THERMAL PERFORMANCE OF BUILDING FORMS FOR HOT DRY CLIMATE

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ARCHITECTURE

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in thesis entitled **"Thermal Performance Of Building Forms For Hot Dry Climate"** in partial fulfillment of the requirement for the award of the Degree of Master of Architecture submitted in the Department of Architecture & Planning of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from July 2005 to June 2006 under the supervision of Prof. Rita Ahuja and Prof. Dr. Sarla Sahu.

The matter embodied in thesis has not been submitted by me for the award of any other degree.

(S.M. Vishweshwar Rao)

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

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Date: 30 June 2006 S.M.Vishweshwar Rao.

Preface

This dissertation is an investigation into the thermal performance of different building forms. Every building designed according to the requirements of client and architects view point but the thermal performance of building should be such that it provides the thermal comfort indoor. So for achieving this, thermal performance of basic geometrical building forms is calculated and a ready reckoner of surface area to floor area ratio (practically usable) is presented which can be used by architects and engineers at basic sketch design stage to provide comfort indoor.

Surface area to floor area ratio is calculated using mathematical formulas. And ready reckoner is made. The computation was time consuming hence computer program using C++ language is made for easy calculations.

The computation became extremely complicated and multiple so I have used ecotect v5.20.software to calculate the thermal performance .

Contents

NOTATIONS

T = transmission factor

U = over all heat transmission co efficient .

$\bar{O}$ = mean sol-air temperature.

θ_{sa} = so air temperature amplitude.

h_i = incide film co-efficient.

λ_i = Decrement factor.

Φ = Time lag.

α = phase sol air temperature.

t = Peak hour under consideration .

T = Time period of sinusoidal wave

t_o = Outside temperature.

t_i = Indoor temperature. 25 °C.

q_s = Rate of heat flow through solid wall.

t_i = Total incident solar radiation.

q_s = Rate of heat flow through solid wall.

q_g = PHGF through glass.

PHGF = Peak heat gain through glass.

AHGF = Average heat gain through glass.

I = Total incident solar radiation

I_D = Direct solar radiation.

I_{Dh} = direct solar radiation on horizontal surfaces.

I_{Dv} = direct solar radiation on Vertical surfaces.

I_{Ds} = direct solar radiation on sloping surfaces.

I_{DN} = Direct solar radiation at normal incident.

I_d = Diffused solar radiation.

I_{dh} = diffused solar radiation on horizontal surfaces.

I_{dv} = diffused solar radiation on Vertical surfaces.

I_{ds} = diffused solar radiation on sloping surfaces.

I_{ds} = diffused solar radiation on sloping surfaces.

I_{dN} = diffused solar radiation at normal incident.

I^o = Apparent solar constant.

I_{grv} = reflected solar radiation from ground on vertical surface.

I_{TH} = Total solar radiation on horizontal surface

I_{TV} = Total solar radiation on Vertical surface.

I_{TS} = Total solar radiation on Sloping surface.

H = Altitude.

θ = Angle.

α = Wall solar azimuth

Z = azimuth of Sun

AZ = azimuth of sun.

Introduction

The Bureau of Energy Efficiency constituted by the Government of India in March, 2002, has identified .1) Energy Efficiency in Buildings and Establishments and 2) Energy Conservation Building Codes as the thrust areas of its action plan. The focus of these areas is directed towards improving energy efficiency in existing buildings and development of guide lines so that new buildings be designed and built with energy efficiency considerations having been incorporated right from the designing stage. This is a testimony to the fact that necessity for design of functional and energy efficient buildings has been very well recognized and efforts are needed to design buildings that would function in conformity with climate and not against it. Accomplishment of the aforesaid objective involves three steps

(i) Identification of the climate at the building site in question;

(ii) Determination of the comfort requirements of the relevant climate; and

(iii) Selection of appropriate architectural features like size and shape, orientation, size of fenestration, shading devices, materials of building envelope fabric etc.

The most important design parameters affecting indoor thermal comfort and energy conservation on the building scale are building form, orientation, lighting and thermo physical properties of the building envelope.

Climate is the main factor governing architectural design of building for creating comfort conditions indoors. It is the intense solar radiation of summer incident on external surface of the building, infiltrated to the internal environment, which causes thermal discomfort in unconditioned buildings and contributes 40-60% cooling load on air-conditioned buildings as solar heat gain. If the total building envelope could be designed to have minimum exposure to external environment, there will be minimum solar heat gain per unit floor area (w/m2) and building will prove thermally efficient through architectural control at the design stage itself.

Solar radiation incidence causes substantial cooling loads on building envelope in summer time and involves complex calculations for its assessment. Therefore, architects resort to qualitative judgment while designing buildings. In fact, building envelope needs to be optimized in terms of shape and size, fenestration and orientation etc. for minimum heat gain and heat loss, which may prove to be least energy consuming and comfortable at the same time. Keeping this important aspect in view, to facilitate the architect, a new index has been brought out in the form of surface area to floor are ratio (SA/FA), to be considered as the major determinant for designing thermally efficient building envelope. In this paper, a ready reckoner is presented to assess solar heat gain to various design options at the initial design stage. It is simple to use and least time consuming. It will help to contribute towards minimizing cooling loads in the air-conditioned buildings and optimize thermal comfort in unconditioned buildings.

AIMS AND OBJECTIVES.

The thermal comfort of building occupants should always be satisfied in any enclosure. To ensure conditions of thermal comfort with minimum energy consumption is of great importance for the health of the user and energy conservation.

The aim of this thesis is to introduce a methodology for the determination of the reference building form, from thermal comfort point of view.

The following objectives have been framed

I. To study factors effecting thermal performance of building envelope
II. To analyze mathematically different geometrical forms in terms of surface area to floor area ratio.
III. To study and compare the sa/fa for different geometrical forms.
IV. To study the heat gain for different geometrical building forms in all orientations and to determine the most efficient building form for the hot dry climate.

Scope of work:

As the building form is one of the most important components with respect to total heat gain or loss of whole building envelope, it has been taken into consideration in detail.

I. Study of surface area to floor area ratio for different geometrical forms with constant floor area and varying surface area by increasing the height and studying the surface area to floor area ratio.

II. Analysis of different geometrical building forms in terms of heat gain through the building for each of the sub parts of all the 7 forms

III. Comparative analysis of different geometrical forms for varying surface area

IV. Computation and comparative analysis in terms of SA/ FA ratio, heat gain for each of the geometrical forms with respect to one and another.

Limitation :

Dissertation is limited to purely geometrical forms to achieve at conclusion that the heat gain per unit floor area which can be applied to any composite building form.

The study shall be limited to hot dry region since the heat gain is maximum in this region and there is large diurnal range in temperature between day and night.

APPROACH TO THE PROBLEM:

Factors affecting building form have been studied.

Heat transfer through various building sections have been studied

Geometrical forms have been chosen in such way that all types of surface comes into picture

Mathematical equations are drawn to calculate SA/FA and graphs have been plotted simulation of all the values are plotted on graph and Comparative analysis of SA/FA have been studied

The heat gain through the different geometrical building forms are calculated and graphs are plotted .

Comparison of sa/fa is with the heat gain graphs .

1.0 CLIMATIC CLASSIFICATION

Classification of climate in respect of building design means zoning the country into regions in such a way that the difference of climate from region to region are reflected in the building design, warranting some special provision for each region. Based on these criteria, there are five major climatic zones, (i) hot-dry; (ii) warm-humid; (iii) cold; (iv) temperate ; and (v) composite. Climatic Zone

Table 1.0

Climate Zone	Mean Monthly max, temp,°c	Mean Monthly Relative Humidity, %
Hot -Dry	Above 30	Below 55
Warm Humid	Above 30, above 25	Above 55 , above 75
Temperate	Between 25 – 30	Below 75
Cold	below 25	All values
Composite	-----	-----

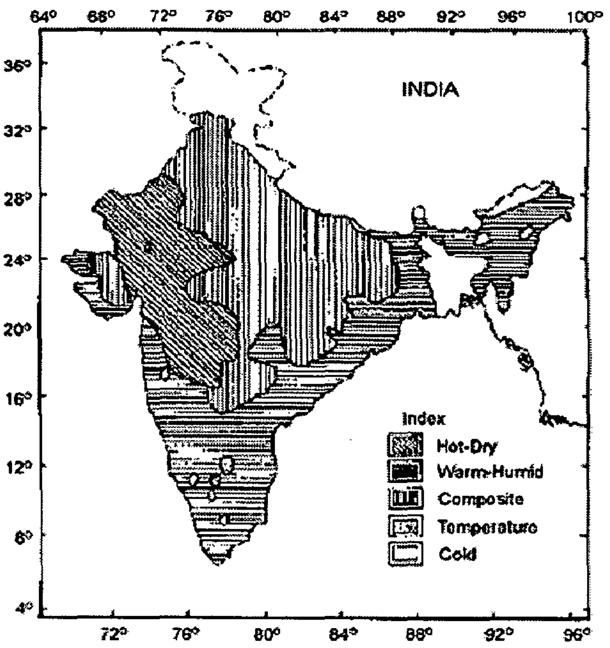


Fig.1 Map of India depicting different climatic zones

A given station is categorized under a particular zone if its climate conforms to that zone for six or more months, otherwise it falls under the composite zone. A map of India depicting various climatic zones is shown in Figure 1. For example, in Jaipur, it is cold in January, Temperate during February, November & December, hot-dry during March to June & October and warm-humid in July to September.

- ## Comfort in hot dry climate :
- **A hot-dry climate**

A hot dry climate is defined as a region that receives less than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year comfort conditions depend upon air temperature, relative humidity, wind speed, as well as on clothing, acclimatization, age, sex, and type of activity of the people. Based on exhaustive studies carried out on thermal comfort at **CBRI Roorkee1,** A Tropical summer index (TSI) representing the combined effect of temperature, relative humidity and wind speed was evolved. The TSI is defined as the temperature of calm air, at 50% relative humidity which imparts same thermal sensation as the given environment. Mathematically,

TSI is expressed as

TSI = 0.75t_a + 0.308t_w - 2 v + 0.841

Where

t_a = Dry Bulb (globe temperature , °c ;

t_w = Wet bulb temperature in °c;

v = air speed in m / sec.

The thermal comfort usually lies between TSI values of 25°C and 30°C with maximum per cent of people being comfortable at 27.5°C. On lower side, the coolness of environment is tolerable between 19°C and 25°C (TSI) and below 19°C (TSI) it is too cold. This clearly indicates that for achieving comfortable environment indoors, heating upto 19°C is necessary in winter, whereas steps need to be taken to achieve indoor conditions conforming to TSI values around 27.5°C in summer. Therefore, in hot-dry climate, emphasis is laid on adopting design techniques that contribute towards reduction in indoor air temperature or globe temperature and provision of adequate night ventilation. On the other hand, provision of ample air motion is an important requirement of building design in warm-humid climate.

The environmental factors which effect thermal comfort are as follows.

Conduction ,Convection , ventilation ,building form , out door air temperature , orientation of building ,.....etc.,

Table 2.0Outside temperature in wave for different orientations at 29 ° N latitude

S..no	Section	U W/m²	Decrement factor	Time lag
1	23 cm brick wall + 1 cm plaster	2.3756	0.14	35°
2	11 cm rcc slab + 0.75 cms dpc + 10cm mud phuska +5 lime tracing	2.305	0.11	32.7°
3	1 cm plaster + 11brk+ 1 cm plaster	3.035	0.27	11.11°
s.no	Orientation	Ōs	θsa	Phase lag α
1	horizontal	40.70	17.10	194°
2	East – 8 hrs	35.40	6.50	163°
3	West -16 hr	38.00	11.00	254°
4	South-12 hrs	32.10	5.30	231°
5	North – 19hr	32.80	5.40	233°
6	South east -10 hr	34.20	6.00	190°
7	South west -12 hr	33.70	9.10	237°
8	North east 10 hr	34.00	5.60	175°
9	North west -17 hr	34.90	11.25	237°

Table 3.0 Total soar radiation in different orientation at peak degree hr

s.no	Orientation	I in W/m²
1	East -8 hr	650.88
2	West -16 hr	605.88
3	North -7 hr	176.47
4	South -12 hr	235.29
5	South east -10 hr	388.23
6	South west – 12 hr	705.88
7	North east -7hr	552.94
8	North west -17 hrs	552.94

CHAPTER 2 HEAT TRANSFER THROUGH BUILDING

2.0 INTRODUCTION:

The human body is considered as a defined unit and its relation to the building which is also a defined entity, is an important criterion for human comfort. Heat exchange process between human body, building envelope and the out door environment affect the human comfort and efficiency. The solar radiation incident on external surfaces is infiltrated in the form of light and heat to the internal environment causing thermal discomfort during summer in unconditioned buildings and contributing to substantial cooling load in the conditioned buildings.

2.1 ROLE OF EXTERNAL ENVELOPE:

The envelope of a building separates the indoor space from the external environment and in this way modifies or prevents the direct effect: of climatic variables, such as outdoor air temperature, humidity, wind, solar radiation, rain, snow etc. The envelope is usually composed of two types of materials, opaque and transparent.

The quantitative effect of the external walls depends upon their thickness and thermo- physical properties. When the windows of a building are open, there is a flow of outdoor air in the indoor space, and there is no difference between the external and internal environments. When the windows are closed the air can infiltrate through the cracks around them or the clearance in the doors, but they offer a very low resistance to heat flow through transparent and translucent materials like glass and plastics and through open windows. Solar radiation can penetrate and heat up the building from the inside, and large quantities of heat may get trapped or stored in, bypassing the modifying influence of the rest of the envelop.. Although the quantitative effect of air flow is also dependent on the properties of the materials.

The materials within the internal space, such as floors, partition of and even the furniture modify the indoor temperature by affecting the heat capacity of the structure as a whole and the rate of absorption of heat generated or penetrating within the building.

2.2 OUT DOOR AIR TEMPERATURE AND SOLAR RADIATION:

They follow diurnal and annual cyclic patterns on a given region of the earth's surface, and depend on the intensity and duration of Irradiation by the sun; the range of variation depends upon the geological location. The annual and diurnal pattern depends on the variation of surface temperature. The indoor thermal conditions in buildings without mechanical means follow this pattern, but in a modified form, which depends on details of design and construction and orientation and shade conditions. The principal modifications are changes in the (1) Amplitude of variation and (ii) Timing of maximum and minimum temperatures.

2.3 RELATION BETWEEN OUTDOOR AND INDOOR TEMPERATURE OR" HEAT GAIN PATTERN."

The factors affecting the internal air and surface temperatures without a typical daily pattern is described and analyzed in the following manner. Before sunrise, both the outdoor air and the external surfaces of the building envelop are at their minimum temperatures. After sunrise the outdoor air temperature increases reaching its maximum in the early afternoon e.g., about 2-4 p.m., (and therefore maximum Heat Gain at that hour). The rise in outdoor air temperature causes heat flow to the external building envelope, raising their temperatures. This effect is almost identical for all the building envelope surfaces, regardless of their position. At the same time solar radiation, whether it is direct, diffused from the sky or reflected from neighboring surfaces impinges on the building. Part of the radiation is reflected, but the rest is absorbed by the surface, further elevating its temperature to a level above that of the air. The position of the surface determines the intensity of incident solar radiation, resulting in different temperature patterns for the roof and each of the walls. The magnitude of the temperature elevation is proportional to the absorptivity coefficient of the surface.

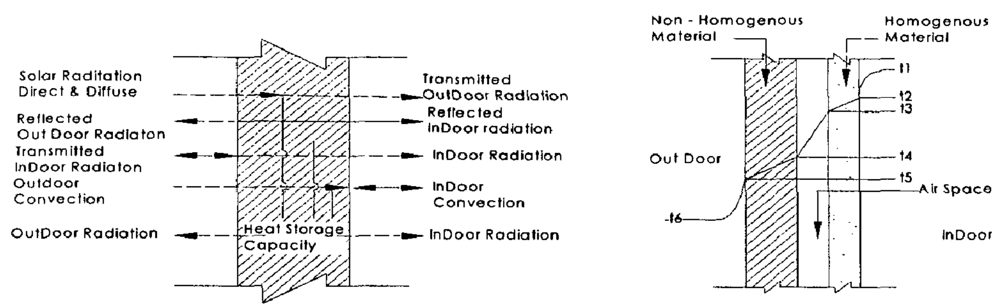
Sunlight falling on a building rises indoor temperature in two different ways, when an incident solar radiation (or insulation) falls on the external envelope of a building the energy that is absorbed increases surface temperature, which in turn causes heat to be conducted inward through the walls and roofs. But when solaria conducted inward through the glass into the interior where it becomes trapped by a process called the green house effect. Direct radiation falling on and through the transparent surfaces on a building contributes disproportionate amounts of energy to the building's heat balance. During cold weather this insulation is a valuable source of heat, but when the interiors temperature are above the comfort range, it only adds to the occupant's discomfort , and more expensive kind of energy must be used to pump it back to outdoors.

2.4 SOLAR RADIATION:

Energy radiated from the sun falling on earth is reflected and transmitted innumerable times before it is finally absorbed. A great deal of solar radiation is scattered and absorbed by dust, water droplets and aerosols in the earth atmosphere. All opaque building materials absorb some proportion of the insulation and reflect away the rest. Transparent materials not only absorb and reflect, but also transmit insulation. Very simple equation expresses the relationship between the proportion of energy that are absorbed (a), reflected (r) and transmitted (t):

$a + r + t = 1.0$

For opaque materials this means that all energy must be either absorbed or reflected. All building materials emit or radiate some proportion of energy that is absorbed. A material's emissitivity (e) is the same as its absorptivity (a) if both value are taken for energy at the same frequency. However, when energy is absorbed by any material, its frequency slows slightly, this means that radiation absorbed at one frequency will have to be emitted at another. In fact the value of building materials absorptivity, reflectivity, and transmissivity are inevitably different for different frequency of radiation



HEAT FLOW THROUGH WALL

STEADY-STATE HEAT FLOW THROUGH WALL

Fig: 2 Heat Transfer Through Wall

2.5 ABSORBED RADIATIONS:

The most effective way the designers can control the amount of heat reaching the interior of a building is to give careful consideration to the way the external envelop either absorbs or reflects solar radiation. Surfaces with low absorptivity to shortwave radiation which reflect off most of the sun's heat and light usually are smooth, light colored surfaces; light colored surfaces ; infact whitewash is one of the most effective reflectors of solar radiation. On the other hand, to capture and absorb the sun's heat, very dark dull surfaces covered with lamp black are among the most effective solar energy absorbers. The amount of energy absorbed (I_a) is the product of the incident solar radiation (I_i) times the absortivity of the surfaces (a);

$I_a = aI_i$

This relation holds for angle of incidence up to about 45°, but beyond this the amount of energy absorbed decreases progressively as the incoming solar radiation becomes more parallel to the wall.

2.6 TRANSMITTED RADIATION:

The solar radiation falling on transparent or translucent surfaces which is not transmitted, must be either reflected or absorbed. Of the energy that is absorbed by a glass or plastic window, roughly half is radiated and convected back to interiors. Thus half of the absorbed energy plus all of the transmitted energy ends up on the inside of the building and very less amount solar energy is transmitted directly into the building.

CHAPTER III PEAK HEAT GAIN FACTORS

3.1 HEAT TRANSMISSION THROUGH WALL SECTIONS

The process of heat flow through a wall from the external surface at an elevated temperature may be visualised by considering the building envelop divided into several layers. The heat flow into each layer causes an elevation of its temperature and the heat used for this is stored in the layer. Thus each layer receives less heat and is subject to a smaller temperature rise than the layer externally adjacent to it. As a result of this heat storage within the structure of the envelop less heat reaches the innermost layer than crosses the outer most one, and its temperature elevations are smaller. After the external surface reaches its maximum temperature and starts to cool, the process

is reversed. First of/the heat accumulated in the wall flows in two directions, inwards and outwards, and later the entire flow is outwards. Then the process may be visualized as a successive cooling of the various layers.

In this way any plane of the wall undergoes wave like cycles of heating and cooling. The amplitude of the Internal wave is smaller than that to which the external surface is subjected and the internal maximum and minimum temperature delayed. The ratio of the internal to the external amplitude depends on the thermo physical properties and thickness of the structure.Heat transmission through solid walls, takes place in the manner, shown in Plate No. 3.1.5

As mentioned in point 2.2 that the heat gain through the solid walls has been calculated by the author while considering both the states of heat flow. The equation for the peak-heat-gain-factor through a section, for indoor air temperature constant at 25°C effective,for optimum comfort, is as following

3.2 HEAT TRANSMISSION COMPUTATIONS

Heat transmission through building envelope is calculated by 2 methods 1 steady state heat flow (not valid for hot and arid reagion where large diurnal swings of temperature are experienced).and periodic state heat flow characteristics experienced in termsof decrement factor and time-lag have been considered simultaneously. A simple method has been adopted to take the periodic variation of temperature and solar radiation into account for predicting actual the actual indoor temperature and air conditioning load caused by solar radiation on the building, with the help of the climatic data.

3.3 Method for computation:

- First a fall heat transmission through solid wall is calculated for all eight orientations by the equation- 1

$$q_s = U(\bar{O}_S - 25) + h_i \lambda_i \theta_{sa} \cos(2\pi t/T - \varphi - \alpha) \qquad \text{--------} (1)$$

The value of different factors are taken from reported and unreported data (C.B.R.I)

- Secondly heat gain factor, (HGF) through glass alone is calculated by the following haet balance equation:

$$q_g = T\mathrm{TOU} + U(t_o - t_i) \qquad \text{--------} (2)$$

T = transmission factor

U = over all heat transmission co efficient .

$\bar{O}$ = mean sol-air temperatura.

θ_{sa} = so air temperatura amplitude.

h_i = incide film co-efficient.

λ_i = Decrement factor.

Φ = Time lag.

α = phase sol air temperatura.

t = Peak hour under consideration .

T = Time period of sinusoidal wave

t_o = Outside temperature.

t_i = Indoor temperature. 25 °C.

q_s = Rate of heat flow through solid wall.

t_i = Total incident solar radiation.

q_s = Rate of heat flow through solid wall.

I = Total incident solar radiation $I_D + I_d$

q_g = PHGF through glass.

PHGF = Peak heat gain through glass.

AHGF = Average heat gain through glass.

I_D = Direct solar radiation.

I_d = Diffused solar radiation.

Heat Transfer Through Glass :

3.4 Heat Transmission through Glass

"The fact that glass and certain other non-opaque or transluscent materials such as plastics have relatively little insulation value and that they transmit solar or short-wave radiation with very little loss in heat energy does not seem to be appreciated by many design of buildings. The present trend to use more and more glass for architectural purposes is evidence of this. large buildings whose exterior walls consist mainly of glass, unprotected from the sun in any way, are increasing in number and are now found in almost every country of the world. This indiscriminate use of glass cannot be recommended from a functional point of view and, if this trend continues, It may well lead to a new fashion in architecture of which there is already evidence in certain countries, that Is, the rejection of glass in favour of windowless buildings.

On the other hand it is still possible to enjoy these advantages, aesthetic and otherwise, without paying too high a pried for thermal comfort.

There Is certainly no doubt that glass is one of the most remarkable building materials. It has not only been in use for many centuries but its popularity is still increasing. Although glass in sheet form is not very

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Spectral Transmission of Glass

Typical spectral transmission curvet for ordinary clear glass and three other types of glasses, viz., a heat-absorbing glass, a heat-reflecting glass, and a heat-absorbing / heat,-reflecting glass,

It was observed that the glasses transmit radiation in varying degrees depending on their wave-length practically all the radiation from the sun received at the earth's surface lies in the wave-length band extending from about 0.3 micron (3,000 Angstrom units) to about 2.5 microns (25,000 Angstrom units. Wave-lengths below about 0.38 and 0.6 micron visible energy or radiation and those beyond 0.8 micron infra-red or heat radiation. Glass transmits radiation, in varying degrees, within the wave-length region 0.3 to 0.8 microns and is opaque to both very short wave and long-wave or low-temperature radiation outside this region. As far as the latter is concerned, glass is in fact opaque to longwave radiant energy emitted from all sources at a temperature below about 450 p. V

The basic differences between the different glasses lie in their transmission characteristics. Whilst clear glass for example, transmits the major portion for the energy over the visible and infra-red parts of the spectrum, the heat-absorbing glass reduces light transmission more than it reduces heat transmission. Heat-reflecting glass, on the other hand, is selective in that it transmits a higher percentage of light than heat. The heat-absorbingheatreflecting glass behaves in more or less the same way as ordinary clear glass except that the transmission is considerably reduced throughout the whole spectrum."

Mechanism of Solar Heat Gain Through Glass

The mechanism of solar heat transmission through ordinary glass glass, heat-absorbing glass, and ordinary glass with a internal vanetian blind, is illustrated schematically in figure 3*

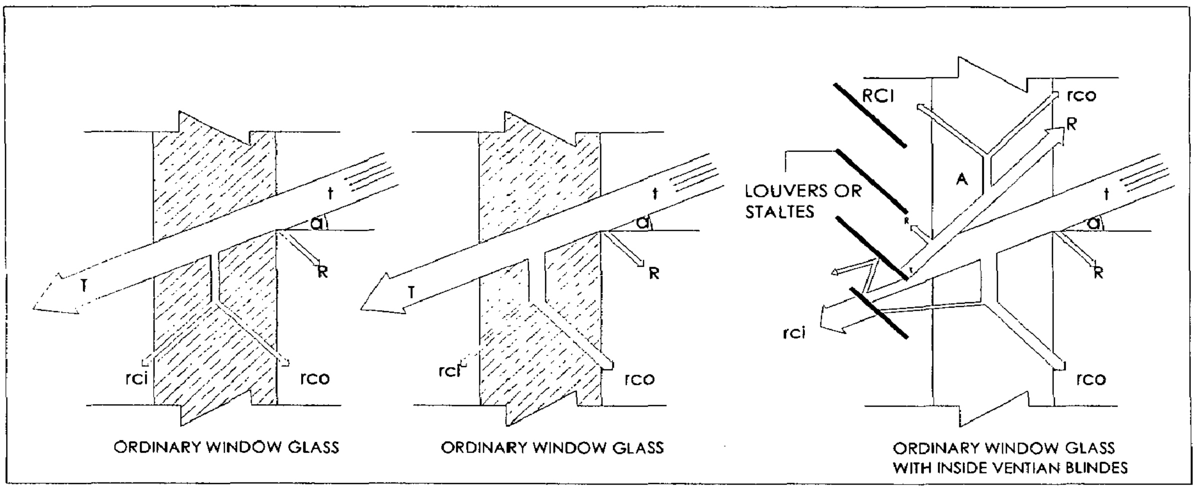


Fig 3 Heat Transmission Through Transparent Material

The heat flow per unit time through unit area of glass can be expressed by the following heat balance

Equation heat gain factor, (HGF) through glass alone is calculated by the following haet balance equation:

$$q_g = TTOU + U\,(t_o - t_i)$$

Total Heat transferred through glass = solar radiation directly transmitted heat gain as a result of solar radiation absorbed by glass+ heat transfer as a result of difference in temperature between indoor and outdoor air

The simplified version of the above can be stated in equation form as follows:

q_g =tx I + U(t_Q –t_1) here T »is transmission factor

I -total incident solar radiation in Kcal/m²

U overall heat transfer coeeficient.

All the computations for the different wall sections have been done using the above explained equation with the help of the data presented

Mathematical Equations to Derive Surface Area to Floor Area Ratio.

The following forms cube , rectanglar base ,

1. **Cube :**

Floor Area of a cube (A) = $a \times a = a^2$ where a is side of an cube .

Surface area of a cube = $4 (a \times h) + (a \times a)$. where h is the height.

Surface area / floor area = $(4 (ah) + a^2) / a^2$

= $(4h + a)/a \times N$ where N is the number of floors

70 % fenestration = surface area of 4 walls x .7

= $(4ah) \times .7$

= $2.8ah$

% of fenestration to floor are = $(2.8ah/a^2) \times 100$

= $280(h/a)$

2. **Rectangular Base:**

Floor Area of a Rectangular Base (A) = $a \times b = ab$ where ab are sides of Rectangular Base.and

Surface area of a Rectangular Base = $2 (a \times h) + 2(b \times h)$. where h is the height

Surface area / floor area = $(2h (a + b)+ab)/ab \times N$ where N is the number of floors

70 % fenestration =surface area of 4 walls x .7

= $2h (a + b) \times .7$

$=1.4h\ (a + b)$

% of fenestration to floor are = $1.4h\ (a + b)/ab \times 100$.

$= 140h(a+b)/ab \times N$ where N is the number of floors

3. **cone:**

Floor Area of a cone (A) $= \pi \times r^2$ where r is the radius of the base circle.

Surface area of a cone $= \pi \times r \sqrt{(r^2 + h^2)}$ where h is the height.

Surface area / floor area $= \pi \times r \sqrt{(r^2 + h^2)}\ / \pi \times r^2$

$= \sqrt{(1+(h/r)^2}\ / \ (N+n)$ where N is the number of floors

Since as we go up the floor area goesw on reduces so for calculating the floor ane on nth floor is is calculated by the formula.

$A' = \{(N+3xN(N-1)x(2N-1)/2xh^2 - 3N(N-1)/h\} x \pi x r^2$ where N is the number of the floor

70 % fenestration = surface area of walls x .7

$= \pi \times r \sqrt{(r^2 + h^2)} \times .7$

$= 2.199\ r \sqrt{(r^2 + h^2)}$

% of fenestration to floor area = $70 \times \sqrt{(1+(h/r)^2}$

4. **Cylinder:**

Area of a Cylinder (A) $= \pi r^2$ where r is the radius of the base circle.

Surface area of a Cylinder $= 2\ \pi rh + \pi r^2$ h is the height.

Surface area / floor area $= (\ 2\ \pi rh + \pi r^2\ )\ /\ \pi r^2$.

$= (2h + r)/r$

$= (2h/r+1)\ /\ N$ where N is the number of floors

70 % fenestration = surface area of walls x .7

$= 2\ \pi rh\ x.7$

$= 1.4\pi rh.$

% of fenestration to floor area = $(1.4\pi rh / \pi r^2)\ x\ 100.$

$= 140h / r\ x\ N$ where N is the number of floors

5. **Triangular Cylinder :**

Area of base triangle (A) $=\sqrt{3}\ x\ a^2/4$ where a is side of Eqilateral triangle.

$= 0.433a^2$

Surface area of Triangular Cylinder $= 3ah + A$ h is the height.

$= (3ah + 0.433a^2)$

Surface area / floor area $= (3ah + 0.433a^2) / 0.433a^2$

$= (6.928h+a)/axN.$ where N is the number of floors

70 % fenestration = surface area of walls x .7

$= 3ah\ x.7$

$= 2.1ah.$

% of fenestration to floor area $= (2.1ah / 0.433a^2)\ x\ 100.$

$= 484.988\ h / a\ x\ N$ where N is the number of floors

6. **Pyramid:**

Area of a Pyramid (A) $= a^2$ where a is base side of a Pyramid.

Surface area of a Pyramid $= a\sqrt{\ } (4h^2+a^2)$ h is the height.

Surface area / floor area $= a\sqrt{\ } (4h^2+a^2)/ a^2\ x\ A'$

$= \sqrt{(4(h/a)^2+1)}\ )/N+A'$ where N is the number of floors and $A' = \{(N+3xN(N-1)x(2N-1)/2xh^2 - 3N(N-1)/h\}x\pi xr^2$ where N is the number of the floor

70 % fenestration = surface area of walls x .7

$= a\sqrt{(4h^2+a^2)}\ x.7$

% of fenestration to floor area $= a\sqrt{(4h^2+a^2)}\ x.7/\ a^2\ \ x\ 100.$

$= 70\sqrt{(4(h/a)^2+1)}/\ N$ where N is the number of floors

7. **Hexagonal Cylinder:**

Area of base hexagon (A) $= 3\sqrt{3}/2xa^2$ where a is base side of a hexagon

$= 2.598\ a^2$

Surface area of a Hexagonal Cylinder $=6ah + 2.598\ a^2$ h is the height.

Surface area / floor area $= (6ah + 2.598\ a^2)/2.598\ a^2$

$= (2.309h/a +1)/N$ where N is the number of floors

70 % fenestration = surface area of walls x .7

$= 6ah\ x.7$

$= 4.2ah$

% of fenestration to floor area $= 4.2ah/2.598\ a^2\ \ x\ 100.$

$= 161.66h/a\ x\ N$ where N is the number of floors.

SURFACE AREA TO FLOOR AREA RATIO

The aim of this thesis is to introduce a methodology for the determination of the efficient building form from the point of view of thermal comfort and heating energy conservation. The thermal comfort of building occupants should always be satisfied in any enclosure. To ensure conditions of thermal comfort with minimum energy consumption is of great importance for the health of the user and energy conservation. As the energy demand increases due to thermal comfort requirements, a considerable portion of energy is consumed for heating purposes in buildings. The most important design parameters affecting indoor thermal comfort and energy conservation on the building scale are orientation, building form and thermo physical properties of the building envelope. As the building form is one of the most important components with respect to total heat gain of whole building, it has been taken into consideration in detail. The efficient building form is determined by means of the calculated heat gain of the whole building envelope. A building form which provides minimum heat gain is qualified as the reference building form.

Two methods have been adopted so far to determine reference building form which are as follows:

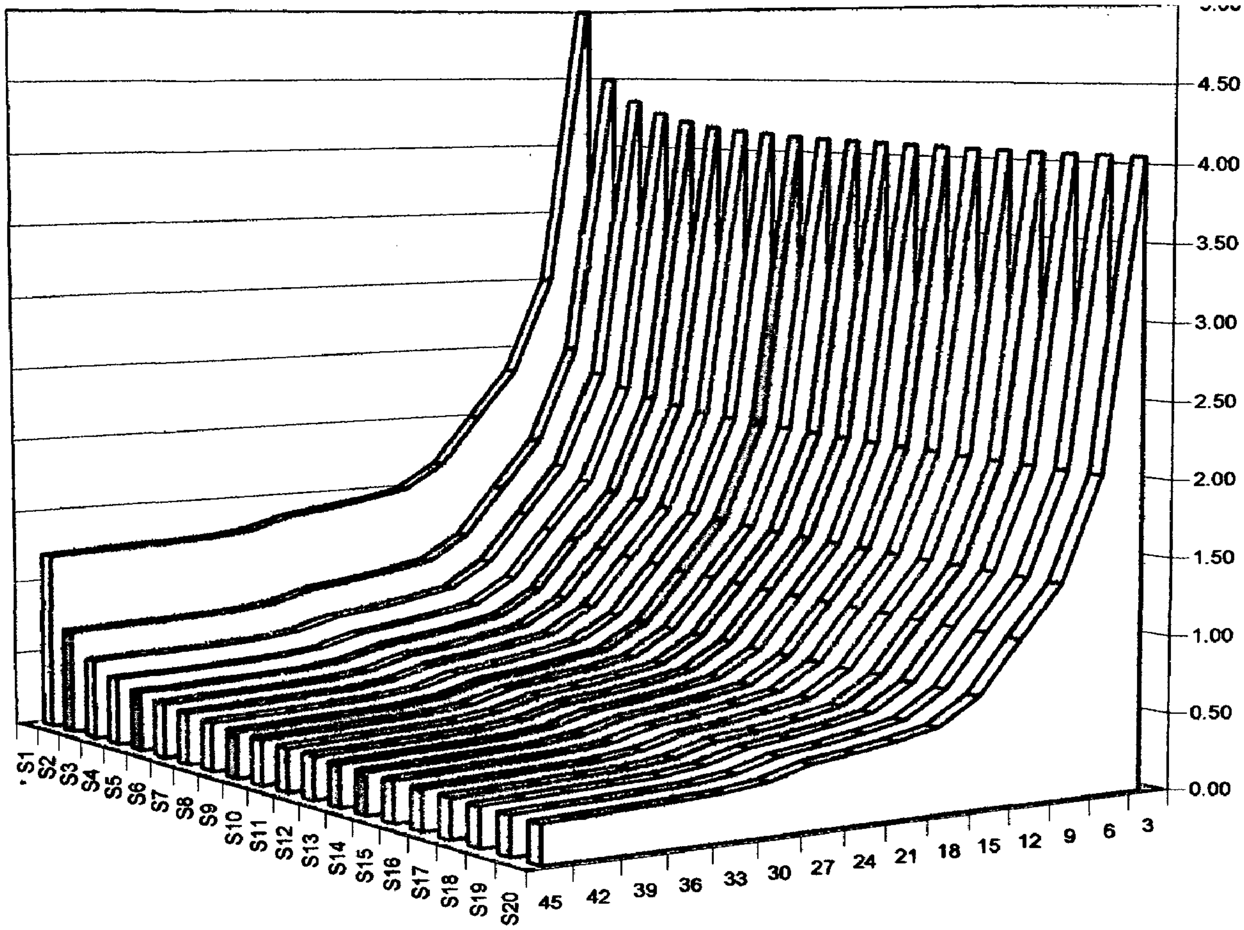
1. Surface area to volume **(A/V)** ratio.
2. Surface area to floor area ratio **(SA / FA)** ratio.

Since surface area to volume ratio is not practical method as architects are familiar to floor area rather than volume space enclosed. In both the cases reference building forms are calculated i.e., the building form which has optimum thermal performance. In order to determine the reference building form for each floor area, the total heat gain through the whole building envelope has been compared by means of graphic systems .The ratio of the individual sides of the enclosed space is also an important aspect since the heat gain through the wall for that particular surface oriented to a particular direction at peak degree hour determines the heat gain through that surface.

Surface area to floor area ratio ***(SA/FA)*** has been calculated for seven geometrical forms (the reason for selecting these geometrical forms is mentioned in chapter 1) and programming is done using **C++** language(given at the end of this chapter).

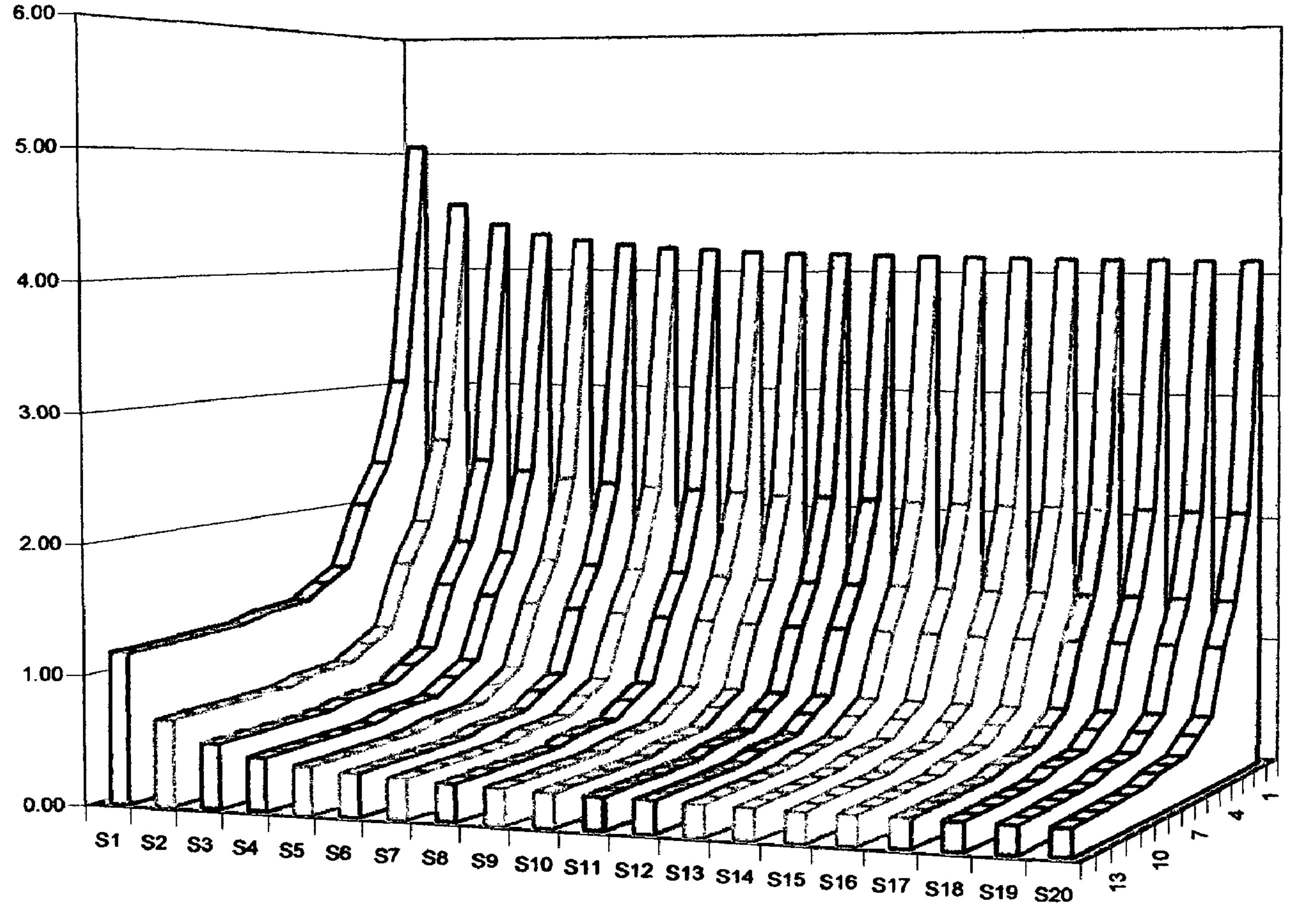
The resultant data of surface area to floor area ratio ***(SA/FA)*** of the seven geometrical forms is presented in graphical and tabular form as under.
The reference building form is determined by means of the calculated heat gain/loss, through the whole building envelope. A building form which provides minimum heat gain is qualified as the reference building form and the A/F (surface area / Floor Area) ratio which defines this form is also qualified as the reference A/F ratio.
In order to determine the reference building form for each floor area, the total heat gain through the whole building envelope has been compared by means of graphic systems in this study. It is can be seen here itself that among the five geometrical forms one which has the sa/fa will have the Heat heat gain in the graphs given below series number refer to floor number

Cube: Surface Area To Floor Area Ratio



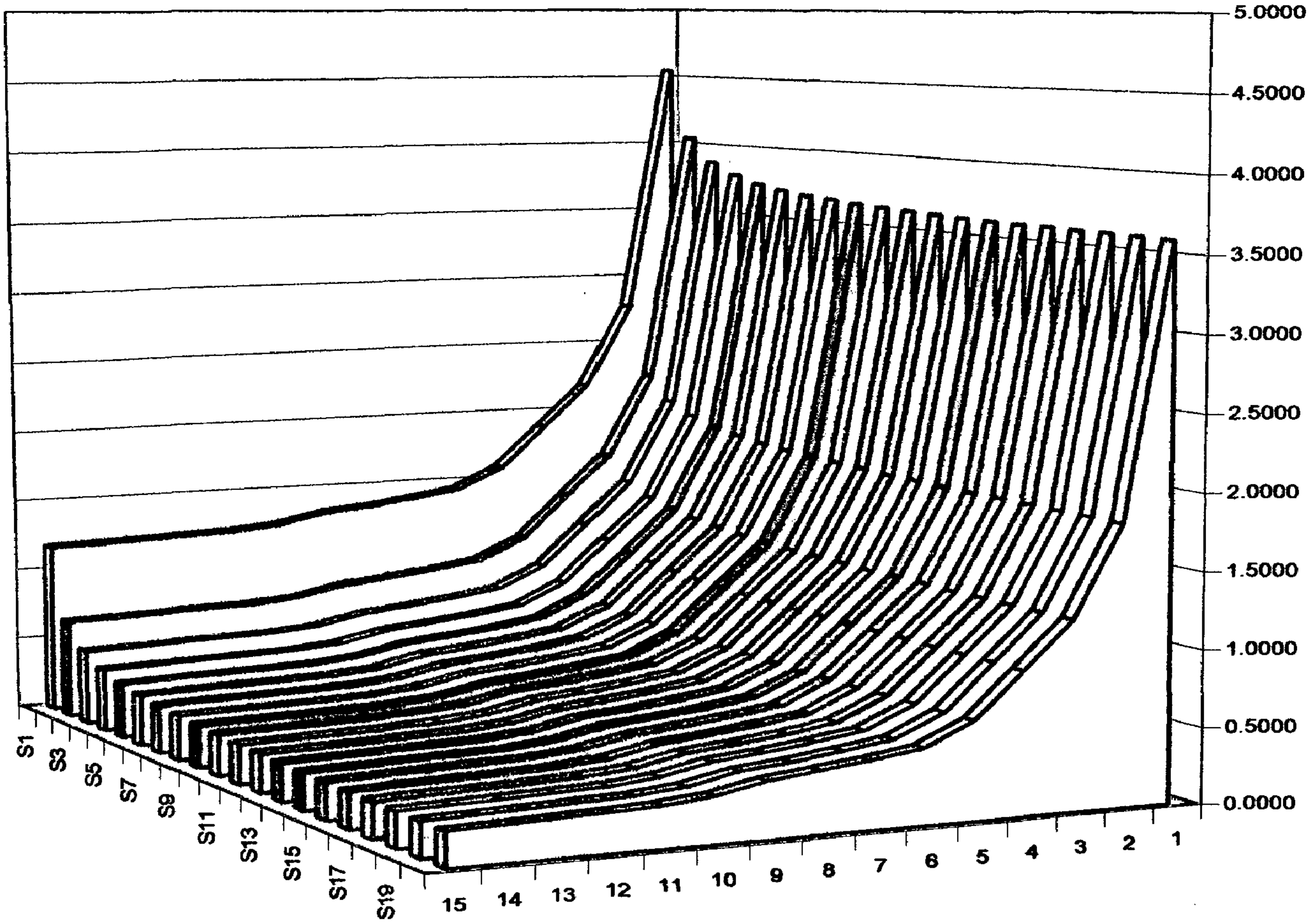
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
Series1	5.00	3.00	2.33	2.00	1.67	1.50	1.44	1.40	1.36	1.29	1.25	1.24	1.22	1.21	1.20
Series2	4.50	2.50	1.83	1.50	1.17	1.00	0.94	0.90	0.86	0.79	0.75	0.74	0.72	0.71	0.70
Series3	4.33	2.33	1.67	1.33	1.00	0.83	0.78	0.73	0.70	0.62	0.58	0.57	0.56	0.54	0.53
Series4	4.25	2.25	1.58	1.25	0.92	0.75	0.69	0.65	0.61	0.54	0.50	0.49	0.47	0.46	0.45
Series5	4.20	2.20	1.53	1.20	0.87	0.70	0.64	0.60	0.56	0.49	0.45	0.44	0.42	0.41	0.40
Series6	4.2	2.2	1.5	1.2	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Series7	4.14	2.14	1.48	1.14	0.81	0.64	0.59	0.54	0.51	0.43	0.39	0.38	0.37	0.35	0.34
Series8	4.13	2.13	1.46	1.13	0.79	0.63	0.57	0.53	0.49	0.41	0.38	0.36	0.35	0.34	0.33
Series9	4.11	2.11	1.44	1.11	0.78	0.61	0.56	0.51	0.47	0.40	0.36	0.35	0.33	0.32	0.31
Series10	4.10	2.10	1.43	1.10	0.77	0.60	0.54	0.50	0.46	0.39	0.35	0.34	0.32	0.31	0.30
Series11	4.09	2.09	1.42	1.09	0.76	0.59	0.54	0.49	0.45	0.38	0.34	0.33	0.31	0.30	0.29
Series12	4.08	2.08	1.42	1.08	0.75	0.58	0.53	0.48	0.45	0.37	0.33	0.32	0.31	0.29	0.28
Series13	4.08	2.08	1.41	1.08	0.74	0.58	0.52	0.48	0.44	0.36	0.33	0.31	0.30	0.29	0.28
Series14	4.07	2.07	1.40	1.07	0.74	0.57	0.52	0.47	0.44	0.36	0.32	0.31	0.29	0.28	0.27
Series15	4.07	2.07	1.40	1.07	0.73	0.57	0.51	0.47	0.43	0.35	0.32	0.30	0.29	0.28	0.27
Series16	4.06	2.06	1.40	1.06	0.73	0.56	0.51	0.46	0.43	0.35	0.31	0.30	0.28	0.27	0.26
Series17	4.06	2.06	1.39	1.06	0.73	0.56	0.50	0.46	0.42	0.34	0.31	0.29	0.28	0.27	0.26
Series18	4.06	2.06	1.39	1.06	0.72	0.56	0.50	0.46	0.42	0.34	0.31	0.29	0.28	0.27	0.26
Series19	4.05	2.05	1.39	1.05	0.72	0.55	0.50	0.45	0.42	0.34	0.30	0.29	0.27	0.26	0.25
Series20	4.05	2.05	1.38	1.05	0.72	0.55	0.49	0.45	0.41	0.34	0.30	0.29	0.27	0.26	0.25

Rectangle base: Surface Area To Floor Area Ratio



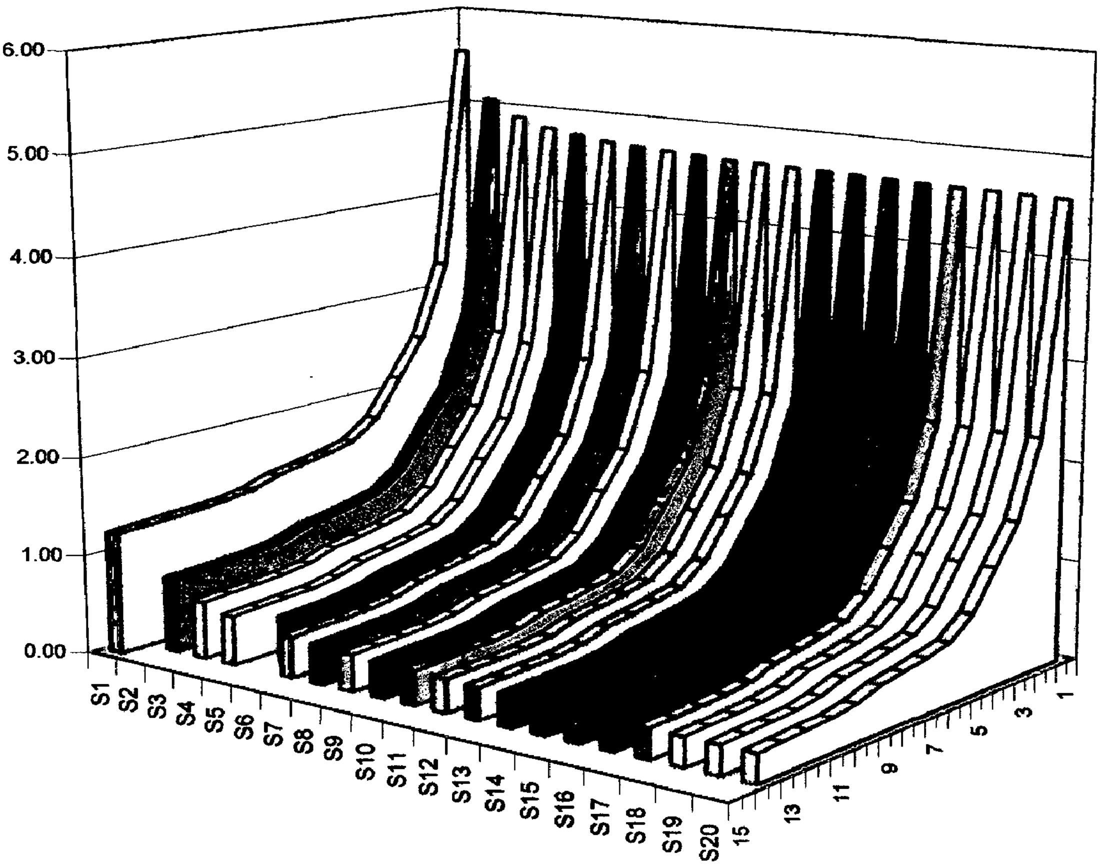
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Series1	5.05	3.03	2.35	2.01	1.51	1.41	1.29	1.27	1.25	1.20	1.19	1.18	1.18	1.17	1.16
Series2	4.55	2.53	1.85	1.51	1.01	0.91	0.79	0.77	0.75	0.70	0.69	0.68	0.68	0.67	0.66
Series3	4.39	2.36	1.68	1.35	0.84	0.74	0.62	0.60	0.59	0.54	0.53	0.52	0.51	0.50	0.50
Series4	4.30	2.28	1.60	1.26	0.76	0.66	0.54	0.52	0.50	0.45	0.44	0.43	0.43	0.42	0.41
Series5	4.25	2.23	1.55	1.21	0.71	0.61	0.49	0.47	0.45	0.40	0.39	0.38	0.38	0.37	0.36
Series6	4.22	2.19	1.52	1.18	0.67	0.57	0.46	0.44	0.42	0.37	0.36	0.35	0.34	0.34	0.33
Series7	4.20	2.17	1.49	1.16	0.65	0.55	0.43	0.41	0.40	0.35	0.34	0.33	0.32	0.31	0.30
Series8	4.18	2.15	1.48	1.14	0.63	0.53	0.41	0.40	0.38	0.33	0.32	0.31	0.30	0.29	0.29
Series9	4.16	2.14	1.46	1.12	0.62	0.52	0.40	0.38	0.36	0.31	0.30	0.30	0.29	0.28	0.27
Series10	4.15	2.13	1.45	1.11	0.61	0.51	0.39	0.37	0.35	0.30	0.29	0.28	0.28	0.27	0.26
Series11	4.14	2.12	1.44	1.10	0.60	0.50	0.38	0.36	0.34	0.29	0.28	0.28	0.27	0.26	0.25
Series12	4.14	2.11	1.43	1.10	0.59	0.49	0.37	0.35	0.34	0.29	0.28	0.27	0.26	0.25	0.25
Series13	4.13	2.10	1.43	1.09	0.58	0.48	0.37	0.35	0.33	0.28	0.27	0.26	0.25	0.25	0.24
Series14	4.12	2.10	1.42	1.08	0.58	0.48	0.36	0.34	0.32	0.27	0.26	0.26	0.25	0.24	0.23
Series15	4.12	2.09	1.42	1.08	0.57	0.47	0.36	0.34	0.32	0.27	0.26	0.25	0.24	0.24	0.23
Series16	4.12	2.09	1.41	1.08	0.57	0.47	0.35	0.33	0.32	0.27	0.26	0.25	0.24	0.23	0.22
Series17	4.11	2.09	1.41	1.07	0.57	0.46	0.35	0.33	0.31	0.26	0.25	0.24	0.24	0.23	0.22
Series18	4.11	2.08	1.41	1.07	0.56	0.46	0.35	0.33	0.31	0.26	0.25	0.24	0.23	0.22	0.22
Series19	4.11	2.08	1.40	1.07	0.56	0.46	0.34	0.32	0.31	0.26	0.25	0.24	0.23	0.22	0.21
Series20	4.10	2.08	1.40	1.06	0.56	0.46	0.34	0.32	0.30	0.25	0.24	0.23	0.23	0.22	0.21

Cylinder Surface Area To Floor Area



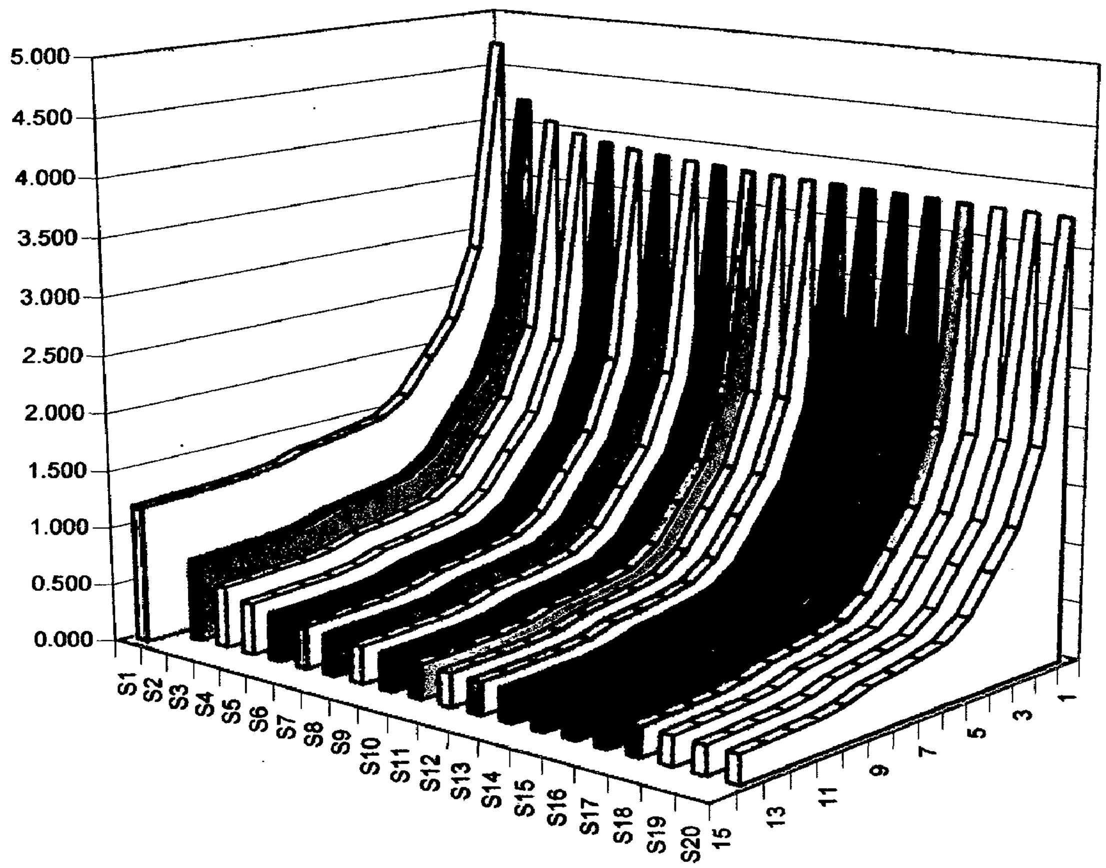
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Series1	4.5461	2.7730	2.1820	1.8865	1.5910	1.4433	1.3940	1.3546	1.3224	1.2533	1.2216	1.2086	1.1970	1.1866	1.1773
Series2	4.0461	2.2730	1.6820	1.3865	1.0910	0.9433	0.8940	0.8546	0.8224	0.7533	0.7216	0.7086	0.6970	0.6866	0.6773
Series3	3.8794	2.1064	1.5154	1.2199	0.9243	0.7766	0.7273	0.6879	0.6557	0.5866	0.5550	0.5419	0.5303	0.5200	0.5106
Series4	3.7961	2.0230	1.4320	1.1365	0.8410	0.6933	0.6440	0.6046	0.5724	0.5033	0.4716	0.4586	0.4470	0.4366	0.4273
Series5	3.7461	1.9730	1.3820	1.0865	0.7910	0.6433	0.5940	0.5546	0.5224	0.4533	0.4216	0.4086	0.3970	0.3866	0.3773
Series6	3.7	1.9	1.3	1.1	0.8	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3
Series7	3.7	1.9	1.3	1.0	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
Series8	3.67	1.90	1.31	1.01	0.72	0.57	0.52	0.48	0.45	0.38	0.35	0.33	0.32	0.31	0.30
Series9	3.66	1.88	1.29	1.00	0.70	0.55	0.51	0.47	0.43	0.36	0.33	0.32	0.31	0.30	0.29
Series10	3.65	1.87	1.28	0.99	0.69	0.54	0.49	0.45	0.42	0.35	0.32	0.31	0.30	0.29	0.28
Series11	3.64	1.86	1.27	0.98	0.68	0.53	0.48	0.45	0.41	0.34	0.31	0.30	0.29	0.28	0.27
Series12	3.63	1.86	1.27	0.97	0.67	0.53	0.48	0.44	0.41	0.34	0.30	0.29	0.28	0.27	0.26
Series13	3.62	1.85	1.26	0.96	0.67	0.52	0.47	0.43	0.40	0.33	0.30	0.29	0.27	0.26	0.25
Series14	3.62	1.84	1.25	0.96	0.66	0.51	0.47	0.43	0.39	0.32	0.29	0.28	0.27	0.26	0.25
Series15	3.61	1.84	1.25	0.95	0.66	0.51	0.46	0.42	0.39	0.32	0.29	0.28	0.26	0.25	0.24
Series16	3.61	1.84	1.24	0.95	0.65	0.51	0.46	0.42	0.38	0.32	0.28	0.27	0.26	0.25	0.24
Series17	3.60	1.83	1.24	0.95	0.65	0.50	0.45	0.41	0.38	0.31	0.28	0.27	0.26	0.25	0.24
Series18	3.60	1.83	1.24	0.94	0.65	0.50	0.45	0.41	0.38	0.31	0.28	0.26	0.25	0.24	0.23
Series19	3.60	1.83	1.23	0.94	0.64	0.50	0.45	0.41	0.38	0.31	0.27	0.26	0.25	0.24	0.23
Series20	3.60	1.82	1.23	0.94	0.64	0.49	0.44	0.40	0.37	0.30	0.27	0.26	0.25	0.24	0.23

Triangle:Surface Area To Floor Area Ratio Graph



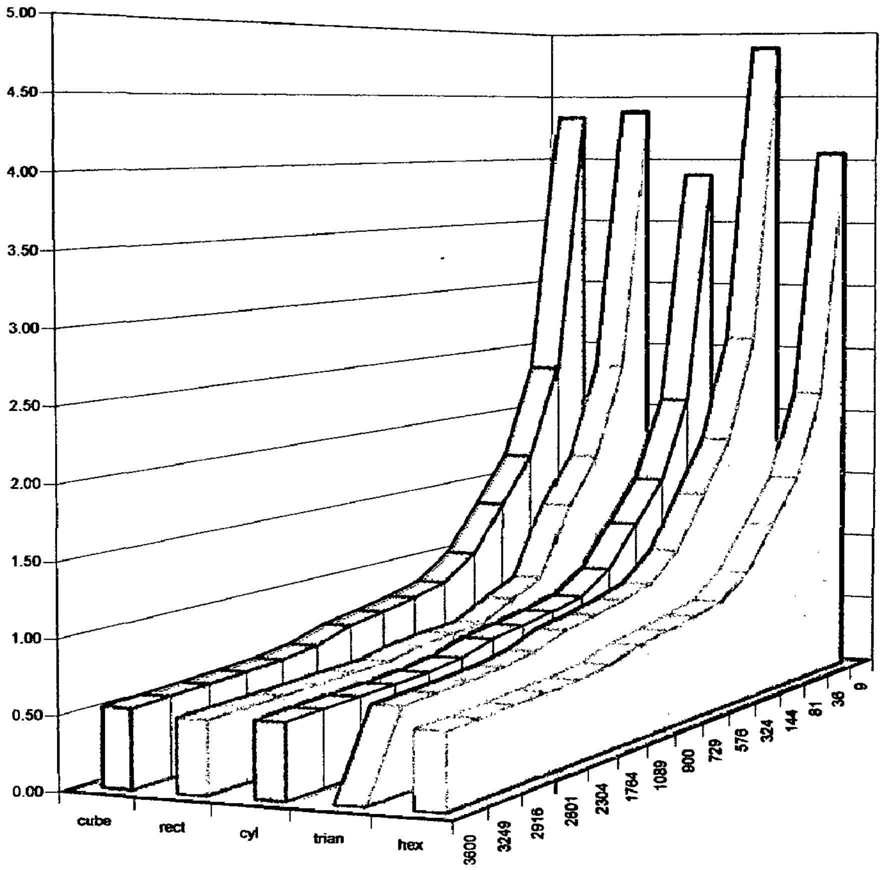
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Series1	5.56	3.28	2.52	2.14	1.76	1.57	1.51	1.46	1.41	1.33	1.28	1.27	1.25	1.24	1.23
Series2	5.06	2.78	2.02	1.64	1.26	1.07	1.01	0.96	0.91	0.83	0.78	0.77	0.75	0.74	
Series3	4.89	2.61	1.85	1.47	1.09	0.90	0.84	0.79	0.75	0.66	0.62	0.60	0.59	0.57	
Series4	4.81	2.53	1.77	1.39	1.01	0.82	0.76	0.71	0.66	0.58	0.53	0.52	0.50	0.49	
Series5	4.76	2.48	1.72	1.34	0.96	0.77	0.71	0.66	0.61	0.53	0.48	0.47	0.45		
Series6	4.73	2.45	1.69	1.31	0.93	0.74	0.67	0.62	0.58	0.49	0.45	0.43	0.42	0.41	
Series7	4.70	2.42	1.66	1.28	0.90	0.71	0.65	0.60	0.56	0.47	0.43	0.41	0.40	0.38	
Series8	4.68	2.40	1.64	1.26	0.88	0.69	0.63	0.58	0.54	0.45	0.41	0.39	0.38	0.36	
Series9	4.67	2.39	1.63	1.25	0.87	0.68	0.62	0.57	0.53	0.44	0.40	0.38	0.36	0.35	
Series10	4.66	2.38	1.62	1.24	0.86	0.67	0.61	0.56	0.51	0.43	0.38	0.37	0.35	0.34	
Series11	4.65	2.37	1.61	1.23	0.85	0.66	0.60	0.55	0.51	0.42	0.38	0.36	0.34	0.33	
Series12	4.64	2.36	1.60	1.22	0.84	0.65	0.59	0.54	0.50	0.41	0.37	0.35	0.34	0.32	
Series13	4.64	2.36	1.60	1.22	0.84	0.65	0.58	0.53	0.49	0.40	0.36	0.35	0.33	0.32	
Series14	4.63	2.35	1.59	1.21	0.83	0.64	0.58	0.53	0.49	0.40	0.36	0.34	0.32	0.31	
Series15	4.63	2.35	1.59	1.21	0.83	0.64	0.57	0.52	0.48	0.39	0.35	0.33	0.32	0.31	
Series16	4.62	2.34	1.58	1.20	0.82	0.63	0.57	0.52	0.48	0.39	0.35	0.33	0.32	0.30	
Series17	4.62	2.34	1.58	1.20	0.82	0.63	0.57	0.51	0.47	0.38	0.34	0.33	0.31	0.30	
Series18	4.61	2.33	1.58	1.20	0.82	0.63	0.56	0.51	0.47	0.38	0.34	0.32	0.31	0.30	

Triangle:Surface Area To Floor Area Ratio Graph



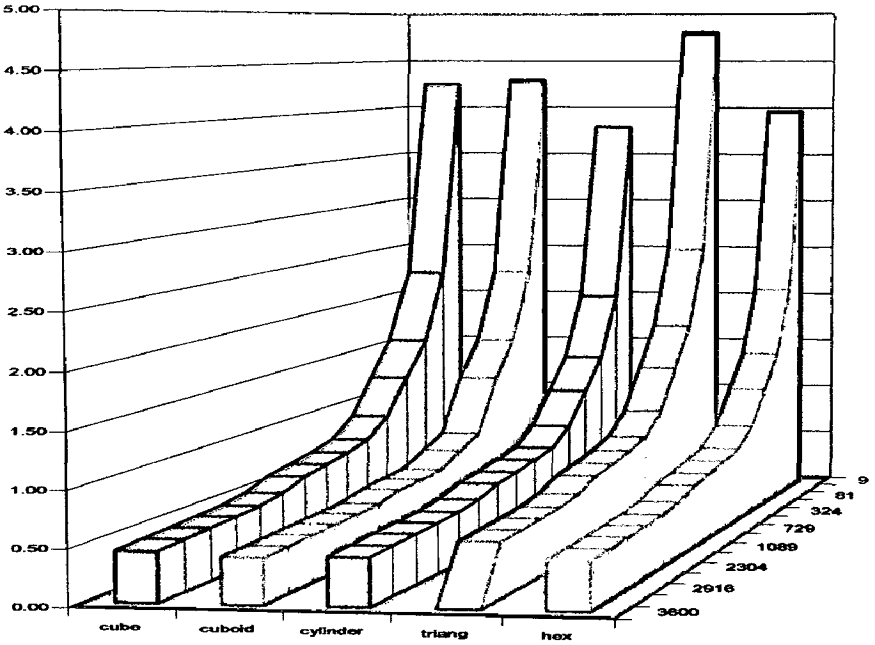
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Series1	4.724	2.862	2.241	1.931	1.621	1.466	1.414	1.372	1.339	1.266	1.233	1.219	1.207	1.196	1.186
Series2	4.224	2.362	1.741	1.431	1.121	0.966	0.914	0.872	0.839	0.766	0.733	0.719	0.707	0.696	
Series3	4.058	2.195	1.575	1.264	0.954	0.799	0.747	0.706	0.672	0.599	0.566	0.552	0.540	0.529	
Series4	3.974	2.112	1.491	1.181	0.871	0.716	0.664	0.622	0.589	0.516	0.483	0.469	0.457	0.446	
Series5	3.924	2.062	1.441	1.131	0.821	0.666	0.614	0.572	0.539	0.466	0.433	0.419	0.407	0.396	
Series6	3.891	2.029	1.408	1.098	0.787	0.632	0.580	0.539	0.505	0.433	0.399	0.386	0.374	0.363	
Series7	3.867	2.005	1.384	1.074	0.764	0.608	0.557	0.515	0.481	0.409	0.376	0.362	0.350	0.339	
Series8	3.849	1.987	1.366	1.056	0.746	0.591	0.539	0.497	0.464	0.391	0.358	0.344	0.332	0.321	
Series9	3.835	1.973	1.353	1.042	0.732	0.577	0.525	0.484	0.450	0.377	0.344	0.330	0.318	0.307	
Series10	3.824	1.962	1.341	1.031	0.721	0.566	0.514	0.472	0.439	0.366	0.333	0.319	0.307	0.296	
Series11	3.815	1.953	1.332	1.022	0.712	0.556	0.505	0.463	0.429	0.357	0.324	0.310	0.298	0.287	
Series12	3.808	1.945	1.325	1.014	0.704	0.549	0.497	0.456	0.422	0.349	0.316	0.302	0.290	0.279	
Series13	3.801	1.939	1.318	1.008	0.698	0.542	0.491	0.449	0.415	0.343	0.310	0.296	0.284	0.273	
Series14	3.796	1.934	1.313	1.002	0.692	0.537	0.485	0.444	0.410	0.337	0.304	0.290	0.278	0.267	
Series15	3.791	1.929	1.308	0.998	0.687	0.532	0.480	0.439	0.405	0.333	0.299	0.286	0.274	0.263	
Series16	3.787	1.925	1.304	0.994	0.683	0.528	0.476	0.435	0.401	0.329	0.295	0.282	0.269	0.259	
Series17	3.783	1.921	1.300	0.990	0.680	0.524	0.473	0.431	0.397	0.325	0.292	0.278	0.266	0.255	
Series18	3.780	1.918	1.297	0.987	0.676	0.521	0.469	0.428	0.394	0.322	0.288	0.275	0.262	0.252	

Comparative SA/FA graph:

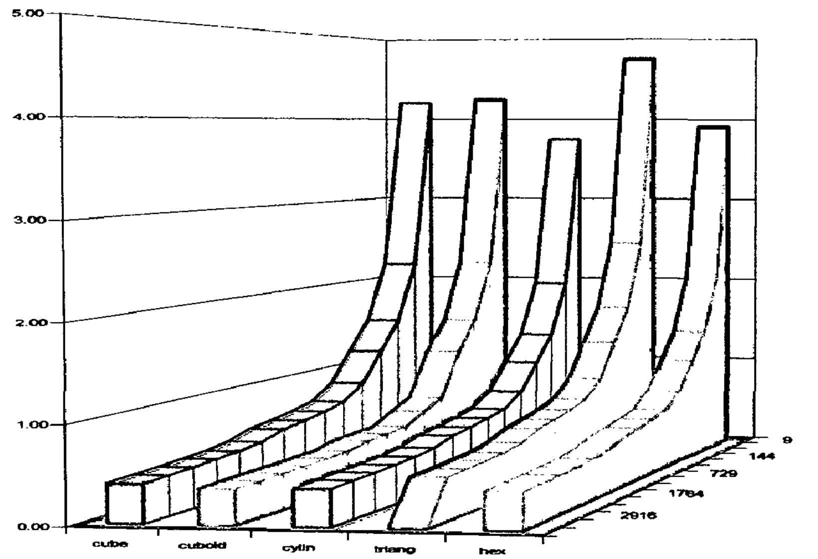


	9	36	81	144	324	576	729	900	1089	1764	2304	2601	2916	3249	3600
cube	4.33	2.33	1.67	1.33	1.00	0.83	0.78	0.73	0.70	0.62	0.58	0.57	0.56	0.54	0.53
rect	4.39	2.36	1.68	1.35	0.84	0.74	0.62	0.60	0.59	0.54	0.53	0.52	0.51	0.50	0.50
cyl	3.8794	2.1064	1.5154	1.2199	0.9243	0.7766	0.7273	0.6879	0.6557	0.5866	0.5550	0.5419	0.5303	0.5200	0.5106
trian	4.89	2.61	1.85	1.47	1.09	0.90	0.84	0.79	0.75	0.66	0.62	0.60	0.59	0.57	
hex	4.058	2.195	1.575	1.264	0.954	0.799	0.747	0.706	0.672	0.599	0.566	0.552	0.540	0.529	0.520

Height 12mtrs



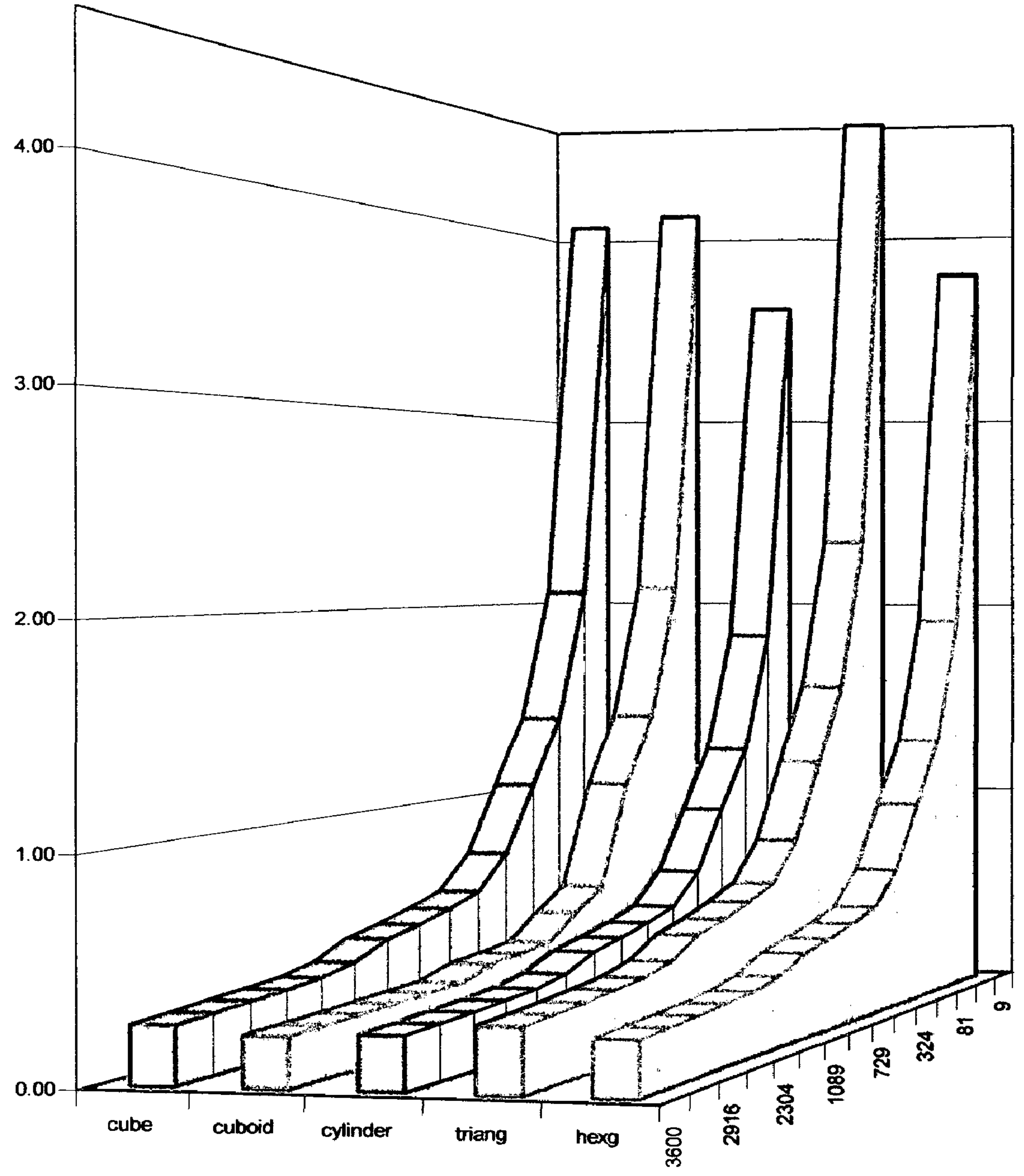
	9	36	81	144	324	576	729	900	1089	1764	2304	2601	2916	3249	3600
cube	4.25	2.25	1.58	1.25	0.92	0.75	0.69	0.65	0.61	0.54	0.50	0.49	0.47	0.46	0.45
cuboid	4.30	2.28	1.60	1.26	0.76	0.66	0.54	0.52	0.50	0.45	0.44	0.43	0.43	0.42	0.41
cylinder	3.7961	2.0230	1.4320	1.1365	0.8410	0.6933	0.6440	0.6046	0.5724	0.5033	0.4716	0.4586	0.4470	0.4366	0.4273
triang	4.81	2.53	1.77	1.39	1.01	0.82	0.76	0.71	0.66	0.58	0.53	0.52	0.50	0.49	
hex	3.974	2.112	1.491	1.181	0.871	0.716	0.664	0.622	0.589	0.516	0.483	0.469	0.457	0.446	0.436



	9	36	81	144	324	576	729	900	1089	1764	2304	2601	2916	3249	3600
cube	4.20	2.20	1.53	1.20	0.87	0.70	0.64	0.60	0.56	0.49	0.45	0.44	0.42	0.41	0.40
cuboid	4.25	2.23	1.55	1.21	0.71	0.61	0.49	0.47	0.45	0.40	0.39	0.38	0.38	0.37	0.36
cylin	3.7461	1.9730	1.3820	1.0865	0.7910	0.6433	0.5940	0.5548	0.5224	0.4533	0.4216	0.4086	0.3970	0.3866	0.3773
triang	4.76	2.48	1.72	1.34	0.96	0.77	0.71	0.66	0.61	0.53	0.48	0.47	0.45	0.44	0.00
hex	3.924	2.062	1.441	1.131	0.821	0.666	0.614	0.572	0.539	0.466	0.433	0.419	0.407	0.396	0.386

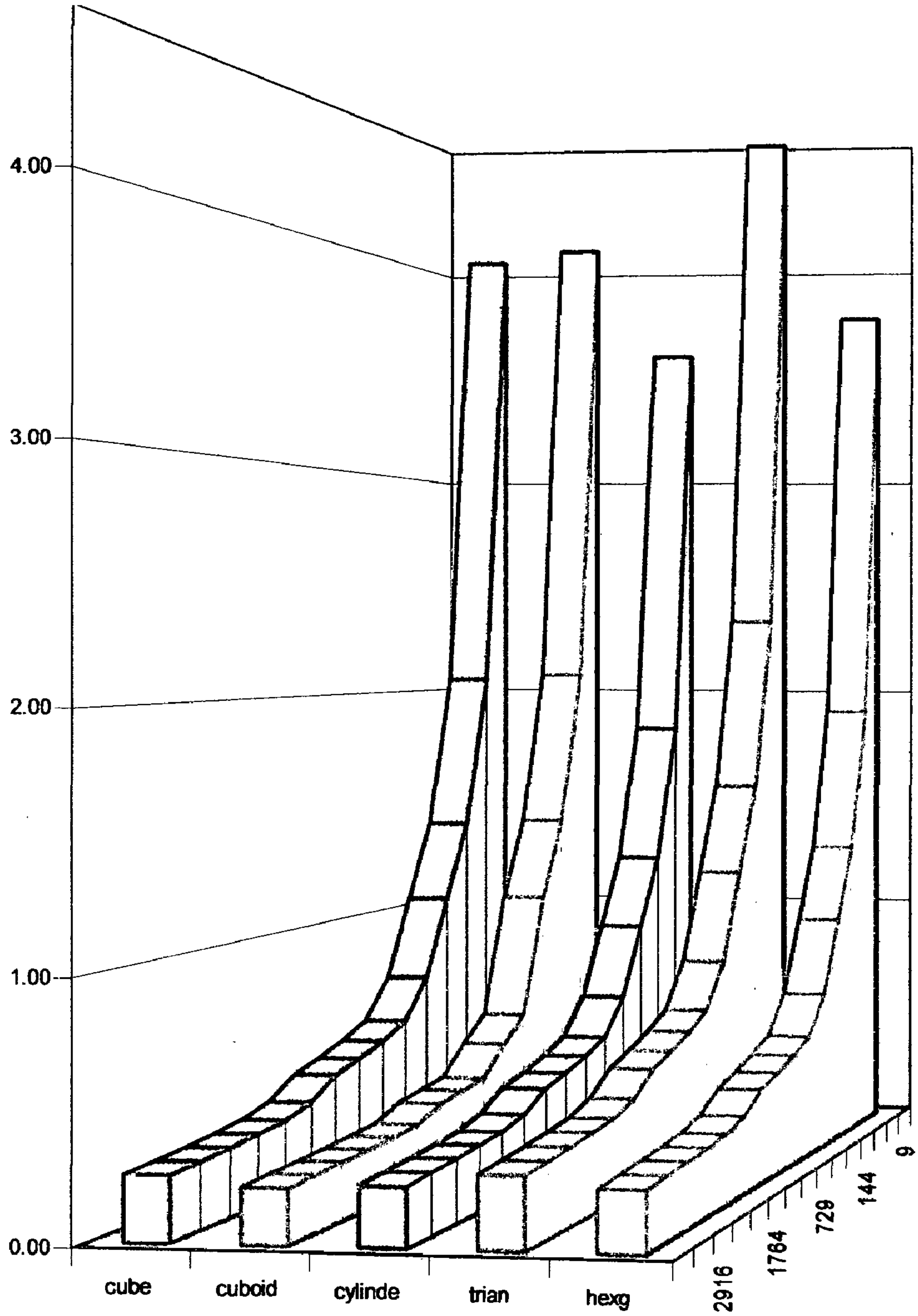
Height 27mtrs

Height 48mtrs.

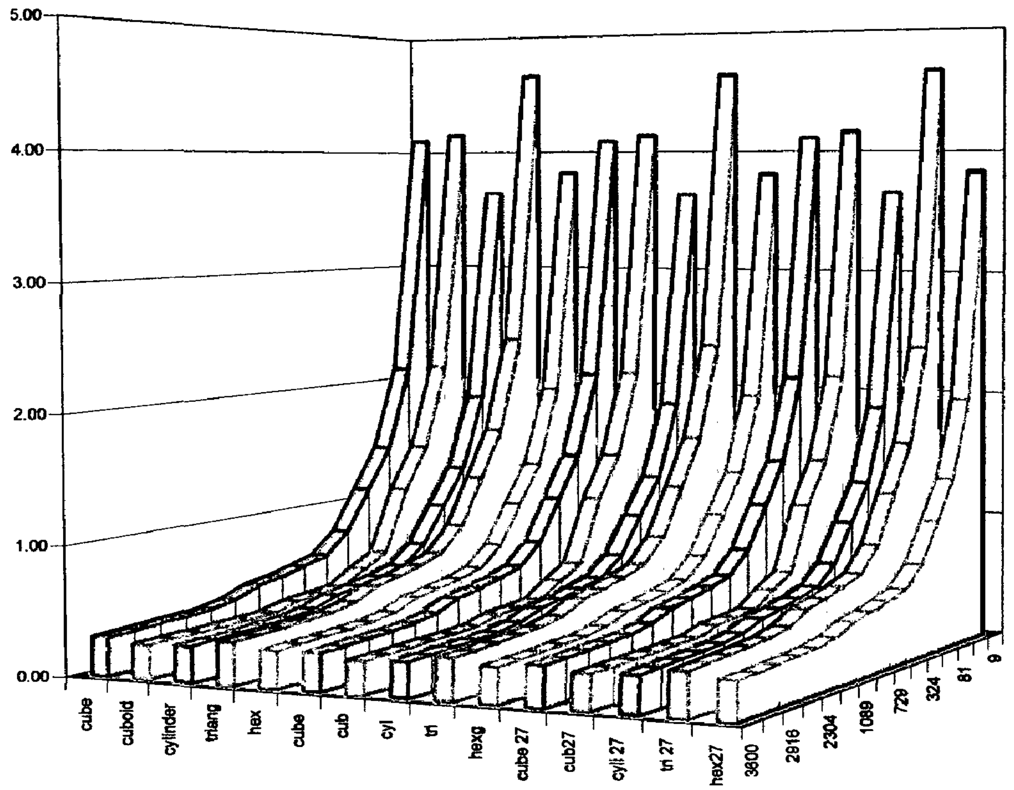


	9	36	81	144	324	576	729	900	1089	1764	2304	2601	2916	3249	3600
cube	4.06	2.06	1.40	1.06	0.73	0.56	0.51	0.46	0.43	0.35	0.31	0.30	0.28	0.27	0.26
cuboid	4.12	2.09	1.41	1.08	0.57	0.47	0.35	0.33	0.32	0.27	0.26	0.25	0.24	0.23	0.22
cylinder	3.61	1.84	1.24	0.95	0.65	0.51	0.46	0.42	0.38	0.32	0.28	0.27	0.26	0.25	0.24
triang	4.62	2.34	1.58	1.20	0.82	0.63	0.57	0.52	0.48	0.39	0.35	0.33	0.32	0.30	0.29
hexg	3.787	1.925	1.304	0.994	0.683	0.528	0.476	0.435	0.401	0.329	0.295	0.282	0.269	0.259	0.249

57M Height



	9	36	81	144	324	576	729	900	1089	1764	2304	2601	2916	3249	3600
cube	4.05	2.05	1.39	1.05	0.72	0.55	0.50	0.45	0.42	0.34	0.30	0.29	0.27	0.26	0.25
cuboid	4.11	2.08	1.40	1.07	0.56	0.46	0.34	0.32	0.31	0.26	0.25	0.24	0.23	0.22	0.21
cylinde	3.60	1.83	1.23	0.94	0.64	0.50	0.45	0.41	0.38	0.31	0.27	0.26	0.25	0.24	0.23
trian	4.61	2.33	1.57	1.19	0.81	0.62	0.56	0.51	0.47	0.38	0.34	0.32	0.31	0.29	0.28
hexg	3.777	1.915	1.294	0.984	0.673	0.518	0.466	0.425	0.391	0.319	0.285	0.272	0.260	0.249	0.239



	9	36	81	144	324	576	729	900	1089	1764	2304	2601	2916	3249	3600
cube	4.10	2.10	1.43	1.10	0.77	0.60	0.54	0.50	0.46	0.39	0.35	0.34	0.32	0.31	0.30
cuboid	4.15	2.13	1.45	1.11	0.61	0.51	0.39	0.37	0.35	0.30	0.29	0.28	0.28	0.27	0.26
cylinder	3.65	1.87	1.28	0.99	0.69	0.54	0.49	0.45	0.42	0.35	0.32	0.31	0.30	0.29	0.28
triang	4.66	2.38	1.62	1.24	0.86	0.67	0.61	0.56	0.51	0.43	0.38	0.37	0.35	0.34	0.33
hex	3.824	1.962	1.341	1.031	0.721	0.566	0.514	0.472	0.439	0.366	0.333	0.319	0.307	0.296	0.286
cube	4.09	2.09	1.42	1.09	0.76	0.59	0.54	0.49	0.45	0.38	0.34	0.33	0.31	0.30	0.29
cub	4.14	2.12	1.44	1.10	0.60	0.50	0.38	0.36	0.34	0.29	0.28	0.28	0.27	0.26	0.25
cyl	3.64	1.86	1.27	0.98	0.68	0.53	0.48	0.45	0.41	0.34	0.31	0.30	0.29	0.28	0.27
tri	4.65	2.37	1.61	1.23	0.85	0.66	0.60	0.55	0.51	0.42	0.38	0.36	0.34	0.33	0.32
hexg	3.815	1.953	1.332	1.022	0.712	0.556	0.505	0.463	0.429	0.357	0.324	0.310	0.298	0.287	0.277
cube 27	4.11	2.11	1.44	1.11	0.78	0.61	0.56	0.51	0.47	0.40	0.36	0.35	0.33	0.32	0.31
cub27	4.16	2.14	1.46	1.12	0.62	0.52	0.40	0.38	0.36	0.31	0.30	0.30	0.29	0.28	0.27
cyli 27	3.66	1.88	1.29	1.00	0.70	0.55	0.51	0.47	0.43	0.36	0.33	0.32	0.31	0.30	0.29
tri 27	4.67	2.39	1.63	1.25	0.87	0.68	0.62	0.57	0.53	0.44	0.40	0.38	0.36	0.35	0.34
hex27	3.835	1.973	1.353	1.042	0.732	0.577	0.525	0.484	0.450	0.377	0.344	0.330	0.318	0.307	0.297

Comparative graph.

Chapter IV Simulation And Heat Gain Calculation

The heat gain are computed using the equations mentioned in Chapter IV they plenty of calculation made presenting them in this report is practically not feasible so I'm attaching a cd in which all the calculations are in corporated.

Conclusions :

1. Conclusions drawn from SA/FA graphs is that cylinder has the least SA/FA so its heat gain is minimum and it can be seen by calculations
2. The least sa/fa ratio form are given below in theier descending order,cylinder, Hexagon , cube , rectangle(1:1.6 ratio) and the triangle,
3. Graph trend of surface area to floor area ratio and heat gain are same for geometrical forms having same floor area on all the floors.

4. Heat gain through walls and window remain same for the geometrical forms like cube rectangular base, triangular base, cylinder hexagon (having same floor area on all surfaces) even when the number of floor increases since its distribution on floor area also increases simultaneaously.

5. Heat gain through roof goes on decreasing when distributed on all the floors.It is maximum for ground floor and as the number of floors increases the heat gain goes on decreases. Resulting in follow of same graph trend as of surface area to floor area ratio.
6. Heat gain is maximum at ground floor and goes on reduces as we increases number of floors that is upto 27- 30 M ht then on the heat gain gets constant or negligible above 27-30 Mtrs height.

7. Heat gain, for diminishing floor area geometrical forms like cone, pyramid, hemisphere, ellipsoid.......etc., goes on increasing.

8. So the forms whose floor area diminishes as the number of floor increases are not recommended for hot dry climate.

9. comparative analysis shows that the building forms having least heat gain with respect to orientations in decreasing order are as follows

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Appendix

Heat gain calculation for geometrical forms

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
void main()
{clrscr();
int c,d,e,p;
char ch;
float qs,u,b,h,l,bs,t,z=24,a,f,qg,tao,i,t0,t1;
do
{
cout<<"choose the one which you want to calculate"<<endl<<"\n";
cout<<"  1.  rate of heat flow through solid wall"<<endl<<"\n";
cout<<"  2.  rate of heat flow through glass"<<"\n";
cin>>c;
if (c==1)
{ cout<<"\n"<<"\n";
cout<<"choose the required section of construction from the following"<<"\n"<<"\n";
cout<<"  SECTION"<<"\t"<<"\t"<<"\t"<<"U  VALUE."<<"\t"<<"D  Factor."<<"\t"<<"time lag."<<endl<<"\n";
cout<<"1)                    23                    cm                    brick wall"<<"\t"<<"\t"<<"2.376"<<"\t"<<"\t"<<".14"<<"\t"<<"\t"<<"35"<<endl ;
cout<<"with 1 cm plaster"<<endl;
cout<<"2)          11          cm          RCC          slab+10cm mud"<<"\t"<<"2.305"<<"\t"<<"\t"<<".11"<<"\t"<<"\t"<<"32.7"<<endl;
cout<< "+5 cm lime terracing"<<endl;
cout<<"3)          1          cm          plaster+11          cm brick"<<"\t"<<"3.035"<<"\t"<<"\t"<<".27"<<"\t"<<"\t"<<"11.11"<<endl;
cout<<" +1 cm plaster"<<endl;
cout<<"4)          33          cm          brick          wall with"<<"\t"<<"1.67"<<"\t"<<"\t"<<".042"<<"\t"<<"\t"<<"62.77"<<endl;
```

```
cout<<" 1 cm plaster"<<endl;
cout<<"5)        1        cm        plaster        +        8        cm        brick
"<<"\t"<<"1.823"<<"\t"<<"\t"<<".11"<<"\t"<<"\t"<<"20"<<endl;
cout<<" wall+5 cm air gap+ 5 cm"<<endl;
cout<<" brick wall+1 cm plaster"<<endl;
cout<<"6)        11        cm        brick        wall+        5
cm"<<"\t"<<"1.564"<<"\t"<<"\t"<<".06"<<"\t"<<"\t"<<"33.3"<<endl;
cout<<" air gap +11 cm brick wall"<<endl;
cout<<"+1 cm plaster"<<endl;
cout<<"7)        11        cm        RCC        slab+5        cm
floor"<<"\t"<<"4.117"<<"\t"<<"\t"<<".36"<<"\t"<<"\t"<<".88"<<endl;
cout<<" finish"<<endl<<"\n";
cout<<" enter the digit" <<"\t";
cin>>d;
if(d==1)
{u=2.376;
l=.14;
a=35;}
if(d==2)
{u=2.305;
l=.11;
a=32.7;}
if(d==3)
{u=3.035;
l=.27;
a=11.11;}
if(d==4)
{u=1.67;
l=.042;
a=62.77;}
if(d==5)
{u=1.823;
```

```
l=.11;
a=20;}
if(d==6)
{u=1.564;
l=.06;
a=33.3;}
if(d==7)
{u=4.117;
l=.36;
a=.88;}

 cout<<"\n"<<"\n";
cout<<"choose the required temprature waveform in different
orientations"<<endl<<"\n";
cout<<"orientation for peak"<<"\t"<<"M.solar temp"<<"\t"<<"Sol-air-
temp.amplt"<<"\t"<<"phase lag"<<endl;
cout<<"   hour"<<endl;
 cout<<"\n"<<"\n";
 cout<<"1)
horizontal"<<"\t"<<"\t"<<"40.7"<<"\t"<<"\t"<<"17.1"<<"\t"<<"\t"<<"\t"<<"194"<<endl;
 cout<<"2)                                                    east-8
Hours"<<"\t"<<"\t"<<"35.4"<<"\t"<<"\t"<<"6.5"<<"\t"<<"\t"<<"\t"<<"163"<<endl;
 cout<<"3)                                                    west-16
Hours"<<"\t"<<"38"<<"\t"<<"\t"<<"11"<<"\t"<<"\t"<<"\t"<<"254"<<endl;
 cout<<"4)                                                    south-12
Hours"<<"\t"<<"32.1"<<"\t"<<"\t"<<"5.3"<<"\t"<<"\t"<<"\t"<<"231"<<endl;
 cout<<"5)                                                    north-19
Hours"<<"\t"<<"32.8"<<"\t"<<"\t"<<"5.4"<<"\t"<<"\t"<<"\t"<<"233"<<endl;
 cout<<"6)                                                    south_east-10
Hrs"<<"\t"<<"34.2"<<"\t"<<"\t"<<"6.00"<<"\t"<<"\t"<<"\t"<<"190"<<endl;
 cout<<"7)                                                    south_west-12
Hrs"<<"\t"<<"33.7"<<"\t"<<"\t"<<"9.1"<<"\t"<<"\t"<<"\t"<<"237"<<endl;
```

```
cout<<"8)                                                        north_east-10
Hrs"<<"\t"<<"34"<<"\t"<<"\t"<<"5.6"<<"\t"<<"\t"<<"\t"<<"175"<<endl;
cout<<"9)                                                        north_west-17
Hrs"<<"\t"<<"34.9"<<"\t"<<"\t"<<"11.25"<<"\t"<<"\t"<<"\t"<<"237"<<endl<<"\n";
cout<<"enter the digit"<<endl;
cin>>e;
if(e==1)
{b=40.7;
bs=17.1;
f=194;}
if(e==2)
{b=35.4;
bs=6.5;
f=163;}
if(e==3)
{b=38;
bs=11;
f=254;}
if(e==4)
{b=32.1;
bs=5.3;
f=231;}
if(e==5)
{b=32.8;
bs=5.4;
f=233;}
if(e==6)
{b=34.2;
bs=6.0;
f=190;}
if(e==7)
{b=33.7;
```

```
bs=9.1;
f=237;}
if(e==8)
{b=34;
bs=5.6;
f=175;}
if(e==9)
{b=34.9;
bs=11.25;
f=237;}
 cout<<"\n"<<"\n";
cout<<"enter the value of inside film coefficient"<<endl;
 cout<<"\t";
 cin>>h;
  cout<<"enter the peak hour under consideration"<<endl;
   cout<<"\t";
   cin>>t;
 qs=u*(b-25) +h*l*bs*cos(2*3.14*t/z -a-f) ;
  cout<<"\n"<<"\n";
 cout<<"The rate of heat flow through the solid wall is   "<<qs<<endl;
 }
 if (c==2)
 {cout<<"Following is the total solar radiation in different"<<endl;
 cout<<"  Orientations at peak degree hour";
  cout<<"\n"<<"\n";
  cout<<"ORIENTATION"<<"\t"<<"\t"<<"\t"<<"I(w/m2)"<<endl<<"\n";
  cout<<"1) east-8 Hours"<<"\t"<<"\t"<<"\t"<<"605.88"<<endl;
  cout<<"2) west-16 Hours"<<"\t"<<"\t"<<"605.88"<<endl;
  cout<<"3) north-7 Hours"<<"\t"<<"\t"<<"176.47"<<endl;
  cout<<"4) south-12 Hours"<<"\t"<<"\t"<<"235.29"<<endl;
  cout<<"5) south_east-10 Hrs"<<"\t"<<"\t"<<"388.23"<<endl;
  cout<<"6) south_west-12 Hrs"<<"\t"<<"\t"<<"705.88"<<endl;
```

```
cout<<"7) north_east-7 Hrs"<<"\t"<<"\t"<<"552.94"<<endl;

cout<<"8) north_west-17 Hrs"<<"\t"<<"\t"<<"552.94"<<endl<<"\n";
 cout<<"enter the required digit"<<"\t";
cin>>p;
if (p==1)
{i=605.88;}
 if (p==2)
{i=605.88;}
 if (p==3)
{i=176.47;}
 if (p==4)
{i=235.29;}
 if (p==5)
{i=388.23;}
 if (p==6)
{i=705.88;}
 if (p==7)
{i=552.94;}
 if (p==8)
{i=552.94;}
cout<<"enter the value of transmission factor"<<endl;
  cout<<"\t";
  cin>>tao;
 cout<<"enter overall heat transmission factor(U) for glass"<<endl;
  cout<<"\t";
 cin>>u;
 cout<<"enter outside temperature  "<<endl;
  cout<<"\t";
 cin>>t0;
 cout<<"enter inside temprature"<<endl;
  cout<<"\t";
```

```
 cin>>t1;
 qg=i*tao + u*(t0-t1);
 cout<<"The heat gain factor through glass is  "<<qg<<endl;
}
cout<<"\n"<<"\n";
cout<<"Do you want to continue(Y/N)";
cin>>ch; }
while(ch=='y');
getch();
}
```

Mathematical equations


```
#include<iostream.h>
#include<conio.h>
#include<math.h>
void main()
{
  clrscr();
   cout<<"                program for solar heat gain calculation"<<endl;
   float h,r,alt;
   float lo= 1.9,a=1.8,re=0.2;
   int z,y;
   cout<<"                  you want to calculate for "<<endl<<"1. cone " <<endl<<"2.
pyramid"<<endl;
   cin>>z;
   if (z==1)
   {
      cout<<"           enter the height of cone"<<endl<<endl;
      cin>>h;
      cout<<endl<<endl<<"           enter the radius of base"<<endl<<endl;
      cin>>r;
```

```
    float t1=sqrt(r*r+h*h);
    float s=r/t1;
    float c=h/t1;
  }
  if (z==2)
  { cout<<"              enter the height of pyramid"<<endl<<endl;
    cin>>h;
    cout<<endl<<endl<<"              enter the edge length of base"<<endl<<endl;
    cin>>r;
    float t2=sqrt(r*r+4*(h*h));
    float s=r/t2;
    float c=(2*h)/t2;
  }
    cout<<endl<<endl<<"              enter the altitude of place"<<endl<<endl;
    cin>>alt;
    float IDn= Io * exp(-1 * a/ sin(alt));
    cout<<endl<<endl<<"  IDn is "<<IDn<<endl<<endl;
    float IDh= IDn * sin(alt);
    cout<<endl<<endl<<"  IDh is "<<IDh<<endl<<endl;
    float IDv= IDn * cos(alt);
    cout<<endl<<endl<<"  IDv is "<<IDv<<endl<<endl;
    float IDs=(IDh*s)+(IDv*c);
    float q=0.12;
    float Idh1= q*IDn;
    float Idv1= Idh1/2;
    float Ids1= Idh1*((1+s)/2);
    float ITh= IDh+Idh1;
    //float Ir= re*0.5*Th;
    float ITv= IDv+Idv1+Ir;

}getch();
    }
```