REDEVELOPMENT OF SOKOTO AIRPORT TERMINAL BUILDING

BY

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A Thesis submitted to the post-graduate School, Ahmadu Bello University, Zaria in partial fulfilment of the requirements for the degree of Master of Science Architecture.

Department of Architecture.
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DECLARATION

I solemly declare that the material composed hereafter has been the product of my research work for the thesis on the Redevelopment of Sokoto Airport Terminal Building, under the supervision of Mr. O.O. Ogunsote of the Department of Architecture, Ahmadu Bello University, Zaria. All sources of information are acknowledged and listed in the bibliography.

Idris, Ahmed Shehu.

QUOTATION

If structural invention is to allow the efficient solution of the new problems offered daily by the ever-growing activity in the field of building construction, it must become a harmonious combination of our personal intuition and of an impersonal objective, realistic and vigorous structural science. Future architects, even if they can entrust the final calculation of a structure to specialist, must themselves first be able to invent it and to give it correct proportions. Only then will a structure be born healthy, vital and, possibly, beautiful.

- Pier Luigi Nervi.

CERTIFICATION

This thesis entitled Redevelopment of Sokoto Airport Terminal Building by Ahmed Shehu Idris meets the regulations governing the award of the degree of M.Sc. Architecture of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

_____

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Member, Supervisory Committee Date: _____

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Member, Supervisory Committee

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Head of Department

_____ Date: _____

Dean, Post-Graduate School

DEDICATION

To my Grand mother Aishatu and my Sister Nafisatu

for their love.

ACKNOWLEDGEMENT

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ABSTRACT

TOPIC: DEVELOPMENT OF SOKOTO INTERNATIONAL AIRPORT TERMINAL BUILDING.

The problem of very high wind velocity is not new to Sokoto and its environment. Windstorm had been a seasonal affair, and has become a very serious regional hazard . Despite the seriousness of this phenomenon, the authorities concerned have done nothing to see that this pehnomenon is thoroughly investigated, and appropriate solutions found to prevent future occurance. The Sokoto International Airport Terminal Building is one of the victims of this neglect. The otherwise beautiful terminal was reduced to debris after a devastating windstorm in May, 1984. A few months after it was commissioned. The roof, a steel space frame structure was uplifted from the windward side by the storm and thrown backwards breakung some columns on the lee-ward side as it went, causing some serious structural damage to the building itself.

It is the intention of this thesis, therefore, to findout why the Sokoto Airport Terminal building have been an architectural failure due to lack of consideration for the wind effects in this region. It is hoped that by end of our investigations, greater insight into this inconspicuous and invisible, yet powerful phenomenon - the wind will be gained. And solution not only to the Terninal building, but other buildings in general will be provided.

Bearing in mind our present economic predicaments, and need to maintain other existing infrastructure like the runway, parking area, access roads and the control tower. An attempt will be made to produce a new Terminal Building, that is functional, practical and financially feasible. And ofcourse extensive use of locally available materials.

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1. INTRODUCTION

For many centuries, the action of wind forces on structures has been classified as an act of a Supernatural Deity (Allah). While this is fundamentally correct, it is only recently that serious, attemps have been made to measure, firstly the speed of wind, and secondly the wind force on a structure. To this date, investigations of wind effects follow structural failures more often than they precede construction, and the increase in light weight, prepackaged but large units like the destroyed Sokoto Air port terminal building leads to little diminishment in this failure rate. There is no year since the start of "zinc roof craze" in this part of the country in the 1950s, when we have less than 50% of such roofs destroyed by wind. Resulting in lost of lives and property worth thousands of naira then and millions of naira now. Nothing could explain this better than Na'inna (1985).

> The Scenario: a block of classrooms and a stone are unroofed by a spiralling storm and the books available to the school are distroyed; the only modern stall buit by the Local Government in a remote, long-forgotten village is left roofless after a windstorm; a multi-million Naira Air port terminal and all its computers and other costly imported gadgets are ruined by a devastating storm.
>
> Storms that cause such disasters do happen seasonally, leaving in their wak extensive damage worth millions of Naira. And in the case of poor individuals who do not have the means of effect immediate repairs, there is untold human suffering.

In some of this cases it is not always the fault of the designers. Many failure reports stress design adherence to some foreign codes of practice which proved insufficient, and in some cases does not even take local conditions into consideration.

Basically, wind energy itself is considered on a statistical basis, acting on a flexible or inflexible object, whose movement strain and stresses are then calculated from wind-tunnel and site measurements.

The result of subsequent wind force calculations should be specific and statical. They are specific in that they refer to a defined structure at a particular site; they will not be approximatious unless the measurement data is also approximate, and in that case the degree of uncertainty can be translated directly into the margin of errow of the structural effects. They are also statistical in that it is never possible to define a maximum wind force in any area. Instead, the probability that a particular wind force may not be exceeded is stated, and this probability can be translated into a probable lifetime for the structure. The choice of a life-duration is then consciously made. It must be stressed that any code of practice which guarantees a maximum wind force is unrealistic.

It is in view of the neglect given to this very serious and important problem that the Redevelopment of Sokoto International Air Port Terminal Building was

conceived. Sokoto Airport is just one of the many buildings that were destroyed by the action of wind, which could otherwise be unharmed by such winds. Had the local condition been considered right from the design stage. This thesis will therefore, try to unmask the behaviour and action of wind as regards building structures. And in particular the turbulent flows in the boundary layer. In addition to the primary concern with mean velocity of the wind, two aspects of these turbulent flows are of interest: the state of turbulance of the natural wind approaching a structure and the local or "signature" turbulence provoked in the wind by the structure itself. Since most buildings present bluff form to the wind, emphasis is placed on bluff-body aerodynamics.

2. ENVIRONMENTAL ANALYSIS

2.1 Climate

The principal climatic elements, when human comfort and building design are being considered, are solar radiation, temperature, wind, humidity, precipitation and special characteristics such as lightning, earthquakes, dust storms and so forth.

2.1.1 Solar Radiation

Solar radiation, which occurs in the so-called shortwave length, is the source of almost all the earths energy and is, as a result, the dominant influence on all climatic phenomena. The intensity of solar radiation at the upper limits of the atmosphere varies according to the earth's distance from the sun and the solar activity, but the everage intensity on a surface perpendicular to the solar rays is 1.94 cal/cm^3/min (or 1353 watts/M^2) and this value is called the solar constant.

Solar radiation varies greatly with the geographic location, the altitude and the weather; in otherwords with the length of the day, the angle of the sun's rays to the ground, with the length and quality of the atmosphere through which it passes, and particularly with the cloud coverage. The four main channels of radiant heat transfer affecting buildings are, in order of importance: direct short-wave radiation from

the sky-vault; short-wave radiation reflected from the surrounding terrain; and long wave radiation from the heated ground and nearby objects. These affect buildings in two ways: firstly, by entering through windows and being absorbed by internal surfaces, thus causing a heating effect and, secondly, through being absorbed by the outside surfaces of the building creating a heat input, a large proportion of which is conducted through the structure and eventually emitted to the interior. Another major form of heat transfer affecting buildings is the outgoing long wave radiation exchange from building to sky - an effect which is reduced when the sky is clouded and is strongest when the atmosphere is clear and dry as in hot arid zones like Sokoto, where it can be utilised as a source of energy for cooling buildings.

2.1.2 Length of Day, Cloud and Sunshine

The Sokoto airport site is located on latitude $12^{o}55'$ North, does not have large variations in the length of day. The longest day is about 12.9 hours, the shortest about 11.3 hours. Variations in the amount of solar radiation are therefore mainly caused by cloud cover and Harmattan haze and dust.

The cloud cover increase gradually to its maximum in August and decreases sharply towards the end of the year. The densest cloud cover normally can be

expected in the early afternoon, and the least around midnight.

Cloud cover and dust haze cause cold days and warm nights because of less incoming and outgoing radiation. Therefore, diurnal variations in termperature are least during cloudy or hazy days and highest during clear days.

The mean duration of bright sunshine varies with the length of the day and the cloud cover. In the first months of the year, the duration of sunshine increases with the lenght of day and absence of cloud. Towards April, cloud cover increases more rapidly than the length of day leading to a secondary minimum. Towards May-June, cloud cover increases less rapidly than the length of day leading to a secondary maximum of sunshine. In July, August and September, cloud cover is dominant and the duration of sunshine reaches its minimum. Short days in December and January are the cause of less sunshine.

2.1.3 Air Temperature

The climate is Hot Arid type which is characterised by relatively wide and rapid changes in temperature. The highest mean monthly temperature is 40C^{O} in April while the lowest mean monthly of 15^{O}C occur in December and January.

TEMPERATURE: Monthly mean max.— Mean min.
(Period 1970– 1985)

SOURCE: SOKOTO AIRPORT

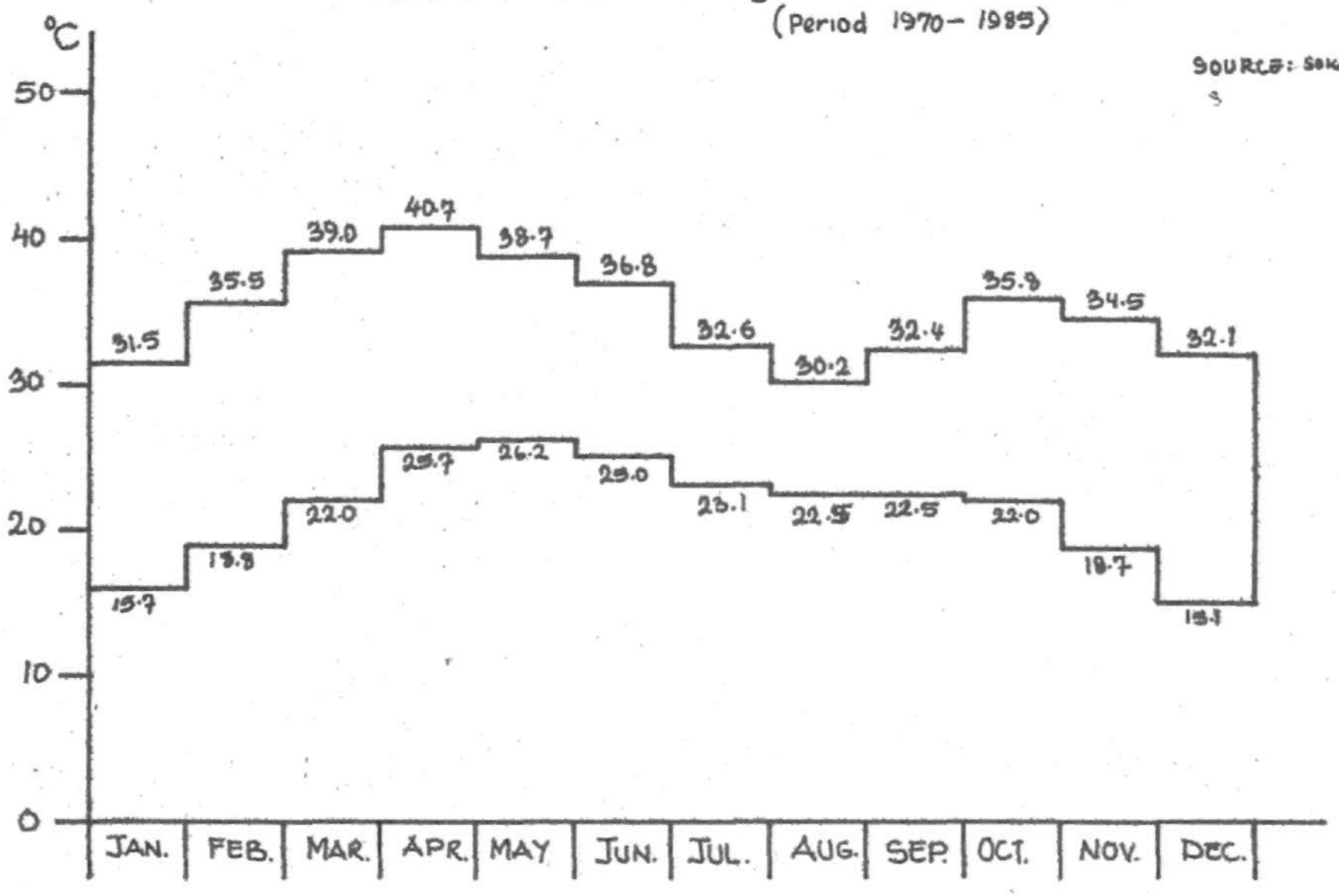


Fig. 1.1

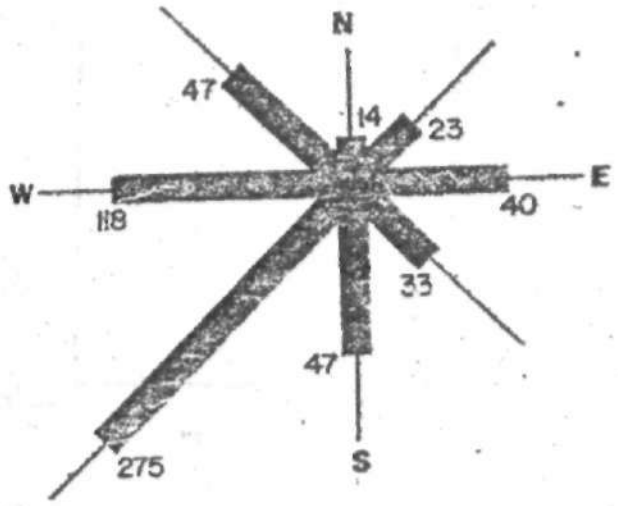
Since air temperature varies from one side of the building to another, from shaded to unshaded areas, from grassed or paved fields to paved roads, it is an element which is difficult to define and in measuring it, one could only hope to find a value which represents some average value of the temperature condition of a heterageneous mixture of air.

The rate of heating and cooling of the surface of the earth is the main factor determining the temperature of the air above it. It is important for the designer to obtain not only the monthly mean maximum temperatures, but also the monthly mean minima, which will give an indication of the diurnal (day and night) variation. These can be large, for instance, in the hot arid zones, and building design must make allowances for this. A large diurnal range is indicative of dry weather and clear skies, which means intensive solar radiation by day and strong outgoing radiation by night. Pointing, broadly speaking, to the importance of shading, reflective coloring and good landscaping.

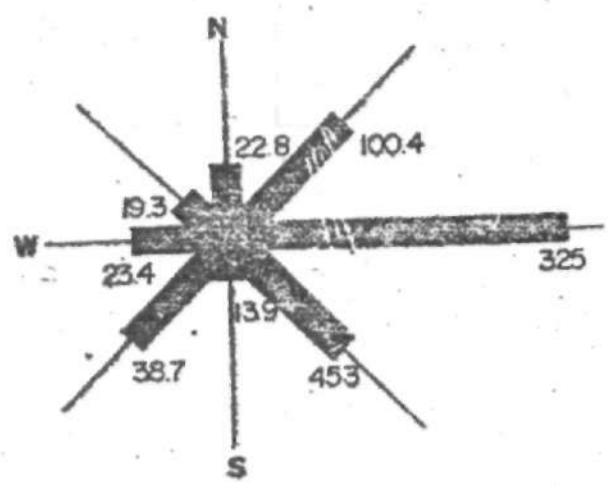
2.1.4 Surface Wind

Sokoto is affected by two wind currents: the Harmattan from the north-east with northern and eastern components. And the Monsoon from the South-west with western and to a lesser degree southern components. The Harmattan predominates from November to March, the monsoon from May to September. In October and April

WINDROSE FOR SOKOTO (1970 – 1985).



APRIL – SEPTEMBER



OCTOBER – MARCH

NOTE: The numbers represent days during which the wind of 1–33knots is blowing from the direction shown in the figure.

Fig. 1.2

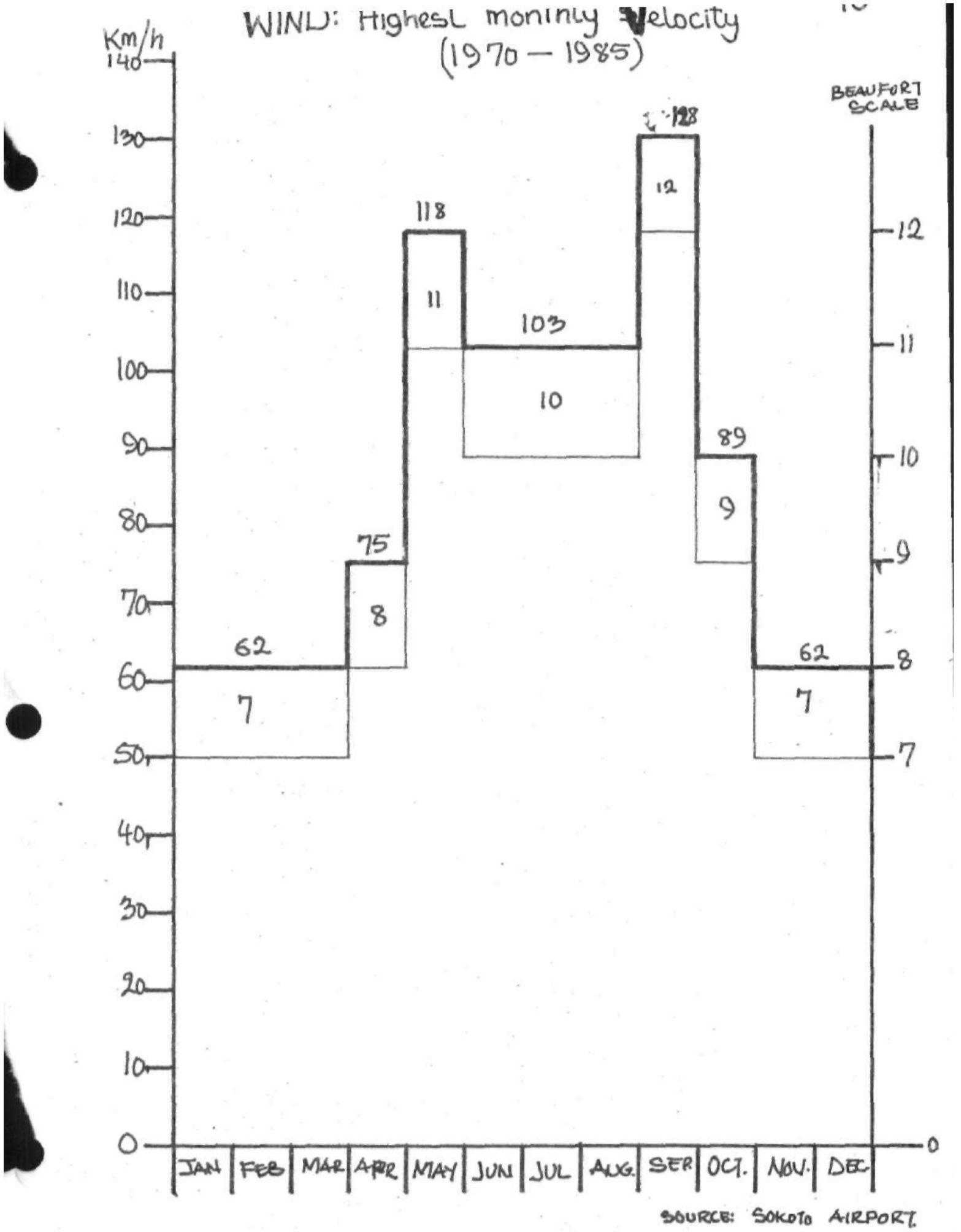

WIND: Highest monthly Velocity
(1970 – 1985)
Km/h
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
BEAUFORT SCALE
12
11
10
9
8
7
0
128
118
103
89
75
62
62
12
11
10
9
8
7
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG.
SEP
OCT.
NOV.
DEC.
SOURCE: SOKOTO AIRPORT.

Fig. 1.3

TABLE 1: BEAUFORT SCALE OF WIND FORCE - AS ADAPTED FOR LAND USE.

Force	Description	Equivalent speed 10m above the ground			
		Knots		km/h	
		Mean	Limits	Mean	Limits
1	Light Air	2	1-3	3	1-6
2	Light Breeze	5	4-6	9	6-13
3	Gentle Breeze	9	7-10	16	13-20
4	Moderate Breeze	13	11-16	24	20-29
5	Fresh Breeze	19	17-21	34	29-39
6	Strong Breeze	24	22-27	45	39-50
7	Near Gace	30	28-33	56	50-62
8	Gace	37	34-40	68	62-75
9	Strong Gace	44	41-47	82	75-89
10	Storm	52	48-55	95	89-103
11	Violent Storm	60	56-63	110	103-118
12	Hurricane	-	> 64	-	> 118

both winds directions occur about equally because of the secondary movements of the low pressure belt proceeding southward or northward. The wind really blows from southeast or northwest. The yearly windrose (Figure) shows clearly the predominant wind directions. East, South west and Northeast direction each predominate for more than 25 percent of the year.

Generally, the wind speed at the surface is low. High wind speeds occur only as gusts of short duration which are generally associated with thunder storm or line squalls. Most gusts occur at the beginning of the raining season in May and June; a secondary maximum is reached in September. Gusts are mos t frequent in the afternoon when most of the thunder storms form, and least frequent in the morning. Their main direction is between North and North west coinciding with the main direction of thunderstorms and line squalls.

Benjamin Franklin was the first to discover that storms moves with their inner own inner circle of winds and do not move in the direction of the wind they bring with them. This discovery was a landmark in meteorology.

Direction, speed, gustiness, and a frequency of calms are all important characteristics of wind, which is a very unstable parameter in most part of the world, fluctuating markedly within a matter of minutes or

hours and changes direction with passing weather systems. The variability of the wind is revealed in both its direction - which always refers to the direction from which the wind is coming - and its speed.

The wind over a region, their distribution and characterstics, are determined by several global and local factors. The principal determinants are the seasonal differences in atmospheric pressure between places, the rotation of the earth, the daily variations in heating and coooling of land and sea, and the topography of the given region and its surroundings.

It would be impossible to discuss here all the causes, or to investigate all the influences which are responsible for the complx and changing atmospheric movements, but it is important to point out that there are types of winds which occur, and recur, in place and time with some regularity. Some of the patterns of air circulation are those which stem from unequal heating at lower and higher latitudes.

The weather at any place, however can be affected not only by air moving under the influence of huge air masses, but also by winds of a more local origin which are typical of that area and are caused by a feature of the particular locality such as open terrain like the Sokoto airport site, mountains, a lake or sea.

Because wind affects ventilation, can be used for cooling, can cause driving rain, can carry dust and can require structure to be strengthened, the designer must determine the direction, speed and predictable daily and seasonal shifts of prevailing winds and analyse how best to utilise or block the positive and negative aspects.

2.1.5 Atmospheric Humidity

The relative Humidity in Sokoto range between monthly mean minimum of 11% in February to 81% in August. The term atmospheric humidity refers to the water vapour content of the atmosphere gained as a result of evaporation from exposed water surfaces and moist ground, and from plants transpiration. For any given temperature there is a limit to the amount of water that can be held as vapour, and the air's capacity increases progressively with its temperature. The vapour distribution is as a result, not uniform and varies parallel with the pattern of annual solar radiation and temperature average, but is highest in the tropical region and decrease towards the pole.

As relative humidity affects the behaviour of many building materials and their rate of deterioration, and vapour pressure affects the rate of evaporation from the human body, these two expressions of atmospheric moisture content, both of which vary greatly with the

RELATIVE HUMIDITY:

Mean monthly max.— min. Values
(1970 — 1985)

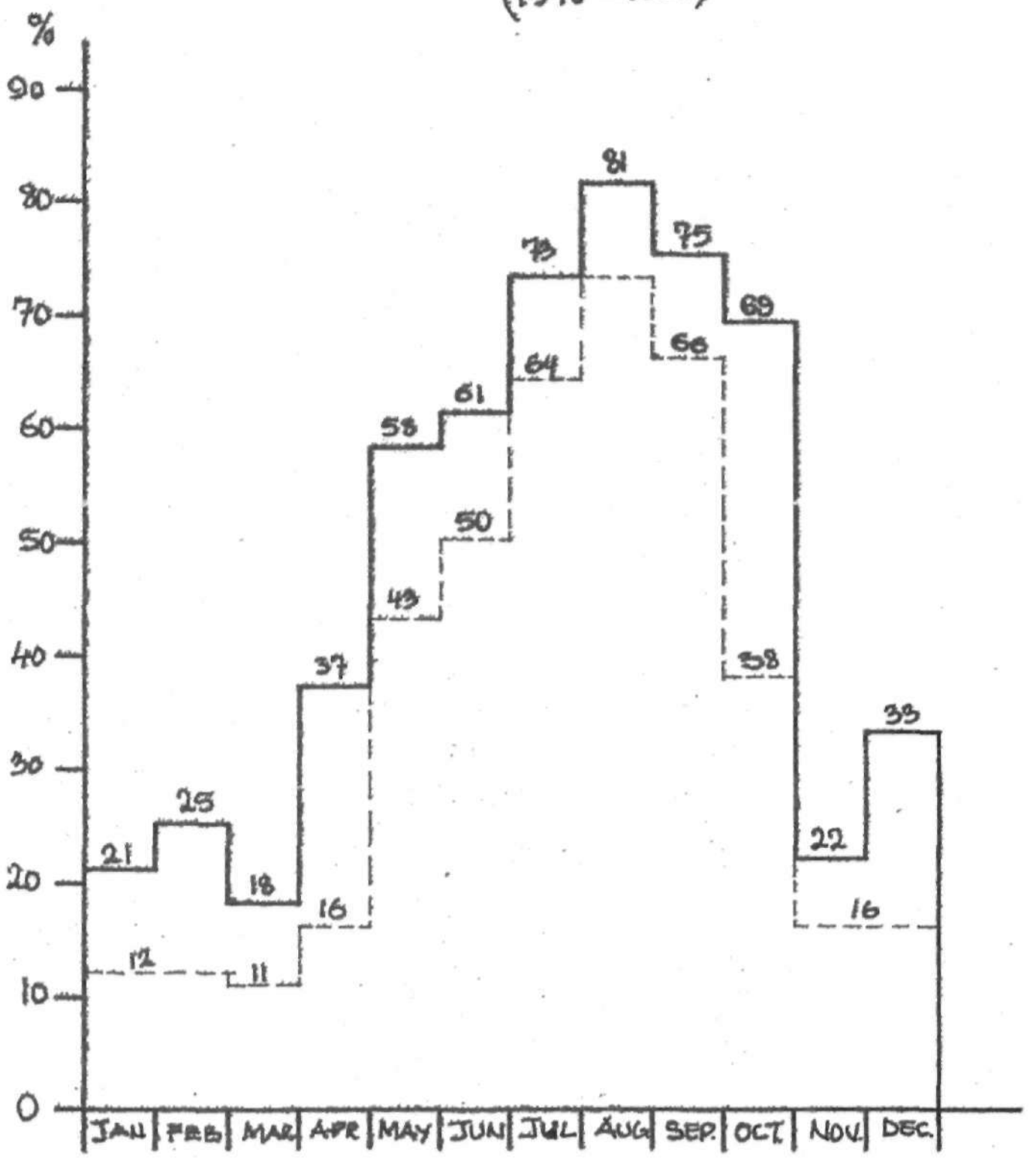


Fig. 1.4

place and time, are most important from the designers point of view. Whereas the diurnal differences in vapour pressure levels are small they are subject to wide seasonal variations and are usually higher in summer than in winter. Relative humidity of the diurnal and annual changes in air temperature which determine the potential moisture capacity undergo wide variations even when the vapour pressure remain almost constant.

2.2.6 Precipitation

The total average annual rainfall1 in Sokoto is about 732.5mm, most of which falls between July and September with highest amount of 306mm falling in month of August. Hardly any rain falls in the months of November, December, January and February. During this months, the worst effects of the cold, dust carrying Harmattan winds are experienced. The prevailing winds blow mainly from the East between the months of October and March with secondary winds blowing from North East. Between April and September (season known locally as damina) the prevailing winds blow mainly from South West direction while the secondary wind blow from the west. These South West wind usually brings rain along with it.

2.2 Architectural Aerodynamics

All of our buildings and structures, and we ourselves in the main, exist on the bottom of the immense

RAINFALL: Monthly max. & min. Values (1970 – 1985)

SOURCE: SOKOTO AIRP

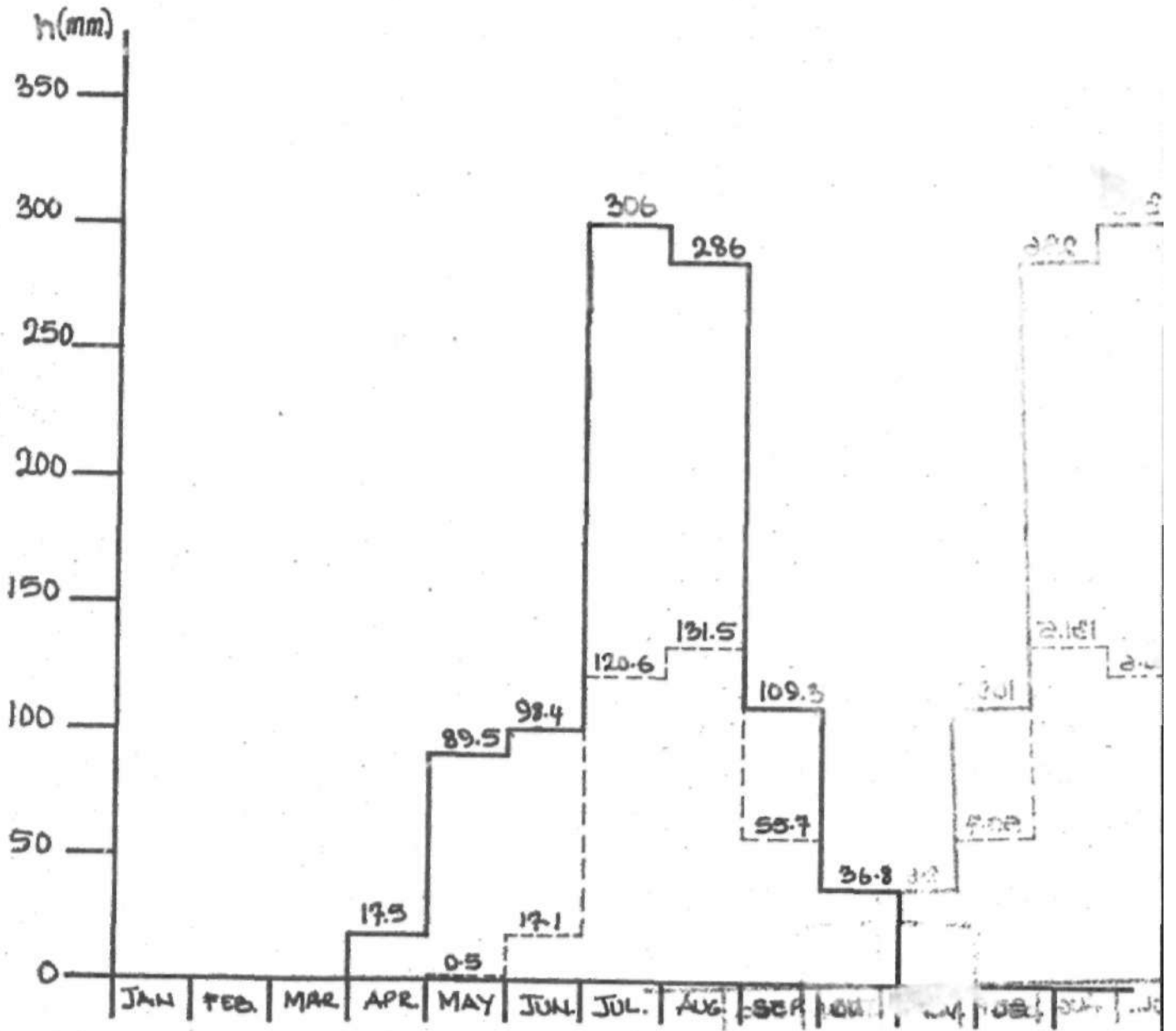


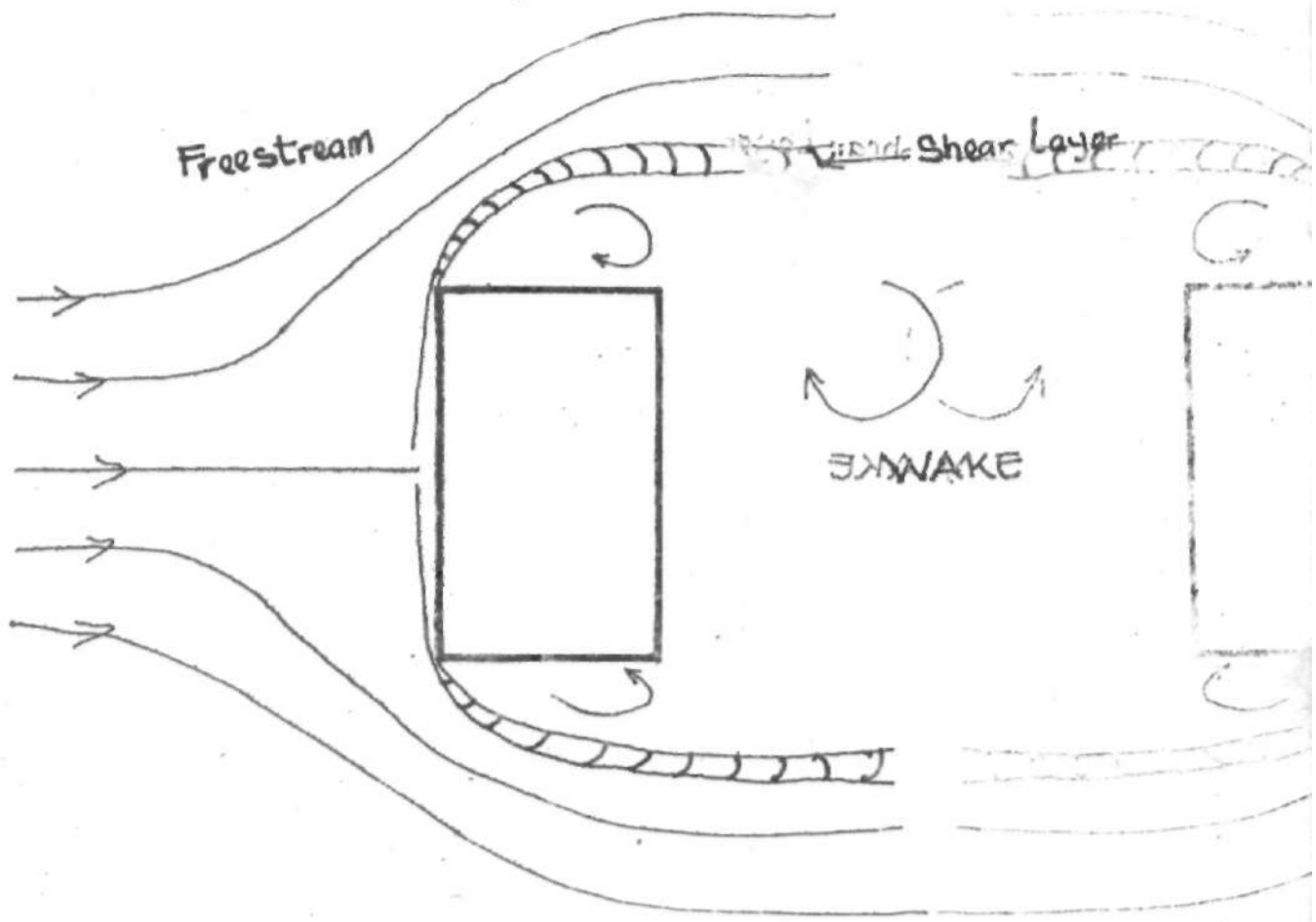
Fig 1.3

ocean of air many kilometres deep. Every exposed surface must sustain a static pressure which arises from the weight of the atmosphere above pressing down on and blanketing everything. Under normal still conditions, the pressure inside a ventilated building is the same as that outside, so that no net pressure difference or resultant force is experienced; we cannot perceive this pressure with our natural senses unless its magnitude changes appreciably from the normal.

2.2.1 Flow Fields

When air begins to move, its static press-flow over obstacles, which in turn change its speed locally, the local static pressure felt on the body differs from that of the ambient at large. It is the pressure difference of the local pressure from that of the ambient at large which is felt by the surface as producing a force. Airflow can be either laminar or turbulent. Laminar flow consist of air particles moving along smooth linear paths, or, as the word implies, air moves in stratified liminae or layers that indicate smoothness of flow. Turbulent flow is the opposite; that is, the air particles moves in an erratic and random fashion in all directions, breaking the smoothness of the flow.

Windflow near the earth's surface is turbulent, that is gusty, and unsteady. By unsteady it is meant



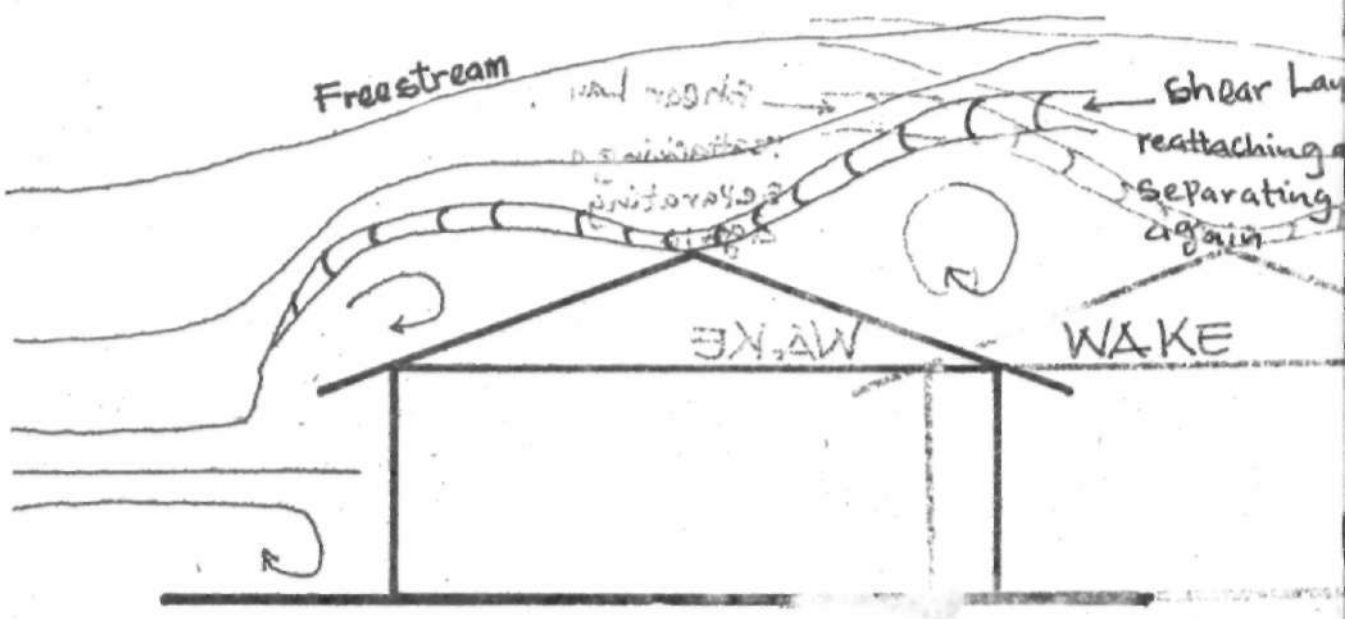


Fig. 2.1 EXAMPLES OF MEAN FLOW FIELDS.

that variables such as velocity and pressure at a fixed point in space are varying with time. Flow fields can be conviniently divided into three flow regions, as shown in Fig. 4.2.1, and can be described as follows:

(1) Freestream flow

The freestream flow is the flow ahead of and outside of the immediate influence of the body. Most importantly, this is the region where mean shear rates are negligibly small.

(2) Shear layers

Shear layers are regions of relatively high mean shear rate. A boundary layer of fluid through which the mean velocity changes from zero at a solid boundary to free stream velocity at the outer edge is a very important shear layer. When a boundary layer separates from a surface or at an edge, it becomes a freee shear layer separating freestream flow on one side from a wake or re-circulating flow region on the other side.

(3) Wakeflow

The wake region developed behind a separating shear layer contains low velocity (relative to free stream) re-circulating eddies, or vortices as they are sometimes called.

A boundary layer is that portion of the air where the speed of the air particles is modified by the

presence of a body for instance, a still building in flowing wind. We could say therefore, that the boudary layer is that portion of the air bounded inside by the body itself and outside by the edge of undisturbed air.

> "Prandlt discovered that attached to a body that is in relative motion with air, is a thin film of air that stays with the body. Each superimposed layer of air is retarded by friction, but less as the distance between laminae and body increases".

Note that the flow within the boundary layer can be laminar or contain areas of turbalance.

2.2.2 Basic Consideration

When a structure lies in an air stream, the air velocity is stopped on the windward side, accelerated at the sides, and creates an eddy at the rear. The pressure on the structure is therefore positive on windward surface and negative (suction) elsewhere.

Wind creates pressures or suctions on building surfaces, depending upon the angle of incidence between the wind direction and the surfaces. In general, pressures are created on windward surfaces that have an included angle of more than about 30^{o} between the wind direction and the surface plane. Suctions are generated on all parallel and leeward surfaces. Such suction forces can be considerable and become critical with respect to the fastening of the skin or cladding to the building frame. Light weight residential and commercial siding or curtain wall

\LM

WIND EFFECTS ON PLAN ORIENTATION

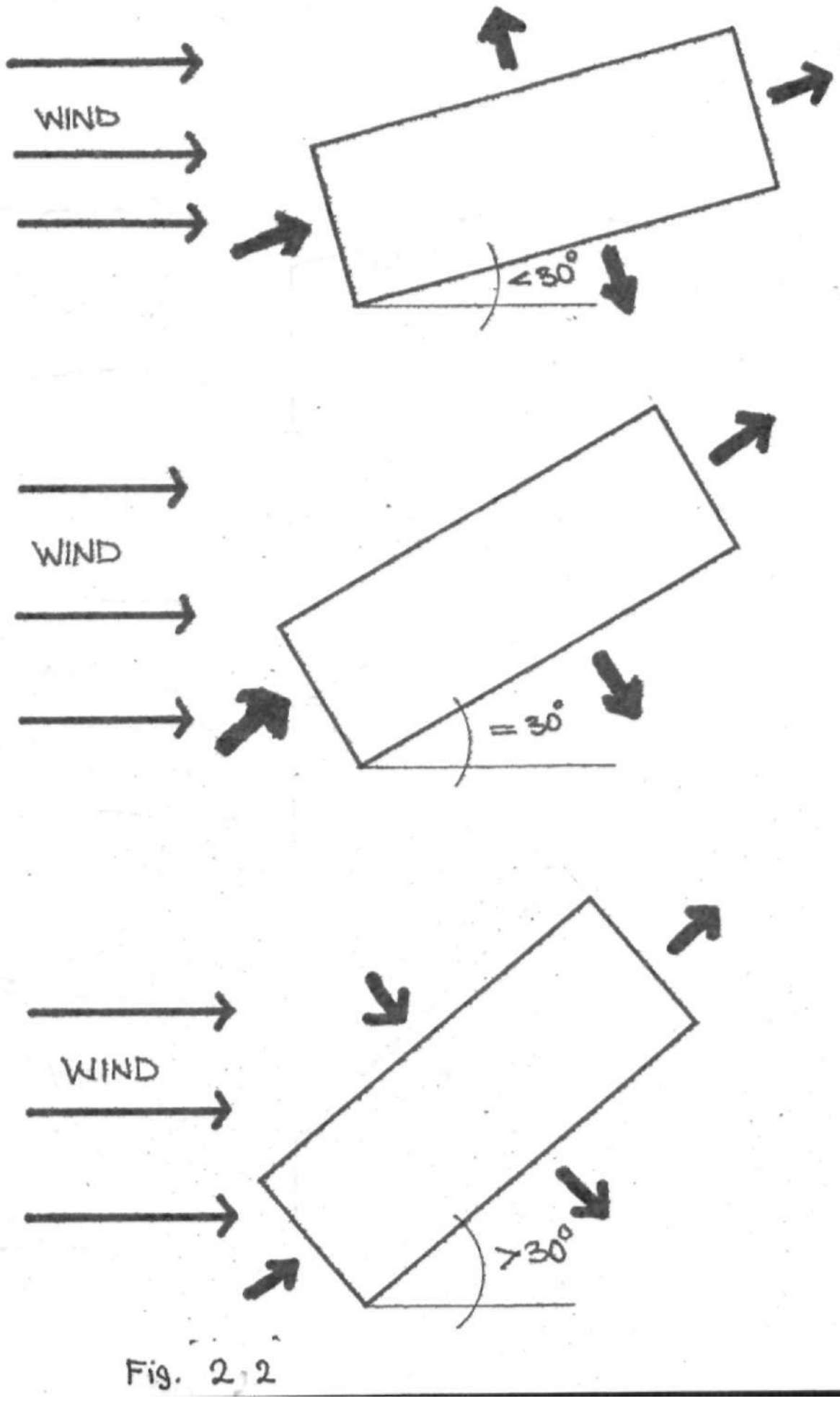
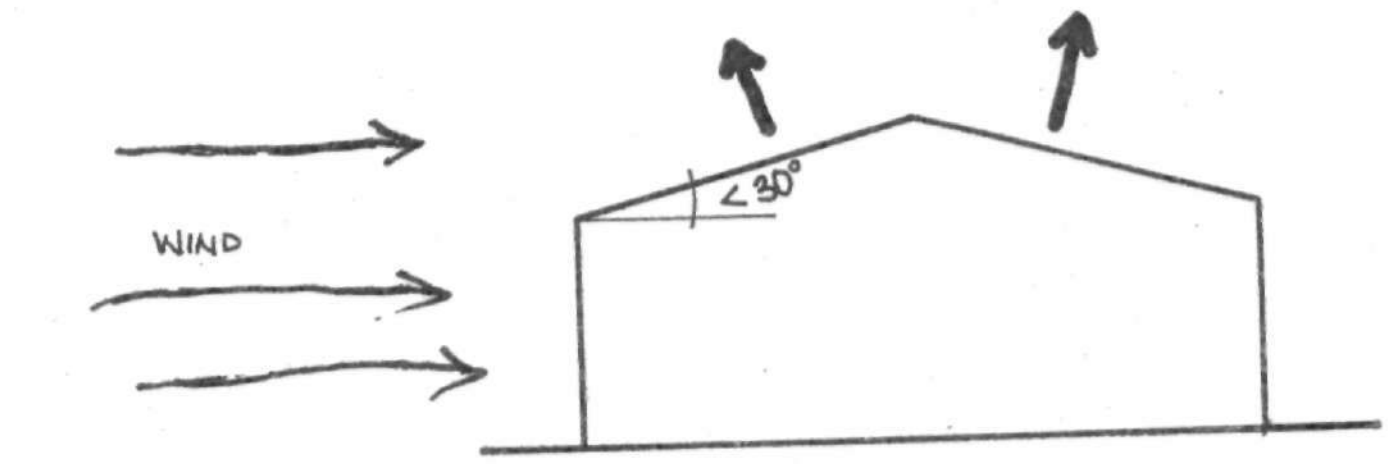
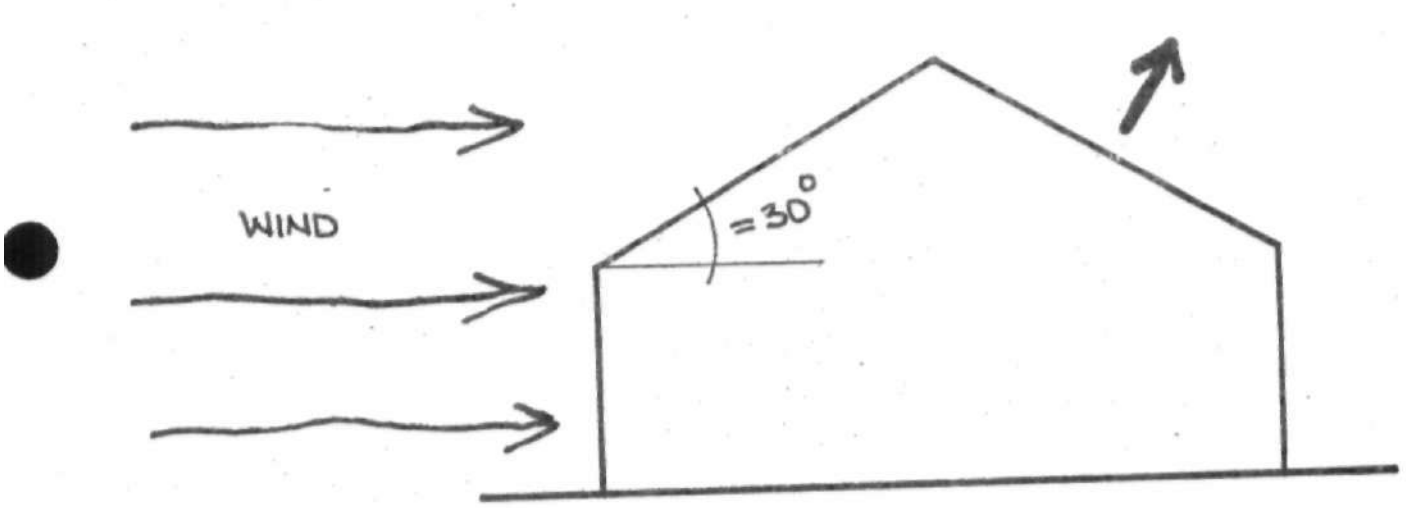


Fig. 2.2

WIND EFFECT ON ROOP SLOP





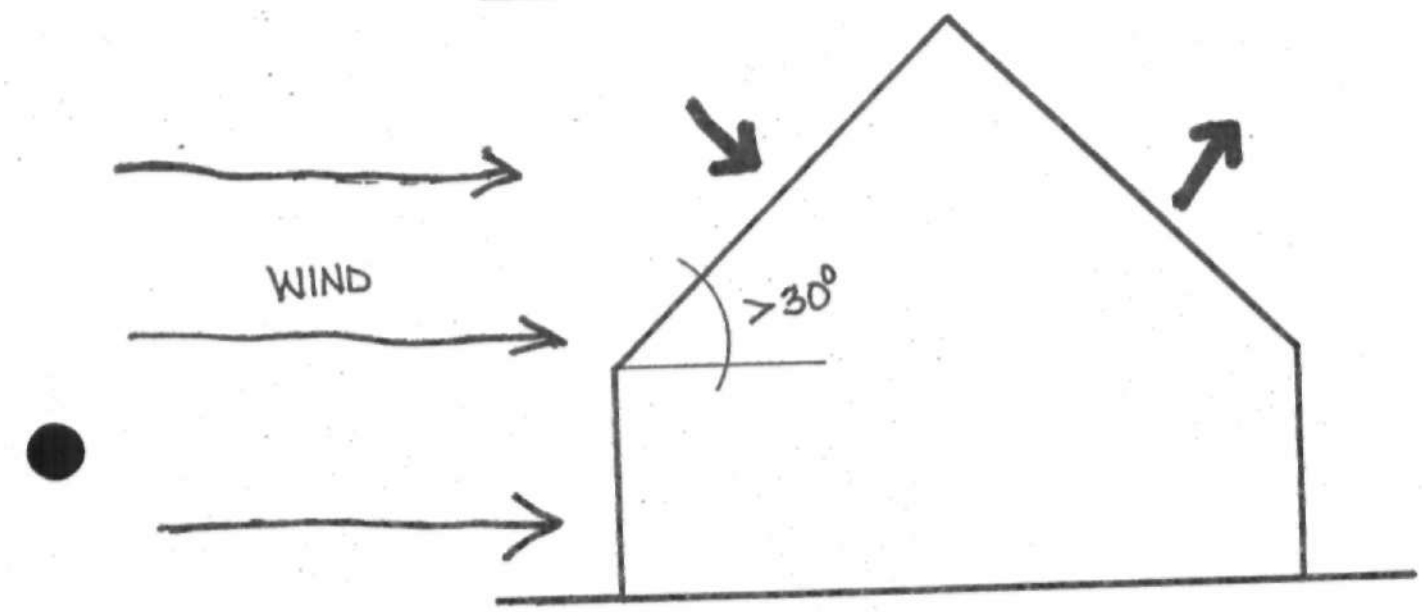


Fig. 2.3

components are often pulled off at building corners by the powerful "eddy" force there. Tornados and hurricanes can lift entire roofs from small buildings by airfoil action unless proper anchorage is provided.

2.3 The People

Although it can be argued and quite rightly too, that Sokoto is fast becoming a comsmopolitant centre. One should appreciate the fact that the indiginous customs and tradition still prevails and in most cases even emphasised, in most of the activities of the city. The majority of the inhabitants of the city are predominantly Hausa/Fulani and practice the religion of Islam. This is not suprising or unexpected, as Sokoto was the capital of the famous Sokoto Caliphate. In view of the facts stated above, one will be failing as a designer if he ignores them. Konya (1980) "any good building should relate and respond not only to the climate and other environmental conditions in its own area, but also to the traditional way of life of its users". The community's objective in the design of an important institutional building like the Airport, which is a gate way to their city is the building should render a unique and appropriate expression and impression of the community. And ofcourse be responsive to their needs relative to convenience, comfort, and personal requirements.

3. THE PROBLEM

3.1 Preamble

Windstorms have been known to claim the life of many people, killed by falling walls, flying metal roofing sheets or uprooted trees. And apart from damaging buildings and houses, windstorms are known to raise a cloud of dust so thick that it can stop traffic, force airlines to cancle flights and cause darkness during daylight. These storms that cause such disasters do happen seasonally leaving in their wake, extensive damage to lives and property worth millions of Naira.

Winds of high speed occur only as gusts of short duration which are generally associated with thunderstorms or line squals. Most gust occur at the beginning of rainy season in May and June; a secondary maximum is reached in September. Gusts are most frequent in the afternoon when most of the thunder storm form, and least frequent in the morning. Their main direction is between North and Northwest coinciding with the main direction of thunderstorm and line squals.

3.2 The Terminal Disaster.

The Sokoto Airport Terminal building was destroyed by a devastating windstorm in May, 1984. The roof, a space frame structure. Measuring 26 x 60m was anchored by 4 - 12mm bolts inbeded in each of the 18 reinforced concrete columns (12 x 12m grid) supporting the roof structure. The roof which has a 5^{o}



PLATE: I FULL VIEW OF THE DESTROYED TERMINAL BUILDING

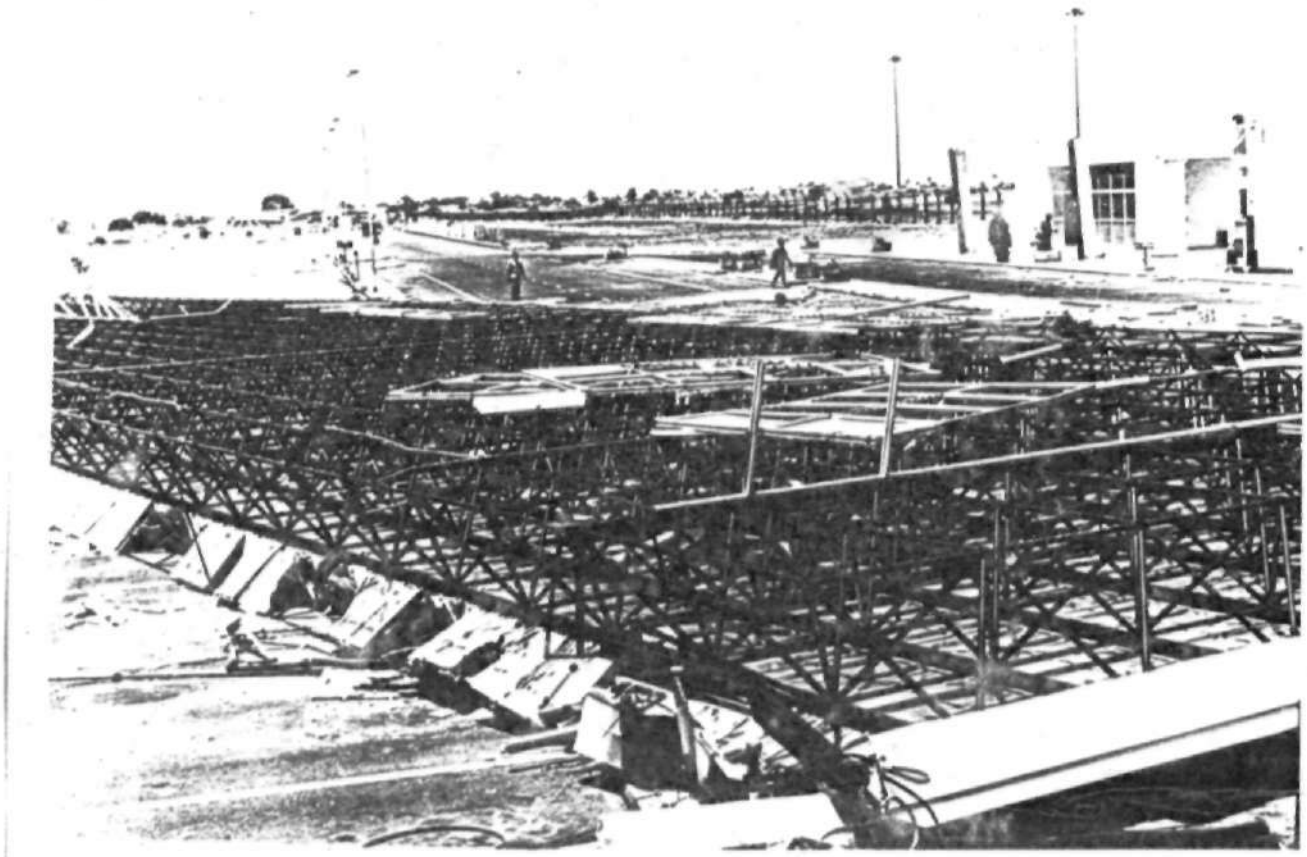


PLATE: II – CLOSE VIEW OF THE ROOF, EVERYTHING INTACT INCLUDING THE ROOFING SHEETS.

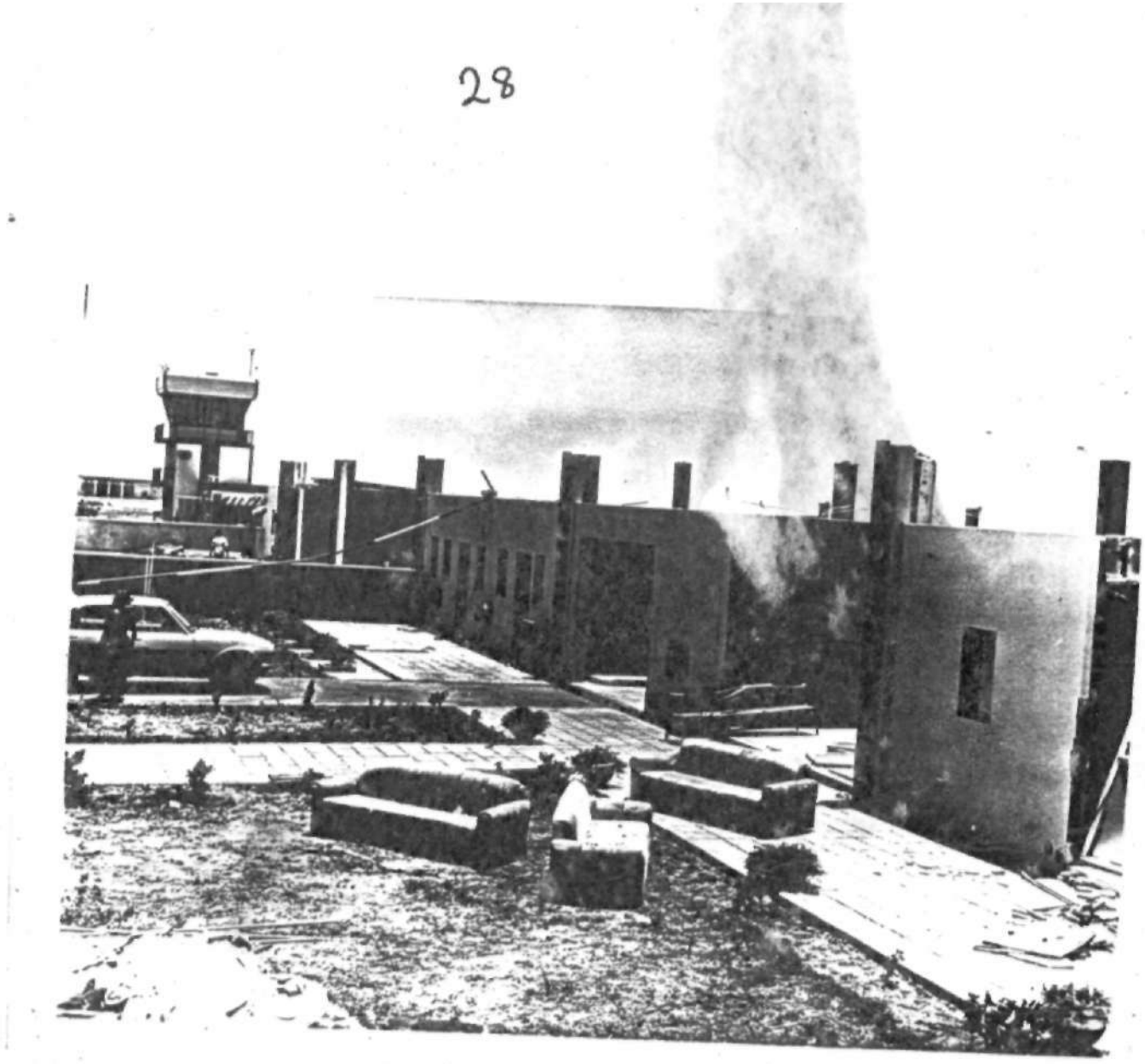


PLATE: III – VIEW OF THE TERMINAL FROM THE APRON



PLATE: IV – EXTERIOR VIEW OF THE INTERNATIONAL – DEPARTURE LOUNGE

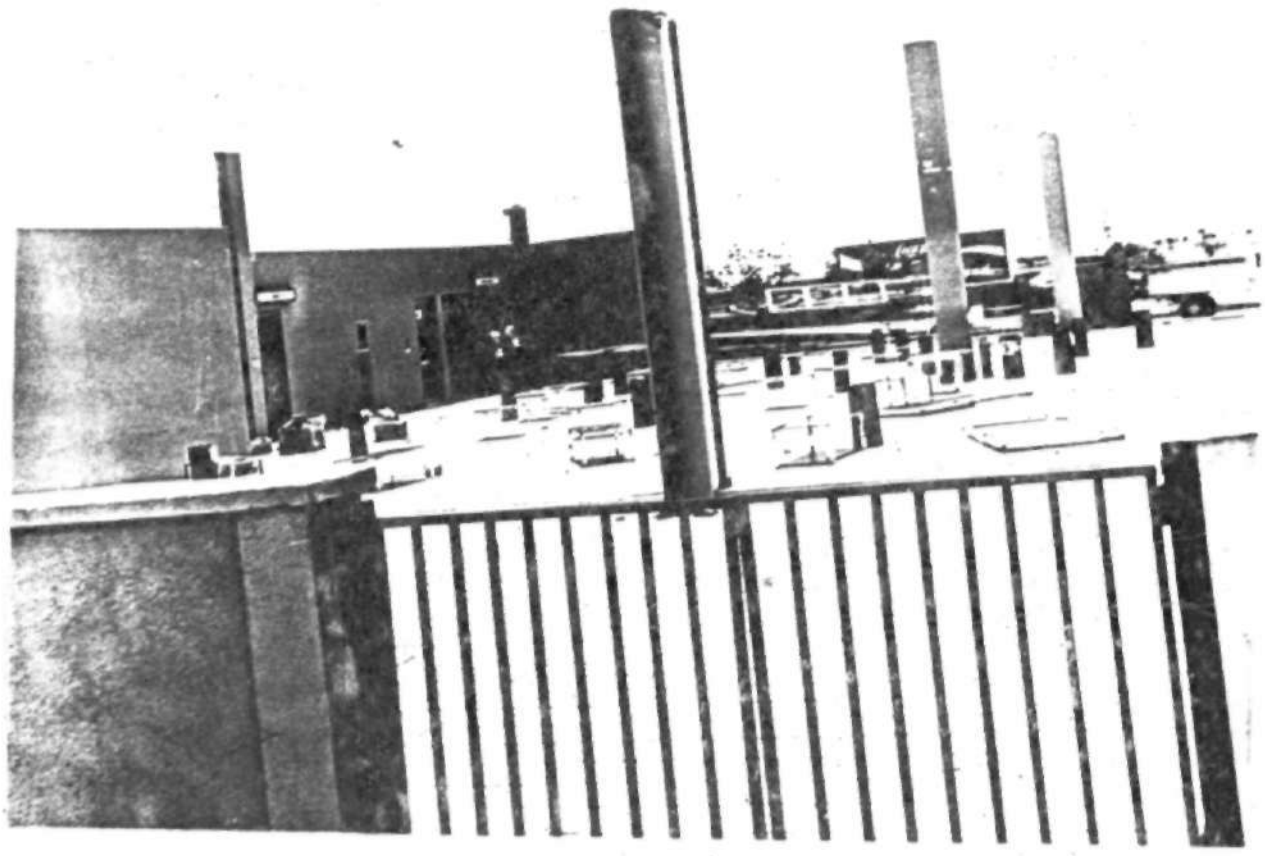


PLATE: V — VIEW OF THE WAITING LOUNGE



PLATE VI - ROOF INSULATIONS DESTROYED BY THE WIND

pitch (slope) was uplifted from the windward side and thrown backwards breaking some of the columns on the leeward side. Including all the wall claddings that are attached to the roof. On physical examination of the wreckage after the disaster, it was discovered that, neither the space frame structure nor the roofing sheets attached to it were damaged. Everything was in a very good condition. Plate II

Alot of things could have contributed, in one way or the other in the destruction of the terminal building. But, like in many other buildings around, that are destroyed by the action of wind. The most striking single factor was that the anchorage was designed to withstand the wind pressure that caused the destruction. Alternatively, the anchorage was not properly inbeded in the reinforced concrete columns, as to withstand the pulling force the uprooted it. The wind velocity on that fateful day might not be very high. As to cause the destructuion had the designers done the work properly. Although we have no record to prove this, since no accurate wind data for that complete month exist. One would expect the roofing sheets to give in first, had the wind velocity at that particular time been very high as to cause such a serious destruction.

The designers of this Terminal Building, The Netherlands Airport Consultants (NACO), a foreign consulting firm made use of a very low loading code of 0.5KN/M wind pressure for the roof. While the local code for Sokoto is between 1-1.5KN/M.

This provision is not very adequate, considering the very high wind speed that are recorded in Sokoto in recent years. Wind speed of more than 120KM/H which measure 12 - (The strength of a hurricane) on Beaufort Scale of winds has been recorded. During gust periods wind speed could exceed this limit, since it is difficult to record them unless they happen to pass over a meteorological station which is very rare. This brought us to the case of Awolowo's helicopter that was destroyed by wind storm on the same airport in 1983.

3.2.1 How it Happened.

To understand fully, how the terminal building was destroyed. Some understand of architectural aerodynamics introduced in chapter 2 is required. First we place our Terminal Building in the way of a windstorm. Pressure will be created on the windward side, suction on the leeward side and the parallel sides and a lift (suction) on the roof since the pitch of the roof is 5^{O} (Fig. 3.1). The terminal building roof structure has a free and open overhang which further aggravate the lifting action. The present of large glass areas on the windward side confounded the situation as some of the doors and windows might be left open or even destroyed by missiles driven by wind during the storm. In the event of this happening, another pressure will be created under the roof tending to push it upwards. This will contribute tremendously in the further upliftment of roof structure.

FORCES ACTING ON DIFFERENT SURFACES OF THE TERMINAL BUILDING.

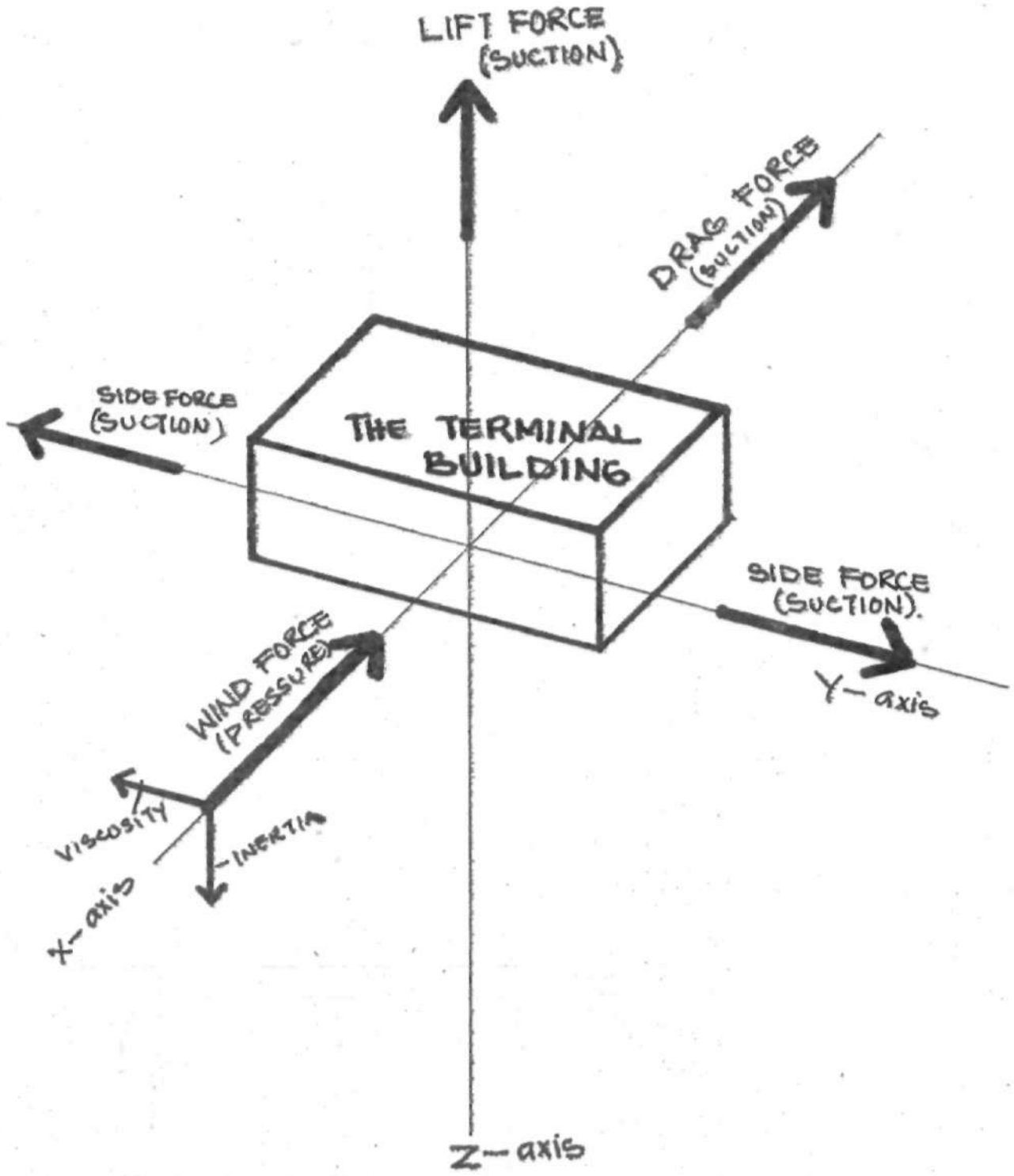


Fig. 3.1

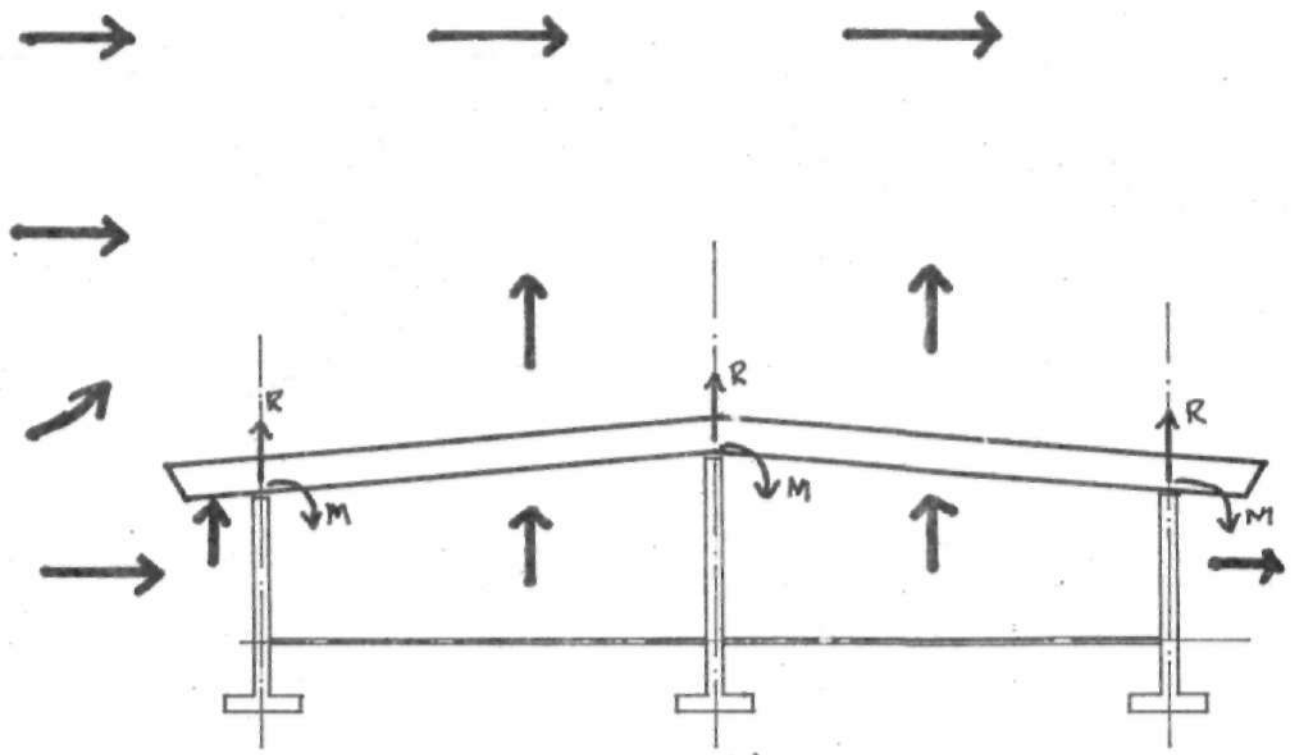


fig. 3.2(a)

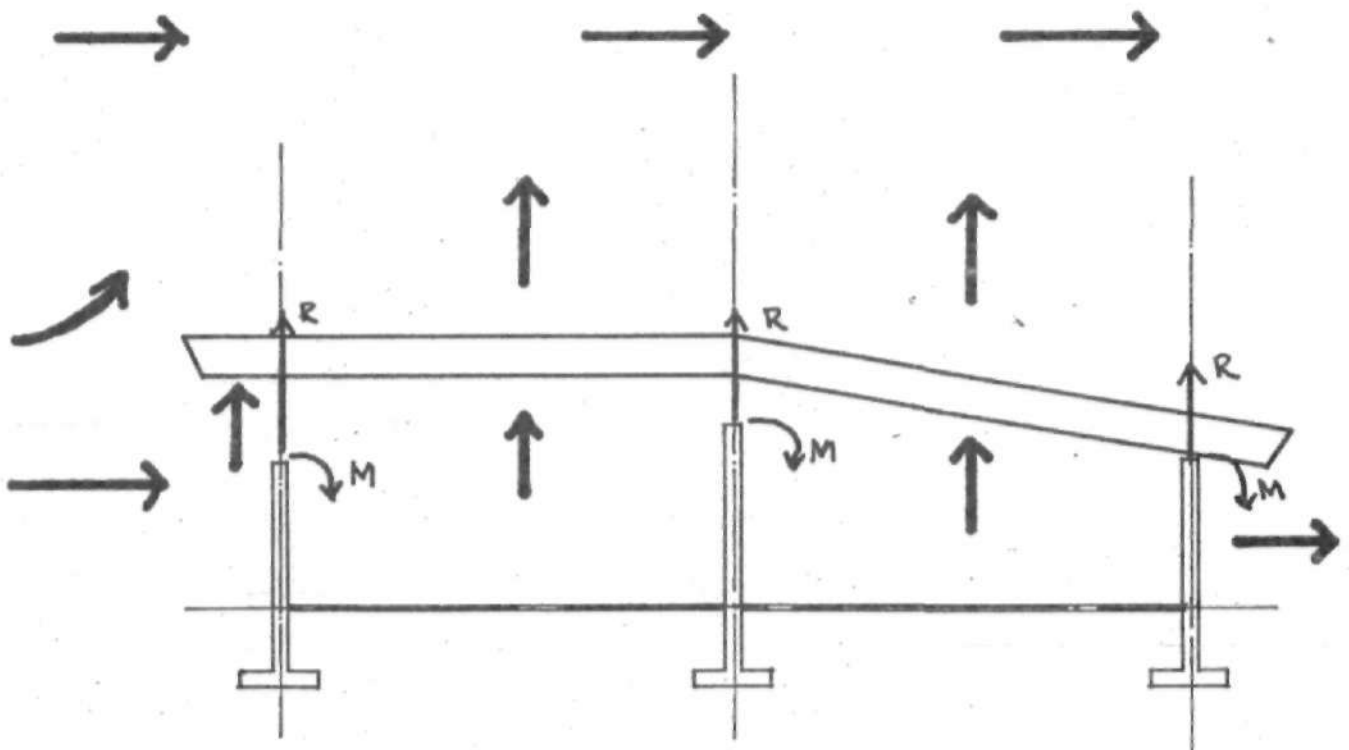


Fig. 3.2(b)

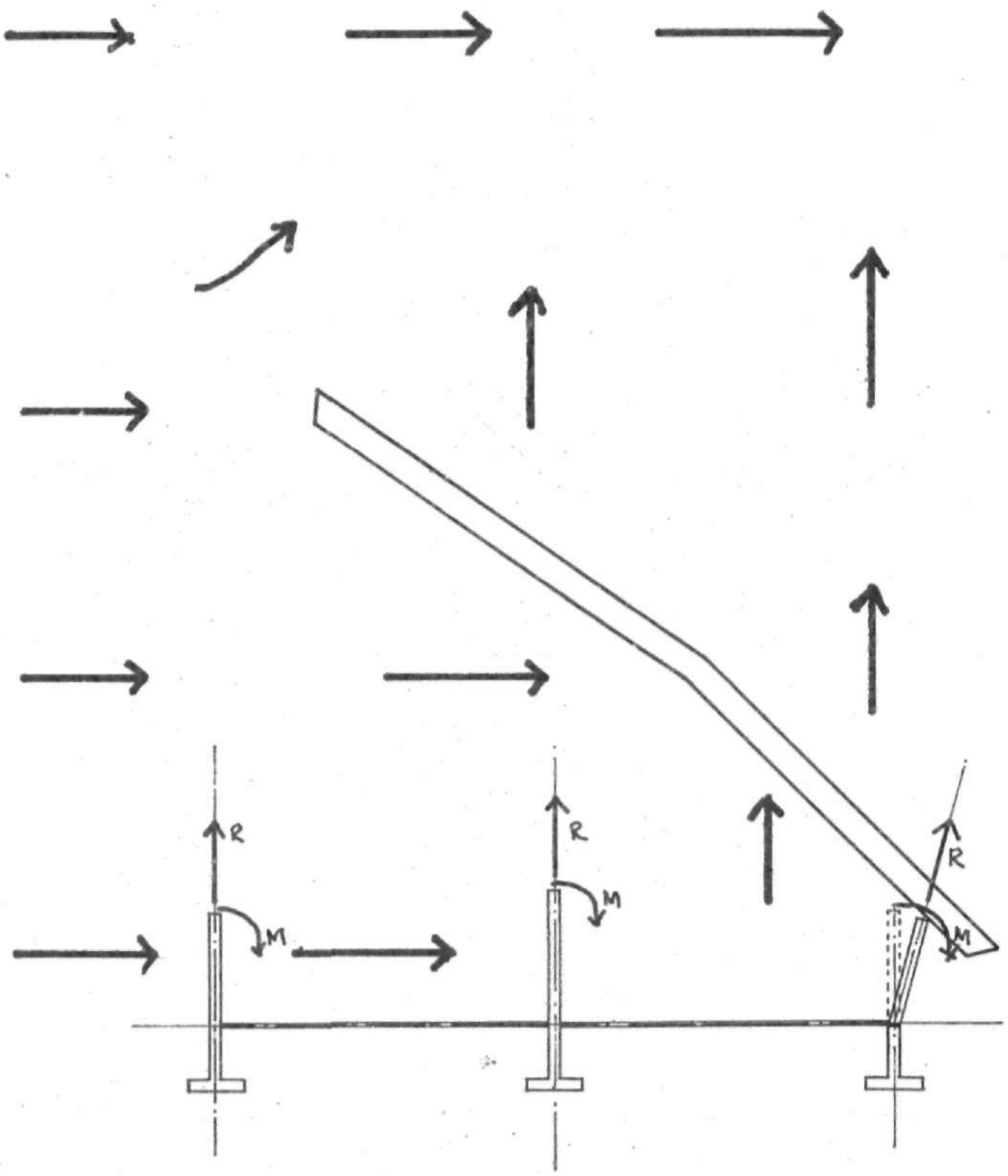


Fig 3.2(c)

We now have a combination of suction on the top and a push (pressure) from the bottom of the roof (Fig. 3.2a). Until eventually the anchorage on the windward side fails. This side then start moving upwards, while the middle and leeward side is still active (Fig. 3.2b). At this stage the loading on the remaining anchorage particularly those in the middle will increase tremendously until eventually they fail too. This will allow the roof structure to be raised higher by a combine action of suction from the top and pressure from below. Until it finally rises to a hight that the free streem will act on it directly. It is at this point that some of the columns on the leeward side got broken (Fig. 3.2c).

3.2.2 Structural Failure.

The process of uplifting the roof structure has resulted into some structural damage in the Terminal building. First the columsn, which by their slandeness ratio also classified as long columns, are seriously weakened if not completely damaged. By the action of pulling out the anchorage from the column tops. This single act will send very tremendous shockwave through the columns down to the foundation which will similarly be weakened or even damaged depending on the intensity of the shock. Secondly, there is the lateral force of the wind itself which tend to overturn the structure and throw it backwards. This result in a sought of turning movement trying to break the columns from their base.

The wind act on both the roof and the building structure at the same time. Therefore all the loading were being carried by the columns which transfer the same to the foundation. This is an unusual loading and the foundation is not designed to carry it. Thus, resulting in the failure of both the columns and the foundation.

These two actions of the wind - the pulling and bending are responsible for all the structural damage done to the Terminal Building. The structure could have been saved, if the footing were rigidly fixed by a ground beam and the columns given adequate wind bracing. The destroyed Sokoto Airport Terminal Building is indeed an architectural failure. The ruin should be pulled down to give way for a new Terminal Building which will take local climatic conditions into consideration. Anything short of this will be calling for another disaster. Hassa (1983) the then Airport Manager, in his annual report made this observation "The design of the airport building and utilities are not suitable for the climatic condition of the area. This means year in year out, the same problem of civil maintainance are posed - the blowing off of almost 50% of the roof tops; these in turn expose and affects sensitive mechanical, electrical and electronic equipments". That was in his 1983 annual report. Bnd barely four (4) months later the roof of the terminal building was completely removed and the building destroyed.

3.3 General Trend.

Part of the task this thesis set itself to achieve is to findout what precautions are necessary, when building to protect our structures from hazardous windstorm. This include wind-induced actions and wind manifestations that have been discovered to affect the success of architectural and environmental design. Bearing in mind that structural response of buildings varies according to the forces involved.

Most of the building structures, errected in this region, can be classified as architectural failures, because, they did not take wind effects into consideration in their design. It is very pathetic to see the way and manner our primary schools, rural clinics, market stalls and even houses were constructed. The realities of our built environment painfully a shame. Though not completely hopeless. The truth of the matter is we do not really understand our own environemtn. And of particular interest here is the behaviour of wind, as it affect building structures. It seems, we have forgotten how to design with nature and tends to ignore the climate while we become preoccupied with forms currently fashionable - The modern building. Our designers must have a very good knowledge wind behaviour. This includes its speed, direction, gustiness and the frequency of calms. These are very unstable parameters fluctuating markedly within a matter of minutes or hours and changes direction with passing weather system. All these must be determined and then analyse how best to utilise or block

the positive and negative aspects. This has been discussed in detail in Chapter 2.

The most striking observation among the destroyed buildings however, is that, most of the destructions would have been avoided if proper anchorage were provided to the roofs of these buildings. The common practice is to fix the roof structure to the last two courses of blockwork at certain intervals. And even where a concrete ring beam is provided, they simply use steel wires to anchor the rafters to the beam, which will eventually fail after a strong wind. They will then come to the rescue by constructing another course of blockwork on top of the roofing sheets. This uncivilised practice beside making the building j looks awful, is also dangerous. As these blocks can be blwn down by strong wind, and cause serious injury or even death ot people around. Building, whether completely destroyed or partially damaged, are probably the highest contributors to missile attack. Roofs and walls produce debris such as timber pieces, boards, nails, blocks and metal roofing sheets. This last item, in particular is extremely dangerous. The major individual cause of death and injury is, infact, the corrugated sheet metal panels popularly used as roofing material. These become deadly missiles during storm, cutting like razor blades flying in the air. In addition, there are similar examples of metal sheets used in buildings for general cladding or roofing, which become wind borne when the panels were detached or ripped from their anchors. This type of material is also used as temporary structures especially in squatter settlements.

CHAPTER 4

4. GENERAL SOLUTION

4.1 Poor Building Performance

It is very important for the designer, before getting involved in the business of building construction, to form an understanding of the fabric's functions as a whole. The present situation of poor building performance in an age of unprecedented technological expertise can be traced partly to the general lack of an overall, explicit design philosophy or system to govern and give guidance to, the multitude of detailed decisions which shape the evolving building design.

Such a situation could not exist in design fields where the price of failure is disaster. If a supersonic aircraft, for instance, were to be designed without the discipline of an overall set of controlling functional requirements against which detailed decisions could be tested constantly, the resulting catastrophic would be spectacular. In the case of buildings, the consequences of haphazard decision-taking are less newsworthy. The building merely causes misery to its inhabitants by leaking, overheating or even left roofless. These inconveniences are more easily ignored than air disasters, so architects tends to disregard the complaints of building users. And the problems mentioned above are with us constantly.

4.2 Need for Environmental Control.

Why does man build? Most of the reasons can be summed up in the phrase "environmental control" . People need shelter from wind, sun, dust and rain. They require certain conditions of temperature, humidity and air movement if they are to be physically comfortable. They require security and, at certain times, privacy. They like views of the world outside; they dislike excessive noise; they desire certain condition of light, and so forth.

The main purpose of building has always been to provide an environment that will satisfy these needs. It is our success in controlling or modifying the natural environment that will enable mankind to progress from an existance of bare survival to one of ease and comfort.

Many of these needs will not necessarily be quantifiable (for example privacy). But there are several kinds of psycophysical needs which can, in principle, be translated into quantified environmental standards. For instance, appropariate physical condition for thermal comfort could in many cases be specified. On this basis, specification can be developed for the environmental performance required of the building fabric - for example, thermal insulation value and capacity of the external envelope. The ultimate standards to be realised are those which will provide reasonable comfort. This will involve not only resistance standards for elements of buildings but a proper balance between these and the

corrective effect of energy installations.

It is not suggested that all the desired psycophysical qualities of the internal environment can be fully specified; in detailed way at present. Probably it will never be wholly possible. The present lack of adequate data for this purpose is not only due to an insufficiency of research efforts. What is more distressing is the ease with which this type of research has tended to be divorced from the reality of building, thus leading to unreliable results.

4.3 The Roof.

4.3.1 Climatic Problems

Whereas external walls are the building elements most closely associated with the separation of spaces (inside from outside; public from private) and with the creation of street-scapes, the roof is the element most closely associated with the concept of shelter. In otherwords 'not having a roof over one's head' is equivalent of been homeless.

There is good reason for the close linguistic connection between roofs and shelter. In some climates, walls can practically be dispensed with as sheltering elements, or reduced to forms as elementary as screens. Even in more rigorous climates they usually do not need to come up to the performance standards required of roofs.

On the other hand, roofs are an essential element of shelter and have to perform an impressive range of functions. First, a roof must keep out rain which might be acompanied by

driven wind. Secondly, a roof has to give protection against the sun not merely in the sence os screening solar radiation, but possibly to provide thermal insulation; resist the destructive effects of radiation and alternate exposure to heat and cold. And finally, in a climate like ours, a roof most withstand the pressure of wind.

4.3.2 Structural Problem.

In addition to the function of exersing environmental control, the roof is required to defy gravity by spanning across space. This may not be thought of as a major technological challenge in the present era of reinforced concrete and easily fabricated timber or metal trusses. But for the local builder, relying on materials such as mud, stones, tree trunks and so forth, the problem is there - particularly if the space to be spanned is large and substantial loads therefore are involved.

In areas where timber is available, the simple traditional solution was the sturdy horozontal timber beam. This is both structrueturally effective if span is not excessive, and not dependent on advanced craft skills. It is a good solution to many areas with dry climates where flat roof can be used. Prevelance of rain, however, will necessitate a pitched roof, this will result in more sophisticated forms of construction requiring more advanced craft skills. The most inportant thing to note here is, where the flat roof is the most appropriate solution, well and good. But it should not

be taken for granted. And what ever the indicated solution it requires more careful design/ Than it usually gets. This applies structurally and functionally.

Having said all this, let us now go back to the main issue - resistance to wind. But, how can we evaluate the effects of storm on different building types? It is particularly helpful in this respect to use results collected for structures exposed to nuclear blasts. A certain analogy existing between storm force and nuclear explosions makes this possible. Infact, although nuclear blasts and storms are different phenomena, several aspects of the forces involved are comparable, such as the drag force of the wind and the pressure differential on opposite sides of walls, and roofs.

On 17 March, 1953 and 5 May, 1955, nuclear test were conducted (Plate VII). Buildings of various types were located at different distances from the centre of the explotion inorder to evaluate damage caused by a variety of loadings. From the analysis of the damage, it is deduced that wood-framed dwellings collapse first, ordinary masoury construction differs a little from wood-framing in overall strength. On the other hand, seismic-resistant structures consisting reinforced concrete panels and reinforced concrete block walls can tolerate extremes of pressures with damage limited to doors and windows.

This test clearly indicate that buildings of ordinary construction are vulnerable to forces similar to those

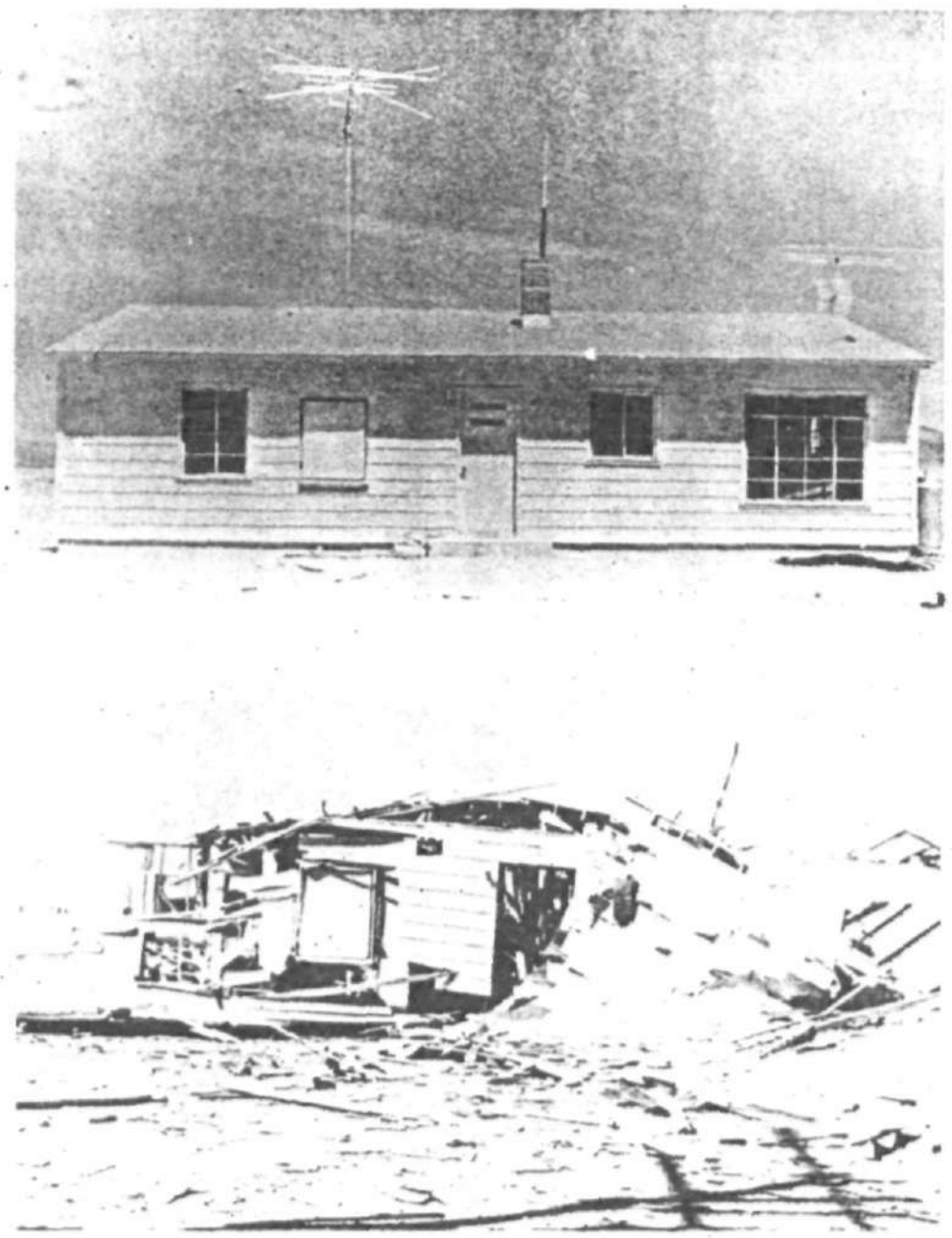


Figure 2.49. Structural testing on houses consisting of different construction types conducted in the Nevada Proving Ground in 1955. (Courtesy of U.S. Atomic Energy Commission) *a*, Rambler-type house before testing. *b*, After testing. Overpressure: 5 psi = 720 psf.

expected in storms. However, the use of materials such as concrete, and the adoption of special techniques such as those used for earthquake-resistant structures, improve tremendously the strength of the buildings.

4.3.3 Wind Action

Roofs and ancillaries of buildings are subject to the largest suctions and presures, and they also present the greatest variations in design.

Problems encountered are:-

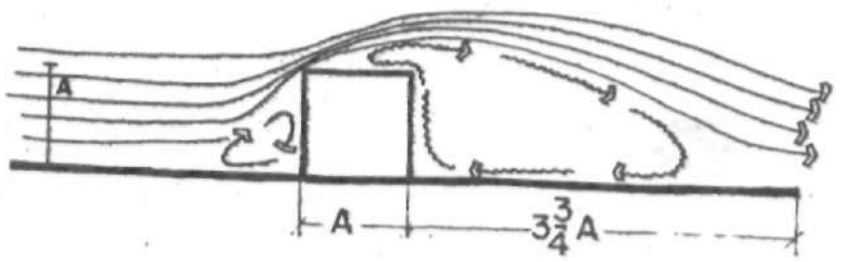
(i) forces on flat, pitched and circular roofs.

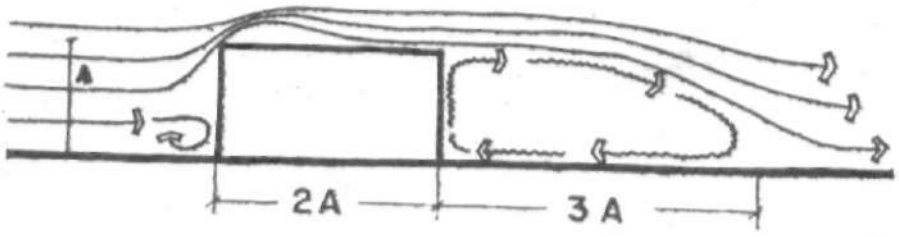
(ii) roof ventilation of interior spaces.

The suctions on roofs may be divided into three regions, the corners, where very high suctions may occur, roof edge and ridge and the main roof. The variation of suction at the corners of roofs of various pitch and buildings of different size indicates maximum suction at pitch angles between 0° and 15°. Suction at the corners of hipped roofs may be high, even at high pitch angles. For a gabled roof, maximum suctions occur at the windward bottom corner, except with a side wind on a 40° pitched roof. There is an equally high suction to the lee of the leeward diagonal ridge.

There are various ways of alleviating high local suctions, by vortex spoilers. Tests on a particular shape of flat roof indicate that a 1-in. Parapet reduces the maximum suction coefficient from

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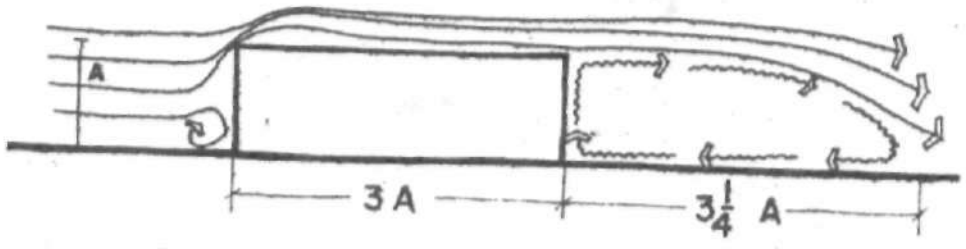


Figure 4-38 Length of leeward eddy area for flat-roof building.

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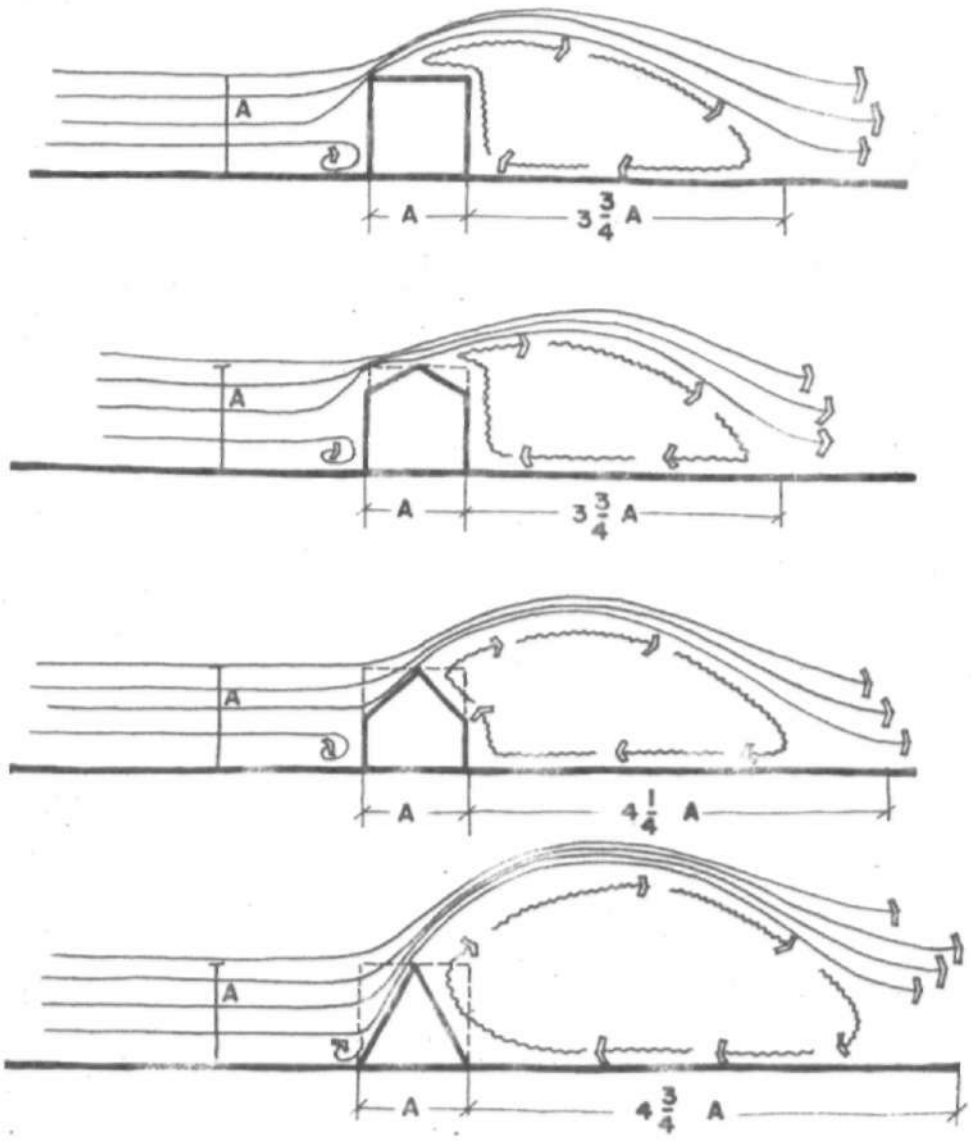


Figure 4-24 Length of the leeward eddy area for buildings with different roof pitch, having a depth equal to the height.

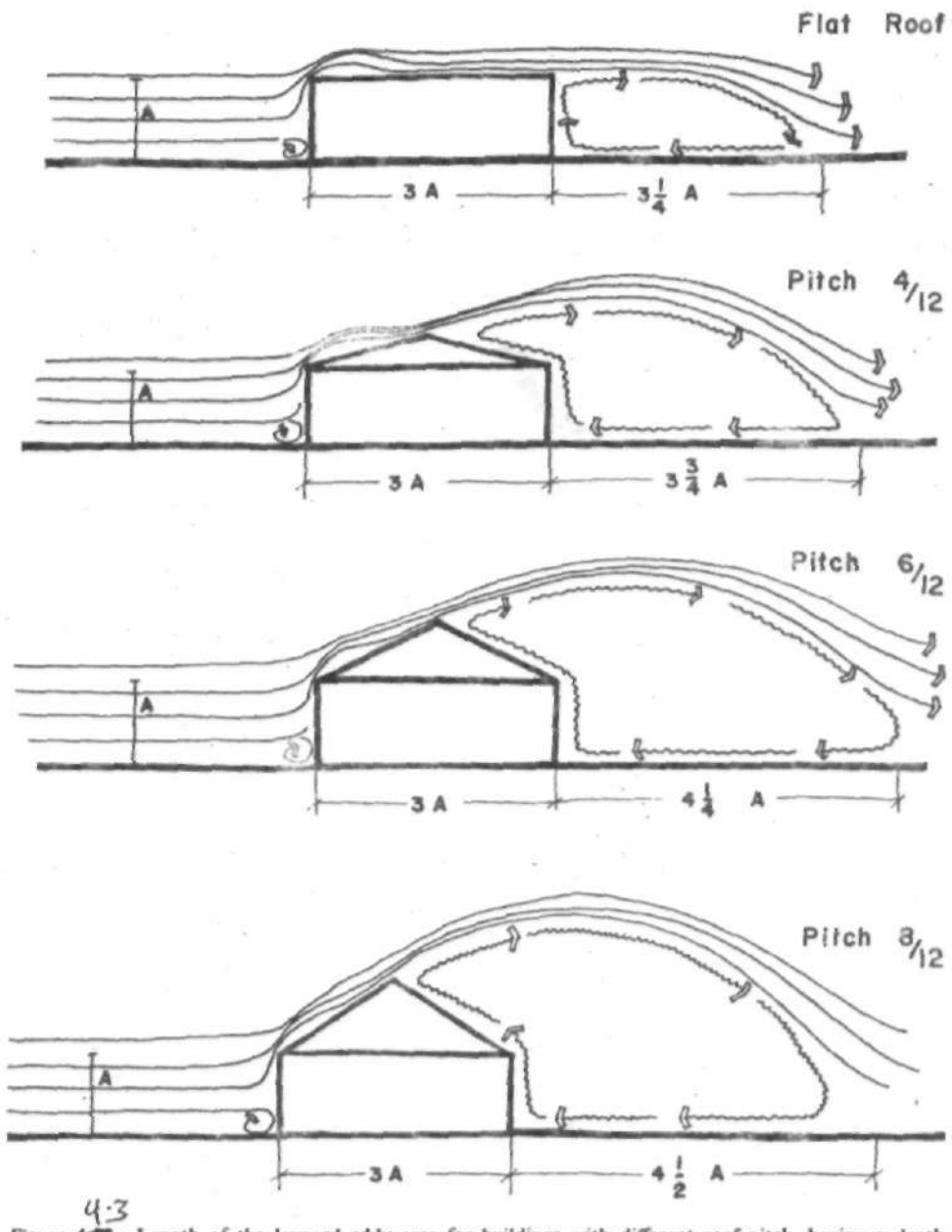
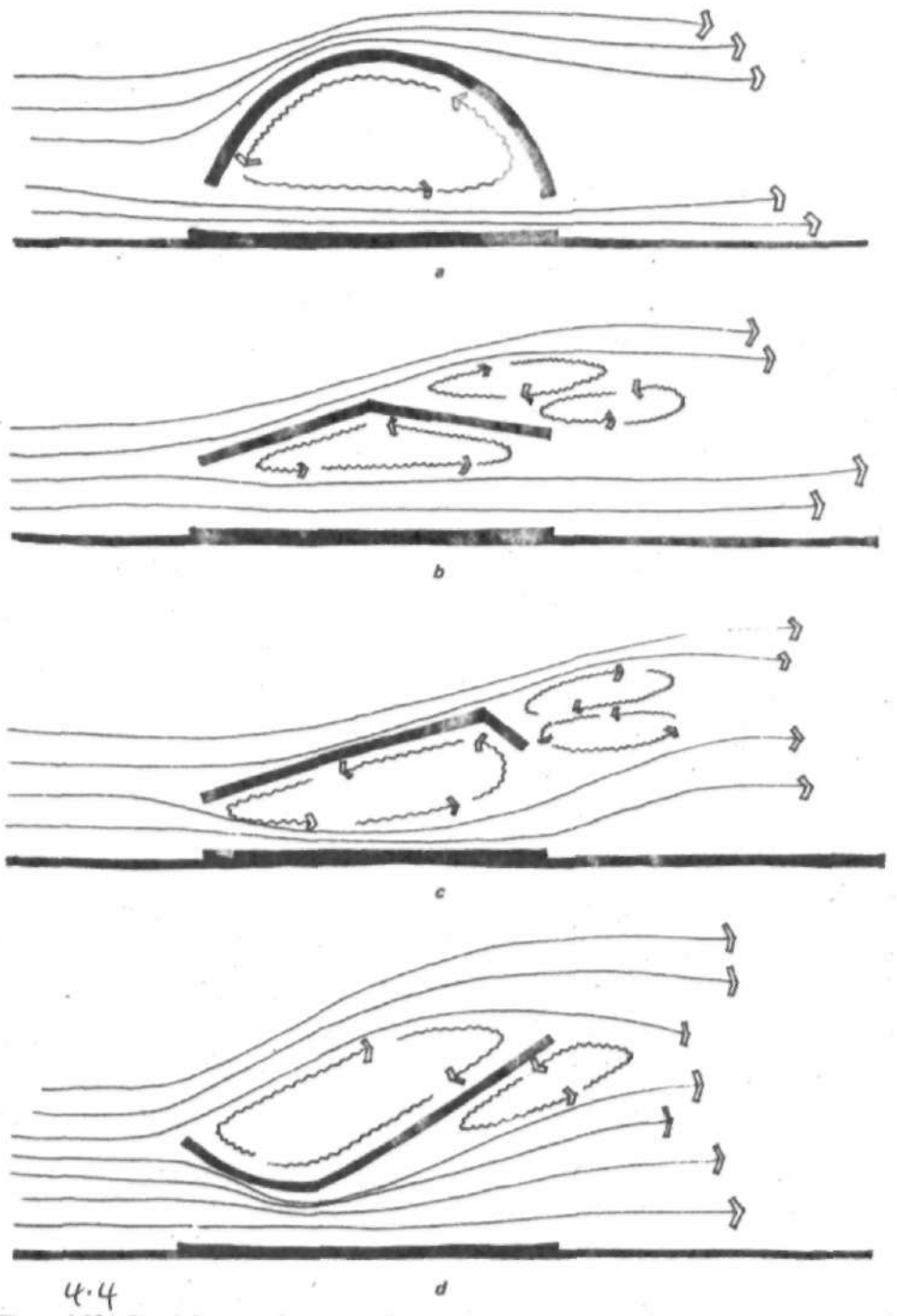


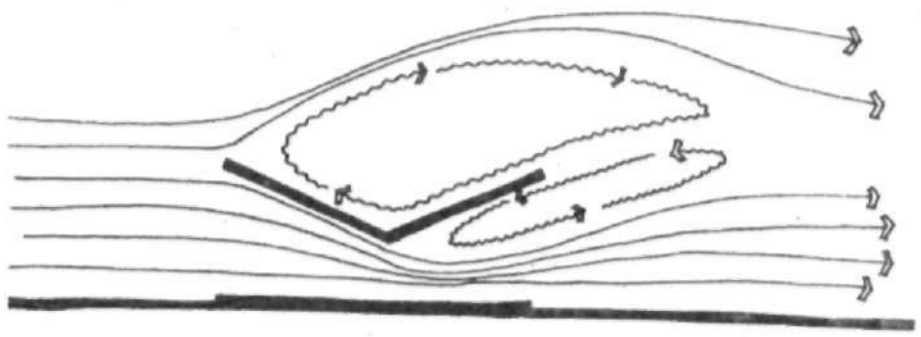
Figure 4-3 Length of the leeward eddy area for buildings with different roof pitch, having a depth equal to three times the building height.

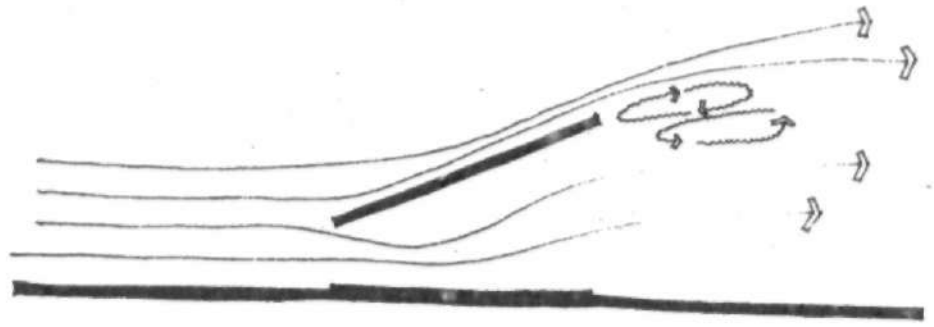
Open structures exposed to the wind separate the streamlines so that the air flows not only over and around them, but also under them. Convex, flat or concave roof configurations generate zones of eddy formation over and under the structure and deflect wind in various ways, as illustrated in Figures 4-23a–g. As the air is deflected, the velocity also varies, increasing as the streamlines converge and decreasing as they diverge and their spacing widens.



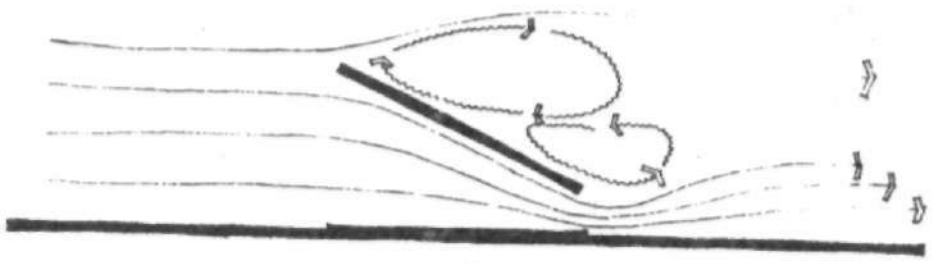
4.4

Figure . The deflection of the streamlines gives a visual representation of the airflow over and below open structures. (As the spacing between the streamlines increases, the velocity decreases; on the other hand, as the spacing gets smaller, the velocity gets higher.) Velocity changes and eddy zones produced by the interaction of wind and structures are shown for various configurations.





f



g

Figure 4.4. Continued.

4.4

+S.5 to -0.6, by simply lifting the corner vortex away from the roof surface. It also appears that a decrease in roof overhand decreases the corner suction. In a low building with a large roof surface, such as a factory, wall openings on the windward side wall provide a positive internal pressure which, when added to the high suction on a low pitched roof, creates large forces at the edges of the roof and at the central ridge. The central force can be reduced by inserting a ridge ventilator in the roof, which has a triple role of minimizing the ridge vortex and suction, lowering the internal pressure and ventilating the inner space.

Since the results of investigations conducted has shown that most of the disasters under study were caused by certain building failures. Structural oscillation are rarely catastrophic at once. Normally, many oscillating cycles occur before the structural member breaks, and the failure is then as a result of fatigue. If the peak stress at each cycle is low, there will be many cycles before failure and at higher peak stress level there will be fewer cycles. The designer should therefore give special attention to details of anchoring rafters, bolts and nuts should be used instead of ordinary nails which could easily fail when subjected to slightest fatigue. While in fixing the rafter to the builing, the anchorage should be

properly inbded in the supporting structure, which should itself be capable of withstanding the excessive windloading that will be applied to it. The problem of joint failure can be alleviated by avoiding this joints where possible. Instead, the use of monolithic material like reinforced concrete should be emphasised. Another reason for joints failure is lack of adequate supervision at our construction sites. Materials specification and handling procedure were hardly adhered to. This is because most of our local contractors are either illiterates or lacking in the field of building technology. Until all these things are corrected and very urgently too, our desire for safe buildings will remain depressing elusion, to be pursued, but will never be attained.

4.3.4 Foundation.

For a windstorm of high forward speed, it is more probable that the rate of loading can be high enough to produce a dynamic magnification with more severe consequences to the struc ture and foundation. Studies on resistance of soils under dynamic conditions have indicated that for sandy granular soils, the shear strength and the bearing capacity decrease as the rate of loading increase. This is true, however only upto a value of 0.002 in/sec. for dry or saturated soil conditions. Furthermore, it was found that the

wedge of soil under shear stresses was smaller as the rate of loading increase (Casagraude and Shannou 1949, Seed and Lundgne 1954, Whitman 1957, Whitman and Healy 1962). Further studies (Bank 1963) Woodard 1964) indicated that as the rate of loading was increased on to 10in/sec. the bearing capacity of dry sand increased upto the static value and then remain constant. For saturated sand instead, not only did the bearing capacity increase sharply but the ultimate strength become several times larger than the value under static loading. However, at ultimate strength, it was found that the settlements could reach 4% of the diameter of the footing, which cannot be considered acceptable for ptractical purposes.

Horizontal forces applied to foundations are opposed by reactions generated either by passive soil pressure or by friction between foundation and soil. In the case of large dynamic horizontal loads, researchers studied the response of the system. They conclusded that in the case of frictional reaction acting alone, displacements are small and negligable. On the ohter hand, when reacitons from friction and passive pressure act together, it was expected that the lateral displacement could be as high as 4% of the foundation depth. In view of these findings, it is recommended that, to reduce such

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displacement, the foundation should be so designed to provide a reaction due to pressure that is twice the required minimum.

4.4 Windbreaks

In addition to its general effect on climate and consequently on humans, wind also directly affects human habitats. People seek protection against wind damage through natural and artificial means. For instance in siting settlements, humans historically have not depended solely on the effects of natural land formations on wind, but have also constructed windbreaks, including planting of shelter belts.

Their basic function, ofcourse, is to create and area relatively protected from the full force of the wind. The area of maximum protection is on the leeward side, but even on the windward side there is a zone of reduced wind speed. In general, one could say that the area affected by the windbreak has a width of about 30 times its height on leeward side and 10 times on the windward side. It is interesting to note that each end of the windbreak, there is a small area where the speed is higher than the speed of the unobstructed wind itself.

4.4.1 Shelterbelts.

A shelterbelt is a natural or artificial windbreak made out of trees and/or shrubs. The most effective orientation for a shelterbelt is perpendicular to the direction of the wind.

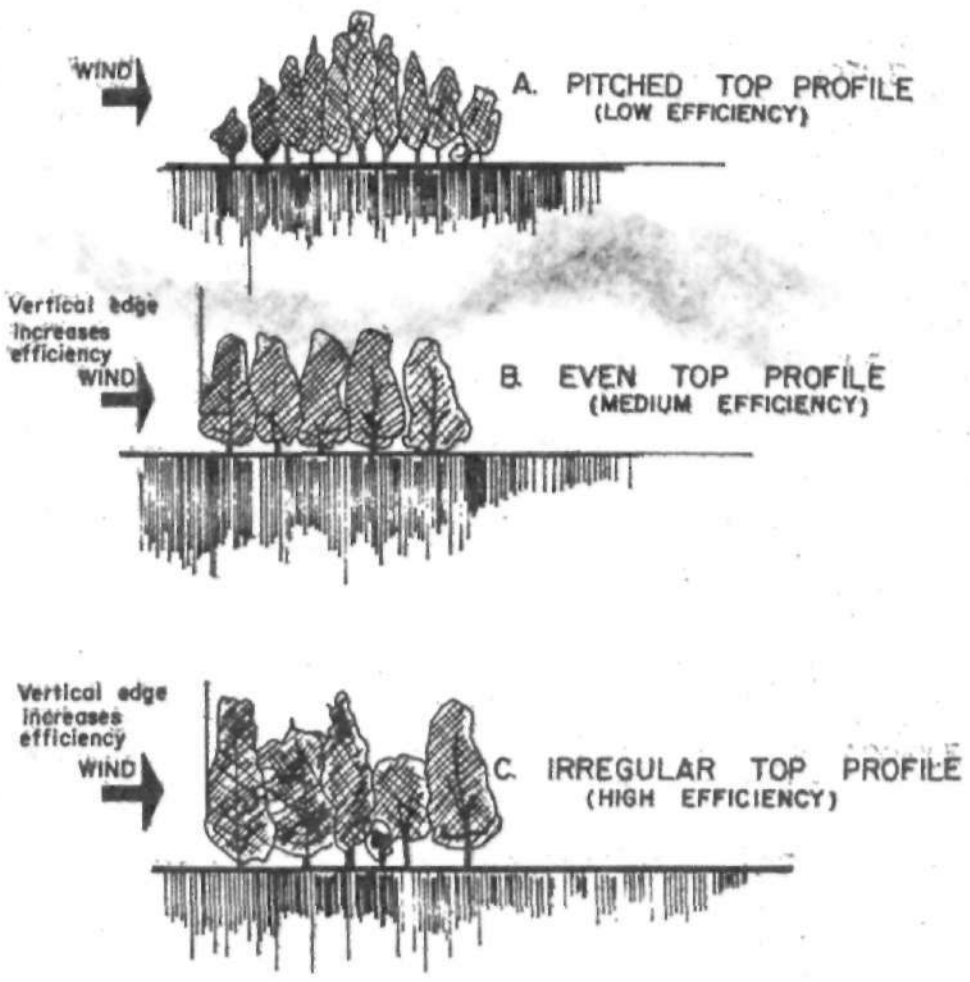


Figure . Efficiency of top profile for shelterbelts.

4·5

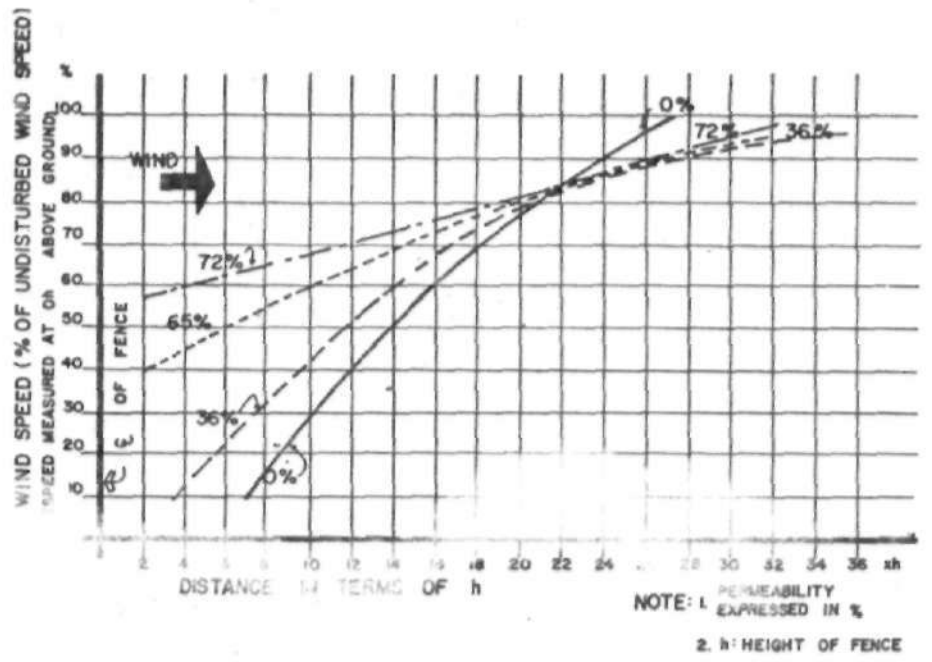
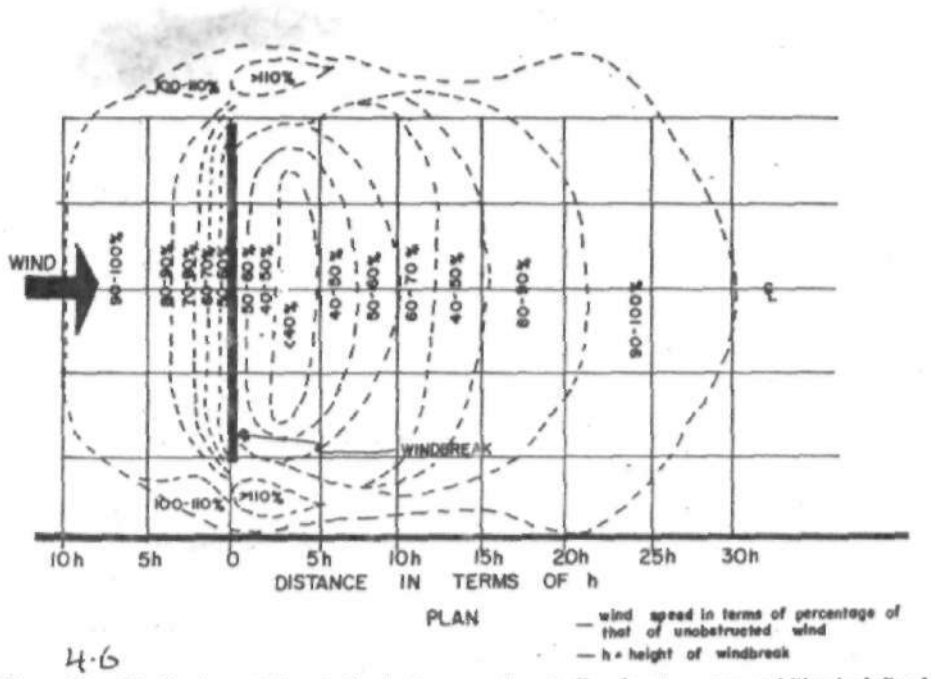


Figure 5-7. Reduction of wind speed for fences of various permeability.



4-6

Figure Distribution of the wind velocity around a windbreak whose permeability is defined as "moderately dense." The velocity is expressed as a percentage of the speed of the unobstructed wind. Notice that while the speed is reduced on the leeward and also on the windward side of the windbreak, it increases around the end edges up to 110%.

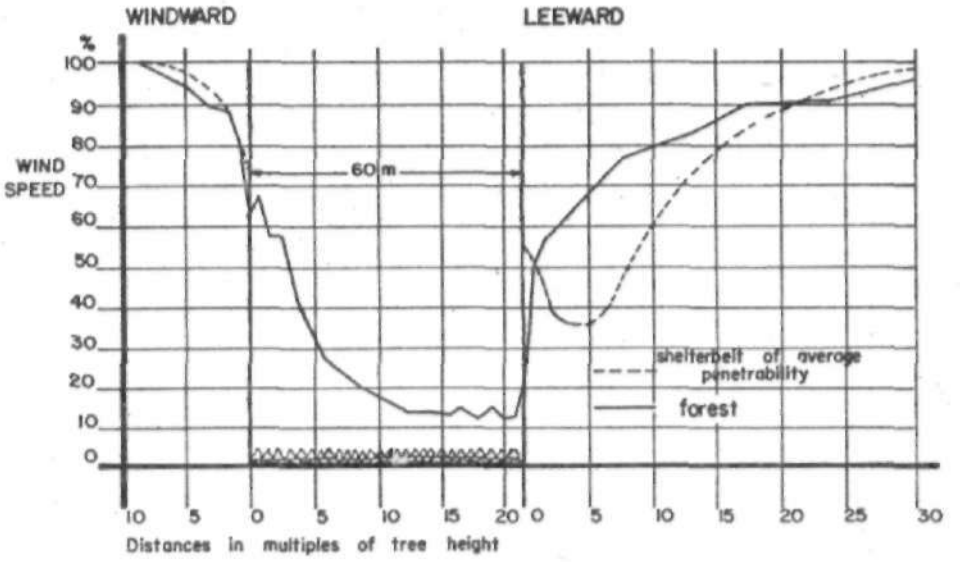
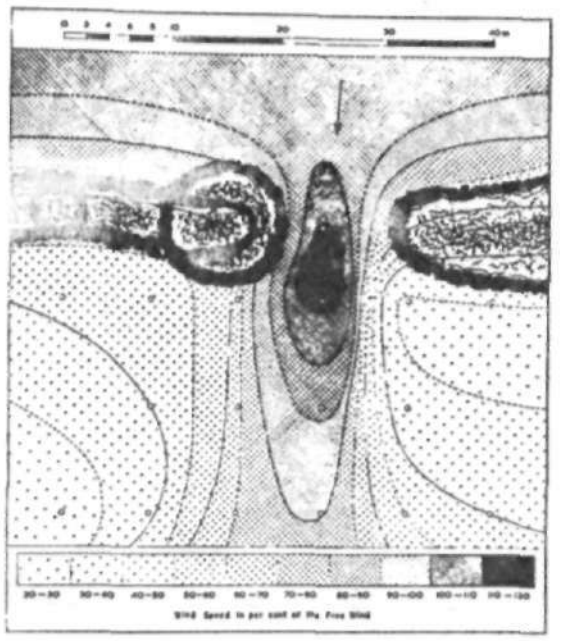


Figure 5-9. Profiles of the wind velocity produced by a forest and by a shelterbelt of average penetrability. As indicated, the shelterbelt is more efficient than the forest in reducing the wind speed, up to a distance of about 20 times the tree height on the leeward side.



4.7

Figure [illegible]. Effects of discontinuities in shelterbelts. An opening in a shelterbelt produces changes in the wind speed in the areas near the opening on the leeward and windward sides. Wind speeds through the opening can reach 120% the speed of the free wind. (After Nägeli, courtesy of J. M. Caborn)

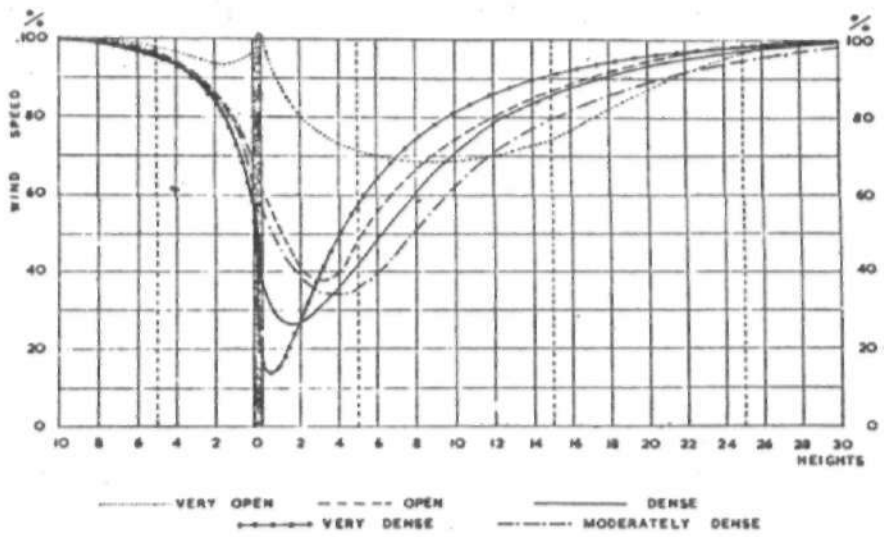


Figure 5-11. Profiles of wind velocity for various shelterbelts having different density. (After Nägeli, courtesy of J. M. Caborn)

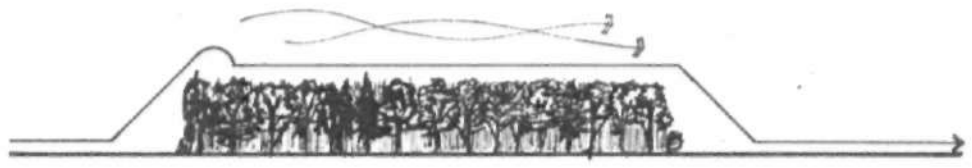


Figure 5-12. The depth of the sheltered area on the leeward side of a wide shelterbelt is very small, especially when compared with the depth of the area behind a narrow shelterbelt.

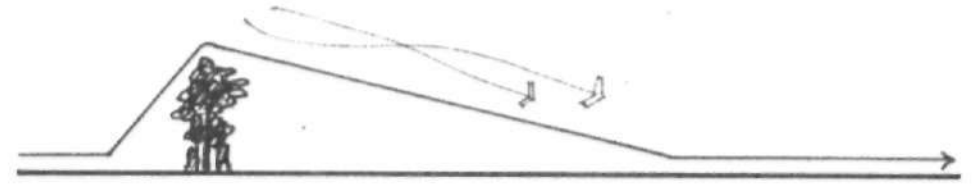


Figure 5-13. Profile of the sheltered area on the leeward side of a narrow shelterbelt shows the higher efficiency of narrow shelterbelts compared to thick ones.

Fig. 4.8

The width of the sheltered area near the sides of a shelterbelt is reduced, because conditions there are different. It is advisable not to make shelterbelts shorter than 12 times the height that they reach. For shelterbelt length up to 20 heights, the protected area increases at a sharp rate, but above this value, the rate of protection increases in direct proportion to the length of the shelterbelt.

The density of a shelterbelt is inversely proportional to the amount of air filtering through it. The denser a shelterbelt is, the lower the wind speed. The density can be classified in terms of the lowest wind speed on the leeward side, as follows:

Density	Lowest Wind speed.
Very Dense	15% of unobstructed wind speed.
Dense	25% of unobstructed wind speed.

Density	% of unobstructed Wind Speed
Very Dense	15%
Dense	25%
Moderately dense	35%
Open	38%
Very Open	68%

4.4.2 Windscreens.

In general, the efficiency of windscreens in reducing windspeed vary according to their permeability. Solid windscreens with zero permeability are not the most efficient. Infact, violent eddies are formed just behind the screen and extended for a distance of approximately five heights. When a certain amount of air is allowed to go through the windscreen, such eddies are reduced. With a permeability of 30%, the eddies are practically eliminated, and the air flowing through and over the fence is steady and limanar. Up to a permeability of 35%, the efficiency increases, but for larger permeability, it starts to decline.

4.5 Design Requirements.

The designer requires the following wind data for a site on which he intends placing a structure.

(i) Maximum gust speed for the structure's lifetime.

(ii) Prevailing wind directions and that of the storm.

(iii) The state of turbulence of the natural wind approaching a structure.

(iv) The local turbulence that will be provoked by the structure itself.

(v) Annual frequency distribution of wind speeds.

Technically, a roof is either flat or pitched. The roof is defined of "flat" upto a pitch of 10 degrees.

(NB 10° represent a slope of about 1in 5.7). All roof elements must be designed so that there is adequate resistance of the whole or each part of the roof to failure by overstressing. It is also necessary to accomodate dimensional changes and to reduce movements within the roof construction to acceptable limits. Deplection must also be considered. A long span roof might deflect sufficiently to destroy the pattern of falls.

The effect of wind pressure or suction on the roof form should be studied. Generally, the local conditions at the edges or ridge of the roof will be critical for component parts of the roof, including fixings, and the total stability of the roof will take account of both overall and local pressures. To counteract suction on a low-pitched roof, particularly where lightweight material are used for covering, special precautions should be taken to anchor the roof to the main structure. This is particularly important since most of the roofs failure recorded in this area are due to inadequate anchorage.

Changes in design, use of new materials and new methods of construction may tend to move the roof system nearer to the critical point of failure and several insignificant defects can combine together to cause a major breakdown of the roofing system.

This is particularly true of flat roof design. To avoid failure a careful choice of materials and components, and a competent specification of the method of construction must be made, followed by knowledgeable supervision and adequate inspection of the construction process.

4.6 Climatic Control.

Roof construction must prevent entry af rain and dust. The degree of rain penetration is related to amount of rain and associated wind speed. Maximum intensity of rainfall is a more important consideration than total quantity or duration.

4.6.1 Sloping Roof

On a roof slope, gravitational forces move water down the slope and tend to move moisture inward. As the slope decreases the resistance of gravity to the inward flow becomes less and therefore on roof water proofed by over lapping units laid dry, water penetration occurs when the slope or pitch in relation to the overlap of the units is insufficient.

4.6.2 Flat Roof.

On a flat or low-pitched roof, rain penetration can be prevented only by the use of a continuous watertight membrane. However, this is not always

easy to achieve or maintained in practice. If a roof surface is designed to be level, ponding will inevitably occure as it is physically responsble to produce a flat surface over a large area and because most materials used for roof decking are flexible and will follow the shape of the material below.

This will lead to accelerated deterioration as shallow pools of water left behind cuase local variations in temperature between the wet and dry areas of the roof, resulting in excessive differencial thermal movement. Fhis movement can cause breakdown of the roof surface, particularly in bituminous sheeting. The practical limits of screed thickness coupled with rational and economic gutter layout and reasonable downpipe positions usually impose some discipline on flat roof layout and maximum falls.

4.6.3 Thermal Performance.

The design of roofs in respect of thermal properties involves controlling heat loss and heat gain within the roof space and mitigating effects of extreme temperatures. Control is achieved by increasing the overall resistance to heat flow through the roof by using insulating materials between exterior and interior environments. Also, a light-coloured roof can be used to reflect solar radiation, thus controlling the excessive heat gain. The economic thickness of insulation necessary is determined by comparing two factors:-

. The cost of the insulating material plus installation.

. The cost of installing and operating cooling system over a given period.

The service life of certain materials is dependent on the range of temperatures experienced. Hifh temperatures increase the rate of deterioration of some materials by oxidative processive (soft bitumious and certain plastics).

Daily and seasonal changes in air temperature, solar heating and cooling causes temperature variations sufficient to incur dimentional changes in roofing materials. As each part of the construction experiences a different temperature range and cycle, differential movements occur.

4.6.4 Drainage.

Decide first whether the roof is to have concelled intergral gutters, an exposed applied gutter system or even no gutter at all. The rate at which water will run off a roof is a fundamental question. Pitched roofing has a high rate of run-off and provided that the detail of overlap or jointing of the water proofinf element is satisfactory, the pitch is a significant contributory factor to roofing durability. The run-off from a flat roof is very slow and consequent ponding will have a detrimental effect on durability.

Alternatively it si possible to design roofs to retain a considerable depth of water to protect and insulate the roof surface so that the construction has freedom from diurnal temperature change. The water must be deep enough to withstand evaporation and must not stagnate. This is difficult in practice; one problem is weight of water on the roof. Even 300mm of water will weight 300kg/m^2 or virtually equal to a floor loading rather than the usual roof loading. Secondly, open water should be avoided around the airport becuase it is a very good attraction to birds.

In a nutshell, proper arrangements should be made to drain run-off water from the roof to the main municipal drains. This is particularly important in a situation where the water is allowed to fall direct to the ground. Beside the problem of eroding the surface it fall on to, it could also sip down areound the foundation and soften the soil. This will result in building settlement or even total collapse.

CHAPTER 5

THE NEW TERMINAL BUILDING

5.1 Reason for Change.

The choice of this thesis was necessitated by the destruction of the Sokoto Airport Terminal Building in the mouth of May, 1984. Unfortunately though, neither the Federal Government nor the Sokoto State Government set up any commission of enquiry to look into the cause of the disaster. And to worsen the situation there is no wind data for the whole of that month, not to talk of the day and time the incidence occured. All efforts to get an alternative wind data for correlation purpose, from other meteorological stations around Sokoto also proved abortive. This initial setback makes the investigations very difficult and had to rely mostly on assumptions and the physical evidences available to us. This include the remains of the destroyed terminal building and the photographs taken when the incidence occured.

After a careful analysis of the data available, inspection of the damaged terminal building and the photographs. We managed to trace how the incidence happened and the extend of the structural damage caused to the terminal building. First, there was very serious damage to the footings of the columns which not rigidly connected to each other which could

have minimize the extend of the damage. Secondly, most of the reinforced concrete columns were damaged at the floor level including two that were physically broken, due to the combine bending moment of the wind force and the action of removing the roof. While all the columns were damaged at the top by the action of uprooting the anchoring bolts that fixed the roof structure to the concrete columns.

After careful consideration of the result of the analysis of the findings with the help of two structural engineers. It was decided that the structure has failed and should therefore be demolished.

In view of the above findings it become necessary to design a new terminal building for the Sokoto Airport. A terminal that will not only withstand the force of windstorm, but also the other harsh climatic conditions that are peculiar to Sokoto. The solution arrived at will go along way in not only solving the problem of Sokoto Airport terminal, but will serve as a model of appropriate design solution for the Sokoto climate - with certain modifications for other areas.

5.2 The New Structure.

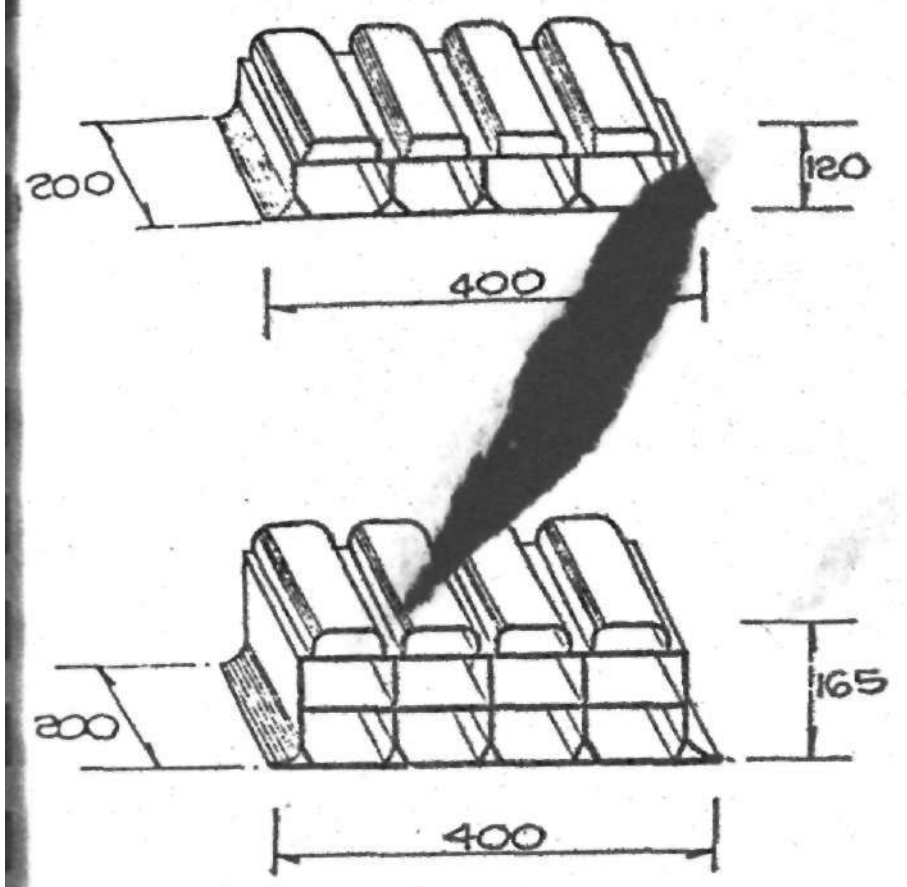
The structural arrangement for the new terminal building was arrived at in strict adherence to the results of wind tests conducted on building structures which are discussed in detail in Chapter 4 (the general solution). The structure is a reinforced

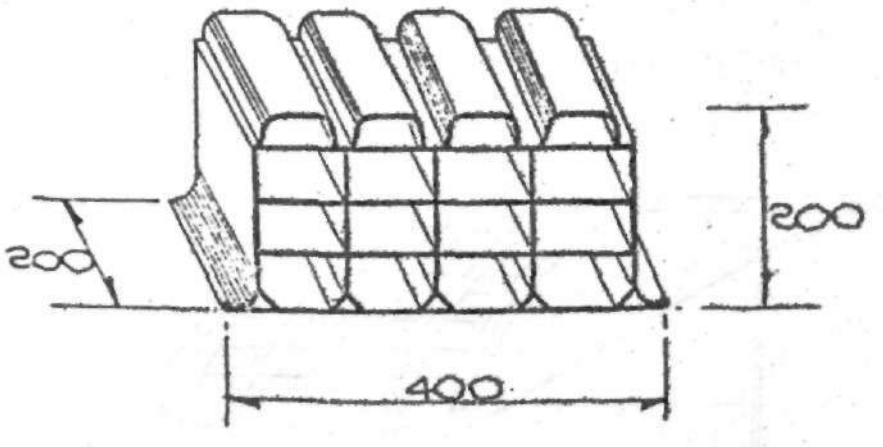
concrete frame structure which is rigidly fixed at both the footings and the top. This will not only work against the wind force but will also prevent the structure from failing due to sound vibration and possibly earth movement which is very common in Sokoto because of limestone mining. The roof will be of hollow clay pot decking which will be given a gentle slope by the supporting slanting beams below.

The choice of hollow clay pots as the roofing material is a deliberate one. First, it has the advantage of connecting to the main structure monolithically thereby eliminating the need for anchorage which is major problem responsible for roof failures. Secondly, it has a very good thermal property which makes it a very good heat insulator for the very high temperature recorded in Sokoto.

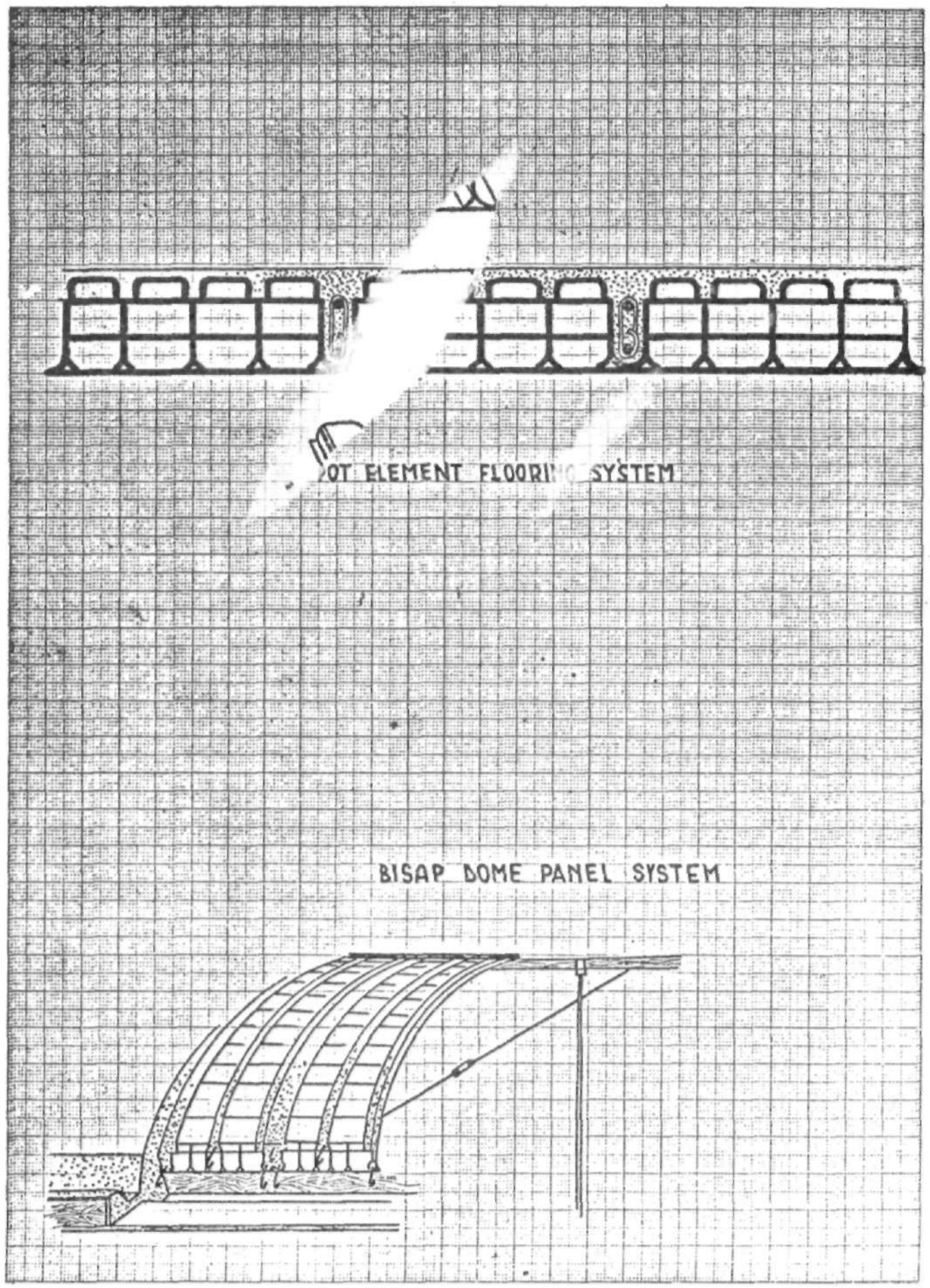
The system uses hollow clay pots laid on a flat formwork deck as a permanent void formers in insitu concrete, ribbed floor construction. The system has the following advantages:

- The system result in considerable economies because of the reduction in concrete, steel and formwork which are very costly constrution materials.
- The deeper floor construction permits longer floor spans uniterrupted by columns or beams.





POT ELEMENTS-FIG 5.1


OT ELEMENT FLOORI SYSTEM
BISAP DOME PANEL SYSTEM

- The system permits flat slab construction which avoids obstrusive beams and column heads.
- Construction time is considerably reduced by avoiding the need for complex formwork.

5.3 Design Brief.

In developing criteria for the design of the new passenger terminal complex, there are a number of different factors which enter into statement of overall design objectives. From these factors, general and specific goals are established which set the framework on which design progresses.

In the redevelopment of the Sokoto Airport Terminal building, the general design objectives are as follows:-

1. The development and sizing to accomplish the stated mission of the airport within the parameters defined in the master plan.
2. It should be capable of meeting immediate and future demands.
3. To be functional, practical and financially feasible.
4. To maximise the use of existing facilities.
5. To consider seriously the environmental sensitivity.
6. Maintainance of flexibility to meet future requirements.

The following specific design objectives were derived from these overall objectives which included the needs of various categories of airport users.

Passengers Objectives:

1. Responsiveness to the needs of the people relative to convenience, comfort and persona requirements.
2. Provision of effective passenger and access orientation through concise and comprehensive directional graphics.

Airlines Objectives:

1. Provision of direct and officient means of passenger and baggage flow for all passenger, including domestic and international and tranfer passenger.
2. Provision for economic, efficient and effective security.

Airport Management Objectives:

1. Maintenance of the existing terminal operation, access system, runway system and ancillary facilities.
2. Provision of facilities which generate maximum revenues from concessionaires and other sources.
3. Provision of facilities which minimize maintainance and operating expenses.

Community Objectives:

1. To render a unique and appropriate expression and impression of the community.

The combination of all these objectives will form the concept on which the design of the new terminal complex will be based.

5.4 Design Report.

The terminal area is the major interface between the airfield and the rest of the airport. It includes the facilities for passenger and baggage processing, cargo handling and airport administration, operations and maintainance. For the purpose of this thesis however, we will be concentrating on the passenger and baggage processing aspect of the terminal buildings which is the area destroyed by the storm of May, 1984.

5.4.1 The Passenger Terminal System.

The passenger terminal system is the major connection between ground access and the aircraft. The purpose of this system is to provide the interface between the passenger and the airport access mode, to process the passenger for the orignation or termination of an air trip and to convey the passenger and baggage to and from the aircraft.

TABLE 2
APPLICABLE CONCEPTS FOR AIRPORT DESIGN. (Federal-Aviation Administration).

	CONCEPTS APPLICABLE				PHYSICAL ASPECTS OF CONCEPTS							
	LINEAR	PIER	SATELLITE	TRANSPORTER	SINGLE LEVEL CURB	MULTI LEVEL CURB	SINGLE LEVEL TERMINAL	MULTI LEVEL TERMINAL	SINGLE LEVEL CONNECTOR	MULTI LEVEL CONNECTOR	APRON LEVEL BOARDING	AIRCRAFT LEVEL BOARDING
AIRPORT SIZE BY ENPLANED PAX/YEAR												
FEEDER UNDER 25,000	X				X		X				X	
25,000 to 75,000	X				X		X				X	
75,000 to 200,000	X				X		X	X	X		X	
200,000 to 500,000	X	X			X		X	X	X		X	
500,000 to 1000,000	X	X	X		X		X	X	X	X	X	X
500,000 to 1000,000	X	X	X		X		X	X	X	X	X	X
1,000,000 to 3,000,000		X	X	X	X	X		X	X	X	X	X
1,000,000 to 3,000,000		X	X		X	X		X	X	X	X	X
3,000,000		X	X	X	X	X		X	X	X	X	X
3,000,000		X	X		X	X		X	X	X		X

The passenger terminal system is composed of three major components. Fhese components and the activities that occur between them are as follows:

1. The access interface where the passenger transfers from the access mode of travel to the passenger - processing component.
2. The processing component where the passenger is processed in preperation for starting or ending an air trip. The primary activities that take place here are ticketing, baggage check-in, baggage claim, waiting, federal inspection services and security.
3. The flight interface where the passenger transfers from the processing component to the aircraft. The activities that occur here includes assembly, conveyance to and from the aircraft and aircraft loading and unloading.

5.4.2 Terminal Concepts.

Aircraft gate configuration and the way aircrafts gates are connected with one another and with the main terminal building are the dominant features of the of the terminal concepts, of which it can be distinguished. The concepts nearly always occur in variations and combinations.

1. Satelite: In this concept, the aircrafts are parked in cluster surrounding a structure which is connected to the main terminal building by a passenger corrodor or concourse position below on or above ground level.

2. Pier: Here the aircrafts are parked in line at either side of structure - the passenger corridor or concourse attached to the main terminal. In both pier and satellite concepts, passenger ticket, inbound and out bound baggage handling are usually centralised in the main terminal building but variations and exceptions do occur

3. Linear: In this concept, the aircrafts are parked in single line in front of the terminal building. While passenger corridor connect the functional elements of the terminal.

4. Transporter: In this concept the aircraft positions are placed at a distance from the terminal building. The passenger are transported by vehicles between the terminal and the aircraft. The passenger handling is however centralised in the main terminal building.

5.4.3 Schedule of :ccomodation.

The determination of space requirements for the new terminal building is strongly influenced by the level of services desired. These include among others the requirement for the terminal to meet immediate and futre demands. International standards of space allocation were strictly adhered to except where local tradition and practice demands otherwise. It is based on the above fact and the nature of the airport's activity rate (which can be said to developing from figures of passengers passing through the airport) that

1ST. QUATER JAN – MAR.	574	293	18260	8710	—	495	15716	1298	—	3792	2940	5075	182	330	182	330		10211		10384	—	7572	—	4978	—	—	—	—	263	213	263	213	16348	9855	14871	10062	—	—	19220	4980	—	—	2314	241
2ND QUATER APR. – JUN.	435	435	11786	11588	4490	1862	2766	2885	210	210	7785	8652	—	—	—	2444	312	312	15265	14486	—	—	19074	—	—	2448																		
3RD QUATER JUL – SEP.	574	574	18260	11818	—	15716	—	2940	182	182			—	—	—	—	263	263	16348	14871	—	—	19220	—	—	2314																		
4TH QUATER OCT. – DEC.	387	387	11678	13276	—	5700	—	1424	221	221			—	—	—	—	267	267	11623	12849	—	—	19074	—	—	2448																		
TOTAL	3338		96131						1886		78818						2110		105444																									
YEAR	1983								1984								1985																											

we arrive at our figures.

Because of the low activity rate of the airport particularly the international part. It is decided that both the domestic and international operations will be conducted in a single terminal, so that the international facilities can sometimes be used for domestic operations when not in use. This arrangement will not only reduce over provision of space but will also reduce its operational cost. It is afterall these considerations that we come to our peak hour passenger of 200 people.

Departure:

Check-in	- 325m^2
Waiting Hall	- 550m^2
Security Checks	- 250m^2
Departure Lounge	- 480m^2
V.I.P. Lounge	- 250m^2
Toilets	- 60m^2

Arrivals:

Security Checks	- 250m^2
Baggage Reclaim	- 400m^2
Arrival Hall	- 400m^2
V.I.P. Lounge	- 250m^2
Toilets	- 60m^2

Common Facilities

Viewing Gallary	- 430m^2
Shops	- 96m^2
Bank	- 108m^2
Restaurant and Snacks	- 325m^2
Praying Area (Mosque)	- 80m^2
Kerbfront	- 360m^2

Operations

Station Manager	- 20m^2
Security Officer	- 24m^2
6 Airline Offices 16m^2 each	- 96m^2
Crew Centre	- 190m^2
Communication Centre	- 80m^2
Storage	. 120m^2
Baggage Handling	- 150m^2
Toilets	- 16m^2

5.4.4 The use of Landscape.

In a hot-dry climate as obtained in Sokoto, the beneficial effects of even the lightest plant cover is quite considerable. The landscaping will not only enhance the beauty of the place but can also provide protection against the excessive solar radiation, glare, errosion and also act as a very good windbreak to complement the structural form choosen. The use of trees, can, on the other hand,have disadvantages when it is close to a building, as roots can damage foundation and drain pipes, leaves can block open gutters and in the case of the

airport, the forliage of the trees can block the desired view of the airfield from the control tower. It is in view of this fact that the Australian Pine tree is choosen as the tree to be used in the provision of windbreak and sunshade. The tree apart from having very light forliage that will not block the from the control tower and cause turbulent eddies after the sheltered area of windbreak, is also an evergreen that will not block gutters or even make the place dirty.

5.5 Effects of Wind on Airport Design.

The influence of wind, alone or combined with atmospheric temperatures, greatly affects the design of airports. Infact, the wind is the factor that determines the length and orientation of runways, as well as their number.

The general rule relating wind to runway lenght is that head winds decrease the necessary lenght of runways, where as tail wind increase it. This is true, ofcourse, for both landings and takeoffs. Infact, what counts in flying is the velocity of the plane with respect to the air, not the ground. However, for an aircraft, air speed and ground speed coincide when the air is still. With frontal winds, the air velocity is the sum of the ground speed and the air speed. In this case the air speed is higher, which consequently reduces the length required for the runway and vice-versa.

Thus, the equivalent length of a given runway under a certain load condition varies according to the wind speed. That is, landing and takeoff length have to be established for

each wind velocity. In general, the primary runways are as close as possible to the direction of the prevailing wind. Any divagance between the orientation of the runway and the direction of wind creates a wind component that is perpendicular ot the runway which affects considerably the safety of airplanes in both landing and takeoff. Such perpendicular wind components are usually referred to as cross winds. Fhe maximum cross wind allowed for an aircraft depends on many factors, including the size of the plane and the configuration of the winds. Single engine planes or other lightweight aircraft cannot operate safely in cross winds greater than 24km/h. On the other hand, transport airplanes, which are much less sensitive to corss winds, can operate in winds up to 60 km/h. However, 25km/h cross wind speed is usually adapted for all cases. Consequently, the orientation of runways is such that 95% of the time airplances do not experience cross winds in excess of 25kn/h in either landing or takeoff.

CONCLUSION

The thesis begin by the study of wind, not just as a natural phenomenon, but also in terms of its influence on human environment. Particularly its effects on building structures and how different forms respond to the force of wind. This leads us to investigate the destruction of the Sokoto Airport Terminal Building. Like in many other buildings that had their roofs blown off by wind, the causes of the terminal building disaster can be summerised as follows.

- Inadequate and poor anchorage.
- Indiscriminate provision of roof over hang.
- Lack of proper specifications from the designers.
- Inadequate supervision.

After analysing what remains of the destroyed terminal building, the structure was cosindered not safe because of columns and foundation failure. This then necessitate the design of a new terminal building, which turn out to be an opportunity to come up with a solution based on the studies conducted. The structure evolved will not only provide solution to the terminal building disaster, but can also be applied to other buildings in the area that are faced with similar problems. The thesis will also be a good design guide to anybody engaged in designing for this area. The solutions provided did not only take the local climate into consideration, but are also more economical than the other systems now in use.

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