.8	30.9	30.8	30.8	30.7	30.6	30.5	30.5	30.5	30.5	30.5	30.6	30.6	30.7	30.8	30.9	31.0	31.1	31.2	31.2	31.2	31.1	31.1	31.0	31.0
3	32 1	34.1	33.2	33.0	32.9	32.7	32.5	32.3	32.2	32.1	32.2	32.4	32.7	33.0	33.3	33.6	33.8	34.0	34.1	34.1	34.0	34.0	33.8	33.7	33.5	33.4	33.2
4	33.0	35.4	34 2	34.1	33.9	33.7	33.5	33.3	33.1	33.0	33.0	33.1	33.4	33.6	33.9	34.3	34.6	34.9	35.2	35.4	35.4	35.2	35.1	34.9	34.7	34.5	34.3
5	25.9	34.5	29 9	28.4	27.8	27.3	26.8	26.4	26.0	25.9	26.3	27.1	28.0	29.1	30.3	31.5	32.6	33.5	34.2	34.5	34.2	33.4	32.5	31.5	30.7	29.8	29.1

MONTH = 9 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	24.4	33 4	28.4	26.5	26.0	26.0	25.8	25.3	24.9	24.5	24.4	25.0	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
1	31.9	34.1	33.0	33.1	32.9	32.7	32.6	32.4	32.2	32.0	31.9	31.9	32.0	32.1	32.4	32.7	33.1	33.4	33.8	34.0	34.1	34.0	33.9	33.7	33.6	33.4	33.2
2	30.5	31.2	30.9	30.9	30.8	30.8	30.7	30.6	30.5	30.5	30.5	30.6	30.7	30.7	30.7	30.8	30.9	31.0	31.0	31.1	31.2	31.2	31.2	31.1	31.1	31.0	31.0
3	32.2	34.3	33.3	33.2	33.0	32.8	32.7	32.5	32.3	32.2	32.3	32.6	32.8	33.1	33.4	33.7	34.0	34.2	34.3	34.3	34.2	34.1	34.0	33.9	33.7	33.5	33.4
4	32.9	35.3	34.1	34.1	33.9	33.7	33.5	33.3	33.1	32.9	32.9	33.0	33.2	33.5	33.8	34.1	34.5	34.8	35.1	35.3	35.3	35.2	35.0	34.9	34.7	34.5	34.3
5	25.9	34.4	29.9	28.4	27.8	27.3	26.8	26.4	26.0	25.9	26.3	27.1	28.1	29.2	30.4	31.6	32.6	33.5	34.1	34.4	34.1	33.3	32.4	31.5	30.6	29.8	29.0

MONTH = 9 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	24.4	33.4	28.4	26.5	26.0	26.0	25.8	25.3	24.9	24.5	24.4	25.0	27.1	28.9	30.4	31.3	32.3	32.7	32.7	33.4	32.8	31.3	29.4	28.8	27.8	27.3	26.9
1	31 7	33.8	32.7	32.9	32.7	32.5	32.4	32.2	32.0	31.8	31.7	31.7	31.8	31.9	32.2	32.5	32.8	33.2	33.5	33.8	33.8	33.7	33.6	33.5	33.3	33.2	33.0
2	30.5	31.3	31.0	31.0	30.9	30.8	30.8	30.7	30.6	30.5	30.6	30.7	30.8	30.9	30.9	31.0	31.1	31.1	31.2	31.2	31.3	31.3	31.3	31.2	31.2	31.1	31.0
3	32.3	34.4	33 4	33.3	33.1	32.9	32.8	32.6	32.4	32.3	32.4	32.6	32.9	33.2	33.5	33.8	34.1	34.3	34.4	34.4	34.4	34.3	34.1	34.0	33.8	33.7	33.5
4	32.7	35.1	33.9	34.0	33.8	33.6	33.4	33.2	33.0	32.8	32.7	32 8	33.0	33.2	33.6	33.9	34.2	34.6	34.9	35.1	35.1	35.0	34.9	34.7	34.5	34.3	34.1
5	25.8	34.4	29.8	28.4	27.8	27.3	26.8	26.4	26.0	25.8	26.3	27.1	28.1	29.2	30.4	31.5	32.6	33.6	34.2	34.4	34.1	33.3	32.4	31.4	30.6	29.8	29.0

PROBLEM = 10

DAY = 21 MONTH = 10

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96 -11.49 0.00 -11.49

4576.88 -11 49 0 00 0 00

4577 96 -11.49 0.00 0.00

4577.96 0.00 0.00 0.00

760.14 0.00 0.00 0.00

MONTH = 10 DAY = 21 PLAN ROTATION = 0.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	16.4	27.4	21.1	19.0	18.5	18.4	17.5	17.0	17.0	16.9	16.4	17.3	19.8	21.2	23.4	26.0	27.1	27.4	27.4	26.8	25.2	23.3	21.8	20.7	19.8	19.2	19.1
1	25.9	28.4	27.1	27.2	27.0	26.8	26.6	26.4	26.2	26.0	25.9	25.9	26.1	26.3	26.7	27.1	27.5	27.9	28.2	28.4	28.4	28.2	28.1	27.9	27.7	27.5	27.3
2	24.2	25.2	24.7	24.8	24.7	24.7	24.6	24.5	24.4	24.3	24.2	24.2	24.2	24.2	24.2	24.3	24.5	24.7	24.9	25.1	25.2	25.2	25.1	25.1	25.0	25.0	24.9
3	24.6	26.3	25.6	25.5	25.4	25.2	25.1	24.9	24.8	24.6	24.7	24.8	25.0	25.3	25.5	25.8	26.0	26.2	26.3	26.3	26.3	26.2	26.1	26.0	25.9	25.8	25.6
4	26.0	28.4	27.3	27.1	27.0	26.8	26.6	26.4	26.2	26.0	26.0	26.2	26.5	26.8	27.2	27.5	27.9	28.2	28.3	28.4	28.3	28.2	28.0	27.9	27.7	27.5	27.3
5	19.2	28.9	23.6	22.0	21.4	20.9	20.4	19.9	19.5	19.2	19.5	20.2	21.4	22.6	23.9	25.2	26.7	27.9	28.7	28.9	28.2	27.3	26.3	25.3	24.3	23.4	22.6

MONTH = 10 DAY = 21 PLAN ROTATION = 15.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	16.4	27.4	21.1	19.0	18.5	18.4	17.5	17.0	17.0	16.9	16.4	17.3	19.8	21.2	23.4	26.0	27.1	27.4	27.4	26.8	25.2	23.3	21.8	20.7	19.8	19.2	19.1
1	25.7	28.1	26.9	26.9	26.7	26.6	26.4	26.2	26.0	25.8	25.7	25.7	25.8	26.0	26.3	26.7	27.1	27.5	27.9	28.1	28.1	28.0	27.8	27.7	27.5	27.3	27.1
2	23.9	24.8	24.4	24.5	24.5	24.4	24.3	24.2	24.1	24.1	24.0	23.9	23.9	24.0	24.0	24.1	24.2	24.4	24.6	24.8	24.8	24.8	24.8	24.8	24.7	24.7	24.6
3	24.8	26.6	25.8	25.7	25.6	25.4	25.3	25.1	25.0	24.8	24.9	25.1	25.3	25.6	25.8	26.1	26.3	26.5	26.6	26.6	26.6	26.5	26.4	26.3	26.2	26.0	25.9
4	26.2	28.6	27.4	27.3	27.1	26.9	26.7	26.5	26.3	26.2	26.2	26.3	26.6	26.9	27.3	27.6	28.0	28.3	28.5	28.6	28.5	28.4	28.3	28.1	27.9	27.7	27.5
5	19.2	28.9	23.6	22.0	21.4	20.9	20.4	19.9	19.5	19.2	19.4	20.1	21.2	22.5	23.9	25.2	26.6	27.8	28.7	28.9	28.2	27.3	26.3	25.3	24.3	23.4	22.7

MONTH = 10 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	16.4	27.4	21.1	19.0	18.5	18.4	17.5	17.0	17.0	16.9	16.4	17.3	19.8	21.2	23.4	26.0	27.1	27.4	27.4	26.8	25.2	23.3	21.8	20.7	19.8	19.2	19.1
1	25.4	27.8	26.6	26.7	26.5	26.3	26.1	25.9	25.7	25.6	25.4	25.4	25.5	25.7	26.0	26.4	26.8	27.2	27.5	27.8	27.7	27.6	27.5	27.3	27.2	27.0	26.8
2	23.7	24.5	24.1	24.3	24.2	24.1	24.1	24.0	23.9	23.8	23.8	23.7	23.7	23.8	23.8	23.9	24.0	24.2	24.3	24.5	24.5	24.5	24.5	24.5	24.4	24.4	24.3
3	25.0	26.9	26.0	25.9	25.8	25.6	25.5	25.3	25.1	25.0	25.0	25.2	25.5	25.8	26.1	26.3	26.6	26.8	26.9	26.9	26.8	26.8	26.7	26.5	26.4	26.3	26.1
4	26.2	28.7	27.5	27.4	27.2	27.0	26.8	26.6	26.4	26.2	26.2	26.4	26.6	27.0	27.3	27.7	28.0	28.4	28.6	28.7	28.7	28.5	28.4	28.2	28.0	27.8	27.6
5	19.2	28.9	23.5	22.0	21.4	20.9	20.4	19.9	19.5	19.2	19.4	20.0	21.1	22.4	23.8	25.2	26.8	27.9	28.7	28.9	28.2	27.3	26.3	25.3	24.3	23.4	22.7

MONTH = 10 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	16.4	27.4	21.1	19.0	18.5	18.4	17.5	17.0	17.0	16.9	16.4	17.3	19.8	21.2	23.4	26.0	27.1	27.4	27.4	26.8	25.2	23.3	21.8	20.7	19.8	19.2	19.1
1	25.2	27.4	26.3	26.4	26.2	26.0	25.9	25.7	25.5	25.3	25.2	25.2	25.2	25.4	25.7	26.0	26.5	26.9	27.2	27.4	27.4	27.3	27.2	27.0	26.9	26.7	26.6
2	23.7	24.4	24.0	24.2	24.1	24.0	24.0	23.9	23.8	23.7	23.7	23.7	23.7	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.4	24.4	24.4	24.3	24.3	24.2
3	25.2	27.2	26.3	26.2	26.0	25.8	25.7	25.5	25.3	25.2	25.2	25.4	25.7	26.0	26.3	26.6	26.9	27.1	27.2	27.2	27.1	27.0	26.9	26.8	26.7	26.5	26.3
4	26.3	28.8	27.5	27.5	27.3	27.1	26.9	26.7	26.5	26.3	26.3	26.4	26.6	26.9	27.3	27.6	28.0	28.4	28.7	28.8	28.7	28.6	28.4	28.3	28.1	27.9	27.7
5	19.2	28.6	23.5	22.0	21.4	20.9	20.4	19.9	19.5	19.2	19.5	20.1	21.1	22.3	23.7	25.2	26.6	27.7	28.4	28.6	28.0	27.1	26.2	25.2	24.2	23.4	22.6

MONTH = 10 DAY = 21 PLAN ROTATION = 60.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 16.4 27 4 21.1 19.0 18.5 18.4 17.5 17.0 17.0 16.9 16.4 17.3 19.8 21.2 23.4 26.0 27.1 27.4 27.4 26.8 25.2 23.3 21.8 20.7 19.8 19.2 19.1

1 25.0 27 1 26 0 26.1 26.0 25.8 25.7 25.5 25.3 25.1 25.0 25.0 25.0 25.2 25.4 25.8 26.2 26.6 26.9 27.1 27.1 27.0 26.9 26.8 26.6 26.5 26.3

2 23.8 24.5 24.1 24.2 24.2 24.1 24.0 23.9 23.9 23.8 23.8 23.9 23.9 23.9 24.0 24.0 24.1 24.2 24.3 24.4 24.5 24.5 24.5 24.4 24.4 24.3 24.3

3 25.4 27.5 26.6 26.4 26.3 26.1 25.9 25.7 25.6 25.4 25.5 25.7 26.0 26.3 26.6 26.9 27.2 27.4 27.5 27.5 27.5 27.4 27.2 27.1 26.9 26.8 26.6

4 26.2 28.8 27.5 27.5 27.3 27.1 26.9 26.7 26.5 26.3 26.2 26.3 26.6 26.9 27.2 27.6 28.0 28.3 28.6 28.8 28.7 28.6 28.4 28.3 28.1 27.9 27.7

5 19.2 28.6 23.5 21.9 21.4 20.9 20.4 19.9 19.5 19.2 19.5 20.2 21.3 22.4 23.7 25.2 26.7 27.8 28.5 28.6 28.0 27.1 26.1 25.2 24.2 23.3 22.6

MONTH = 10 DAY = 21 PLAN ROTATION = 75.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 16.4 27.4 21.1 19.0 18.5 18.4 17.5 17.0 17.0 16.9 16.4 17.3 19.8 21.2 23.4 26.0 27.1 27.4 27.4 26.8 25.2 23.3 21.8 20.7 19.8 19.2 19.1

1 24.8 26 8 25.8 25.9 25.8 25.6 25.5 25.3 25.1 25.0 24.8 24.8 24.8 25.0 25.2 25.5 25.9 26.3 26.6 26.8 26.8 26.8 26.7 26.5 26.4 26.2 26.1

2 24 0 24.7 24.4 24.4 24.4 24.3 24.2 24.1 24.1 24.0 24.0 24.1 24.2 24.2 24.3 24.3 24.4 24.5 24.6 24.7 24.7 24.7 24.7 24.7 24.6 24.6 24.5

3 25.7 27.9 26.9 26.7 26.6 26.4 26.2 26.0 25.8 25.7 25.7 25.9 26.2 26 5 26.9 27.2 27.5 27.8 27.9 27.9 27.8 27.7 27.6 27.4 27.3 27.1 26.9

4 26.1 28.7 27.4 27.4 27.2 27.0 26.8 26.6 26.4 26.2 26.1 26.2 26.4 26.7 27.0 27.4 27.8 28.2 28.5 28.7 28.6 28.5 28.4 28.2 28.0 27.8 27.6

5 19.2 28.7 23.5 22.0 21.4 20.9 20.4 19.9 19.5 19.2 19.5 20.3 21.4 22.6 23.8 25.2 26.7 27.9 28.6 28.7 28.1 27.2 26.2 25.2 24.3 23.4 22.6

PROBLEM = 11

DAY = 21 MONTH = 11

PLAN ROTATION : START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96 -11.49 0.00 -11.49

4576.88 -11.49 0.00 0.00

4577.96 -11.49 0.00 0.00

4577 96 0 00 0.00 0.00

760 14 0.00 0.00 0.00

MONTH = 11 DAY = 21 PLAN ROTATION = 0.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 9.5 26.1 16.0 12.7 12.2 11.7 11.2 10.6 10.5 10.0 9.5 9.9 12.4 15.6 20.4 23.3 24.5 26.0 26.1 25.2 21.6 18.2 16.6 15.2 14.6 13.7 13.2

1 21.0 23.7 22.4 22.5 22.3 22.1 21.8 21.6 21.4 21.2 21.0 21.0 21.1 21.4 21.7 22.2 22.6 23.1 23.5 23.7 23.7 23.6 23.4 23.2 23.1 22.9 22.7

2 19.4 20.5 20.0 20.2 20.1 20.0 19.9 19.8 19.7 19.6 19.5 19.4 19.4 19.4 19.4 19.5 19.7 20.0 20.2 20.4 20.5 20.5 20.5 20.4 20.4 20.3 20.2

3 19.5 21.3 20.5 20.6 20.4 20.3 20.1 20.0 19.8 19.6 19.5 19.6 19.8 20.0 20.2 20.5 20.7 21.0 21.1 21.2 21.3 21.2 21.2 21.1 21.0 20.8 20.7

4 21.1 23.6 22.4 22.4 22.2 22.0 21.8 21.6 21.4 21.2 21.1 21.2 21.5 21.8 22.1 22.5 22.9 23.3 23.5 23.6 23.6 23.5 23.4 23.2 23.0 22.8 22.6

5 13.9 25.4 19.0 17.7 16.9 16.2 15.6 15.0 14.5 14.0 13.9 14.5 15.4 16.7 18.4 20.2 22.1 23.8 25.0 25.4 24.9 23.9 22.7 21.6 20.4 19.4 18.5

MONTH = 11 DAY = 21 PLAN ROTATION = 15.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 9.5 26.1 16 0 12.7 12.2 11.7 11.2 10.6 10.5 10.0 9.5 9.9 12.4 15.6 20.4 23.3 24.5 26.0 26.1 25.2 21.6 18.2 16.6 15.2 14.6 13.7 13.2

1	20.7	23.3	22.0	22.2	22.0	21.8	21.6	21.4	21.2	21.0	20.8	20.7	20.8	21.0	21.4	21.8	22.2	22.7	23.1	23.3	23.3	23.2	23.1	22.9	22.7	22.6	22.4
2	19.1	20.1	19.7	19.9	19.8	19.7	19.6	19.5	19.4	19.3	19.2	19.2	19.1	19.1	19.2	19.3	19.4	19.6	19.9	20.1	20.1	20.1	20.1	20.1	20.0	20.0	19.9.
3	19.8	21.6	20.8	20.8	20.7	20.5	20.3	20.2	20.0	19.8	19.8	19.9	20.0	20.3	20.5	20.8	21.1	21.3	21.5	21.6	21.6	21.6	21.5	21.4	21.2	21.1	21.0
4	21.2	23.9	22.6	22.6	22.4	22.2	22.0	21.8	21.5	21.3	21.2	21.3	21.6	21.9	22.2	22.7	23.1	23.5	23.7	23.9	23.8	23.7	23.6	23.4	23.2	23.0	22.8
5	13.9	25.4	19.0	17.7	16.9	16.2	15.6	15.0	14.5	14.0	13.9	14.4	15.3	16.7	18.4	20.3	22.1	23.7	25.0	25.4	24.9	23.9	22.7	21.5	20.4	19.4	18.5

MONTH = 11 DAY = 21 PLAN ROTATION = 30.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	26.1	16.0	12.7	12.2	11.7	11.2	10.6	10.5	10.0	9.5	9.9	12.4	15.6	20.4	23.3	24.5	26.0	26.1	25.2	21.6	18.2	16.6	15.2	14.6	13.7	13.2
1	20.4	22.8	21.6	21.8	21.6	21.4	21.2	21.0	20.8	20.6	20.4	20.4	20.4	20.6	20.9	21.3	21.8	22.2	22.6	22.8	22.8	22.8	22.6	22.5	22.3	22.2	22.0
2	18.9	19.8	19.4	19.6	19.5	19.4	19.4	19.3	19.2	19.1	19.0	18.9	18.9	18.9	19.0	19.1	19.2	19.4	19.6	19.7	19.8	19.8	19.8	19.8	19.8	19.7	19.6
3	20.0	21.9	21.0	21.1	20.9	20.7	20.6	20.4	20.2	20.0	20.0	20.1	20.3	20.5	20.8	21.1	21.4	21.6	21.8	21.9	21.9	21.8	21.8	21.6	21.5	21.4	21.2
4	21.3	23.9	22.6	22.7	22.5	22.3	22.0	21.8	21.6	21.4	21.3	21.3	21.5	21.9	22.2	22.7	23.1	23.5	23.8	23.9	23.9	23.8	23.6	23.5	23.3	23.1	22.9
5	13.9	25.2	18.9	17.6	16.9	16.2	15.6	15.0	14.5	14.0	13.9	14.2	15.1	16.5	18.3	20.3	22.1	23.6	24.8	25.2	24.7	23.8	22.6	21.5	20.4	19.4	18.5

MONTH = 11 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	26.1	16.0	12.7	12.2	11.7	11.2	10.6	10.5	10.0	9.5	9.9	12.4	15.6	20.4	23.3	24.5	26.0	26.1	25.2	21.6	18.2	16.6	15.2	14.6	13.7	13.2
1	20.1	22.4	21.3	21.5	21.3	21.1	20.9	20.7	20.6	20.4	20.2	20.1	20.1	20.2	20.5	20.9	21.4	21.8	22.2	22.4	22.4	22.4	22.2	22.1	22.0	21.8	21.6
2	18.8	19.7	19.3	19.5	19.4	19.3	19.2	19.2	19.1	19.0	18.9	18.9	18.8	18.8	18.9	19.0	19.2	19.3	19.4	19.6	19.6	19.7	19.7	19.6	19.6	19.6	19.5
3	20.2	22.2	21.3	21.3	21.1	21.0	20.8	20.6	20.4	20.2	20.2	20.3	20.5	20.8	21.1	21.4	21.7	22.0	22.1	22.2	22.2	22.2	22.1	21.9	21.8	21.6	21.5
4	21.3	24.0	22.6	22.7	22.5	22.3	22.0	21.8	21.6	21.4	21.3	21.3	21.5	21.8	22.2	22.6	23.1	23.5	23.8	24.0	23.9	23.8	23.7	23.5	23.3	23.1	22.9
5	13.9	25.1	18.9	17.6	16.9	16.2	15.6	15.0	14.5	14.0	13.9	14.3	15.1	16.4	18.2	20.2	22.1	23.6	24.7	25.1	24.6	23.7	22.6	21.4	20.3	19.3	18.4

MONTH = 11 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	26.1	16.0	12.7	12.2	11.7	11.2	10.6	10.5	10.0	9.5	9.9	12.4	15.6	20.4	23.3	24.5	26.0	26.1	25.2	21.6	18.2	16.6	15.2	14.6	13.7	13.2
1	19.9	22.1	21.0	21.2	21.1	20.9	20.7	20.5	20.3	20.2	20.0	19.9	19.9	20.0	20.2	20.6	21.0	21.5	21.9	22.1	22.1	22.0	21.9	21.8	21.7	21.5	21 4
2	19.0	19.8	19.4	19.6	19.5	19.4	19.3	19.2	19.2	19.1	19.0	19.0	19.0	19.0	19.1	19.2	19.3	19.4	19.6	19.7	19.8	19.8	19.8	19.8	19.7	19.7	19.6
3	20.4	22.6	21.6	21.6	21.5	21.3	21.1	20.9	20.7	20.5	20.4	20.6	20.8	21.1	21.4	21.8	22.1	22.4	22.6	22.6	22.6	22.6	22.4	22.3	22.2	22.0	21.8
4	21.3	24.0	22.6	22.7	22.5	22.3	22.1	21.8	21.6	21.4	21.3	21.3	21.5	21.8	22.1	22.6	23.0	23.5	23.8	24.0	23.9	23.8	23.7	23.5	23.3	23.1	22.9
5	13.9	25.2	18.9	17.6	16.9	16.2	15.6	15.0	14.5	14.0	13.9	14.4	15.2	16.4	18.1	20.2	22.2	23.8	24.8	25.2	24.7	23.7	22.6	21.4	20.3	19.3	18.4

MONTH = 11 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	9.5	26.1	16.0	12.7	12.2	11.7	11.2	10.6	10.5	10.0	9.5	9.9	12.4	15.6	20.4	23.3	24.5	26.0	26.1	25.2	21.6	18.2	16.6	15.2	14.6	13.7	13.2
1	19.7	21.8	20.8	21.0	20.8	20.7	20.5	20.3	20.1	20.0	19.8	19.7	19.7	19.8	20.0	20.3	20.7	21.2	21.5	21.8	21.8	21.7	21.6	21.5	21.4	21.3	21.1
2	19.2	20.1	19.7	19.8	19.7	19.6	19.6	19.5	19.4	19.3	19.2	19.3	19.3	19.3	19.4	19.5	19.6	19.7	19.9	20.0	20.0	20.1	20.0	20.0	20.0	19.9	19.9
3	20.8	23.1	22.0	22.0	21.9	21.7	21.5	21.2	21.0	20.8	20.8	20.9	21.2	21.4	21.8	22.2	22.6	22.9	23.1	23.1	23.1	23.0	22.9	22.8	22.6	22.4	22.2

4 21.2 23.9 22 6 22.7 22 5 22.3 22.0 21.8 21.6 21.4 21.2 21.3 21.4 21.7 22.0 22.5 22.9 23.4 23.8 23.9 23.9 23.8 23.6 23.5 23.3 23.1 22.9

5 13 9 25.3 19.0 17.7 16.9 16 2 15.6 15.0 14.5 14.0 13.9 14.5 15.4 16.6 18.2 20.2 22.2 23.8 25.0 25.3 24.8 23.9 22.7 21.5 20.4 19.4 18.5

PROBLEM = 12

DAY = 21 MONTH = 12

PLAN ROTATION START = 0.0 : INCREMENT 15.0 NO OF STEPS = 6

(HC-U.dT) CURRENT MATRIX

4577.96 -11.49 0.00 -11.49

4576.88 -11.49 0.00 0.00

4577 96 -11.49 0.00 0.00

4577 96 0.00 0.00 0.00

760.14 0.00 0.00 0.00

MONTH = 12 DAY = 21 PLAN ROTATION = 0.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 7.5 21.9 13.6 11.3 10.9 10.4 9.8 8.8 8.3 7.9 7.5 7.6 9.7 13.0 17.1 19.8 20.0 21.3 21.9 21.3 19.4 16.5 14.7 13.6 12.7 12.1 11.7

1 18.9 21 4 20 2 20.4 20.2 20.0 19.8 19.6 19.4 19.2 19.0 18.9 19.0 19.3 19.6 20.0 20.4 20.9 21.3 21.4 21.4 21.3 21.2 21.0 20.9 20.7 20.5

2 17 4 18.3 17.9 18.1 18.0 18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.4 17.4 17.4 17.5 17.6 17.8 18.1 18.3 18.3 18.3 18.3 18.3 18.3 18.2 18.1

3 17.4 18.9 18.2 18.4 18.2 18.1 18.0 17.8 17.7 17.5 17.4 17.5 17.6 17.7 18.0 18.2 18.5 18.6 18.8 18.9 18.9 18.9 18.8 18.8 18.7 18.6 18.5

4 19.0 21.4 20.3 20.3 20.1 19.9 19.8 19.6 19.4 19.1 19.0 19.1 19.3 19.6 20.0 20.4 20.7 21.1 21.3 21.4 21.3 21.3 21.1 21.0 20.8 20.7 20.5

5 12.2 22.6 17.0 16.0 15.4 14.8 14.2 13.6 13.1 12.5 12.2 12.6 13.4 14.7 16.2 18.0 19.7 21.1 22.2 22.6 22.1 21.4 20.4 19.4 18.4 17.5 16.7

MONTH = 12 DAY = 21 PLAN ROTATION = 15.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 7.5 21.9 13.6 11.3 10.9 10.4 9.8 8.8 8.3 7.9 7.5 7.6 9.7 13.0 17.1 19.8 20.0 21.3 21.9 21.3 19.4 16.5 14.7 13.6 12.7 12.1 11.7

1 18.6 21.1 19.9 20.0 19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.6 18.7 18.9 19.2 19.6 20.0 20.5 20.8 21.1 21.0 21.0 20.8 20.7 20.5 20.4 20.2

2 17.1 18 0 17.6 17 8 17.7 17.7 17.6 17.5 17.4 17.3 17.2 17.2 17.1 17.1 17.2 17.3 17.4 17.5 17.7 17.9 18.0 18.0 18.0 18.0 17.9 17.9 17.8

3 17 6 19.3 18.5 18 6 18.5 18.4 18.2 18.1 17.9 17.7 17.6 17.7 17.9 18.1 18.3 18.6 18.8 19.0 19.2 19.2 19.3 19.2 19.2 19.1 19.0 18.9 18.8

4 19.1 21.6 20 4 20 5 20.3 20.1 19.9 19.7 19.5 19.3 19.1 19.2 19.4 19.7 20.1 20.5 20.9 21.2 21.5 21.6 21.6 21.5 21.4 21.2 21.0 20.9 20.7

5 12.2 22.5 17.0 16.0 15.4 14.8 14.2 13.6 13.1 12.5 12.2 12.5 13.4 14.7 16.3 18.1 19.6 21.0 22.1 22.5 22.1 21.3 20.4 19.4 18.4 17.5 16.7

MONTH = 12 DAY = 21 PLAN ROTATION = 30.0

R\T-> MIN MAX AV 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

OUT 7 5 21.9 13.6 11.3 10.9 10.4 9.8 8.8 8.3 7.9 7.5 7.6 9.7 13.0 17.1 19.8 20.0 21.3 21.9 21.3 19.4 16.5 14.7 13.6 12.7 12.1 11.7

1 18.3 20.6 19.5 19.7 19.5 19.3 19.1 19.0 18.8 18.6 18.4 18.3 18.3 18.4 18.7 19.1 19.6 20.0 20.3 20.6 20.5 20.5 20.4 20.3 20.1 20.0 19.8

2 16.9 17.7 17.3 17.5 17.5 17.4 17.3 17.3 17.2 17.1 17.0 16.9 16.9 16.9 17.0 17.1 17.2 17.3 17.4 17.6 17.7 17.7 17.7 17.7 17.6 17.6 17.6

3 17.8 19 6 18.8 18.9 18.7 18.6 18.5 18.3 18.1 17.9 17.8 17.9 18.1 18.3 18.6 18.9 19.2 19.4 19.5 19.6 19.6 19.5 19.5 19.4 19.3 19.1 19.0

4 19 2 21 7 20.5 20.5 20.4 20.2 20.0 19.8 19.5 19.3 19.2 19.2 19.4 19.7 20.1 20.5 20.9 21.3 21.5 21.7 21.6 21.5 21.4 21.3 21.1 20.9 20.7

5 12.2 22 3 16.9 16.0 15.3 14.8 14.2 13.6 13.1 12.5 12.2 12.4 13.2 14.5 16.2 18.1 19.7 20.9 21.9 22.3 21.9 21.2 20.3 19.3 18.3 17.5 16.7

MONTH = 12 DAY = 21 PLAN ROTATION = 45.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	7.5	21.9	13.6	11.3	10.9	10.4	9.8	8.8	8.3	7.9	7.5	7.6	9.7	13.0	17.1	19.8	20.0	21.3	21.9	21.3	19.4	16.5	14.7	13.6	12.7	12.1	11.7
1	18.0	20.1	19.1	19.3	19.1	19.0	18.8	18.7	18.5	18.3	18.1	18.0	18.0	18.1	18.3	18.7	19.1	19.5	19.9	20.1	20.1	20.1	20.0	19.9	19.7	19.6	19.4
2	16.8	17.6	17.2	17.4	17.3	17.3	17.2	17.2	17.1	17.0	16.9	16.9	16.8	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.5	17.6	17.5	17.5	17.5	17.4
3	18.0	19.9	19.1	19.1	19.0	18.9	18.7	18.5	18.3	18.2	18.0	18.1	18.3	18.6	18.9	19.2	19.5	19.7	19.9	19.9	19.9	19.9	19.8	19.7	19.6	19.4	19.3
4	19.2	21.7	20.5	20.6	20.4	20.2	20.0	19.8	19.5	19.3	19.2	19.2	19.4	19.6	20.0	20.4	20.9	21.2	21.6	21.7	21.7	21.6	21.4	21.3	21.1	20.9	20.7
5	12.2	22.2	16.9	15.9	15.3	14.7	14.2	13.6	13.0	12.5	12.2	12.4	13.1	14.3	16.0	18.0	19.7	21.0	21.9	22.2	21.8	21.1	20.2	19.2	18.3	17.4	16.6

MONTH = 12 DAY = 21 PLAN ROTATION = 60.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	7.5	21.9	13.6	11.3	10.9	10.4	9.8	8.8	8.3	7.9	7.5	7.6	9.7	13.0	17.1	19.8	20.0	21.3	21.9	21.3	19.4	16.5	14.7	13.6	12.7	12.1	11.7
1	17.7	19.8	18.8	19.0	18.9	18.7	18.6	18.4	18.2	18.1	17.9	17.8	17.7	17.8	18.1	18.4	18.8	19.2	19.5	19.7	19.8	19.7	19.6	19.5	19.4	19.3	19 2
2	17.0	17.7	17.3	17.5	17.4	17.4	17.3	17.2	17.2	17.1	17.0	17.0	17.0	17.0	17.0	17.1	17.2	17.4	17.5	17.6	17.6	17.7	17.7	17.6	17.6	17.6	17.5
3	18.3	20.4	19.5	19.5	19.4	19.2	19.0	18.8	18.7	18.5	18.3	18.4	18.6	18.9	19.3	19.6	19.9	20.2	20.3	20.4	20.4	20.3	20.2	20.1	20.0	19.8	19.7
4	19.2	21.7	20.5	20.6	20.4	20.2	20.0	19.8	19.6	19.3	19.2	19.2	19.3	19.6	20.0	20.4	20.8	21.2	21.6	21.7	21.7	21.6	21.4	21.3	21.1	20.9	20.8
5	12.2	22.3	16.9	16.0	15.3	14.8	14.2	13.6	13.1	12.5	12.2	12.5	13.2	14.3	16.0	17.9	19.7	21.1	22.0	22.3	21.9	21.2	20.3	19.3	18.3	17.5	16.7

MONTH = 12 DAY = 21 PLAN ROTATION = 75.0

R\T->	MIN	MAX	AV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OUT	7.5	21.9	13.6	11.3	10.9	10.4	9.8	8.8	8.3	7.9	7.5	7.6	9.7	13.0	17.1	19.8	20.0	21.3	21.9	21.3	19.4	16.5	14.7	13.6	12.7	12.1	11.7
1	17.5	19.4	18.5	18.8	18.6	18.5	18.3	18.2	18.0	17.9	17.7	17.6	17.5	17.6	17.8	18.1	18.5	18.8	19.2	19.4	19.4	19.4	19.3	19.2	19.1	19.0	18.9
2	17.2	17.9	17.6	17.7	17.7	17.6	17.5	17.5	17.4	17.3	17.2	17.2	17.3	17.3	17.3	17.4	17.5	17.6	17.7	17.8	17.9	17.9	17.9	17.9	17.9	17.8	17.8
3	18.7	20.9	19.9	19.9	19.8	19.6	19.4	19.2	19.0	18.8	18.7	18.8	19.0	19.3	19.6	20.0	20.4	20.7	20.8	20.9	20.9	20.8	20.7	20.6	20.4	20.3	20.1
4	19.1	21.7	20.4	20.6	20.4	20.2	20.0	19.8	19.6	19.3	19.2	19.1	19.3	19.5	19.9	20.3	20.7	21.2	21.5	21.7	21.6	21.5	21.4	21.3	21.1	20.9	20 7
5	12.2	22.5	17.0	16.0	15.4	14.8	14.2	13.6	13.1	12.5	12.2	12.6	13.4	14.5	16.0	17.9	19.7	21.1	22.2	22.5	22.1	21.3	20.4	19.4	18.4	17.5	16.7

APPENDIX – 6

INPUT DATA FILE FOR REFERENCE HOUSE

INPUT DATA FILE OF REFERENCE HOUSE

Input file of the Reference House is being reproduced as follows_

DEFINE UNIT NAME : REFERENCE HOUSE	
DEFINE WEATHER DATA FILE : ROORKEE	
DEFINE MATERIALS	
8	No of materials Defined
8.29 6.13 6.25 17.3	Hin.v Hin.c Hin.f Hout
445 0.81 0.80	Brick
411 0.72 0.45	Plaster
590 1.74 0.65	Concrete
396 0.52 0.45	Mud Phuska
522 1.74 0.45	Sand
312 0.17 0.25	Plywood
574 0.81 0.29	Glass
560 1.58 0.65	RCC
1	No. of out. Ambiances
0.2	Ground Reflectivity
7	No of sections
Section 01	
3	No of layers in section
0.01 2	Thickness Material
0.12 1	Thickness Material
0.01 2	Thickness Material
Section 02	
3	No of layers in section
0.01 2	Thickness Material
0.23 1	Thickness Material
0.01 2	Thickness Material
Section 03	
3	No of layers in section
0.01 2	Thickness Material

0.35 1			Thickness	Material
0.01 2			Thickness	Material
Section 04				
4			No of layers in section	
0.01 2			Thickness	Material
0.23 1			Thickness	Material
0.01 2			Thickness	Material
0.01 6			Thickness	Material
Section 05				
0			No of layers in section	

3.18 3.71 3.71 0.50 0.10 0.45 0.42 0.40 0.35 0.27 0.14 0.38 Window

Section 06			
4			
0.03 1			
0.08 4			
0.15 8			
0.01 2			
Section 07			
2			
0.15 3			
0.85 5			
DEFINE NODES			
34			No of nodes
Node	X	y	Coordinate
1	0	-0.9	
2	0	0	
3	0	4	
4	0	6	
5	0	6.4	
6	0	10	
7	0	11.8	

8	0	15.8
9	3.25	15.8
10	4.75	15.8
11	8	15.8
12	3.25	13.3
13	4.75	13.3
14	3.25	11.8
15	4.75	11.8
16	8	11.8
17	3.25	10
18	4.75	10
19	8	10
20	3.25	6.4
21	4.75	6.4
22	6.25	6.4
23	8	6.4
24	3.25	6
25	4.75	5.25
26	6.25	5.25
27	3.25	4
28	4.75	4
29	6.25	4
30	8	4
31	3.25	0
32	4.75	0
33	8	0
34	8	-0.9

DEFINE WALLS

70	Node1	Node2	IR1	IR2	Ht	Sec	Fens	Shed Type
1	1	2	-1	-1	3	2	0	3
2	2	3	-1	1	3	2	0	3

3	3	4	-1	6	3	2	0	3
4	4	5	-1	7	3	2	0	3
5	5	6	-1	7	3	2	0	3
6	6	7	-1	8	3	2	0	3
7	7	8	-1	9	3	2	0	3
8	8	9	-1	9	3	2	1	1
1.2	1 8	0	2.1	5				
9	9	10	-1	10	3	2	1	1
0.15	1.2	1.5	2.1	5				
10	10	11	-1	12	3	2	1	1
1.5	1.5	0	2.1	5				
11	12	9	9	10	3	1	1	0
0.9	0.75	0	2.1	5				
12	13	10	10	12	3	1	0	0
13	12	13	10	11	3	1	0	0
14	16	11	12	-1	3	1	0	0
15	14	12	9	11	3	1	1	0
0	1	0	2.1	5				
16	15	13	11	12	3	1	1	0
0	1	0	2.1	5				
17	7	14	9	8	3	1	1	0
0.6	1.2	0	2.7	5				
18	15	16	12	13	3	1	1	0
1.2	0.75	0	2.1	5				
19	17	14	8	11	3	1	0	0
20	18	15	11	13	3	1	1	0
0	0.75	0	2.1	5				
21	6	17	8	7	3	1	0	0
22	17	18	11	7	3	1	0	0
23	18	19	13	-1	3	1	0	0
24	19	16	13	-1	3	1	0	0

25	23	19	-1	-1	3	1	0	0
26	20	21	7	3	3	1	1	0
0	1.2	0	2.7	5				
27	24	20	7	3	3	1	0	0
28	25	21	3	4	3	1	0	0
29	21	22	-1	4	3	1	0	0
30	22	23	-1	5	3	1	0	0
31	26	22	4	5	3	1	0	0
32	25	26	4	3	3	1	0	0
33	4	24	7	6	3	1	0	0
34	27	24	6	3	3	1	0	0
35	29	26	3	5	3	1	1	0
0	1	0	2.1	5				
36	30	23	5	-1	3	1	0	0
37	3	27	6	1	3	1	0	0
38	27	29	3	2	3	1	0	0
39	29	30	5	2	3	1	0	0
40	31	27	1	2	3	1	0	0
41	33	30	2	-1	3	1	0	0
42	2	31	1	-1	3	1	1	2
1.5	1.2	1.2	2.1	5				
43	31	32	2	-1	3	1	1	2
0.15	1.2	0	2.7	5				
44	32	33	2	-1	3	1	1	2
0.15	3	0	2.7	5				
45	34	33	-1	-1	3	1	0	0
46	3	4	-1	14	3	1	0	0
47	4	5	-1	15	3	1	0	0
48	5	6	-1	15	3	1	0	0
49	6	7	-1	16	3	1	0	0
50	7	8	-1	17	3	1	0	0

51 8 9 -1 17 3 1 1 1

1.2 1.8 0 2.1 5

52 9 10 -1 18 3 1 1 1

0.15 1.2 1.5 2.1 5

53 12 9 17 18 3 1 0 0

54 13 10 18 -1 3 1 0 0

55 12 13 18 19 3 1 0 0

56 14 12 17 19 3 1 0 0

57 15 13 19 -1 3 1 0 0

58 7 14 17 16 3 1 0 0

59 17 14 16 19 3 1 0 0

60 18 15 19 -1 3 1 0 0

61 6 17 16 15 3 1 0 0

62 17 18 19 15 3 1 0 0

63 21 18 15 -1 3 1 0 0

64 20 21 15 20 3 1 0 0

65 24 20 15 20 3 1 0 0

66 4 24 15 14 3 1 0 0

67 27 24 14 20 3 1 0 0

68 28 21 20 -1 3 1 0 0

69 3 27 14 -1 3 1 0 0

70 27 28 20 -1 3 1 0 0

0 3.25 2.1 0.3 0.6 starting dist of shed, length of shed, level of shed, thickness of shed

SHADE TYPE 01

0 3.25 3 0.15 0.75

SHADE TYPE 02

0 4 3 0.15 3

DEFINE ROOMS

20 TOTAL NO OF ROOMS DEFINED

HT Heat Cap

3 400

3	200
3	100
3	100
3	100
3	800
3	400
3	500
3	600
3	100
3	100
3	400
3	100
3	100
3	400
3	400
3	600
3	100
3	100
3	100

DEFINE OCCUPANCY LOAD IN EACH ROOM (EACH HOUR)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DEFINE APPLINANCES LOAD IN EACH ROOM (EACH HOUR)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DEFINE VENTILATION RATE (ACPH) IN EACH ROOM (EACH HOUR)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
6	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
8	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
11	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
12	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
13	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
14	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
15	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
16	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
17	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
18	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
19	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
20	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

DEFINE SLABS

13 No. of SLABS DEFINED

1	-1	1	0	6	slab no, room on side 1, room on side 2, area, section
2	-1	2	0	6	
3	-1	3	0	6	
4	-1	4	0	6	
5	-1	5	0	6	
6	-1	14	0	6	

7	-1	15	0	6	
8	-1	16	0	6	
9	-1	17	0	6	
10	-1	18	0	6	
11	-1	19	0	6	
12	-1	20	0	6	
13	-1	13	0	6	

DEFINE PARAPET

1					No of parapet loops
5					No of corners in parapet (parapet should be closed)
0.9					Ht of parapet
2	8	11	33	2	Nodes in parapet

DEFINE FLOORS

20 No. of FLOORS DEFINED

1	1	0	7	floor no, room no, area, section
2	2	0	7	
3	3	0	7	
4	4	0	7	
5	5	0	7	
6	6	0	7	
7	7	0	7	
8	8	0	7	
9	9	0	7	
10	10	0	7	
11	11	0	7	
12	12	0	7	
13	13	0	7	
14	14	0	6	
15	15	0	6	
16	16	0	6	
17	17	0	6	

18	18	0	6
19	19	0	6
20	20	0	6

DEFINE PROBMELS

1 No. of PROBLEMS DEFINED

Date	Month	Plan Rotation Angle (Start)	Increment	No. of Rotations	Temperature
30	5	120	0	0	30