One Day Workshop On

DESIGN OF GREEN BUILDINGS

Organized by
Dnyandeep Education and Research Foundation

On 14th May 2006, at Hotel Pavilion, Kolhapur

This session on

GREEN BUILDING DESIGN STRATEGIES

By

Prof S. L. Kolhatkar
FIIA (India), FBSE (Bahrain), FABE (UK)
Urja Mitra
Solar Passive Design Consultancy
34, Yojana nagar, Chakan Road, Talegaon Dabhade – 410 507
Mobile – 9822409787, 9850883345

What is Green Building Design?
An integrated design & construction process that significantly reduces or eliminates negative impact of buildings on environment & occupants

It has many aspects such as
Sustainability,
Eco-sensitivity,
Energy-efficiency,
Climate-responsiveness,
User-friendliness &
Cost-effectiveness

It focuses on six major elements:

1. Sustainable site planning
2. Optimized energy performance
3. Energy efficient materials & techniques
4. Water & waste water management
5. Indoor environmental quality
6. Passive design

In this session we will focus on
Energy efficiency,
Energy conservation and
Passive design strategies,
Because
Energy is costly and is in short supply. Increased energy generation depletes finite natural resources and degrades environment.
Energy efficiency and energy conservation regime, therefore, become not only imperative but also an obligation dictated by the basic human instinct of self preservation. They should be the prime goals for professionals, whose main aim is to improve the quality of life.

This can be done only by using scientific methods to enable us to make quantitative assessment of the qualitative performance of materials, systems and resources. We should be able not only to identify the problem but also to quantify it, so that appropriate strategies could be formulated to provide an adequate response.

Energy flows into, within and out of the building according to the laws of Thermodynamics. Energy flow is also a function of the form of the envelope and its orientation. An important element of energy flow is Time.

> **The second law of Thermodynamics, which is the science of the possible and the impossible, a discipline that sets severe limits states that, the disorder or "Entropy" of any isolated system always spontaneously increases**

In practical terms this means that, although we can create technological order in local parts of the environment, a concomitant greater quantity of disorder will be created inevitably, not only at site, but in external region from which ordering elements such as energy & materials are drawn. **This is a game that cannot be won.**

For example, IC engines are generally considered to be highly efficient, but the fact remains that the efficiency level of a typical engine is only about 26%. Of the total energy input (100% in terms of fuel burnt) 34% is lost through exhaust, 30% to the cooling medium (coolant) and remaining 36% is converted to useful work, defined as indicated power. Of this another 10% is lost due to engine friction resulting in the final Brake Horse Power of 26% at the output shaft.

Architecture in its widest sense consumes energy, modifies environment & manipulates ecology. Energy Conservation and Efficiency should, therefore, be prime goals of architectural design.

Unlike industrial design, which is a linear process, architectural design is a reiterative, often both simultaneous and cyclic process of analysis, design, evaluation, redesign and re-evaluation for a finer product.

The process can be described as follows

Analysis Techniques:
To understand the problem & its context this would characterize the important variables and establish their relative importance

Design Strategies
To formulate design strategies which are form generating and which also concentrate on revealing the relationships between architectural form, space and energy.

Evaluation Procedures
These differ from analysis techniques in the sense that they are used to evaluate the performance of the design.

Analysis Techniques
1. Analysis of the Precedent.
2. Analysis of Site / Climate.
3. Analysis of Building Programme & Use.
4. Analysis of Building Form & Envelope.
5. Combining Site / Climate, Programme and Form.

Design Strategies.
1. Building Groups.
2. Buildings.
3. Building Components.

Evaluation Procedures
1. Systems Integration.
2. Thermal Design Evaluation.

Let us now review a live case study wherein passive design strategies, meaning non-electrical, non-mechanical means, were used to achieve comfort conditions.

Case Study:
Project- Gymkhana Expansion Programme
Site- Khar Gymkhana ground between Road Nos 15 & 16 at Khar (West), Mumbai
Client- Khar Gymkhana Construction Committee

Architect- Mr. Sanjay Puri, Mumbai
Solar Passive Consultant- Prof. S. L. Kolhatkar, Pune

Problem- To provide Passive Ventilation System for basement car parking which is sunk 600 mm below ground level

Solution- Considering the capital cost & the running & maintenance costs of employing a mechanical ventilation system, as well as Energy Conservation Issues involved, Solar Passive Ventilation System, using Non-Conventional Energy Sources such as the Sun & the Wind was proposed.

An initial proposal was made to use Cross and Stack Ventilation for removal of heat, dust, petrol fumes and smoke. Subsequently, wind turbines were also added to accelerate the ventilation rate so that sizing of passive features like fresh air inlets and stack can be minimal, as well as economical.

The following is the Detailed Project Report on the proposed ventilation system which provides an adequate response to the problem. The scientific method, which is followed here, can be described as a logical approach based on quantitative assessment leading to qualitative design decisions. The fundamental issue of using Natural energy as an embodiment of Sun, and Wind, is the basic paradigm of Passive Design Process.

Designing is not a linear process, like industrial one. Parameters are interrelated and interactive. They often need to be considered simultaneously and in a cyclical manner. It is a reiterative process of analysis, design, evaluation and redesign and if required, re-evaluation for final refinement.

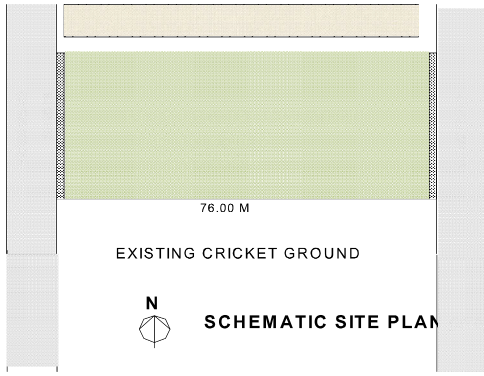
The procedure followed here, is described below:

1. **Analysis of Site and Climate**
2. **Analysis Building Programme and Use**
3. **Analysis of Building's Form and Envelope**
4. **Schematic Design**
5. **Design Development**
6. **Simple Pay-back Period**

1. Analysis of Site and Climate

1.1 The Site:

Location of proposed basement is bound by 15th road on East & 16th road on West, an existing cricket ground on South & existing Gymkhana building on North, which is 3.6m away from proposed basement. Basement is set back from road boundaries by about 1.5m on East & West.



1.2 Geometry:

(a) Floor area: 2,580 M^2
(b) Height: 4.12 M
(c) Volume: 10,629.60 M^3
(d) Air volume & quality: 4120 L / M^2 of floor area. Being car parking area, air sample there, may contain pollutants from car exhausts including CO2 & CO, latter being lethal.

1. 3 Climate:
Climate of Mumbai is characterized by an oppressive summer, dampness in atmosphere nearly throughout the year, & heavy southwest monsoon rainfall. Cold season from Dec to Feb is followed by summer season from Mar to June. Period from June to almost end of Sept constitutes southwest monsoon season. Oct & Nov form post monsoon season.

1. Annul Rainfall **– 1917.3 mm**
2. Highest in one day **– 548.1 mm**
3. Summer Mean monthly maximum temperature (May) – **33.3^{0}C**
4. Summer Mean monthly minimum temperature (May) – **26.9^{0}C**
5. Summer Wind Speed (May) - **2.99 M/S**
6. Predominant wind direction (May) - **NW / W**
7. R. Humidity – June to Sept – **75%**
8. R. Humidity – Nov to Mar – **50 to 65 %**
9. Cloudiness – June to Sept – **Heavily clouded to overcast**
10. Cloudiness – Dec to Mar– **Clear to lightly clouded**
11. Special weather phenomenon – Widespread heavy rain & gusty winds due to Western disturbances, thunderstorms occur mostly during May & June & later in Sept & Oct **(Source - Climate of Maharashtra, IMD)**

2. Analysis of Building programme and Use

3. Analysis of Building's Form and Envelope

2.1 External Heat Gains: (Thro' opaque walls &direct gain)
These are negligible due to insulation provided by 600mm of soil cover on roof & external walls being sheltered by earth on all sides & complete absence of glazing.

2.2 Internal Heat Gains:
(Sun, Wind and Light, G. Z. Brown et al, John Wiley & Sons, New York, 2001)

There are three sources of Internal Heat Gains:

1. Occupancy
2. Electric Lighting and
3. Equipment

(a) Occupancy:
(i) Rate of occupancy- (per 100 M^2 of floor area)

67 cars x 3-4 persons/car = 201-268 nos.
Rate of occupancy = 235 / 25.8
= 9.1 /100 M^2
Say = 10 / 100 M^2

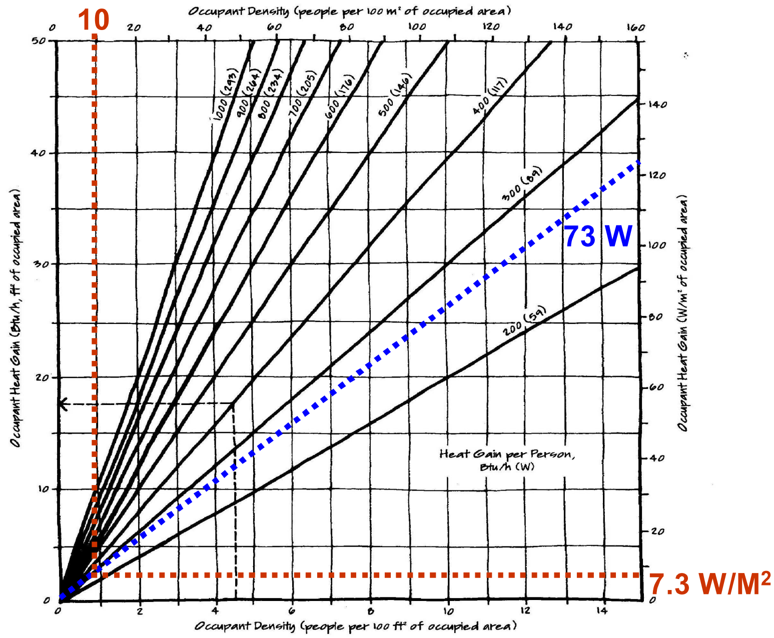
(ii) Metabolic rate of heat generation for particular activity (slow walk) is 73 W / M^2 sensible heat / person. Since rate of occupancy is 10/100 m^2 or 1/10m^2 heat gain will be 7.3 W / M^2.
As people do not occupy space for a longer time, the value of 7.3 W can be safely reduced to 10% of this quantity, that is ----- 0.73 W / M^2 of floor area.

The total heat gain (sensible) from people can be found in Watts by multiplying occupancy of building by the rate of heat gain per person. **(Ashrae, 1972, p. 416)**

TABLE: Rate of heat gains by activity level (Per person)

Degree of Activity	Sensible Heat Gain (Watts)	Latent Heat Gain(Watts)
1. Seated, at rest. Light work	66 to 72	31 to 45
2. Moderate office work, **slow walk**	**73**	59 to 73
3. Bench-work, dancing	80 to 87	139 to 160
4. Fast walk, moderate/heavy work	110	183
5. Heavy work.	170	255

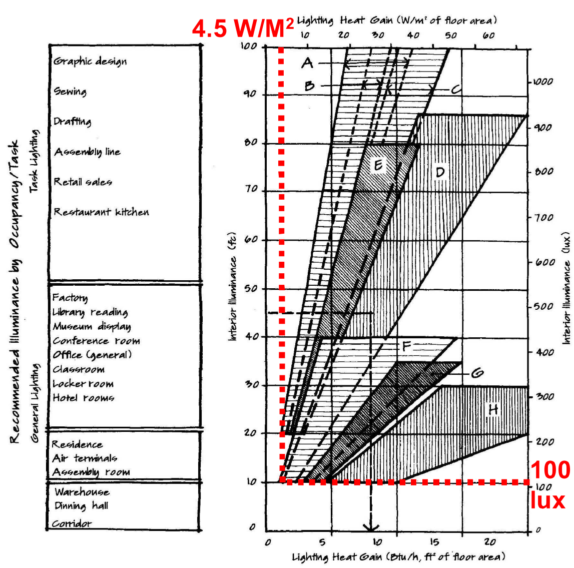
6. Athletics, gymnasium	208	319



Estimating Heat Gain From Occupants

(b) Electric Lighting:

Illumination level required for activity of parking (simple orientation & short stay) is a maximum of 100 lux. Assuming direct, open, compact fluorescent fitting, heat gains by electrical lighting can be estimated as ---- 4.5 W / M^2 of floor area.



Rate of Heat Gain From Electric Lights

(c) Equipment:

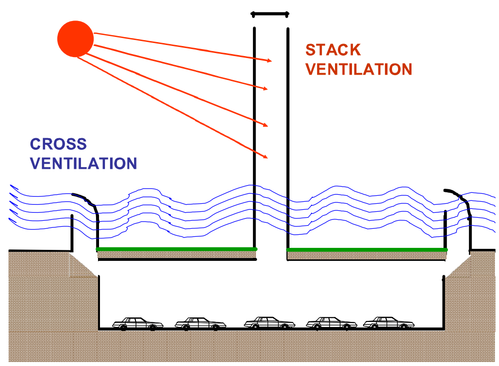
Heat gains due to stalling car and / or stopped engine can be approximated to be 60 W / M^2 of floor area

(d) Total Internal Heat Gain

(0.73 + 4.50 + 60.00)

= 65.23 W / M2 of floor area.

4. Schematic Design

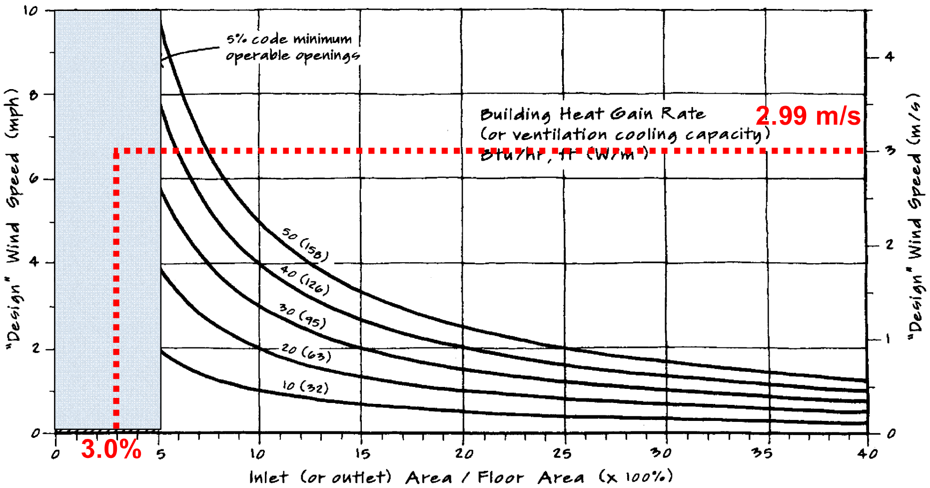


4.1 Cross Ventilation:

Rate at which air flows thro' a space, carrying away heat with it, is a function of area of inlets & outlets, wind speed & direction of wind relative to openings. Amount of heat removed by given rate of air flow depends on temperature difference between inside & outside.

Maximum rate of ventilation occurs when area of inlets & outlets is large & wind is relatively perpendicular to inlets. Most effective cross ventilation occurs when inlets are placed in higher pressure area & outlets in low pressure area. Rate of air flow depends on pressure difference between inlet & outlet.

To attain a ventilation cooling capacity of 65.23 W /M^2 of floor area, or ventilation rate of 15 ltrs./sec./ M^2 of floor area, for a wind speed of 2.99 m/ s & assuming a temperature difference of 1.7^{0}C between inside & outside, area of inlet (as also outlet) works out as 3% of floor area; i.e. **(2580.00 X 3) / 100 = 77.40 M^2**

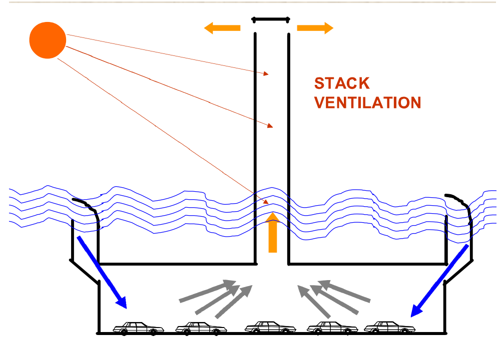


Sizing Openings for Cross-Ventilation

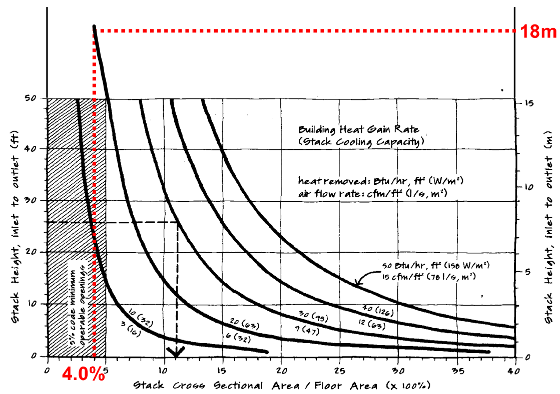
4.2 Stack Ventilation

This strategy has orientation independence, compared to strategy of cross ventilation. The strategy also does not require wind to move air through space. In a space cooled by stack ventilation warm air rises & exits thro' opening at the top of space & is replaced by cool air entering low in space.

Rate at which air moves thro' space, carrying away heat with it, is a function of vertical distance between inlets & outlets, their size & difference between outside temperature & average inside temperature over height of space. This gravity ventilation system deals with design of building's section.



In order to attain stack cooling capacity of 65.23 W/M^2 of floor area, assuming a stack height of 18 M & temperature difference of 1.7^{0}C between inside & outside, cross sectional area of stack works out to be 4% of floor area; i.e.
(2580.00 X 4) / 100 = 103.2 M^2



Sizing Stack-Ventilation

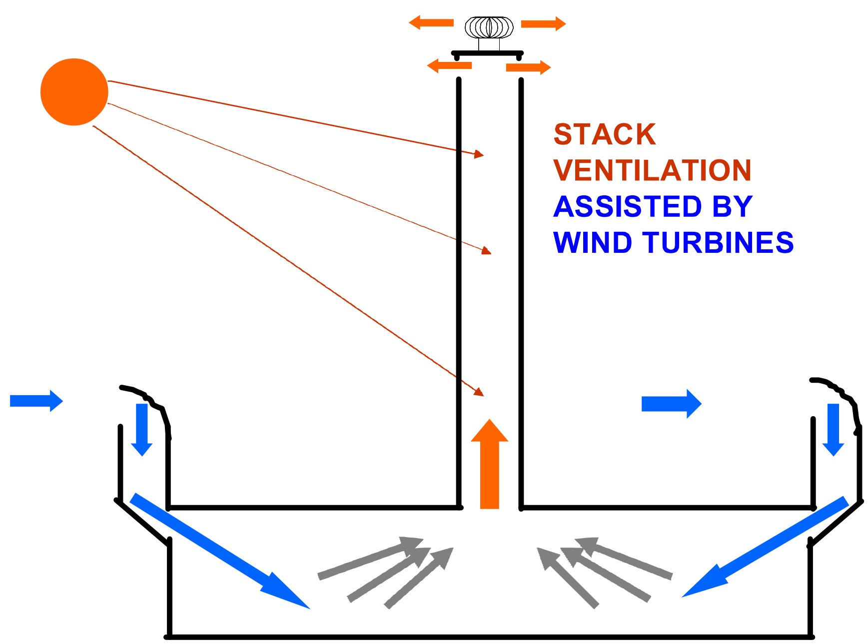
4.3 Combined Effect of Wind and Thermal Force:

Actual air flow results from combined effect of both wind pressure (cross ventilation) and thermal force (stack ventilation). Gradient obtained is algebraic sum of pressure difference generated by each force separately.

Resulting air flow, thro' openings, is proportional to square root of combined pressure difference. **(B. Givony – Man, Climate and Architecture)**

Therefore, resulting air flow can only be slightly higher (at most by 40%), than it would be with greater force. Usually, wind force creates greater pressure difference. Therefore, area of inlet & outlet can be reduced to 55.30 M^2.
(77.40 x 100 / 140 = 55.30)

4.4 Enhanced Air Flow Effect by Wind Turbines:
By using wind driven turbines for exhaust, over top of stack, air flow can be still enhanced. Rating of these turbines is a function of wind speed, & height at which they are mounted.



A 610 mm diameter, wind turbine, with Aluminium alloy blades, mounted at 18.0 heights, with a wind speed of 2.99 m/s, shall provide an air flow capacity of 50 M^3 / min. 4 nos. of such devices shall provide a capacity of 200 M^3 / min., approximately. This translates into 12,000 M^3 / Hr.

Since this would create substantial negative pressure inside shaft, it is estimated that efficiency of shaft shall be tripled & cross sectional area can be reduced to 33 % of above calculation.
55.30 x 33 / 100 = 18.43 M^2

A positive pressure already exists at inlets due to wind force from West side, which experiences further increments due to direction change & constriction at inlet neck.

Stack provides negative pressure at top, resulting in ventilation capacity for complete change of air volume of 10629. 60 M^3 in 0.886 hours, at the rate of 12000 M^3 / hour

At this juncture, we can consider final sizing of Passive features employed in schematic design stage. This is accomplished in next procedure of Design Development.

5. Design Development:

Design strategies used at building component scale play an important role in supporting systemic energy processes of building. Following components shall be considered for design detailing & sizing.

5.1 Fresh Air Inlets and Shafts:

Fresh air inlets, both on East & West Side, face predominant wind direction, which is NW / W. They have to be finished smooth on their inner faces & should be painted white to promote reflection of sun light & consequent reduction in radiation receipt.

Total inlet area provided with Aluminium louvers & bird netting is 47.66 M^2 & is constructed either in RCC or Ferro-Crete & takes support on 200 thk RC retaining walls, bellow.

Total fresh air inlet shaft area is 19.32M^2 & is sufficient. Inlets & shafts provide uniform distribution of fresh air from both East & West sides to whole of basement. No additional duct work is required.

5.2 Ventilation Shaft:

Towering above proposed elevators & just adjoining to it, ventilation shaft reaches to heights more than 18.00 meters, having fixed glazed openings on East, South & West sides, North wall being common both to shaft & elevators. This glazing allows Direct Gain from sun's radiation & promotes heating of air volume inside.
Shaft is constructed of 150/100 thk RC walls, with enlarged head at top to accommodate 4 nos. of wind turbines as well as bottom which is flared on South side to provide maximum area for hot air from basement to rise. Base has an area of 21.36 M^2

Ventilating shaft shall be finished smooth on inside & shall have a darker shade of paint on outside, preferably dark Gray. Since Southern area of basement is 30M away from this shaft, GI sheet ducting, including branching & outlet grills, may have to be provided up to ventilation shaft.

5.3 Fresh Air Inlet:

Supply of Fresh Air from Ramp down to basement, is not considered as it might get short-circuited due to its proximity to ventilating shaft.

5.4 Alterations:

Location of Lift Well needs to be shifted to Westside to align with ventilating shaft.

5.5 Energy Conserving Fixtures:

Replace standard fluorescent lamps (40W with ordinary choke) with 36W fluorescent lamp (with electronic choke) for basement lighting, as energy & cost saving measure.

6. Simple Pay-back Period: (for additional investment reqd.)

6.1 The Stack:

Cost of stack only shall be considered as fresh air inlets shall be a common feature in mechanical ventilation system, also.

R.C.C. work - 30 M^3 x Rs, 5000/- = 1, 50,000/-
Glazing (20% of surface) - 65 M^2 x Rs. 300/- = 19,500/-
Cement Paint-250 M^2 x Rs 90/- = 22,500/-
Wind Turbines - 4 Nos x Rs.7, 500 = 30,000/-
GI ducting -- Lump sum = 50,000/-
Net Investment = Rs. 2, 72,000/-

Connected Load
Exhaust Fans 4 Nos 2.6 kW each = 10.4 kW
Total operating hrs / Year (16Hrs x 300 Days) = 4800 Hrs
Total energy consumed (4800X10.4) = 49,920 kWh
Energy Cost saved (At Rs. 5/- per kWh) = Rs. 2, 49,600/-

Simple Pay-Back Period = Net Invest. / Energy Cost Saved
= 2, 72,000 / 2, 49,600
= 1.09 Years

6.2 Lighting:
No. of Fixtures - 110
No. of Lamps - 220
Connected Load - (50+15) x 220 / 1000 = 14.3 kW
Modified Load - (36+2) x 220 / 1000 = 8.kW
Saving in load - = 5.7 kW
Total Operating Hours (16x300 days) = 4,800 Hrs.
Energy Saving Potential (5.7 x 4800) = 27,360 kWh
Saving in Energy Cost (27,360 x 5) = Rs.1, 36,800/-
Investment required (40+400) x 220 = Rs. 96,800/-

Simple Pay-Back Period
= Net Invest. / Savings in E. Cost
= 96,800 / 1, 36,800
= 0.707 Years

End of Detailed Project Report