THE EFFECT OF CLIMATIC CONDITIONS ON DESIGN OF HOUSING FOR LOW AND MEDIUM INCOME GROUPS, BOMBAY, INDIA

By

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CHAPTER I

INTRODUCTION

Bombay, the capital city of Maharashtra State has been changing rapidly. Citizens notice many examples of deterioration: the monstrous blocks of apartments springing up all over the city, the overcrowded trains, the congested car traffic, and many others. The main crucial problem is population. Let us look at the total picture of the country. India today is a nation of 480 million people; approximately one fifth of this population (i.e. 90 million) lives in urban centers, the rest is scattered in over half-a-million villages. The next thirty five years will see a considerable change in this picture. At the turn of the century, the population is expected to double itself, and if planned industrialisation should fully materialize, approximately $70^{o}/_{o}$ of this population (i.e. 630 million) may seek to live in urban communities.

The problem of overcrowding is estimated to be six times higher than what the official statistics could disclose. Over-housing has resulted in packing together of houses with intolerable closeness whereby ventilation and sanitation have been overlooked to the detriment of health. Absence of incentive for private enterprise in building houses for the lower strata of society has aggravated the problem. The housing problem is a complex one requiring finances on a large scale and dependent for its solution on concerted efforts on the part of individuals, co-operatives, state and union governments to be planned and executed over a number of years. The shortage in urban areas has been largely due to considerable increase in population since 1921, the heavy shift of population from rural to urban areas, the haphazard growth of towns due to lack of sufficient state or municipal control over building activity, and the comparative inability of private enterprise to keep pace with the growing demand.

The responsibility of Government and public bodies to provide adequate accomodation for their employees was recognized even before Independence. The government of Bombay pioneered in this direction in 1921 by establishing a Development Department. In 1949 a special "Housing Board" was set up to build houses for Industrial workers and other lower income groups, developing land and assisting in the production and distribution of building materials. An Improvement Trust in Bombay undertook public housing schemes. Municipalities have also been engaged in building houses not only for their essential staff, but occasionally for low and medium income groups in general. Each apartment complex also has such supplementary buildings as primary schools, kindergartens and markets.

Building projects like these in Bombay, as it has been observed, have to be designed according to the requirements of the climatic and environmental conditions of hot humid areas, taken together with the sociologic, economic and technologic factors to make a significant environment. In the design of housing in the tropics, the principal object is to provide free air movement through the building and to provide effective insulation from the heat outside. The results of this study may influence the design of openings in the walls and the thickness of the exterior walls. The housing in Bombay and its design with particular reference to these considerations is therefore of hot humid interest.

CHAPTER II

CLIMATIC AND SOCIOLOGICAL CONDITIONS

2.1 Location

Bombay, the capital city of Maharashtra State and one of the largest Industrial cities of Asia is located on an island intersected by latitude 18°-55' North and longitude 72°-54' East, with elevation of about 35' above mean sea level. The location of the city has an obvious control over the thermal conditions and points to a probable type of climate prevailing in the area. The heat of the tropics and summer are certainly not congenial to physical efficiency, though winter is quite pleasant.

The situation of Bombay, in some respects, can be compared with the coastal cities of Appalachian regions of the U.S., especially with the New York coastal region: deep sea, unchanged rich hinterland, a mountain wall on the back and easy availability of water and power are some of the idential features in the two cases. A very unique advantage that Bombay has over many Indian cities is the cheap water power. The heavy rainfall of the Western Ghats (mountains) is rushed over the steep slope and is harnessed for power and other use.

2.2 Climate

Bombay has, generally speaking, a warm moist climate. The year in Bombay may be divided into four seasons:

The cool season from December to February. The lowest temperature and longest duration of fog that has ever been registered are 10° C (50°F) and 5 hours, respetively.

The hot weather season from March to May. The highest temperature that has ever been registered is 42.2° C (107.96° F).

The southwest monsoon period from June to September. 94°/₀ of the city's annual rain fall is recorded during this period.

The postmonsoon season from October to November. The average rainfall during this period is about 1.3".

Temperature

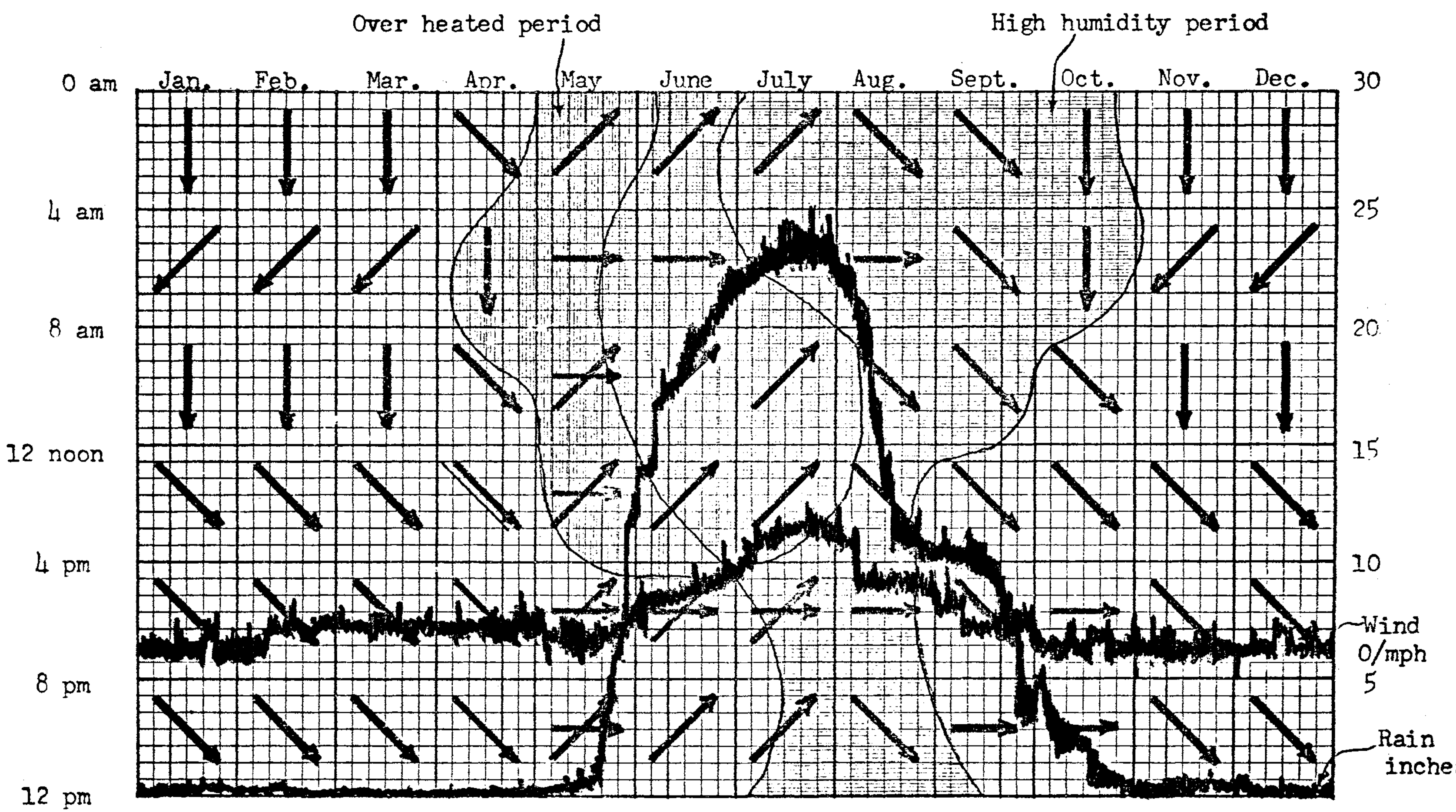
Because Bombay is located near the Tropic of Cancer the temperature generally is high, especially in the afternoon. The city experiences the maximum amount of temperature when the sun is shining vertically over the cancer during the month of June. Since Bombay is located slightly south of the Tropic of Cancer, however, the sun is vertically over Bombay in the last week of May and the first week of June. In May the mean daily maximum and minimum temperatures are 33.11°C (91.6°F) and 26.44°C (79.6°F) respectively. The temperature in June is less than May.

On the other extreme, January is the coldest month of the year. Notwithstanding the latitude, Bombay retains a fairly good temperature even in January and the conditions are quite energizing for human activity. The maximum and minimum mean temperatures in January are 28.44°C (83.2°F) and 19.27°C (66.7°F) respectively. A high range cannot be expected at Bombay, because of its coastal position. The month with the maximum range of temperature is December.

NORMAL CLIMATOLIGICAL DATA FOR BOMBAY

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Temperature (c)												
(f)												
Daily Max. (c)	28.4	28.4	30.1	31.7	32.8	31.4	29.7	29.4	29.7	31.6	31.9	30.3
(f)	83.1	83.1	86.18	89.06	81.04	88.52	85.46	84.92	85.46	88.88	89.42	86.54
Daily Min. (c)	19.3	19.7	22.2	24.5	26.4	25.9	24.8	24.5	24.3	24.2	22.5	20.4
(f)	66.74	67.46	71.96	76.1	79.52	78.62	76.64	76.1	75.74	75.56	72.5	68.72
Highest recorded (c)	35.0	38.3	39.4	40.6	36.2	37.2	35.6	32.2	35.0	36.7	36.1	35.1
(f)	95.0	100.9	102.9	105.0	96.16	98.9	96.08	89.9	95.0	96.0	96.0	95.1
Date and year	26,52	28,49	8,58	19,55	1,59	10,01	11,02	28,48	26,29	29,57	21,57	3,59
Lowest recorded (c)	11.7	11.7	16.7	20.0	22.8	21.7	22.2	22.2	20.0	20.6	17.8	12.8
(f)	53.0	53.0	62.0	68.0	73.0	71.0	71.9	71.9	68.0	69.0	66.0	55.0
Date and year	15,35	1,29	2,05	1,05	25,51	28,36	7,45	19,58	29,47	29,54	20,81	21,29
Rel. Humidity a 8.30o/o	70	71	73	65	74	79	83	83	85	81	73	70
" " a 17.30o/o	63	63	62	67	69	80	86	83	81	73	65	61
Rain fall (inches)												
Mean monthly total	0.14	.08	.05	.03	.65	19.06	24.27	13.39	10.39	2.54	0.53	.08
Mean no. of rainy days	0.2	0.1	0.1	0	0.8	14.6	22.1	19.0	12.7	3.1	0.8	0.2
Total in wettest month	2.98	1.68	1.46	2.51	11.08	43.44	59.03	47.81	49.0	2.0	0.64	0.11
and year	1926	1917	1918	1947	1918	1886	1907	1958	1949	1917	1946	1884
Total in driest month	0	0	0	0	0	4.66	4.3	3.35	1.61	0	0	0
and year	-	-	-	-	-	1939	1918	1882	1896	-	-	-
Heaviest fall in 24 hr	1.94	1.64	1.35	1.47	4.97	1.61	12.0	11.29	21.58	5.58	4.83	0.96
date and year	4,26	3,17	13,18	18,47	29,93	18,86	3,23	3,81	10,30	5,17	13,27	22,84
Wind (m.p.h.)												
Mean daily wind speed	6.57	7.0	7.19	7.06	6.69	9.36	11.5	9.85	7.00	6.07	6.26	6.5

METEOROLOGICAL CHART FOR BOMBAY



Rainfall

The average annual rainfall in Bombay is about 100" with 110 rainy days. The wettest month is July with a normal monthly fall of 24.27". Very heavy rainfalls sometimes exceeding 10" a day, are not uncommon during the monsoon period.

Humidity

Absolute humidity is mostly a matter of temperature in Bombay. The greater the temperature the more will be the absolute humidity, because the air mass on the island can soak up plenty of moisture from the sea. Relative humidity is not directly proportionate with temperature, because decrease in temperature with the same absolute humidity increases the relative humidity. Relative humidity is subject to modification due to impact of monsoon. In Bombay, since the warmest and the wettest months nearly coincide, the relative humidity follows the line of absolute humidity. The lowest recorded relative humidity in the whole year occurs in the month of December, when the humidity is 66%. In January and Fedruary also the relative humidity is fairly low, though the temperature in these months is lower than the average. During the hot season and southwest monsoon relative humidity goes up to 73% to 80%.

Wind

Sea breezes have a considerable effect on the wind direction. During the cool season, December to February, wind is generally from the north and northwest with a mean speed of 7 miles/hour. In hot weather, March to May, wind speed is 6.8 miles/hour with the direction of southwest. The mean wind speed during the monsoon season is about 9 to 10 miles/hour.

2.3 Soil Condition in Greater Bombay

Formerly Bombay was an island with several small islands attached to it. Eventually all these small islands were joined to the main island and filled with whatever material was available. The natural soil of these islands, which is red in color and rich in iron is still found in those hilly places of the city such as Malabar hill, Mazagaon hill and others; which are generally located on the former mainland structure. In the suburbs, the soil is black and is loamy to clayey in texture. They vary in depth, and contain lime kankar zone and free calcium carbonate.

2.4 History of Bombay

A former province (190,700 sq. miles), west central India, on the Arabian Sea, grew up into its present size and position from a group of fishing villages on seven islands then called "Heptanesis". It contained within its borders the former Portuguese colonies of Goa, Daman and Diu. Its remains exist from the period 320-184 B.C. In the 16th century, Portugal was the leading foreign power, but Great Britain predominated in the 17th century and by the early 19th century had formed the Bombay presidency. In 1937 Bombay was made a province.

The rapid rise and development of Bombay into a prosperous city with a flourishing population took place mainly during the last century. Since the opening of the Suez Canal in 1869, Bombay has become a very important international sea-port. In 1960, however, Bombay province was divided into the new states of Gujarat and Maharashtra. Today's Greater Bombay came into being after the merger of the suburban areas and certain villages of Thana District in 1950 and 1957 respectively. The total area of Greater Bombay is over 186 sq. miles and the Municipal limits extended from Colaba on the south to Dahisar and Mulund in the north.

2.5 System of Unit in India

It may be of help to the reader unfamiliar to India to give a brief resume of units in common use in the field of construction. In 1958 the Government introduced a metric system, although the British system has been in use by almost all private organizations. In some cases a mixture of the British and metric systems has been used. The unit of currency of India is the Rupee. After devaluation in 1966, the value of the Rupee became 1 U.S. dollar = 7.5 Rupees.

2.6 The Housing and Family Life in Bombay

The five essential elements conducive to family health are: air, running water, light, effective draniage and general sanitation. Without these essential pre-requisites no house can be considered healthy. Independent bathroom facilities have now come to be recognized as a necessary component of healthy family life. This leads not only to the development of a sense of privacy, but also to the observance of minimal standards of sanitation and cleanliness. To get this amenity of an independent bathroom many of the urban families have been required to convert the "mori" into a sort of closed bathroom. Wherever such an arrangement could not be made, the families have had to share the bathroom with other tenants. This way is always found to be source of dissatisfaction. It has been found that many urban families do not have independent lavatory facilities. The use of the inside "mori" as a urinal at night is the logical outcome of a filthy and inaccessible privy. Many urban households or families live in two-room tenements. There are, however, a large number of households or families, who have just one room within which to function. This obviously means that the entire range of family activities are carried out in the limited space that is available to them. Many of the low income families cannot afford the luxury of an independent living room, independent kitchen, independent bed room, ect... They are very much habituated to put a single room to multiple uses and purposes.

2.7 A Typical Low Income Office Worker's Life Study

The worker's tendency is to buy without paying sufficient thought to the payment of bills. The credit system, be it under a co-operative store or a private grocer's shop has no immediate money value: When the pay packet is received after deduction for provident fund, Employees State Insurance Scheme, Canteen coupons, co-operative stores purchases and co-operative society's loans, the balance on hand is negligible and the employee feels frustrated. If on the top of this his wife or child requires admission in a Government hospital, he has to deposit Rs. 15/ , Rs. 10/ for x-ray and for blood, sputum, faces and urine examinations. The fee ranges from Rs. 3/ to Rs. 5/.

Fixed pay for a month	145.00 Rs.
Dearness allowances	115.00 Rs.
Total	260.00

Deductions:

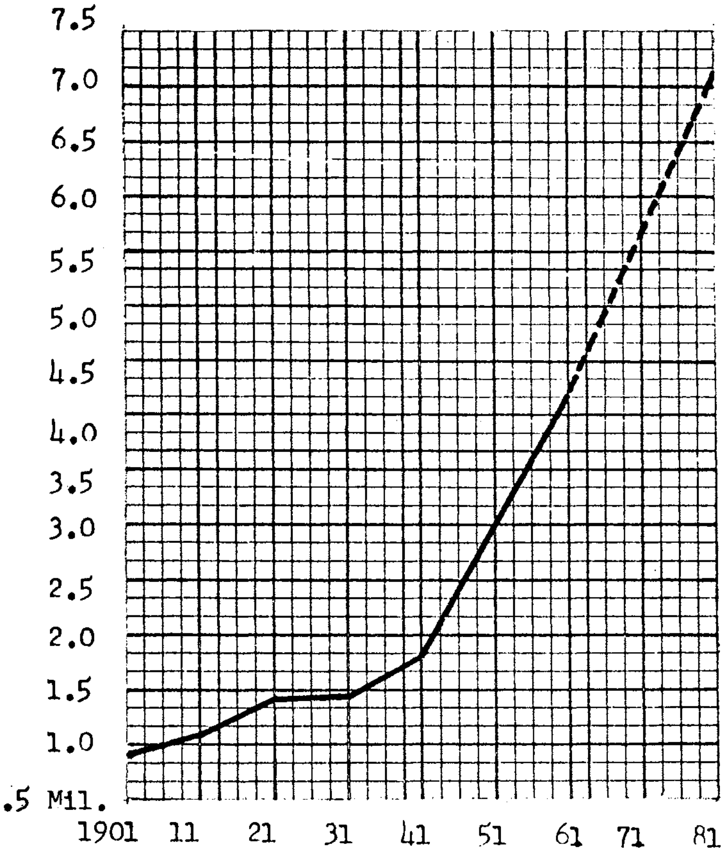
Contribution to P.F. & E.S.I.S.	16.50 Rs.
Tea and snack at canteen	9.60 Rs.
Transport charges	7.00 Rs.
Payment to the man who delivers food from house to office	4.00 Rs.
	37.10 Rs.

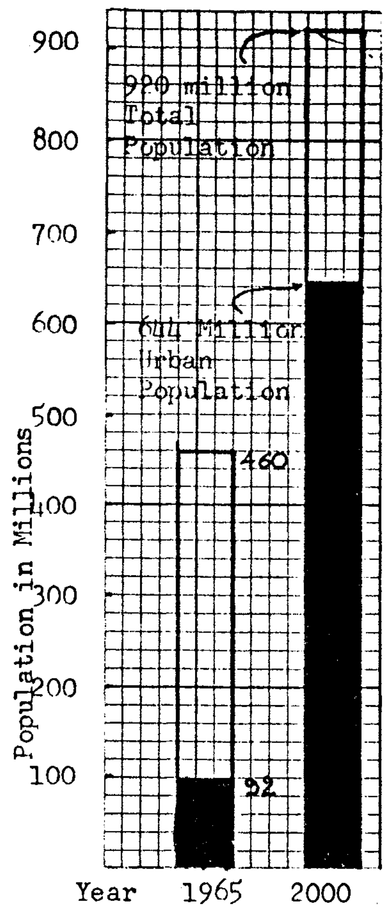
Total income	260.00 Rs.
Total expenditure	37.10 Rs.
Net balance . . . . (if he has taken no loans from society and has not brought from the stores)	222.90 Rs.

2.8. Average Monthly Family Expenditures for Food and Beverages

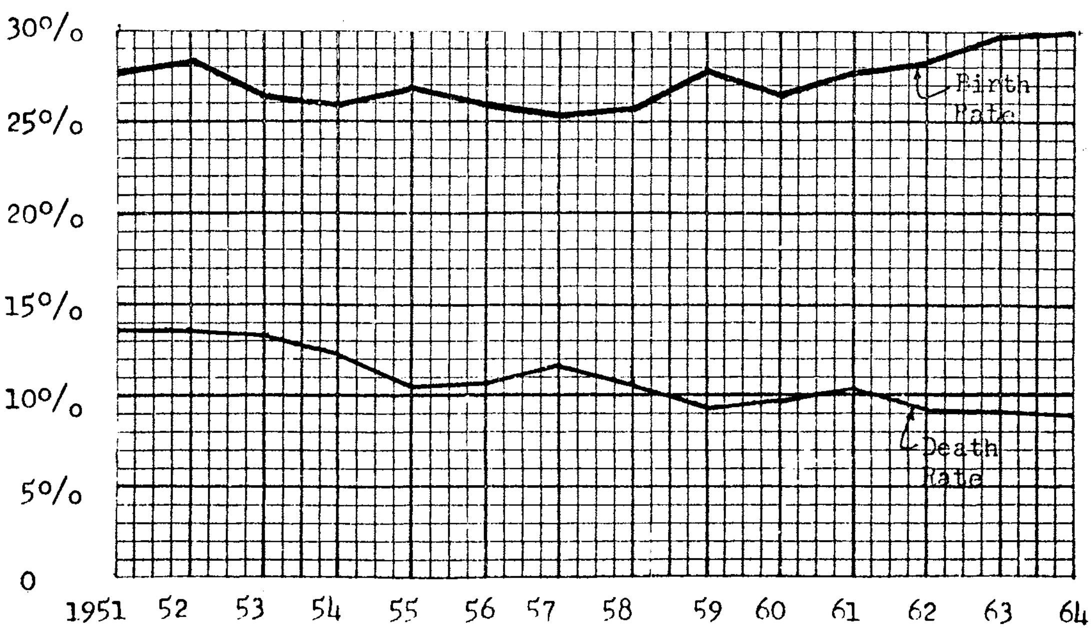
Items	% of total expenditure
Food, beverages, tobacco and intoxicats	39.8 %
Fuel and light	3.7 %
Housing, household requisites and services	18.9 %
Clothing, bedding, head-wear and foot-wear	12.0 %
Miscellaneous	35.6 %
Total	100.0 %

GREATER BOMBAY POPULATION



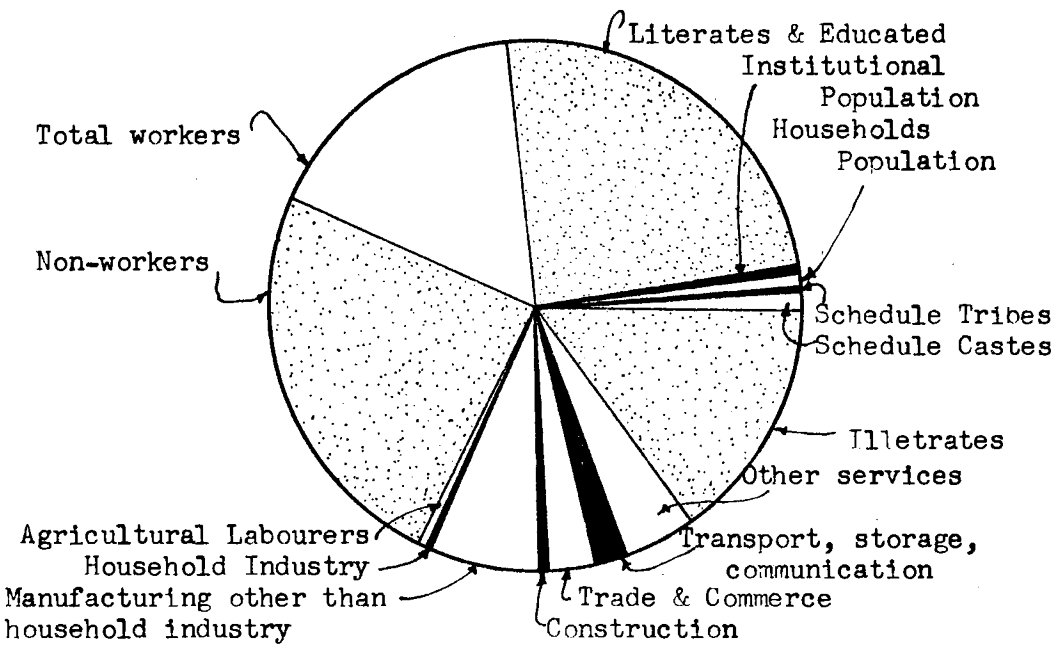


All India Population Growth

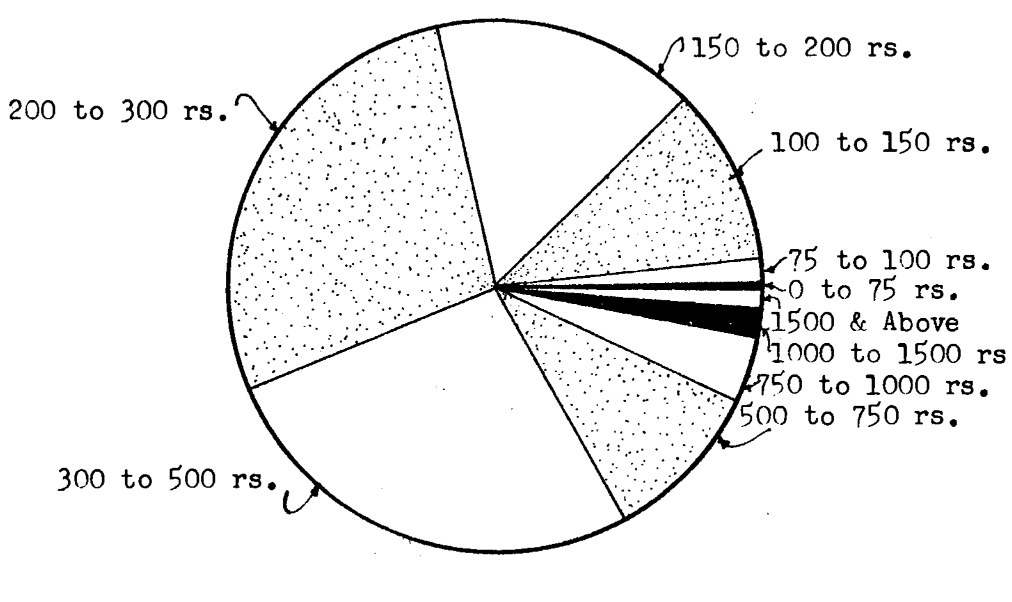


Growth of Greater Bombay

CLASSIFICATION OF POPULATION OF GREATER BOMBAY



DISTRIBUTION OF FAMILIES BY INCOME IN BOMBAY



CHAPTER III

EXISTING URBAN HOUSING IN BOMBAY

3.1 Residential Area

The importance of housing, particularly in an urban environment, can hardly be exaggerated. Housing is an elementary necessity of life, like food, and in congested cities, its value and importance is next to food. The housing shortage is by no means confined to the urban centers. Even rural India suffers from an acute shortage of houses, with the result that people live in dark, congested areas and over-crowded houses, denying themselves the advantages of the free gifts of natural light and air. The conditions in the cities and industrial towns can, therefore, be easily imagined. It not only affects the health and morals of the community, but in the course of time it exerts a cumulative effect upon the biological makeup of the population.

It is true that the housing problem in Bombay has assumed very alarming proportions, particularly in recent times. Sometimes, however, it is sought to be maintained that the housing in the city has generally kept pace with the growth of population and that the present acute housing problem is the outcome of the second world war. The housing panel of the Greater Bombay Scheme pointed out in 1946 that "housing has not made an appreciable progress in the city in the last ten or fifteen years commensurate with the needs of a growing and developing city, nor has it kept pace with the actual growth of the city's increasing population". The Executive Health Officer of the Bombay Municipal Corporation remarked: "To erect a large block of chawls of one pattern of rooms of 100 sq. feet and to allow them to be occupied irrespective of sex and age in addition to goats, fowls etc.... is not the way to diminish overcrowding or to solve the housing problem". He also suggested that "cheap" dwellings must be provided by all employers of labour where possible near the work of the labourer. Estimates of the requirements of housing in urban areas during the decade 1951-61 called for the construction of about 8.9 million houses to make up for the past deficit and obsolescence and to provide for the increase in urban population. The deficit at the end of 1961 has been estimated to be about 5 million in urban areas.

A middle income groups housing scheme introduced in February 1959, as a non-plan scheme financed through corporations or co-operative societies of persons whose income ranges between Rs. 6,001 to Rs. 15,000 per annum. The total loan assistance admissible under the scheme is 80 °/o of the cost subject to a maximum of Rs. 20,000 per house.

A low income group housing scheme introduced in November 1954, provides for the grant of long-term interest bearing loans to the state governments for the purpose of housing persons having an annual income not exceeding Rs. 6,000. The total loan assistance admissible under the scheme is 80°/o of the cost subject to a maximum of Rs. 8,000 per house. "Maharashtra Housing Board" works on no profit - no loss basis. The results are fixed in such a way that they cover just the bare expences of construction, management, repair and maintenance.

3.2 Utilities

Water Supply and Sewerage:

The existing sources of supply from 4 lakes are capable of giving an assured supply of 233 m.g.d. with three service reservoirs located in the city proper, and as no reservoirs in the suburbs. But the supply as proposed in the 1981 development scheme is corrected by four other sources of supply, which would give an additional supply of 576 m.g.d., and 10 more service reservoirs. The sewerage system covers the entire city, and for future population the new 1981 schemes have included the safe and efficient disposal of the waste water.

Town Gas:

Out of the 5.4 million cubic feet per day gas supplied in the city, 4.7 million cubic feet gas per day is distributed to over 18,000 customers as gaseous fuel. The remaining 0.7 is utilized for lighting about 8,100 street lamps. Because of the requirement of higher illumination for roads the gas street lamps are being gradually replaced by electric lights. As per new scheme the town gas is to be supplied to all persons by 1981.

Refuse Disposal:

In Bombay the roads, footpaths and house gullies are swept twice daily. These are also brushed, scraped and periodically washed to remove dirt, mud and dung from the surface.

3.3 Transportation

Bombay city has fairly wide and good concrete roads, but with the growth in population, a phenomenal growth in car ownership is anticipated with car population ratio being reduced from 104 persons per car to 54 persons per car.

The present bus system is the only effective transport system in the city, coupled with the suburban railway services which bring the bulk of traffic from the north to the south and vice-versa, during the peak periods; but the present system is far below the requirements. Buses provide excellent coverage for the entire Greater Bombay, handling the traffic of about 2 million passengers a day. To meet the requirements of 1981, the undertaking proposes to increase its strength.

Bombay, is the head-quarters of the Central and Western Railways. Local transport requirements are mainly met by local train services run by the Central and Western railways can no doubt carry 40,000 passangers per hour.

3.4 Education

Bombay is a very important center for the technical and professional education. It has a University and large number of colleges. Many of the existing Municipal schools do not come up to modern standards of planning so far as adequate facilities regarding light, ventilation and sanitary arrangements are concerned. Many of the school buildings lack playground facilities. From the 1961 census it is safer to assume 11°/o of the population as school-going children between the ages of 6 to 11.

3.5 Recreational Functions

There exists in the city quite a large number of gymnasiums, play grounds, swimming pools, stadiums, cinemas and dramatic theaters. In addition to these easily available avenues of recreation, there are sea-beaches, and picnic places in the neighbourhood, besides Cinema houses scattered all over the city. There are nearly 80 play grounds and more than 40 gardens managed by the Municipal Corporation for the recreation of the public, which provide easy rendezvous for the poor.

3.6 Industry

Greater Bombay has an area of 0.1% of the total area of the Maharashtra State and possesses about one-third of the total number of factories in the whole state. It is the principal center of the cotton textile industry.

CHAPTER IV

PRINCIPLES OF DESIGN IN THE TROPICAL CLIMATE

4.1 Design for Sun

The sun radiates energy to the earth's surface, but a considerable portion of the sun's energy reflects back into space before it even reaches the ground. However, about one-third of it hits the earth's surface and is promptly transformed to other types of energy. Evaporation, convection, heat conduction, radiative pseudo-conduction, reflection, and radiation occur. Psychologically the sun is very important in making life more pleasant but sometimes it can be very uncomfortable to our physical being. This presents a need in buildings designed for human occupancy to be so designed and constructed that they will provide the maximum physical comfort.

For proper design, the main criterion should be to allow a minimum area to be exposed to the solar radiation during summer as also a maximum area during winter season. For this purpose it is just sufficient to include the two extreme days of summer and winter solstices and the equinones i.e. June 22 and December 22 and March 21 or September 23.

4.2 The Angle of Shadow

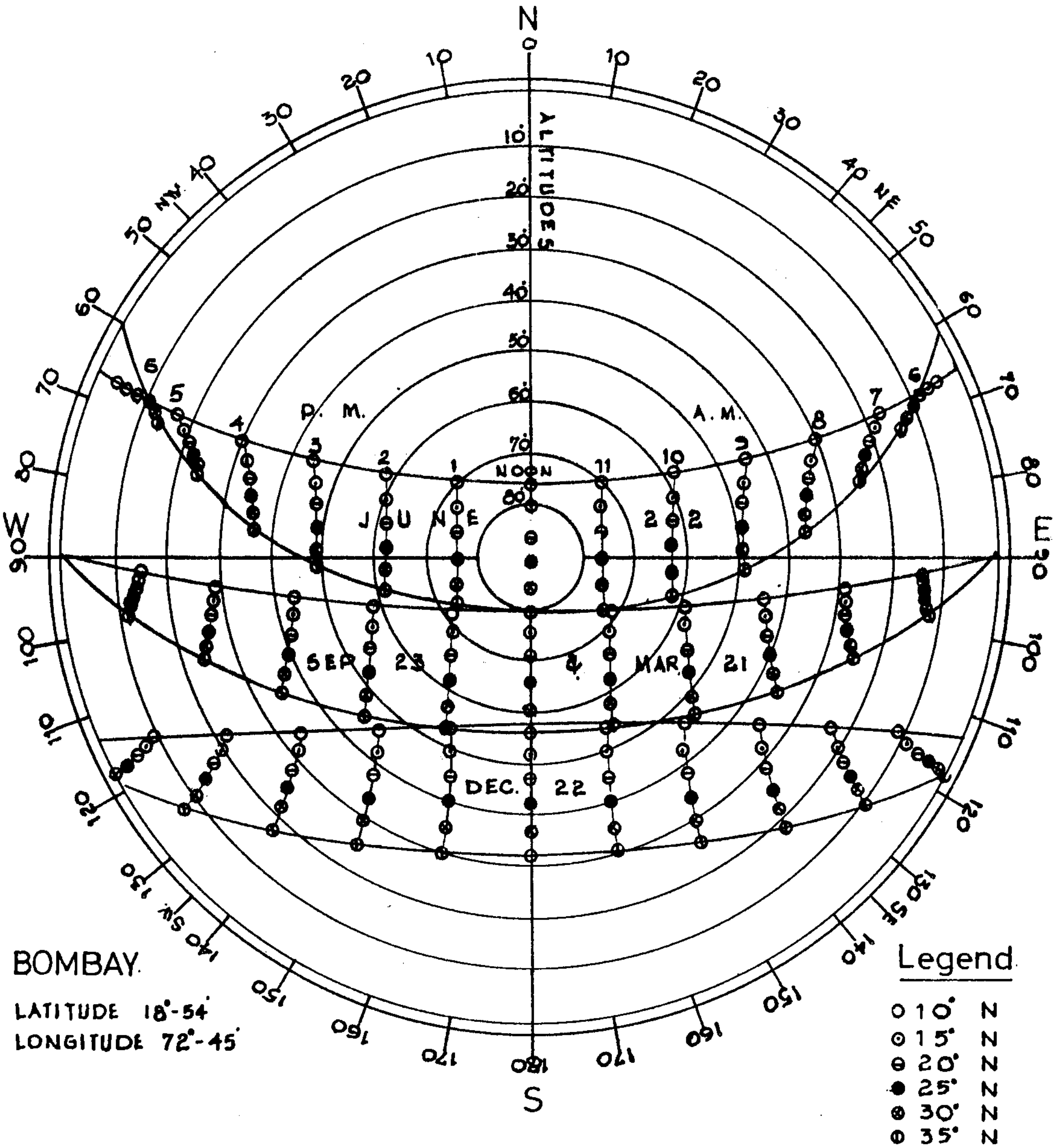
The solar chart is a device to represent the path of the sun on a plane diagram. The observer is assumed to be situated at the center of the diagram. The various directions are represented by the various points of compass around. The altitude of the sun is represented by concentric circles, beginning with zero at the outer periphery and rising to 90° at the center. Now the problem is to keep the sun out of the building and at the same time to provide full ventilation. It is necessary to set up the true shadow angles of the sun in relation to the orientation of the building. Thus the size and spacing of sun-break devices can be determined in detail. For this purpose there are several methods, but let us use a geometric setting up method for one of the medium income group buildings as shown on page no. 23.

4.3 Walls and Openings

A wall unexposed to sun remains at shade temperature, which is as low as one can get, so walls must be in varying degrees protected by projecting eaves, verandahs, sun-breakers for preventing the entry of heat into the interior. It is possible to conceive of a house built of lightweight construction and highly reflective outer surfaces that would be reasonably cool.

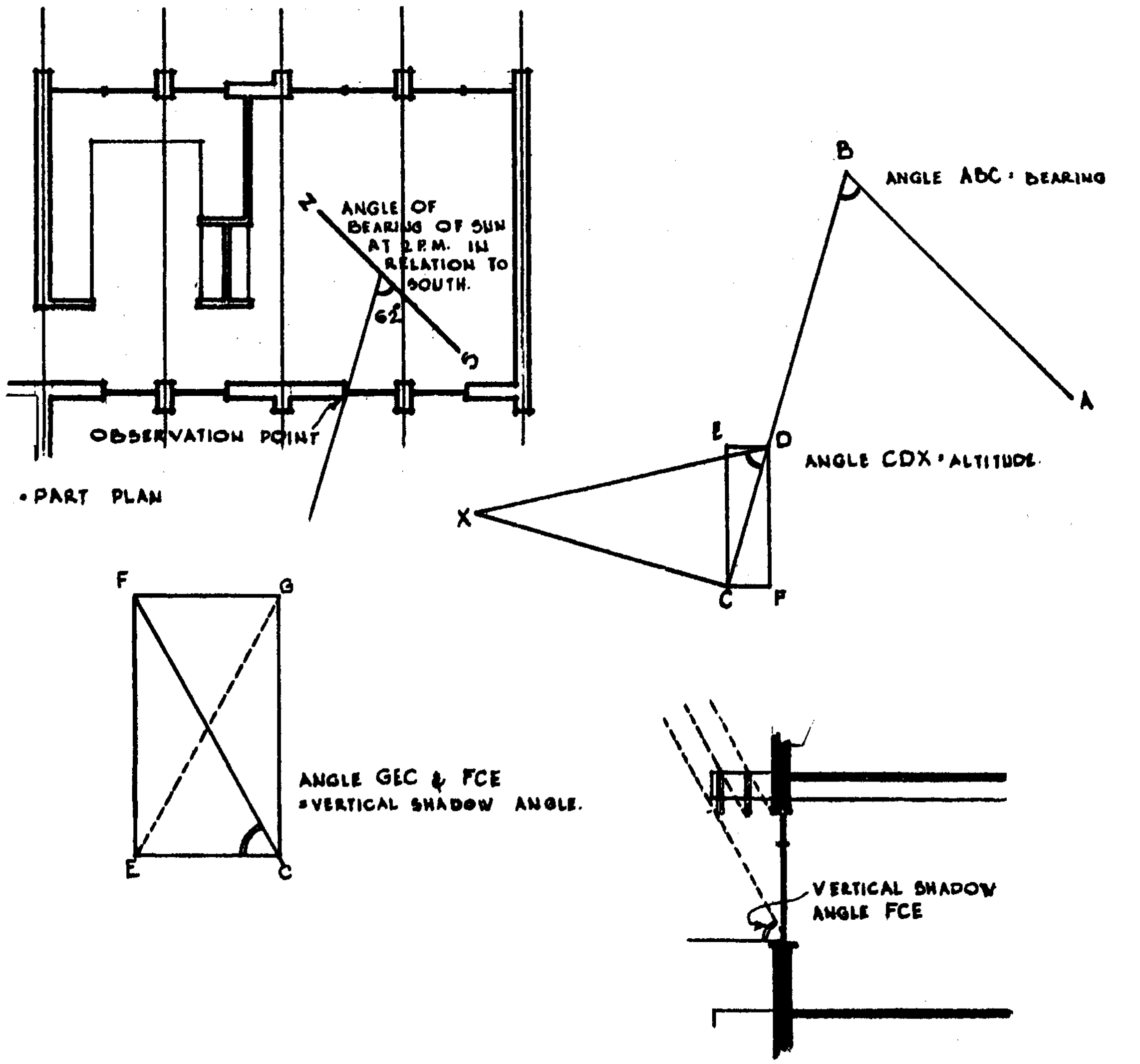
4.4 Roofs

The roof of a house has the greatest exposure to sun. Great heat is generated during the day, and the problem is one of reducing the penetration of heat to the interior, and dispensing any accumulation of day heat to prevent further radiation on sleeping quarters at night. The roof must therefore be protected by an upper embrane or layer of material serving to reflect or deflect the sun's rays.



COMPOSITE SOLAR CHART FOR LATS.

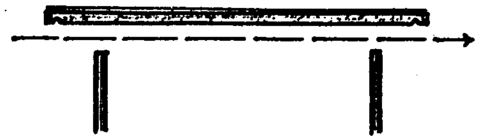
10°, 15°, 20°, 25°, 30° & 35°N



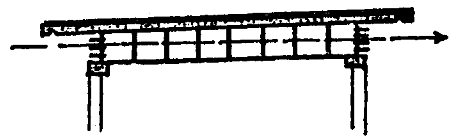
(1). SET UP THE SUN-PATH DIAGRAM ALONGSIDE THE PLAN OF THE BUILDING AS CORRECTLY ORIENTATED.

(2). CONNECT THE OBSERVATION POINT TO THE VITAL TIMES OF THE DAY, IN THIS CASE WE HAVE TAKEN 2 P.M. OF MARCH & SEPTEMBER, WHICH IS THE TIME OF ABOUT THE GREATEST PENETRATION ON PLAN.

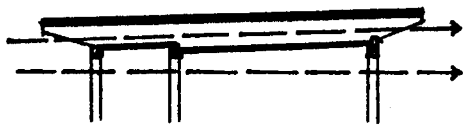
(3). FOR DETERMINING THE TRUE SHADOW ANGLE AT 2 P.M. ON SECTION, THE ANGLE SHOULD BE SET UP AS FOLLOWS: DRAW LINE AC AT THE BEARING ANGLE OF THE SUN RELATIVE TO SOUTH FOR 2 P.M. ON LINE BC CONSTRUCT RECTANGLE DEFC PARALLEL TO THE BUILDING AS ORIENTATED. DRAW DX SO THAT ANGLE CDX IS THE ALTITUDE OF THE SUN AT 2 P.M. DRAW LINE CX AT RIGHT ANGLE TO DC. CONSTRUCT SEPARATE RECTANGLE FGEC WITH BASE EQUAL TO EC AND HEIGHT EQUAL TO CX. FCE IS VERTICAL SHADOW ANGLE AND CAN NOW BE APPLIED TO A SECTION AS SHOWN. THIS METHOD CAN BE APPLIED TO WHATEVER TIMES OF DAY ARE CONCERNED.



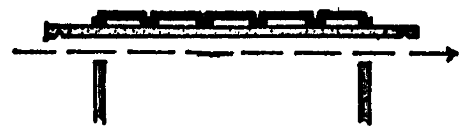
Minimum



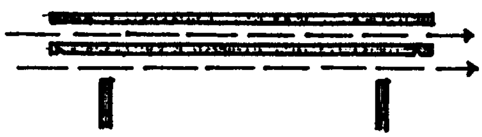
Double roof



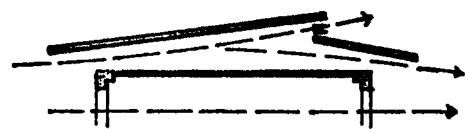
Double roof



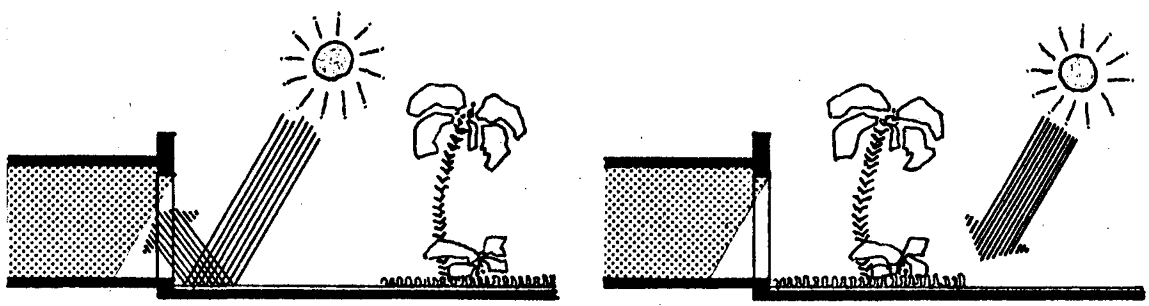
Slabbing



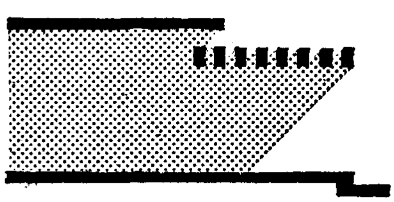
Double roof



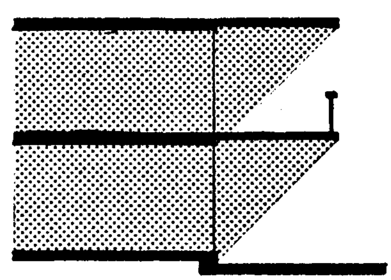
Double roof



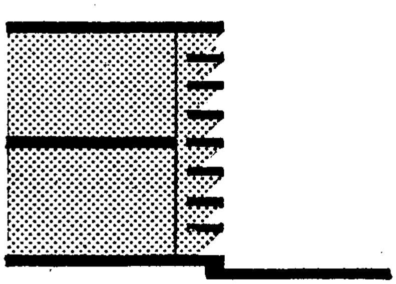
Effect of vegetation



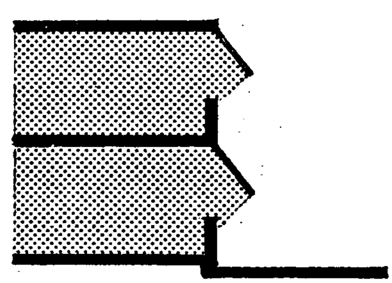
Pierced Canopy



Balconoy



Vertical Screen



External Blinds

4.5 Ground Treatments

Besides satisfying the instinctive need of protection, trees also perform many services to better man's immediate physical environment. Trees and shrubs, if densely planted, reduce air-borne sounds with great efficiency. The more grass and vegetation, the more shade, the less hot pavement or earth, the less light glaring surfaces the better. Vegetation can also secure visual privacy and reduce annoying glare effects. A very beneficial effect of trees, however, is their thermal performance. In summer the grass surfaces and leaves absorb the radiation and the evaporation process cools air temperatures. Above all they provide generous shade at exactly the appropriate seasons. This fact makes deciduous trees especially valuable when placed close to buildings. Trees, also, should be selected according to their attractiveness and usefulness for shading. Climatic and soil conditions, however, should be checked for the particular area under consideration.

4.6 Design for Rain

Rain is a cooling agent and provides moisture. In a heavy rain region like Bombay it is very necessary to have sloped roofs and to provide gutters and downspouts.

4.7 Design for Wind

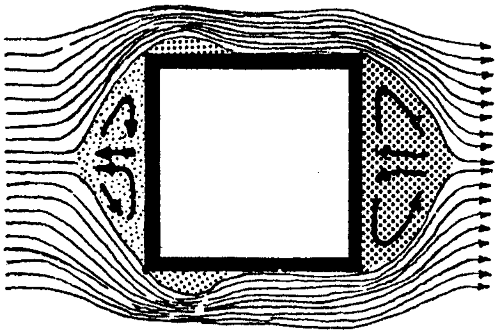
The three main variables affecting human comfort are, as we know, temperature, humidity and air movement. Controlling any one of these variables enables us to adjust human comfort to some extent. But in the absence of temperature and humidity control, as when depending entirely on natural means for summer cooling, the only controllable factor with which to work is air movement.

4.8 Characteristics of Air Flow

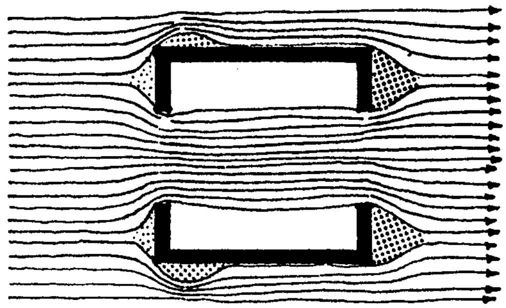
Air is caused to move by two natural phenomena, first by pressure differences, and second by temperature differences which really results in pressure difference. Air flows from high pressure to low pressure regions, and hot air rises.

4.9 Pressure Differences

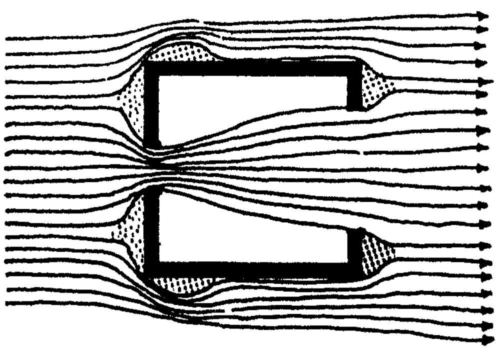
Simple, but of fundamental importance, is the consideration of where the pressure differences exist when the wind envelops a building. When the wind impinges against a building, a region of high pressure is created generally on the windward surface of the building. As the air is deflected around the building, it speeds up and causes relatively low pressure regions (wind shadows) to be created along the two sides just behind the windward face of the building and along the entire lee side. Naturally, the air tends to flow into the building at the high pressure regions and out of the building at the low pressure regions; therefore, all that is needed to allow the air to flow through the building is to locate openings in the high pressure walls to let it in and in low pressure walls to let it out. This, however, will not necessarily always produce the desired air pattern effective for summer cooling. In order to produce a cooling effect on the occupants of the building in hot humid weather, the air movement must be within the living zone of the building around the occupant's bodies; simply providing openings does not necessarily alow the air to flow within the living zone. It has been observed from the experiments in a



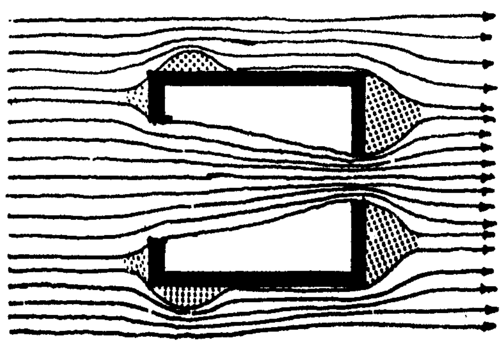
High Pressure and low pressure areas (wind shadow).pattern of air flow surrounding a building.



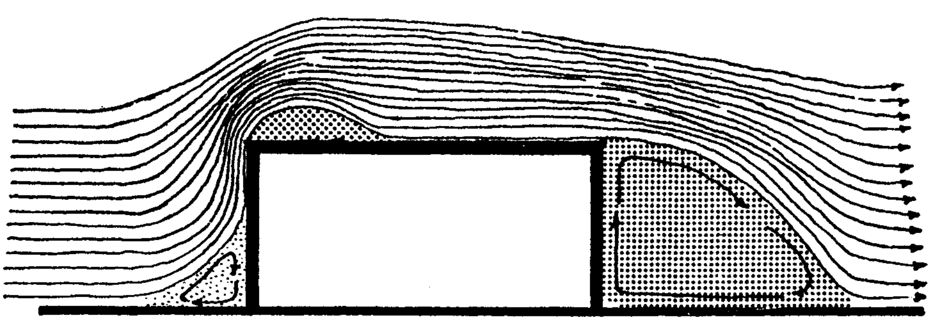
Maximum air changes with large openings of equal size, placed opposite of each other.



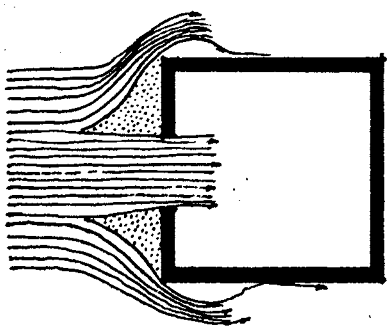
Highest speeds. High velocities after the inlet; therefore highest cooling effect is preserved.



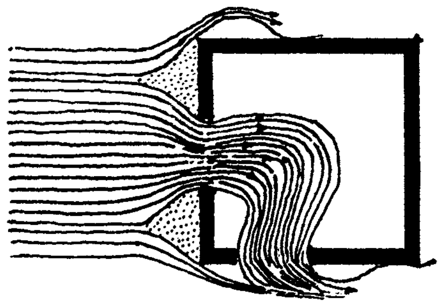
Minimum speeds. High velocities occur beyond the building; therefore its cooling effect is lost.



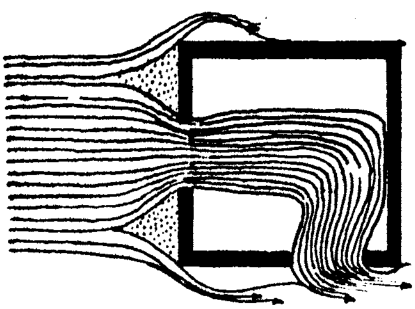
Pattern of air movement at the section of building.



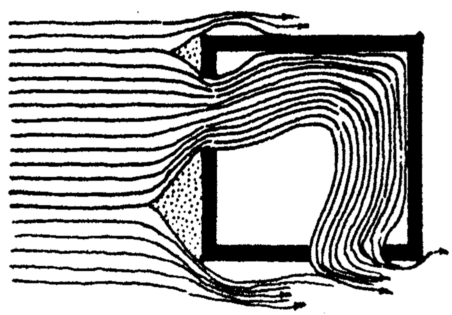
High Pressure and Inertia. No outlet, no air flow in building.



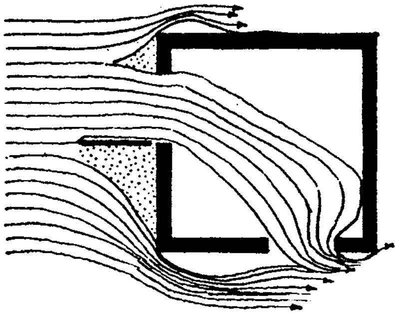
Pressure Differences.

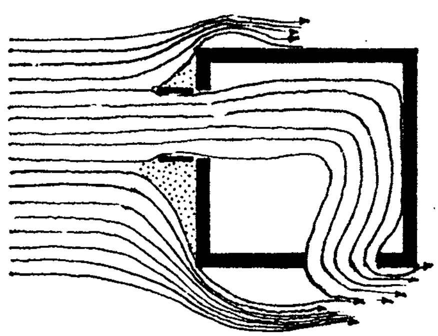


Outlet position changes the air flow.

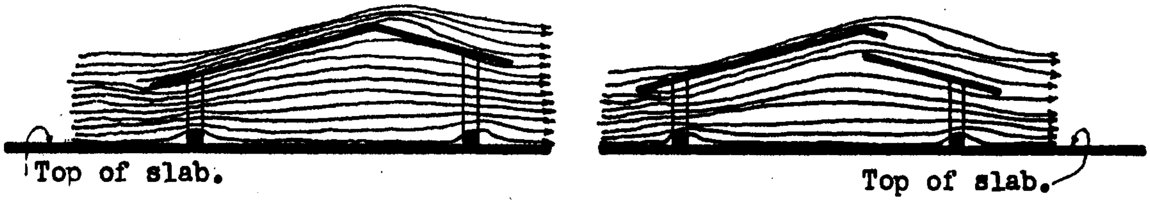


In case of an offset, asymmetrical indoor flow occurs. The side pressure outside the inlet directs flow at an angle.

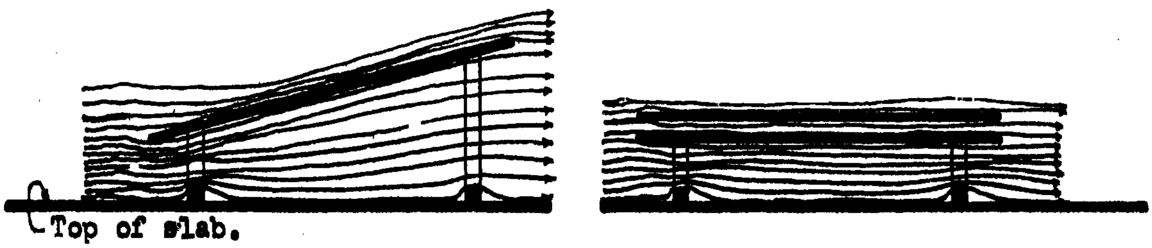




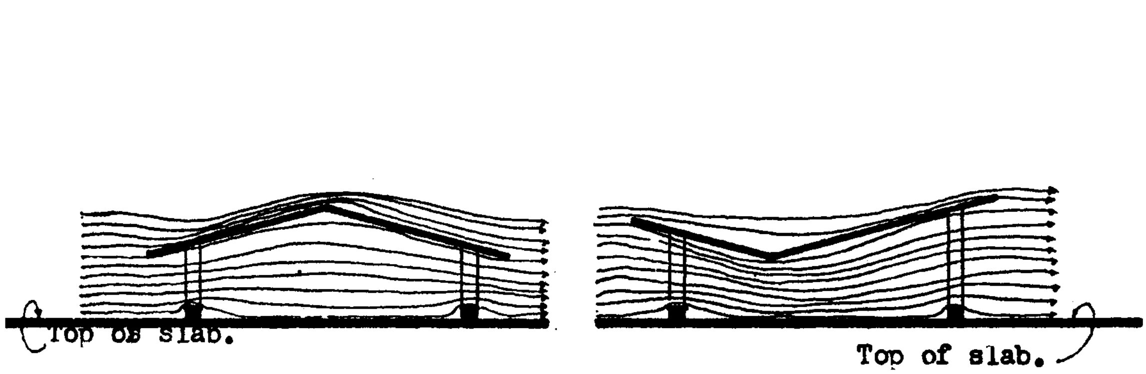
Open windows or louvres change the direction of air flow.



Double Roof - Air Flow Pattern

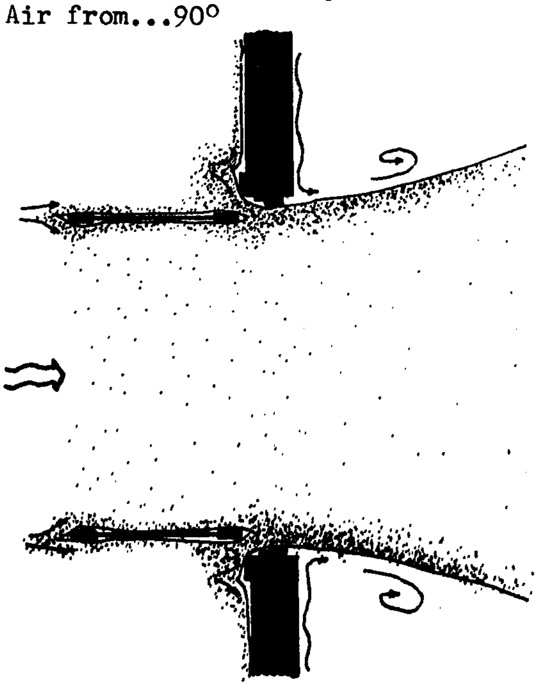


Double Roof - Air Flow Pattern



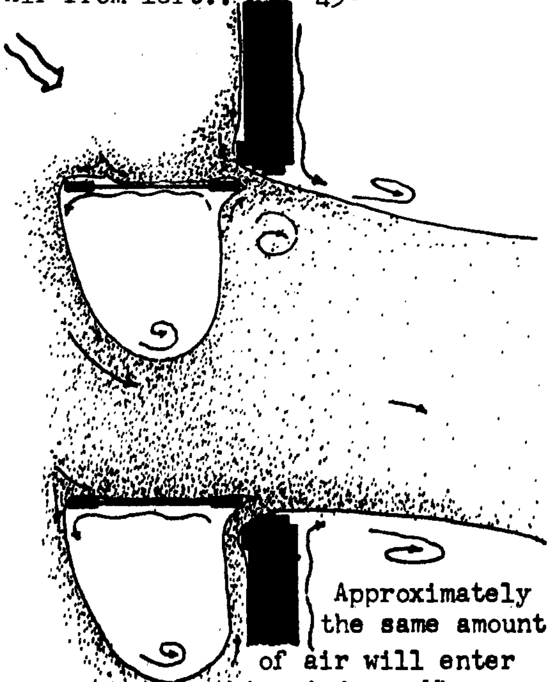
Double Roof - Air Flow Pattern

Right and left sash open..90°
Air from...90°



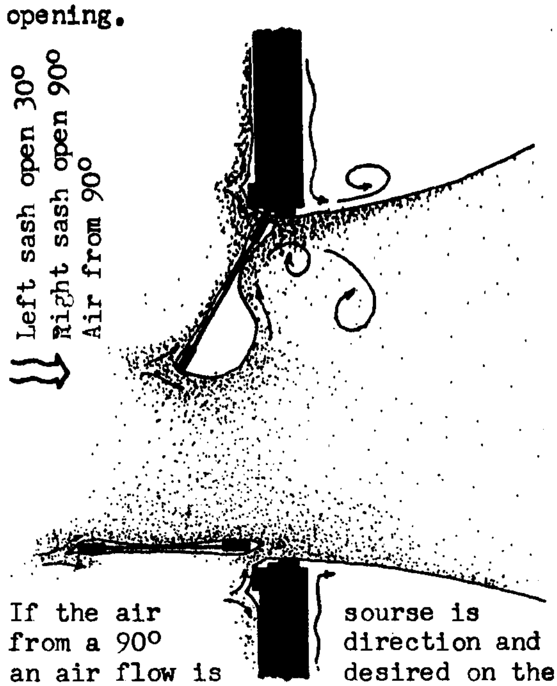
The maximum possible air flow through a window. The air flow through the entire area of the window, which represents a 100°/₀ opening.

Right and left sash open. .90°
Air from left... 45°



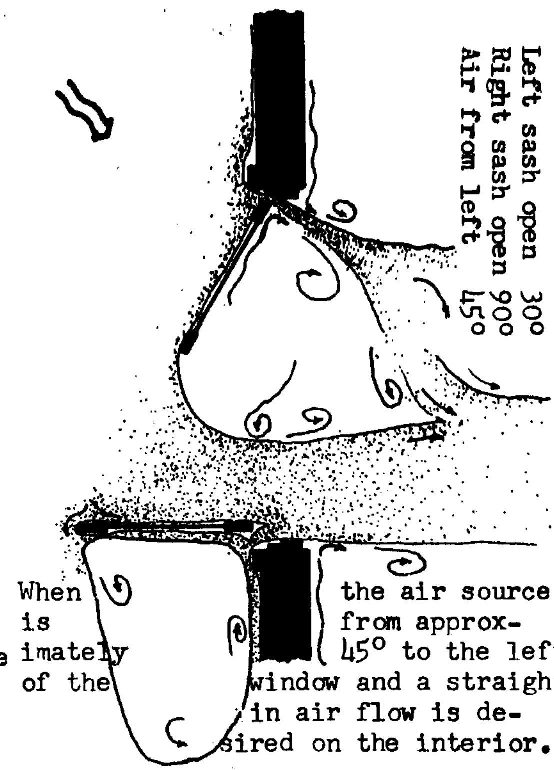
Approximately the same amount of air will enter this window. When the air source is from an angle. The air enters the opening from the sides of the window.

Left sash open 30°
Right sash open 90°
Air from 90°



If the air sourse is from a 90° direction and an air flow is desired on the interior at a full width of the window.

Left sash open 30°
Right sash open 90°
Air from left 45°



When the air source is from approximately 45° to the left of the window and a straight in air flow is desired on the interior.

wind tunnel: (1) The size and shape of the wind shadows do not vary with the wind speed but are determined by the geometry of the building.

(2) To get maximum air changes, openings on the inlets and outlets should be as large as possible, in other words, the greater the openings, the greater the air changes.

(3) To get maximum speed in the building the outlet openings should be larger than inlets, which is very necessary for hot humid region.

(4) The air flow pattern within a room is determined not only by the direction of the wind and the location of high pressure and low pressure areas, but also by the placement of inlet openings in respect to wall areas.

(5) To achive maximum air flow, abrupt directional changes should be kept to a munimum.

(6) Wind direction in the building depends upon the location of openings.

(7) The speed of air flow within the building will be directly proportional to the speed of the wind.

(8) Some windows control the direction of the air flow, and consequently determine the interior air flow pattern.

(9) To obtain the most effective benefits from the air flow through a simple opening, the window should be located at the level and directly in front of the zone where air flow is desired in the interior.

(10) The length of a room has very little effect on the inside air flow when the outside air flow is perpendicular to the wall, but if the outside air flow is diagonal to the room, there is a wind shadow set up within the room.

(11) Very large inlet openings and very small outlet openings will produce very slow air movement within a room.

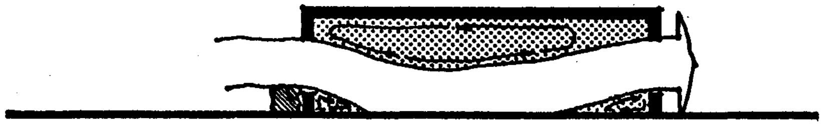
(12) The addition or subtraction of an overhang is capable of completely changing the manner in which the wind will flow through a simple opening.
(13) Whether or not air will flow through clearstory windows above large overhangs will depend on such factors as the slope of overhang, depth of overhang, and size of facia as well as the height of the window opening.
(14) Buildings should be placed in the free sweep of the wind.
(15) To get maximum air flow, the maximum wall area should be perpendicular to the wind.

4.10 Effect of Landscape Development on the Natural Ventilation of Buildings and Their Adjacent Areas

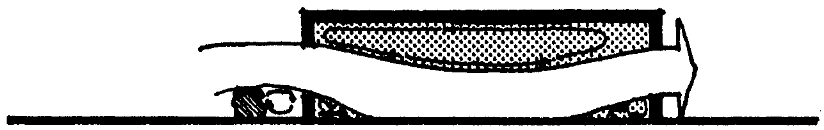
The average ground temperatures remain in the upper levels of air temperature, which is to say that a pavement left ungarded may be at 110°F (43.33°C) on a day when the air is 90°F (32.22°C) and for this reason the treatment of the ground and other surfaces about a house is of first-rate importance. The more grass and vegetation, the more shade; the less hot pavement or earth, the less light glaring surfaces.

This investigations stress the very definite significance between a structure and what happens beyond that structure in terms of landscape development.
(1) The foliage mass of a tree serves as a direct block to the passage of air.
(2) The speed of the air movement directly underneath the tree measurably increased with respect to speeds of the same height on the lee and windward sides of the tree.
(3) Planting can materially affect the movement of air through and about buildings.

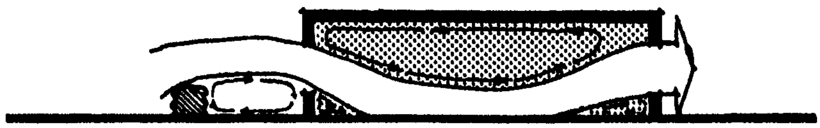
Low Hedge (Less Than 3' High)



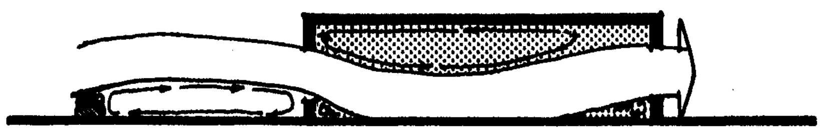
AT BUILDING



5' FROM BUILDING

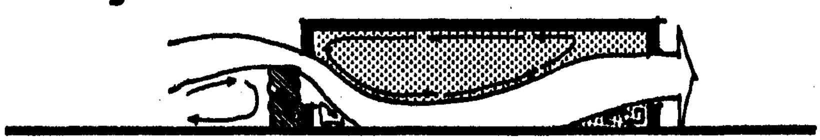


10' FROM BUILDING

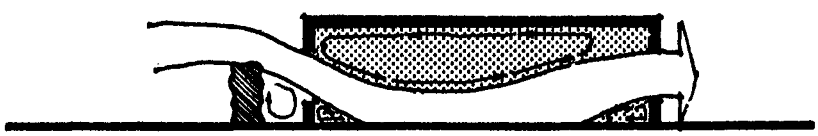


20' FROM BUILDING

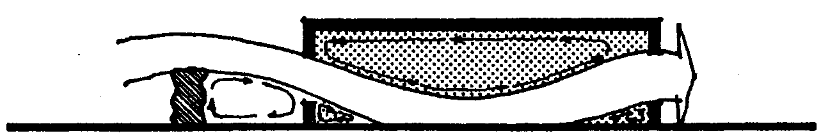
Medium Hedge



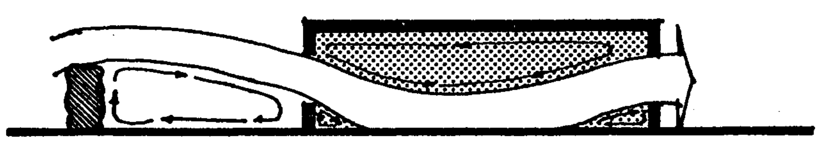
AT BUILDING



5' FROM BUILDING

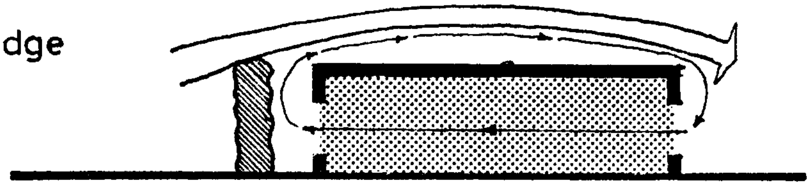


10' FROM BUILDING

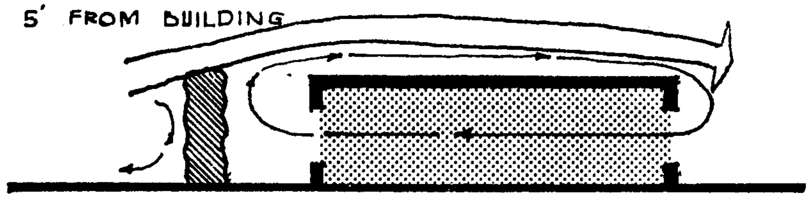


20' FROM BUILDING

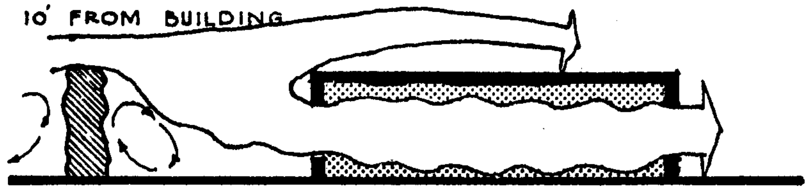
High Hedge



5' FROM BUILDING

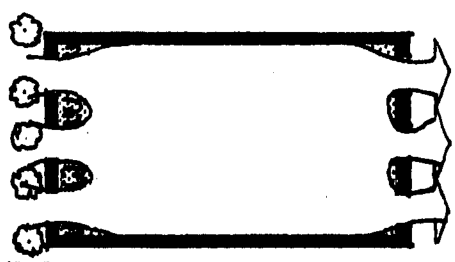


10' FROM BUILDING

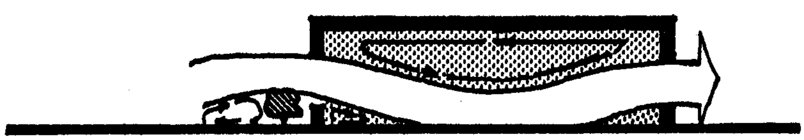


20' FROM BUILDING

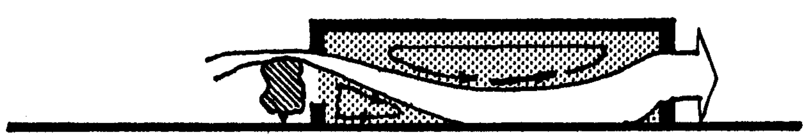
Shrubs



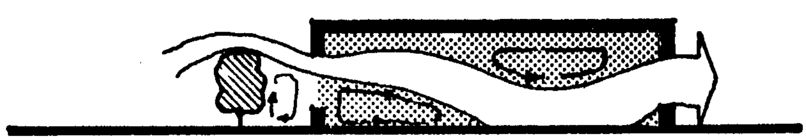
SHRUBS 5' ON CENTER.



AT BUILDING



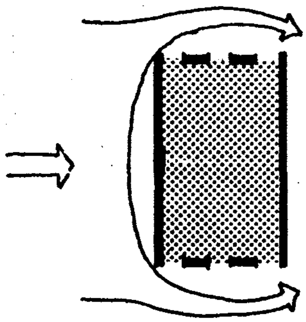
AT BUILDING



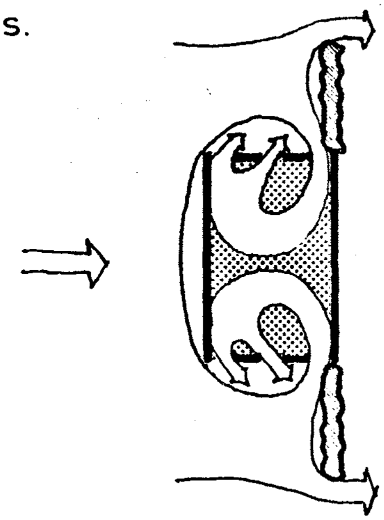
5' FROM BUILDING

10' FROM BUILDING

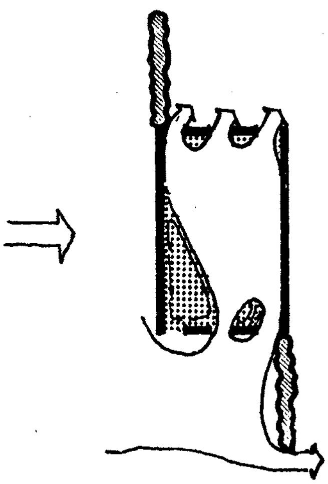
Hedge-Building Combinations.



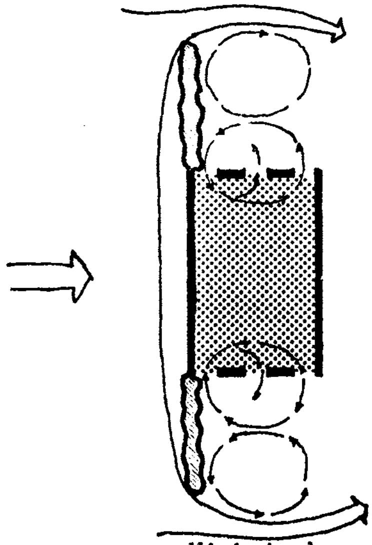
Building turned 90° into the breeze with no planting.



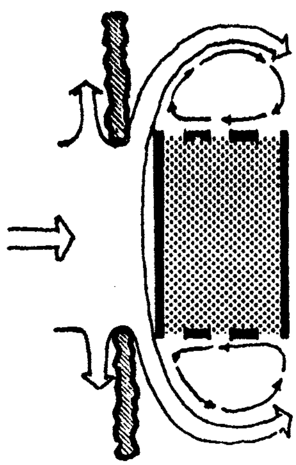
Medium or high hedge.



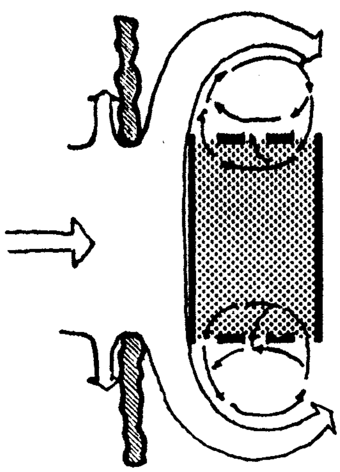
Medium or high hedge.



High hedge.

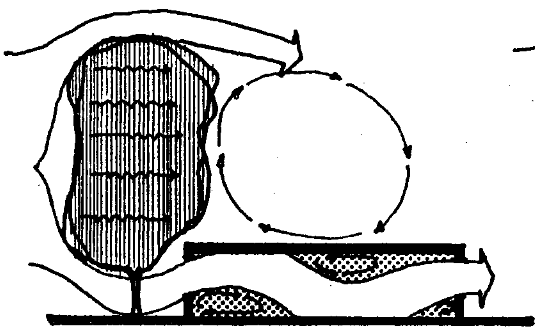


Large hedges 5 feet from building.

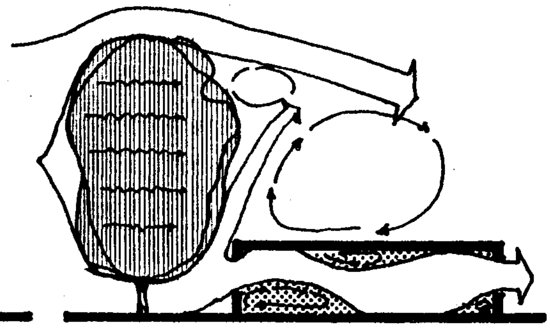


Large hedges 10 feet from building.

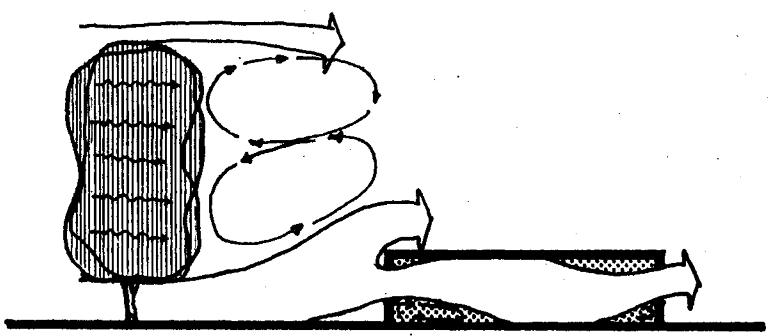
Trees.



5 feet from building at center

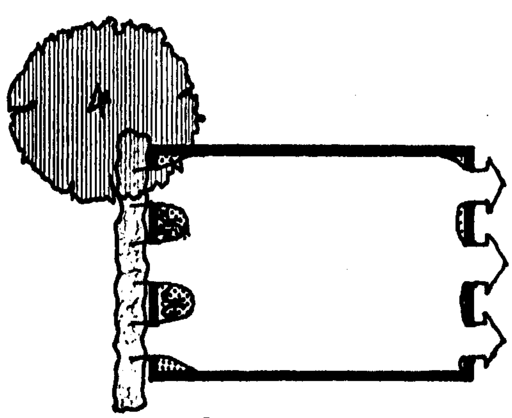


10 feet from building at center

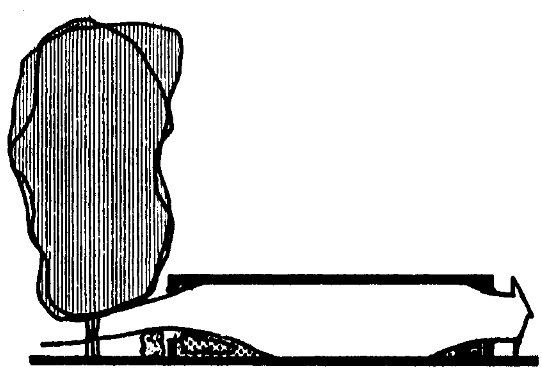


30 feet from building at center

Hedge-Tree Combinations.

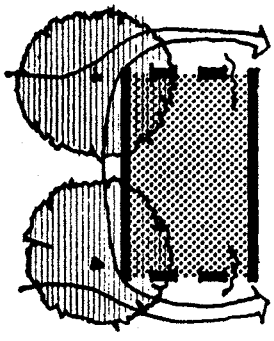


plan

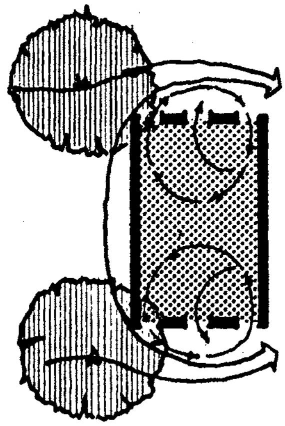


Hedge at building, tree 5 feet from building.

Tree_Building Combinations

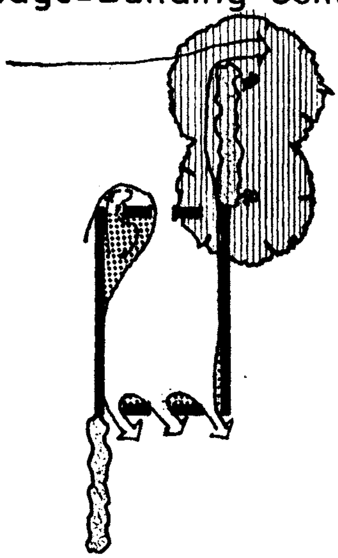


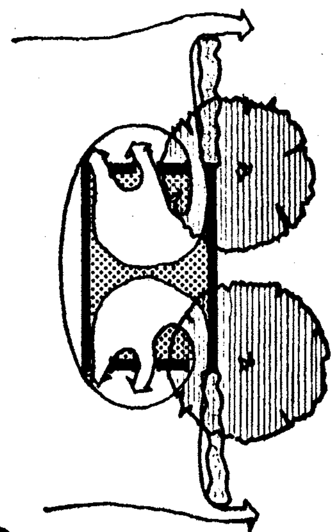
Trees 5 feet from building corners.

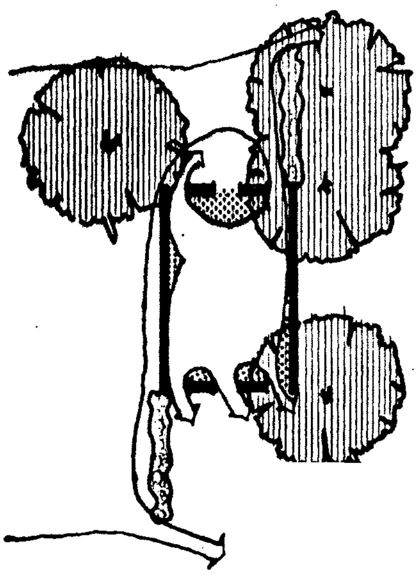


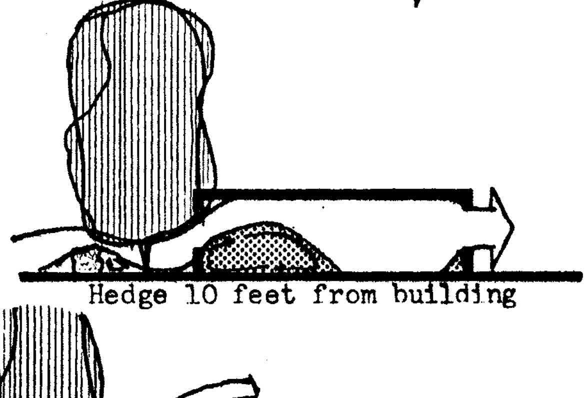
Trees 10 feet from building and 5 feet off corners.

Tree_Hedge_Building Combinations.





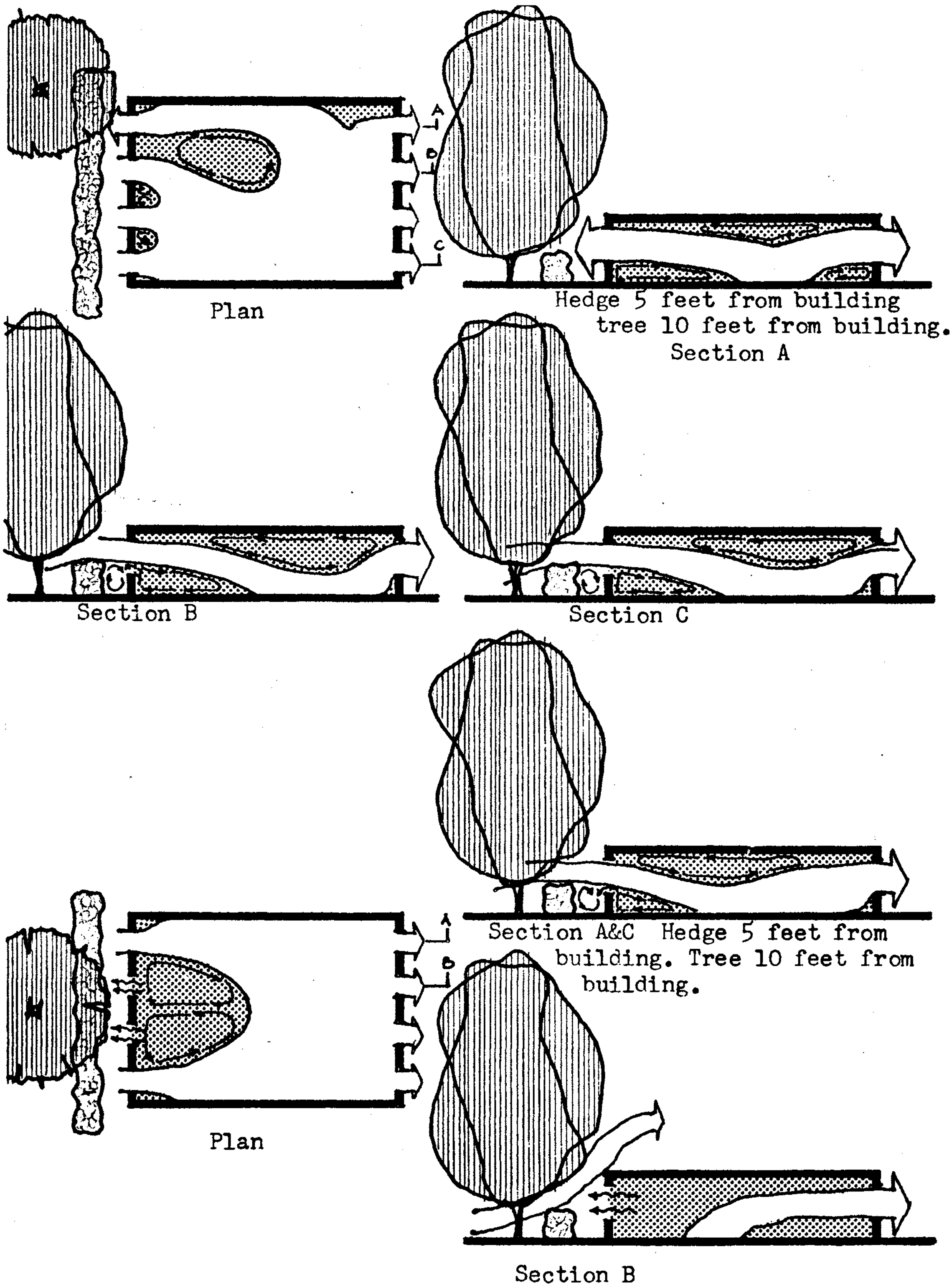




Hedge 10 feet from building

Tree 5 feet from building

Tree-Hedge-Building Combinations.



(4) Depending on the way it is used, planting may either augment or reduce the natural air flow through the building.

(5) Planting may cause actual change of direction of air flow within the building.

(6) Planting on the lee side of buildings has little or no affect on the movement of air through the building unless it is in such a position that it obstructs the outlet openings.

(7) Generally when a fast growing five year tree is planted in a new location it takes only five more years to grow to $80^o/_o$ of its full shading effect.

(8) The landscape design elements, including plant materials, trees and shrubs, walls and fences, can create high and low pressure area around a house with reference to its apertures.

The care should be taken that arrangement do not eliminate the desirable planting should be designed to direct and accelerate beneficial air movements into the building.

4.11 Kitchen

The tropical kitchen reflects its dependence upon servants to a diminishing extent. Where once the kitchen was a wretchedly equipped, smoke-backened annexe to the house, detached and visited only at intervals, it now becomes an integral part of the house, finished in expectation of its being kept clean. What keeps a tropical kitchen backward is smoke, no hot water on tap, and ants. So there should be a food cupboard with rubber-lined, positive-closing doors, similar to refrigerators and microscopic-gauge fly-mesh ventilation. Kitchen should be fly-proofed.

Bedrooms

Bedrooms should have protected south wall and night low cross ventilation at level of bed secured by louvres or doors opening onto verandahs with security and privacy. Cool airs often blow in early morning hours and help to bring the deep refreshing sleep so necessary to tropical life.

Bathrooms

In a humid climate washing or cleansing of the skin is a necessity and a pleasure. Whether the operation should be performed in a shower or a bath is undecided. A shower cleanses the skin quickly and well, consumes the munimum of water, occupies the least space and can be used with hot or cold water. Low income people prefere separate Indian style w.c. and bath for economy, more convinience and tradition; but a combind unit of w.c. and bath becomes a modern fashion in medium income group.

Furniture

The finishes in the tropics should be cool, clean and easy to keep up. Hard surfaces such as smooth concrete, marble or terrazo, marble mosaic and other tiles are suitable floor finishes in both private and dwellings and public buildings. The Indian bed or "Charpai", one of the simplest, cheapest and most comfortable of beds for a humid climate, and even better niwar bed, are examples of practical solutions to the furniture problem.

Storage

Cupboards should open completely, with no dark and inaccessible corners, and should be ventilated top and bottom. In any case occasional airing and exposure to the sun of stored clothes in necessary. Books can be treated but seldom without some disfigurement. They are best left on open shelves in a circulation of air and where they can be taken out from time to time and examined.

4.12 Housing Development

In planning the housing layout, these factors must be carefully considered.

(1) Type of person to be housed; their living habits, and possibility of change, and the rate at which it is taking place.

(2) Provisions should be made for future additions or omissions as the case may be.

(3) Any grouping by class, occupation, religion, race or education to be maintained, or otherwise dealt with.

(4) Size of family, relationships, possibilities of change.

(5) Cost of materials and method of construction, cost of up keep.

(6) Cost of house relative to possible economic rent; subsidies if any; allowances of maintenance rates, interest etc....

(7) Are houses planned on contour lines so that erosion is prevented, but at the same time so that road drainage is secured with scouring?

(8) Is housing so arranged that a through breeze is maintained?

(9) Is the housing so arranged that the mid-day sun follows the length of the roof tops?

(10) Make provision for future expansion.

(11) Is pedestrian separated from vehicular traffic?

(12) What roads and pedestrian ways should be shaded with trees?

(13) Provide sufficient "lungs" of open growing vegetation to reduce temperature and sweeten air.

(14) See that inflections are provided where required, such as at ends of streets and junctions.

(15) See that housing types are varied to suit different orientations.

(16) See that grouping of housing gives a feeling of local unity, social and physical.

(17) See that vehicular roads are so arranged that evening sun will not dazzle the driver.

(18) Preserve all good existing trees.

(19) Consider maintenance together with first cost where assessing costs.

(20) Are the planting and building programs together so that planting can follow house building as soon as possible after the road levels have been established and have irrigation for them been provided?

CHAPTER V

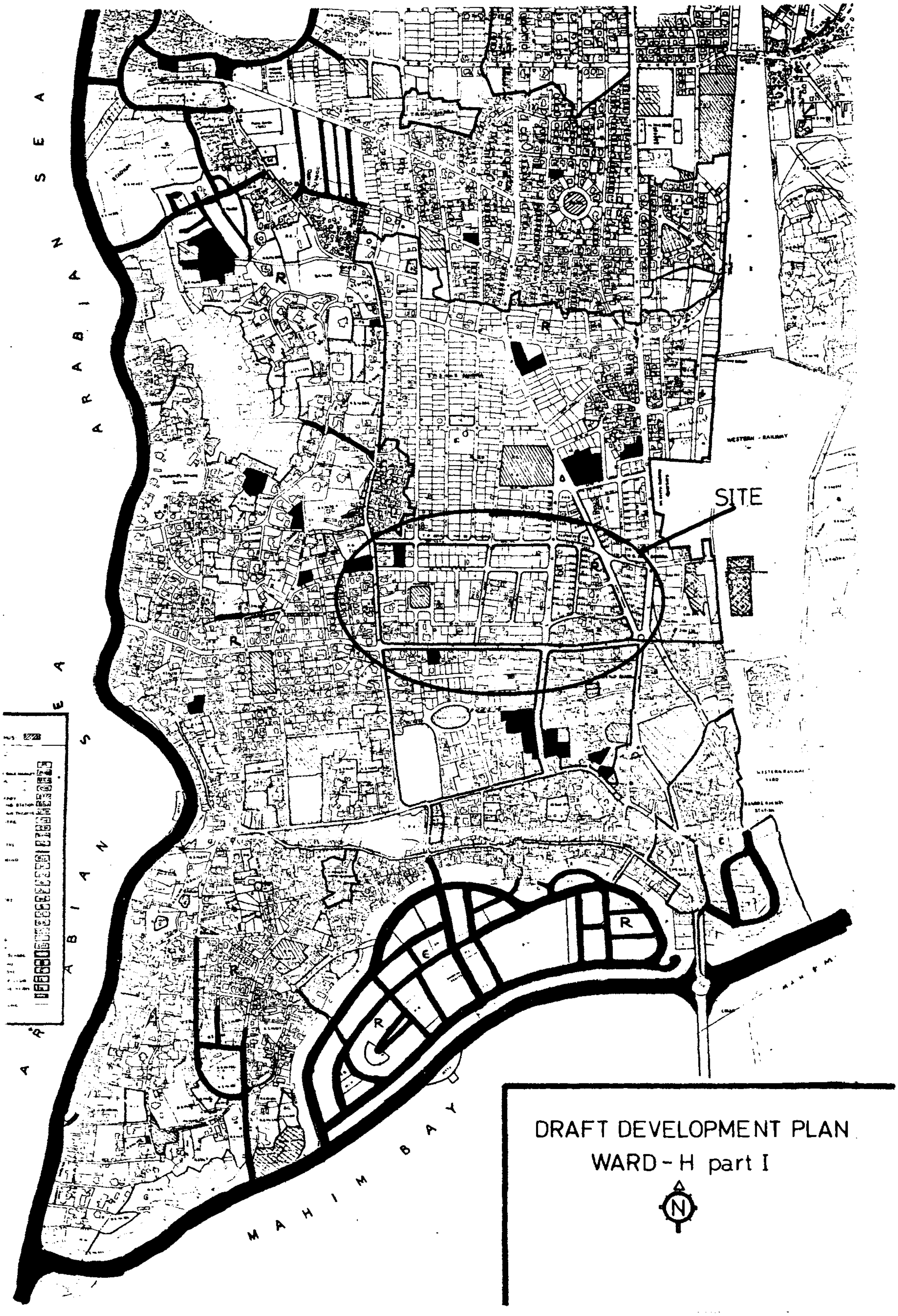
THE HOUSING DESIGN

In many contries of the world today, housing has come to be inseparable related to community planning, but still the Bombay Housing Board - the only organization for housing facilities - does not relize that the design of a housing project is more than a mere engineering problem. They build houses with only one narrow view based primarily on the point of economy. Indeed, there are other family and social aspects which are equally important and which require deep understanding. The creation, for instance, of entirely new housing estates provides exceptional opportunities for the application of social work principles and methods for healthy community living. It is necessary, therefore, to have some knowledge of dimensions of the social policy in relation to housing and process by which it is formulated and implemented.

This prototype study presents one example of the design housing projects at a large scale for low and medium income groups.

Site:

With limited undeveloped area and very high land value in the central city, the choice of location for new housing development is limited to the suburbs. With respect to the study site selected, it offers the possibility of development within proposed criteria. The project can be expanded towards the north side of the site in future.The



DRAFT DEVELOPMENT PLAN
WARD - H part I
N

size of the site selected for this project is about 54 acres of land between west side of "Banda" and "Khar" stations as shown on the map.

Boundaries:

East: Linking Road.

West: Pali Road.

North: 30th Road.

South: Turner Road.

Existing Conditions of Site:

The site is flat. Few families currently live in this area. The soil is black. The west and south areas surrounding the site are already developed. This site has many location advantages: bus service is provided on Linking road and the Bandra and Khar railway stations are within about 10 minutes walking distance; a movie theatre is across opposite the site on Linking road; shopping street and market areas are found to the northwest and southeast of the site; a large recreation garden is on the north side of 32nd road; hospitals, clinics, schools and other public facilities are found on the south and west side of the site.

Factors in Housing Design:

The major factor considered for this housing design is climate. In this housing design, the southeast quarter will receive the morning sun, and the southwest will receive the evening sun at a very low angle. This orientation should render the most exciting and hygienic confort. The overhangs and sun breakers, with the setback of the walls underneath them, are so arranged that no sunlight enters any of the rooms during the hottest times of the day during the warm months of the year. Also, normally, radiation from the roof and walls exposed to the strong tropical sun is the cause of more discomfort than just the hot air, so corrugated asbestos roofs in a gabled form are placed above the main precast roof slab. These protect the insulation below from the direct sun, and consequent overheating which produces excessive temperatures, by reflecting most of the sun's rays back to the air. Ventilation that occurs through the space created by the shape of this double roof also assists in evaporating moisture and keeping the roof cool. The asbestos roof also helps to drain the heavy rain. All the buildings are so oriented that they get north light and effective cross ventilation. Most of the buildings are placed perpendicular to the local prevalent wind direction. More study of natural ventilation and wind are summarized in Chapter VI. These various elements such as sun breakers have not only been devised to intercept the sun and to insulate the interior of the house from heat, but have also given a special character to the buildings. Moreover, through the use of glass windows, the interior of the house is brought effectively in touch with the trees and parks to make a permanent extension of the home. Thus, it is possible for to enjoy the essential joys of life - the sun, space and verdure.

The second factor is cost. There will be a fixed price or rent for each apartment. However, a purchaser may during construction, change to a better floor and other finishes if he so desires at a slightly extra cost. Cupboards, shelves and niches have been designed in walls at useful places in a manner which should prove to be quite economical. The niches also provide means to decorate with a minimum additional expenditure.

The third factor is material and construction. The cheapest material in Bombay is brick. Concrete and stone cost two to three times as much. Use of brick as a bearing wall with the conventional techniques available limits the maximum height to three stories. The load bearing walls are designed with brick piers at five foot spacing to minimize the lintel spans with resultant economy in use of steel for reinforcement. All the interior partition walls are also to be brick with cement or lime plaster. Nine-inches-thick load bearing walls support the precast reinforced concrete joists at each floor and the main roof. The joists, spaced on 2'-6" centers, are bridged with brick tiles of 9"x4 1/2"x3". This method of construction avoids the forming costs. Precast railings, projections and sunbreakers give adequate protection against weather, ensure a sufficient amount of privacy, and provide a sense of security. Doors, windows, ventilators, precast slabs and shelves are predominantly standardized. This facilitates the mass production of these components in factories and specially created central yards. Man power, which is plentiful and includes woman-power and child power, costs much less than mechanical-power.

Community Center:

The newly born baby's education starts from the very moment he takes birth in the worldly surroundings. Therefore, it is necessary to bring up a child in the most pleasant and healthy surroundings in addition to providing food and clothing. When a child attains school age, it is even more important that the schools he goes to are equally pleasant and provide helthier atmosphere. Therefore, the school is located in conjunction with local convenient shopping and community facilities to broaden the students contacts with community activities.

Residential Area:

This constitutes about 8.2% of the total site. The area to be assigned is determined by the character of the occupationsrepresented in the community, family income and other social factors. Importance has been given to the pedestrian walkways throughout the development rather than vehicular roads. Since there will not be many car owners in this community, the right traffic will permit those roads which do exist to be used partly as a pedestrian walkways. For the design purpose one car per family of upper middle class has been assumed, with only parking lots for visitors provided in low and middle class group areas. Some of the pedestrian walkways are wide enough to permit emergency use by ambulance or fire truck.

The above results in a pattern of homes linked by quiet, shaded pedestrian walkways, and centered around the nursery school, post-office, shops, play grounds and park area.

The housing is divided into four categories - scaled to the incomes of its employees with an amoritization based on a period of ten to twenty years:

1. Three story apartment building, efficiency units without bed room (38 units). Each unit contains twelve apartments.
2. Three story apartment building with one-bedroom units (66 units). Each unit contain three apartments.
3. Two story apartment building with two-bedroom units (44 units). Each unit contain two apartments.
4. Two story apartment building with three-bedroom units (20 units). Each unit contains two apartments.

Efficiency units	22.6°/o
One-bedroom units	39.3°/o
Two-bedroom units	26.2°/o
Three-bedroom units	11.9°/o

Efficiency units. (Low-income group).

There are 456 apartments accomodated in 38 building units. For each apartment a multipurpose room - which could be used as living, dining and bedroom - kitchen, Indian style w.c. and bathroom are provided. The plinth is 2'-0" raised over the ground.

Structure: Load bearing walls.

Roof and Floor: Precast R.C.C. slab with corrugated asbestos sheets pitch roof at an angle of 15° over main roof.

Floor finishing: Indian pattern stone and polished shahabad ladi (tiles).

Foundation: Brick walls and mass concrete.

Area of apartment:

Multipurpose room	114.0 sq.ft.
Kitchen	84.5 sq.ft.
Bathroom	16.0 sq.ft.
W.C.	12.0 sq.ft.
Passage	15.0 sq.ft.
Total	241.5 sq.ft.

Total 360 sq.ft. of common verendah is provided for each 4 apartments. Each staircase serves 24 apartments and each apartment will cost about 5,000 rs. to 5,500 rs.

One-bedroom apartment (upper-lower group):

There are 198 apartments accomodated in 66 building units. For each apartment living diningroom, bedroom, kitchen, bathroom, Indian style w.c., passage and balcony are provided. The plinth is 2'-0" raised over the ground.

Structure: Load bearing walls.

Roof and Floor: Precast R.C.C. slab with corrugated asbestos sheets pitch roof at an angle of 15° over the main roof.

Floor finishing: Indian pattern stone and polished shahabad ladi (tiles).

Foundation: Brick walls and mass concrete.

Area of apartment:

Living-dining room	133.0 sq.ft.
Kitchen	84.0 sq.ft.
w.c.	13.5 sq.ft.
Bathroom	20.25 sq.ft.
Bedroom	87.87 sq.ft.
Balcony	24.0 sq.ft.
Passage	45.0 sq.ft.
Lobby	36.0 sq.ft.
Total	443.62 sq.ft.

Each staircase serves 6 apartments and each apartment will cost about 6800 rs. to 7500 rs.

Two-bedroom apartment (medium-income group):

There are 88 apartments accomodated in 44 building units. For each apartment living dining room, two bedrooms, kitchen, toilet, passage and balcony are provided. The plinth is 2'-0" raised over the ground.

Structure: Load bearing walls.

Roof and Floor: Precast R.C.C. slab with corrugated asbestos sheets pitch roof at an angle of 15° over the main roof.

Floor finishing: Indian pattern stone and polished shahabad ladi (tiles).

Foundation: Brick walls and mass concrete.

Area of apartment:

Living-dining room	150.5	sq.ft.
Kitchen	84.0	sq.ft.
Toilet	62.0	sq.ft.
Bedroom I	97.31	sq.ft..
Bedroom II	113.0	sq.ft.
Balcony	50.87	sq.ft.
Passage	38.25	sq.ft.
Total	595.93	sq.ft.

Each staircase serves 4 apartments and each apartment will cost about 9500 rs. to 10,000 rs.

Three-bedroom apartment (upper-middle group):

There are 40 apartments accomodated in 20 building units. For each apartment living-dining room, three bedrooms, kitchen, toilet, passage and balcony are provided. The plinth is 2'-0" raised over the ground.

Structure: Load bearing walls.

Roof and Floor: Precast R.C.C. slab with corrugated asbestos sheets pitch roof at an angle of 15° over the main roof.

Floor finishing: Indian pattern stone and polished shahabad ladi (tiles).

Foundation: Brick walls and mass concrete.

Area of apartment:

Living-dining room	231.0	sq.ft.
Kitchen	74.37	sq.ft.
Toilet I	55.0	sq.ft.
Bed room I	94.0	sq.ft.
Bed room II	105.37	sq.ft.
Bed room III	124.50	sq.ft.
Balcony	42.25	sq.ft.
Toilet II	44.63	sq.ft.
Passage	38.50	sq.ft.
Total	809.62	sq.ft.

Each staircase serves 4 apartments and each apartment will cost about 14,000 rs. to 14,500 rs.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In a hot, humid climate, the prime object of design is to provide free air movement through the building and to prevent the temperature of its inside surfaces rising above shade temperature. A thorough study of natural air flow - its basic characteristics and its probable behavior in proposed structures - provides solutions to specific problems and leads inevitably to the formulation of conclusions upon which to make use of natural air flow for adequate ventilation. These conclusions are not complete by any means. Certainly there is yet much to be researched. Nevertheless, there are some which, at this stage, appear to result in good planning and design from the stand point of natural ventilation of buildings.

To obtain the greatest benefit from air movement on days when there is only a slight breeze, orientation in its prevailing direction is a first consideration though this must be balanced against the optimum shade provided by a north-south orientation. The building should be as open as possible and one room thick so as to ensure through ventilation although this makes the planning of a large scale building complex. Dead air pockets on plan, as well as in section, should be avoided. Ventilation at ceiling level is desirable and sills of openings should be low so as to allow the movement of air through the lower part of a room where the occupants may be seated or in bed. High ceilings in a multi-story building make no contribution to thermal comfort.

Also the conclusion is to be drawn that to acquire the most effective air movement from the natural wind forces for summer cooling, abrupt changes in direction of the air movement within a building should be kept to a minimum. The location and type of outlet opening have little to do with the air flow pattern. Air changes mean very little with regard to summer cooling. Of more importance is the fact that maximum air speeds within a building are acquired when the inlet opening is designed for distribution to the living zone, and the outlet opening is made as large as possible. Many geometric variables in architecture such as overhangs, variations in inlet arrangement and also landscape elements may have a definite effect on air flow. They may either hinder or facilitate natural ventilation. However, in this housing design most of the buildings are so oriented that there is effective cross ventilation. The blocks of apartment buildings are therefore placed perpendicular to the local prevalent wind direction.

From the observance of the path of the smoke for the final design models test, the air flow pattern sketches are illustrated in Chapter VII. Ventilation for low and upper low income groups buildings is very good; first, because the inertia of the air tends to carry it on through the inlet, and second, because the inlet joins a high pressure area and the outlet joins a low pressure area. Certainly a person sitting in line with the openings will be cooled by the air flow. However, areas adjacent to the windowless walls will have little movement of air.

The adjoining bedrooms in medium and upper medium income groups building do not appear to be as good as the living-dining room because the inertia of the air tends to carry it past the opening. It has been also found that having trees at particular places develops enough high pressure to create an appreciable amount of air flow into the bedrooms. Since the outlet opening of the bedrooms adjoins a wind shodow and has relatively low pressure, cross ventilation will therefore be realized. Probably the greatest air movement will be on the downward side of the room.

The shape and orientation of the building, the size and location of openings and the placement of the elements of landscaping all affect the flow of air-flow for comfort. Thus, architects and engineers who are responsible for the comfort of occupants of buildings must give particular emphasis to natural ventilation considerations during the planning process.

All model testings and housing design drawings are illustrated in Chapter IV and VII, so that further investigations can be done in this field with the following suggestions:

Technology of cooling effect of trees, shrubs and vegetations.

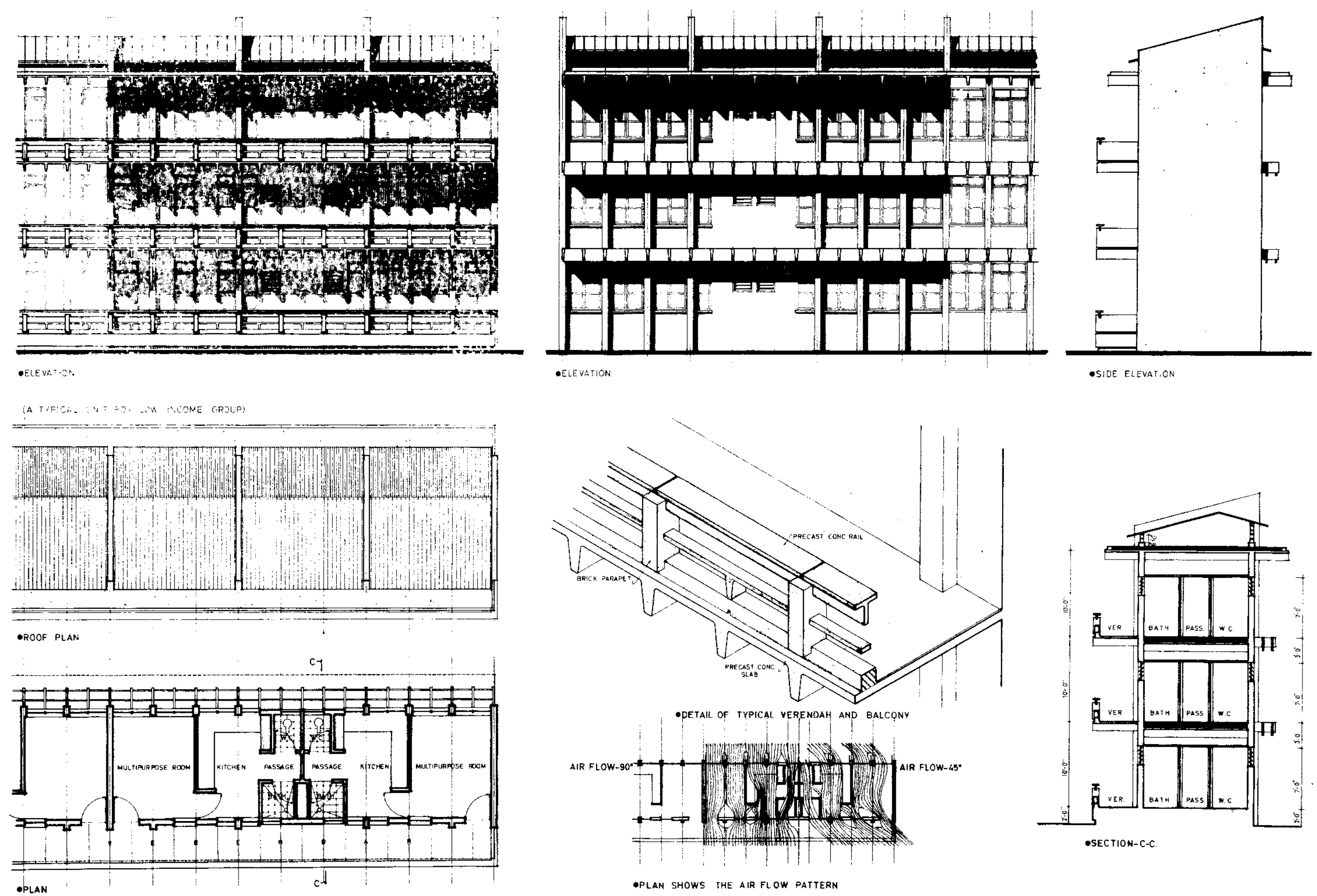
Analysis of different shape of buildings and openings and different type of windows in relation with air-flow patterns.

Heat capacity and distribution of mass in the design of buildings for hot climates.

CHAPTER VII

DRAWINGS OF HOUSING PROJECT

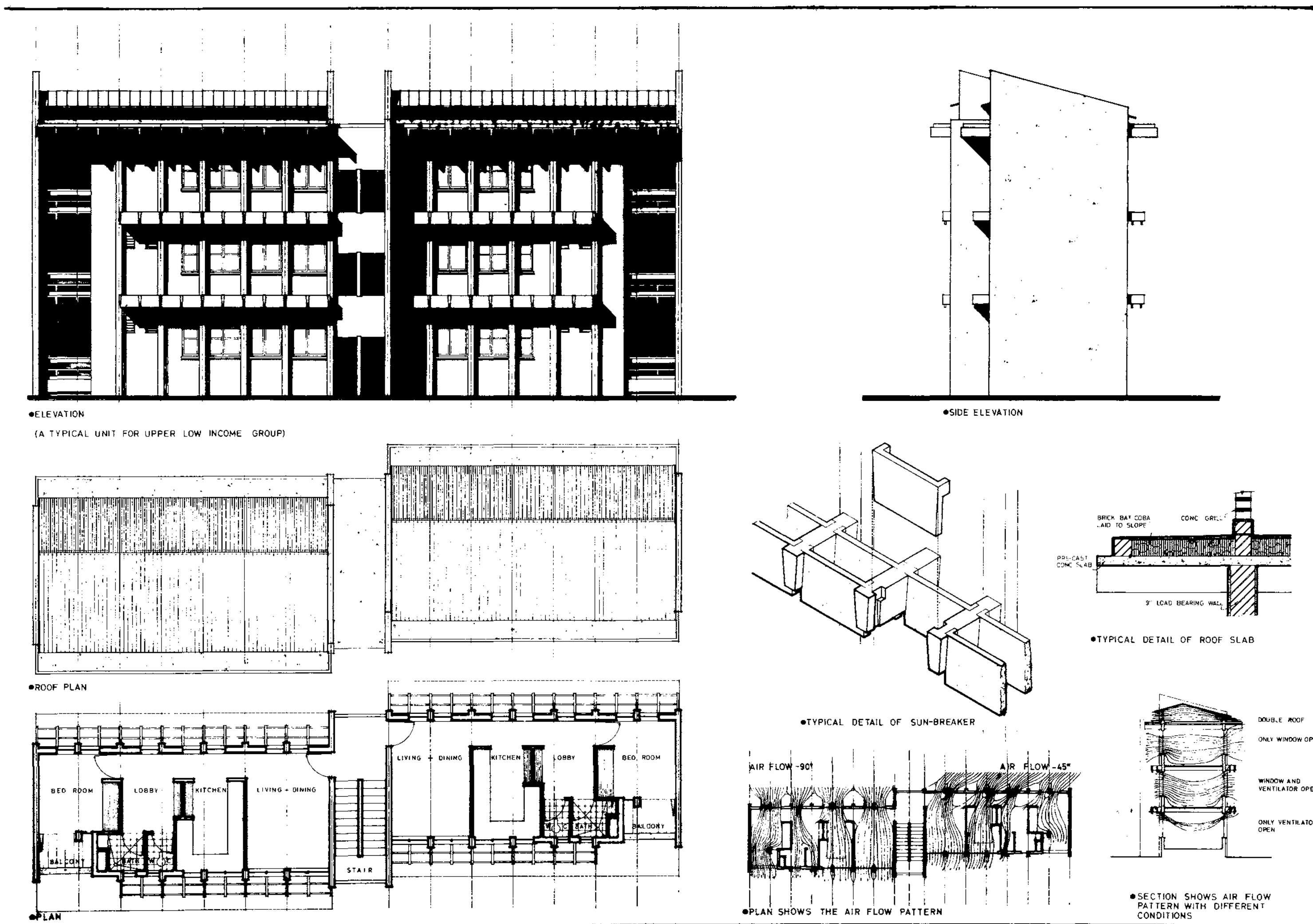
The foregoing assembly of experiment, study of climatic, sociological and other factors and principles of design is the basic foundation upon which the prototype housing project solution is developed. The following reproductions are those of the original concept drawings. The evolved functional relationships of the various elements are best observed in the reduced scale reproductions of the original plans and floor plans of this housing project.



COMMUNITY HOUSING PROJECT · BOMBAY · INDIA

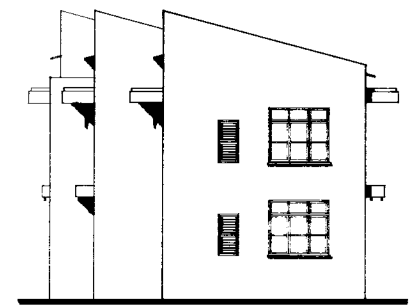
SCALE-1/8" TO A FOOT

1



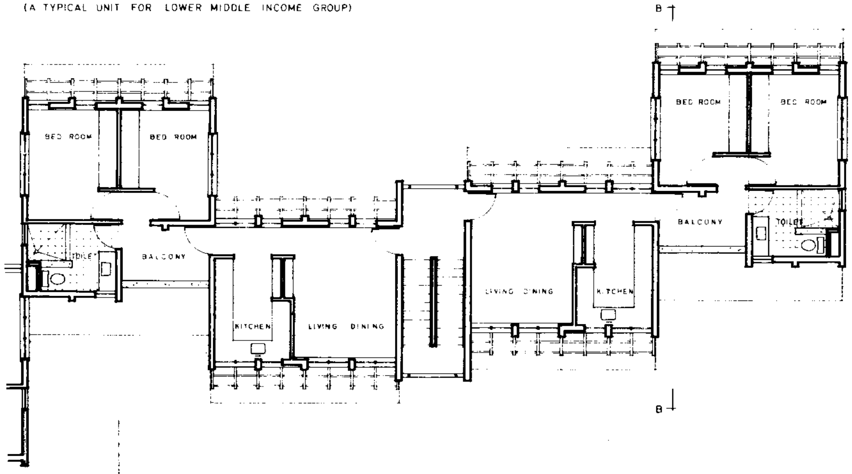
COMMUNITY HOUSING PROJECT · BOMBAY · INDIA SCALE-1/4" TO A FOOT **2**

•ELEVATION

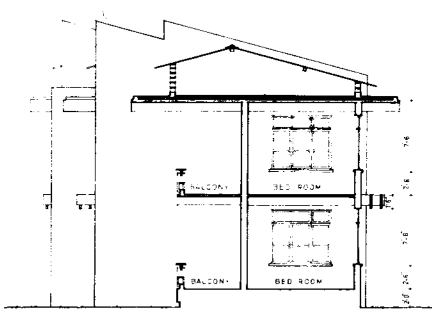


•SIDE ELEVATION

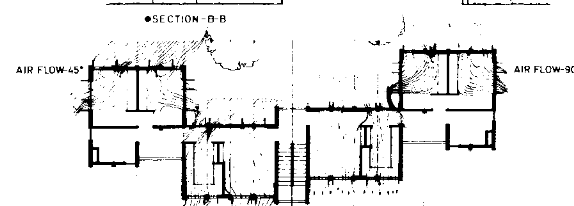
(A TYPICAL UNIT FOR LOWER MIDDLE INCOME GROUP)



•PLAN

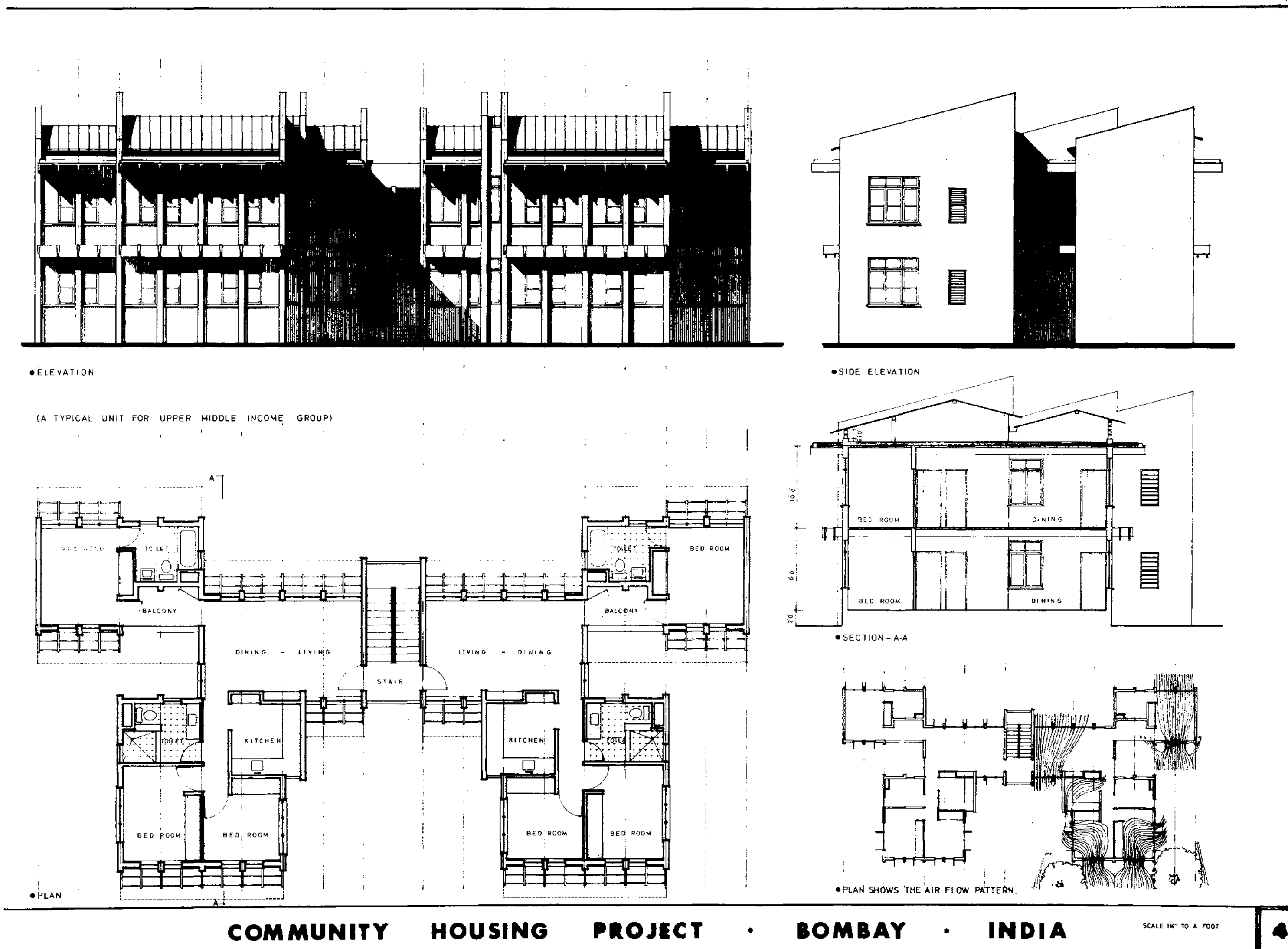


•SECTION–B-B

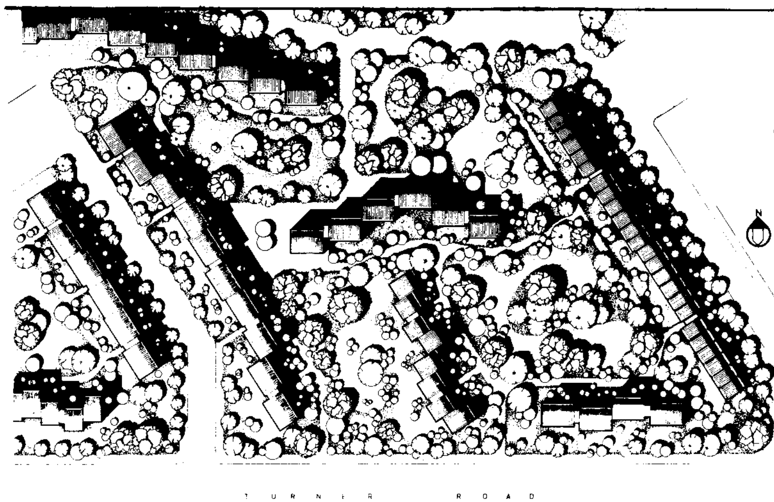


•PLAN SHOWS THE AIR FLOW PATTERN

COMMUNITY HOUSING PROJECT · BOMBAY · INDIA SCALE-1/8" TO A FOOT **3**



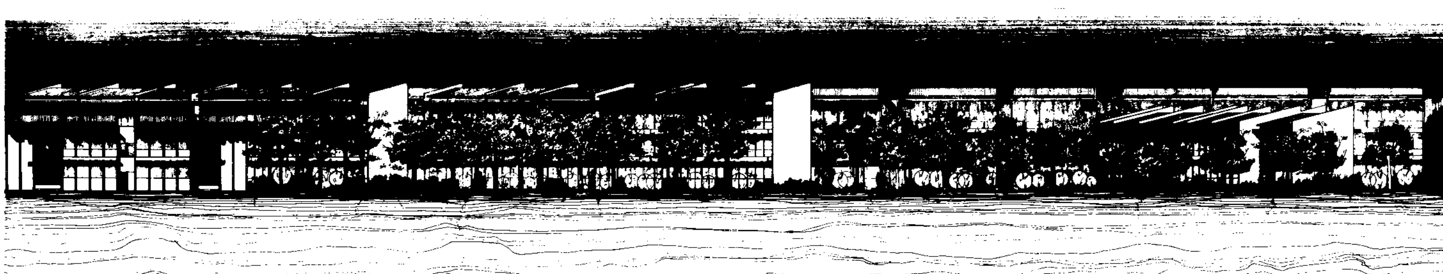
• ELEVATION
• SIDE ELEVATION
(A TYPICAL UNIT FOR UPPER MIDDLE INCOME GROUP)
BED ROOM
TOILET
BALCONY
DINING - LIVING
STAIR
LIVING - DINING
KITCHEN
• PLAN
BED ROOM
DINING
• SECTION - A-A
• PLAN SHOWS THE AIR FLOW PATTERN.
COMMUNITY HOUSING PROJECT · BOMBAY · INDIA
SCALE 1/4" TO A FOOT
4



●PART-LAYOUT

SCALE-40' TO AN INCH

●PERSPECTIVE VIEW

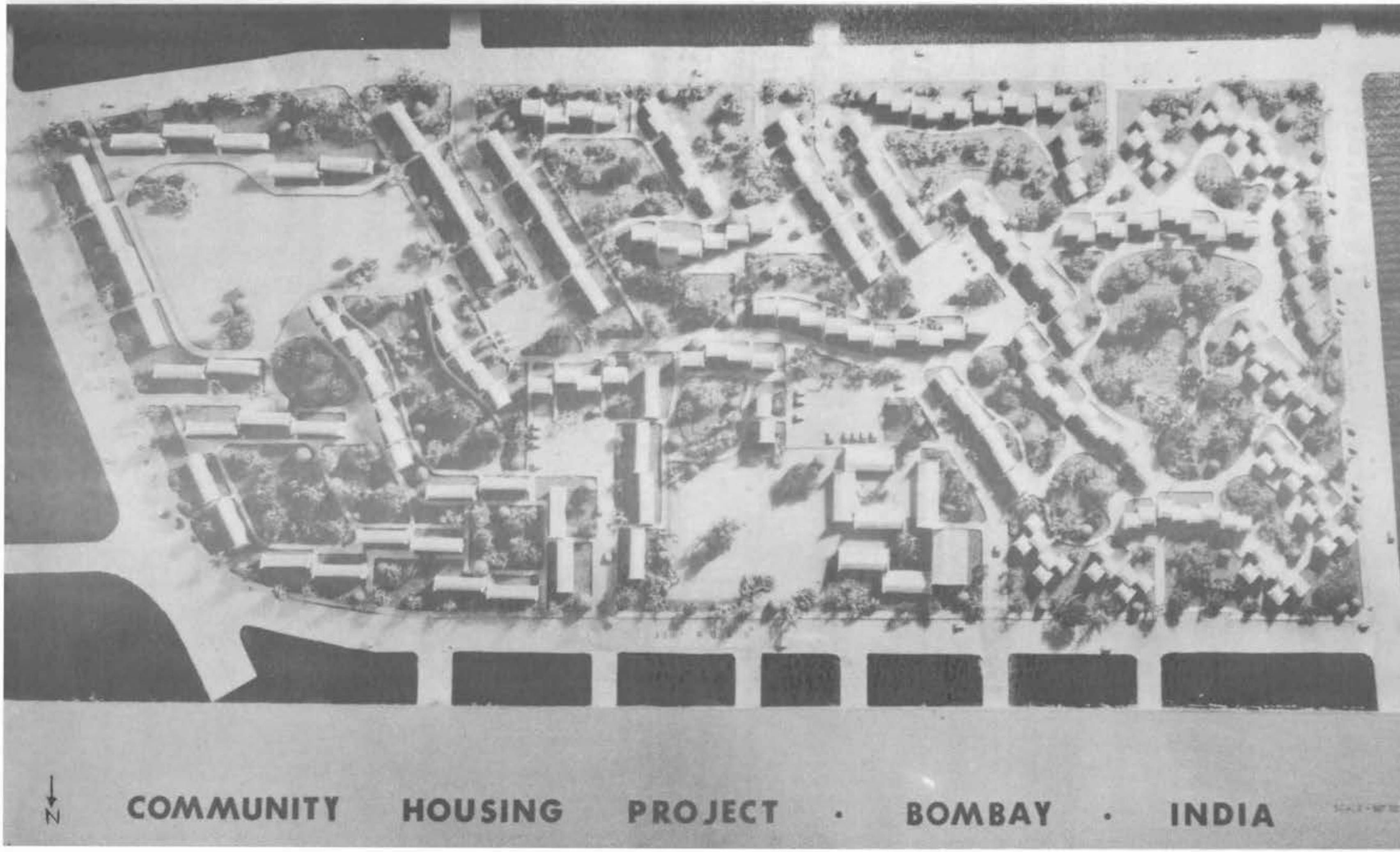


●ELEVATION.

COMMUNITY HOUSING PROJECT · BOMBAY · INDIA

SCALE-3/4"=10'

5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COMMUNITY HOUSING PROJECT · BOMBAY · INDIA

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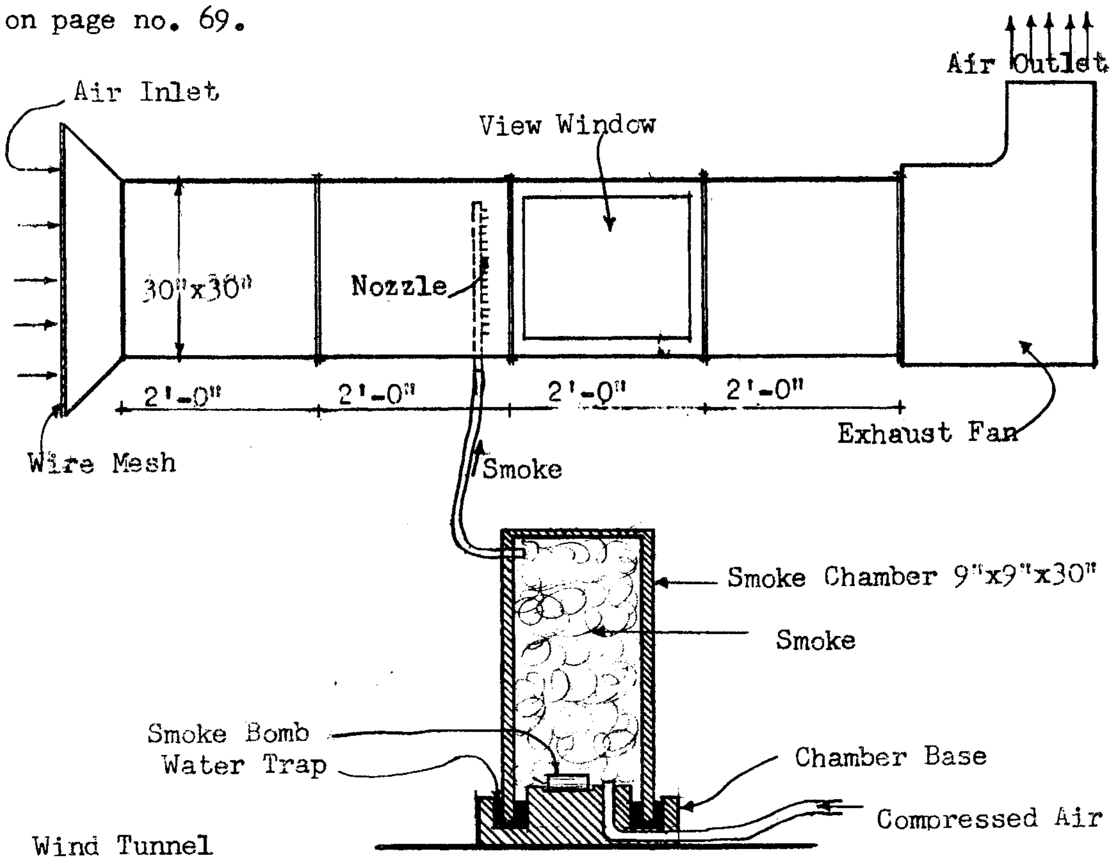
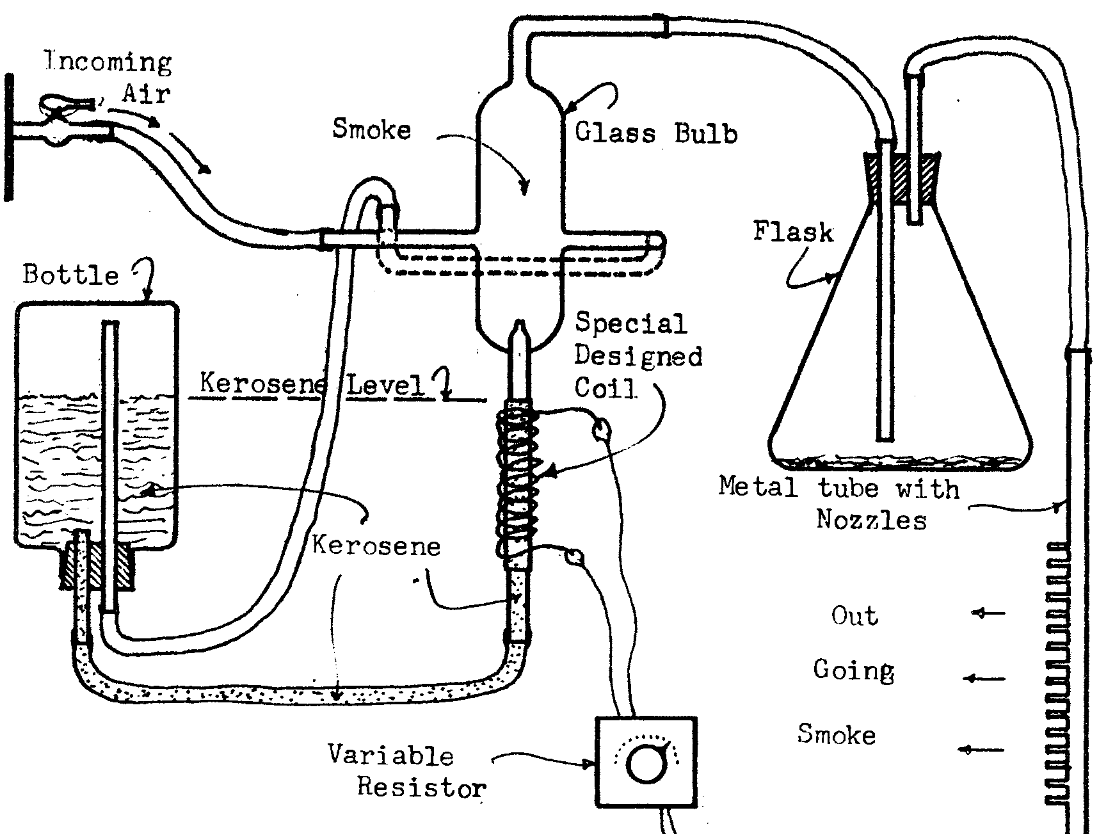
APPENDIX

The tests were conducted in a wind tunnel of a type sketched below with models built of plywood and illustration boards. All the models were tested by using smoke bombs which produce the smoke entering the wind tunnel through a series of nozzles. It has been indicated by "Texas Engineering Experiment Station", Texas, that the speed of flow in a wind tunnel does not make a difference in getting the correct airflow pattern. Therefore the speed of the exhaust fan was kept the same for all the tests.

The alternate method of producing smoke by kerosene is shown on page no. 69.



The smoke bombs used in testing of models were inadequate, so far as producing smoke supply for a sufficient period to analyse. An alternate method developed by Mechanical Engineering Department was used in early phase of this experiment, however the coil required a special design of a type not available, which can produce the desired type of smoke.



Smoke Generator

VITA

Manhar B. Mistry

Candidate for the Degree of

Master of Architecture

Report: THE EFFECT OF CLIMATIC CONDITIONS ON DESIGN OF HOUSING FOR LOW AND MEDIUM INCOME GROUPS, BOMBAY, INDIA.

Major Field: Architecture

Biographical:

Personal Data: Born in Gujarat, India, Sept. 9, 1943, the son of Bhagwanji D. Mistry.

Education: Graduated from Elphinstone Technical High School, Bombay in 1959, received undergraduate degree from "Academy of Architecture", Bombay, with major in Architecture in May 1964, also completed the requirements for the Architectural Draughtsman (2 years) course from "Bandra School of Art", Bombay in May 1961. Completed the requirements for the degree Master of Architecture in May 1967.

Professional Experience: Employed as Architectural Draughtsman for M. M. Bilaney & Co; Bombay from 1962 to 1963, also worked H. R. Thakkar & Co; Bombay in 1963. Employed as an assistant architect for Banaji and Wadia, architects, Bombay from 1963 to 1966, where worked as a chief architect from 1965 to 1966. Employed as a job captain for Hudgins, Thompson, Ball and Associates, Oklahoma City, Oklahoma during summer of 1966. Worked as a Graduate assistant at Oklahoma State University from Jan. 1967 to May 1967.