NIGERIAN AIRFORCE BASE, YOLA

(ARCHITECTURE FOR DEFENCE)

By

JOSHUA BITRUS SAWA

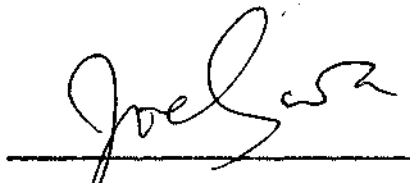
Thesis submitted to the Post-Graduate School, Bello University, Zaria - Nigeria in partial fulfilment of the requirements for the award of the degree of Master of Science in Architecture.
(M . Arch)

DEPARTMENT OF ARCHITECTURE
AHMADU BELLO UNIVERSITY,

OCTOBER 1983

DECLARATION

I do hereby declare that the work presented in this thesis for the degree of Master of Science in Architecture has not been wholly or partially presented for any other degree nor is it concurrently being submitted for any other degree and that all quotations have been to the best of my knowledge duely aknowledged.



JOSHUA BITRUS SAWA (CANDIDATE)

11. 11. 88

DATE

CERTIFICATION

This thesis entitled "Nigerian Airforce Base, Yola (Architecture for defence)" by Joshua Bitrus Sawa 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.

F. C. Addo — 14TH Nov. 1988

CHAIRMAN, SUPERVISORY COMMITTEE — DATE

[illegible] — 14/11/88

MEMBER, SUPERVISORY COMMITTEE — DATE

HEAD OF DEPARTMENT — DATE

DEAN, POSTGRADUATE SCHOOL — DATE

WARNING !!!

For security reasons, a good number of facts have been distorted in the write-up but these have in no way affected the end result of the research. No part of this thesis may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the author or from the Ministry of Defence.

QUOTE 1

ARCHITECTURE IS A PROCESS BASED ON STANDARDS, AND STANDARDS ARE BASED ON LOGIC, ON EXPERIMENTATION AND ON PAIN STAKING STUDY. IN THE FINAL ANALYSIS, ARCHITECTURE IS BASED ON EXPERIMENTATION.

LE CORBUSIER

QUOTE 2

GOOD PLANNING I CONCEIVE TO BE BOTH A SCIENCE AND AN ART. AS A SCIENCE IT ANALYSES HUMAN RELATIONSHIPS, AS AN ART IT COORDINATES HUMAN ACTIVITIES INTO A CULTURAL SYNTHESIS.

WALTER GROPIUS

QUOTE 3

TO EVERYTHING THERE IS A SEASON, AND A TIME TO EVERY PURPOSE UNDER THE HEAVEN: A TIME TO BE BORN, AND A TIME TO DIE; A TIME TO PLANT, AND A TIME TO PLUCK UP THAT WHICH IS PLANTED; A TIME TO KILL, AND A TIME TO BUILD UP; A TIME TO WEEP, AND A TIME TO LAUGH; A TIME TO MOURN, AND A TIME TO DANCE; A TIME TO CAST AWAY STONES, AND A TIME TO GATHER STONES TOGETHER; A TIME TO EMBRACE AND A TIME TO REFRAIN FROM EMBRACING; A TIME TO SEEK, AND A TIME TO LOSE; A TIME TO KEEP, AND A TIME TO CAST AWAY; A TIME TO REND, AND A TIME TO SEW; A TIME TO KEEP SILENCE, AND A TIME TO HATE, A TIME OF WAR, AND A TIME OF PEACE.

ECLCESIATES 3: 1 - 8

DEDICATION

This thesis is dedicated to the Lord God, my entire family especially my Father and Mother, my late teacher and friend Mrs. Agnes Baba and Alhaji Usman Umar Sandah, Jnr, respectively and to the bright future of the Nigerian Airforce.

AKNOWLEDGEMENTS

I would like to start by thanking the Lord God for giving me the inspiration to work out a scheme for the Nigerian Airforce Base, Yola. I am also grateful to the entire members of my family especially dad and mum for the financial, spiritual and moral support and encouragement and the Gongola State Scholarship Board for their assistance. I am also greatly indebted to the Chief of Air Staff, Air Marshal Ibrahim M. Alfa for his personal interest and commitment to the project and my mentor/thesis supervisor Arc. Fred B. Addo who guided me through the programme and freely shared with me his vast knowledge aquired over the years in practice. I would also like to acknowledge my Uncle Col. A.P. Sawa was the first to approve my thesis topic and provided me with links and encouraged me greatly. To my childhood friend and colleague, Mr. Robert T. Unde, I'd like to say "thanks a million" for everything.

I'll also like to extend my most sincere appreciation to the following people for the help they rendered me in various ways:-

LAGOS

Air Vice Marshal Winston Aleyideino, Air Vice Marshal C. Ugah, Air Commodore Ndako Z. Adama, Police Commissioner Fulani Kwajaffa, Wing Commander A.M. Elegbede,

Wing Commander and Mrs. Ishaya AbdulRahman, Mr and Mrs U.S.H. Maigida, Mr. Hadoran Tanzamado, Squadron Leader I. Komo, Arc. Celestine Ikweumesi, Arc. Ngoh, Flight Lieutenant Lawal Alao and the entire members of staff of the NAF Directorate of Works.

KANO

Mr. and Mrs. I.P. Sawa, Wing Commander Peter Gana, Flight Lieutenant Steve Dama and Flight Lieutenant Agonobi,

MAIDUGURI

Mr. James Mshelia, Wing Commander Samson Mshelia, Dr. S.B. Sawa, Mr. M.B. Sawa, Mr. Aliyu Hassan and Mr. Ishaya Abashi.

YOLA

Mrs. Amina Albert, Arc. Aliyu B. Tarfa, Arc. Anjikwi B. Suleiman, Mr. Joshua Malgwi, Mr. Aminu Madani, Flight Lieutenant Okechukwu, Flying Officer Ilyas Usman, Engineer Kamal Hameed Alkali, Mr. Ibrahim Babagana, Mr. Eric, Mr. Fwa, Arc. Gideon Jareed, Olive, Margaret, Leah and Joy Sawa, Oliver, Yahaya, Mahmudu etc.

MINNA

Prof and Mrs. J.O. Ndagi, Arc Stanlay Kolo, Ibrahim Maiyaki, Aminu and Idris Takuma and Saleh Usman,

KADUNA

Mr and Mrs M.O. Liman, Arc. Akin Ogunyide, Arc. Drhambi Kwada, Mr. Maxwell Badau

ZARIA

Group Captain H.Z. Aziz, Arc. Dayo Isimi, all my lecturers and members of staff and students of the department especially Dr. Tukur Sa'ad, Dr. O. Solanke, Arc (Mrs) Altine B. Mohammed, Arc. O. Ogunsote, Arc Sabo, Arc. H.D. Ahmed, Arc. M. Abdulkarim, Arc. M. Folabit, Arc. M.M. Nuftwang, Arc. Yinka Gbotosho, Arc. Mbina, Prof. E.A. Adeyemi, Prof. Shim Adesina, Prof. and Mrs. S.C. Aleyideino, Dr. and Mrs. B. Sawa, Mr. Bala Malgwi, Mrs. Esther Shallangwa, Miss. Sintiki B. Tarfa, Kit, Moji, Aisha, Titi, Wendy, Ada, Hussaini Adamu, Arc. B.N. Ahmed (My mentor), Arc. M.M. Lamina, Musa, Tony, Frank, Dan K. Yaks, Abu Ali, Sani Sale, Tanimu, Dr. P.B.D. Audu, Felix, Zaks, Bolaji, Leo, Stevie, Ashiedu, Busco, Njidda, Sly, and others too numerous to mention but who in one way or another contributed to making my academic persuits a success.

Lastly but by no means the least, I would like to thank Miss. Ann Gabriel and Miss. Bunmi Akanbi who agreed to type this thesis.

Also Dr. J. O. Popoola, Arc. M.A. Muhktar, Ade, Femi, Antones

Joshua Bitrus Sawa

Zaria Oct. 27th 1988

TABLE OF CONTENTS

		Page
-	Declaration	ii
-	Certification	iii
-	Warning	iv
-	Quotations	v
-	Dedication	vii
-	Acknowledgements	viii
-	Table of Contents	xi
-	List of Tables	xv
-	List of Figures	xvii
-	List of Maps	xx
-	Foreward	xxi
-	Abstract	xxii
	PART ONE - THE AIRFORCE SET-UP	1
	CHAPTER ONE	4
1.00	Introduction	4
1.10	History and development of the military	5
1.20	Historical development of the Nigerian Airforce	7
1.30	The Nigerian Airforce Today	11
1.40	The Nigerian Airforce and containment of external threat	18
1.50	Aircraft in use by the Nigerian Airforce	24

CHAPTER TWO

		Page
2.00	The typical airforce base	26
2.10.	The operational zone	27
2.20	The barracks zone	28
2.30	Types of bases	30
2.40	Factors that affect the siting of airforce bases	31
2.50	Military planning - The airforce experience	32
2.60	Difference between military and civil airports and aircraft.	38

PART TWO THE DESIGN ANALYSIS 41

CHAPTER THREE 42

3.00	Airport planning	42
3.10	The Airport master-plan	45
3.20	Airport requirements	46
3.30	Airport site selection	47
3.40	Land-use planning	55
3.50	Environmental study	57
3.51	Ground access and vehicle parking	58
3.52	Economic and financial feasibility and obstruction clearance requirements	59
3.60	Evaluation of noise	71
3.61	Sound intensity	71
3.62	Composite noise rating	75
3.63	Noise exposure forecasts	76
3.64	Community noise equivalent level	78
3.65	Day-night average level	81
3.66	Aircraft sound description system	82
3.70	Airport configuration	85
3.71	Runways	86
3.72	Taxiways	101
3.73	Seperation clearance	118

		Page
3.74	Holding aprons	119
3.75	Holding bays	121
3.76	Terminal area runway relationship	122
3.77	Analysis of wind	122
3.78	Structural design of airport pavements	124
3.79	Airport drainage	124
3.80	Aircraft characteristics related to airport designs	126
3.90	Heliports and short takeoff and landing ports	136
3.91	Nature of helicopter transport	138
3.92	Characteristics and dimension of heloports	138
3.93	Factors related to site selection	139
3.94	Physical characteristics of heliports	141
3.95	Summary	148
	CHAPTER FOUR	150
4.00	Case studies	150
4.10	Case study 1:- Nigerian Airforce Base "A"	151
4.20	Case study 2:- Nigerian Airforce Base "B"	154
4.30	Case study 3:- Nigerian College of Aviation Technology Hangar, Zaria	157
4.40	Study 4:- Pakistani Airforce Base, Sargada	160
4.50	Study 5:- Italian Airforce Hangars, Ortebells I	163
4.60	Study 6:- The Berlin Bunker	167
4.70	Study 7:- Station Airforce Hangars, Ortebells II	174
4.80	Deductions	178

PART THREE - THE THESIS — Page

CHAPTER FIVE — 180

5.00 Aims, objectives and scope — 180
5.10 Site analysis and site selection criteria — 181
5.20 Design concepts and methods — 187
5.30 Form and function in Architecture — 193
5.40 Functional analysis and schedule of accommodation — 197
5.50 The Nigerian Airforce Base, Yola — 200

CHAPTER SIX — 213

6.00 Summary — 213
6.10 Recommendations — 213
6.20 Epilogue — 214

Glossary — 215

Bibliographical entires — 218

(a) Books — 218
(b) Periodicals — 219
(c) Essays and articles in collections — 220
(d) Unpublished materials — 220
(e) Newpapers — 221

LIST OF TABLES

		Page
Table I	Personnel strength of armeds forces of all African Countries	8
II	Personnel strength and equipment of Black, Arab and White Africa	9
III	Imaginary surface dimensions FAR Part 77 (In feet)	66
IV	Imaginary surface dimentions ICAO Annex 14 (In feet)	68
V	Summary of dimensions of ICAO imaginary surfaces	70
VI	Compartible landuses for various levels of NEF	79
VII	ICAO runway standards related to width of structural pavements	95
VIII	FAA runway standards related to width of structural pavements	96
IX	ICAO taciway standards related to width of structural pavements	104
X	FAA runway standards related to width of structural pavements	105
XI	FAA basis for classification of Taxiways	106
XII	Minimum fillet radii recommended by ICAO	117
XIII	Minimum clearance between two wing tips on a wing tip and fixed obstacle	120
XIV	Geometric Design Standards for Heliports	144
XV	Bioclimatic data of Yola	186

		Page
XVI	Functional relationship table of the	198
XVII	Functional relationship table and schedule of accomodation of the hangars	199

LIST OF FIGURES

		Page
Fig 1.	Chain of command of the Nigerian Airforce	17
2.	Airport Systems	43
3.	Dimensions of runway clear zones	54
4.	Passenger car parking systems	60
5.	FAR part 77 classification of airports	62
6.	Principal imaginary surfaces	64
7.	ICAO Annex 14 slope of conical surfaces	69
8.	Graphs showing perceived noise level contours	73
9.	NEF contours for Chicago O'Hare airport	77
10.	Cariation of EPNdB with distance for specific types of aircraft	80
11.	Analysis for a single runway airport with one aircraft type using departure flight paths	83
12.	Runway confifurations	88
13.	Principal elements of runways	93
14.	Typical runway profile	99
15.	Cross section of typical taxiway	103
16.	Radic of curvations for taciways	111
17.	High exit taxiways	112
18a.	90^{o} exit taxiways	113
18b.	Taxiway intersection details	114
19.	Design of fillets for three most common types of taxiway intersections	116

		Page
20.	Terminal building/runway configuration	123
21.	Typical structural pavement section	125
22.	Subgrade subdrainage details	127
23.	Layout of drainage for ponding	128
24.	Details of joints in rigid pavement	129
25.	Aircraft dimensions	132
26.	Vortex movement near the ground	134
27.	Helicopter data	140
28.	Obstruction clearance requirements for heliports	142
29.	Recommended heliport marking	146
30.	NAF Base A	152
31.	NAF Base B	155
32.	NCAT Hangars	158
33.	PAF Base, Sargoda	162
34.	ITAF Hangars, Ortebello I	164
35.	ITAF Hangars, Ortebello I	165
36.	The Berlin Bunker	168
37.	The Berlin Bunker	169
38.	ITAF Hangars, Ortebello II	175
39.	ITAF Hangars, Ortebello II	176
40.	Greater Yola Plan	182
41.	Site analysis	183
42.	Concept of ultimate development	202
43.	Site Plan	203
44.	Ground Floor Plan of the Hangar	204
45.	First and Second floor Plans of the Hangars	205

Page

46. Elevations of the hanger 206
47. Sections of the hangar 207
48. Perspective 208
49. Perspective 209
50. Model of the base. 210

LIST OF MAPS

		Page
Map 1 -	Map of Africa showing the position of Nigeria	2
Map 2 -	Map of Nigeria showing the position of Yola	3

FOREWARD

Practical reality and the process of making theoretical appraisals are two related concepts that are often misconstrued in most intellectual endevours. Once in a while however, a time comes when a workable synthesis is achieved through a harmonious balance of these concepts, crystellizing into an expression of viability.

Joshua Bitrius Sawa has employed architecture as a tool in achieving a brilliant expression of this balance with his proposal for the Nigerian Air Base, Yola, the conception of which is the culmination of critical studies and considerations, making the scheme a suitable response to the trends in defense requirements.

The proposal is made within a framework which reflects relevant analysis of the related criteria for the purpose of articulation, employing the necessary elements of architectural vocabulary in creating a scheme which is both timely and symbolic in it's importance to our existence as a nation.

The thesis should prove invaluable not only to those individuals involved in the noble undertaking of military defence (particularly the Air Force) but also to other Nigerians who wish to acquaint themselves with an important aspect of progressive development.

Robert T. Unde

1988

ABSTRACT

Since the end of world war II (1939-45), brought to an end to a certain degree by the dropping of the 'atomic bomb[1] on Hiroshima and Nagasaki both in Japan by the American Airforce, the role of the airforce in military warfare has taken on a new dimension, with the various world powers taking advantage of it's inherent potentialities to perpetuate an unprecedented advancement within the sphere of strategic arms acquisition. Often expressed in foreign policy initiatives characterised by a growing mistrust or the politico-ideological alliance between concerned parties, these arms have been developed to level of sophistication which makes aerial warfare as typified by airforce operations a decisive defence factor in the general quest for world peace.

This vast web of intrigue and diplomatic manipulations Is among the remote causes of the political and economic turbulence wrecking the African continent and is often manifest in the civil wars, the disturbing situation of the apartheid regime in South Africa - often bordering on full scale armed conflicts and other cases of direct aggression.

Nigeria as the giant of Africa naturally feels strongly about these developments and often takes a clear stand on particular issues, a position which is acknowledged continentally e.g the Angolan Independence struggle.

Her airforce however, belies the challenge of a country acting from a position of strength in matters of self protection from external air raids, territorial surveillance, etc with the attendant reassuring physical presence where necessary, like in neighbouring strife torn countries. This threatens Nigeria's revered leadership position to which other countries defer in matters of continental and global consequence. It is in cognaisance of these factors that the Federal Government of Nigeria has always felt the need to include defence among it's priorities for national development.

This thesis aims at providing a suitable architectural solution to the problem in recognising the effectiveness of the airforce in the dispensation of security related functions for a sovereign country like Nigeria. It also takes into account the prevailing trends in aerial warfare and the technological requirements of base operations by employing the best results of research in construction which is an integral part of national development dating back to the period of post war reconstruction in other parts of the world.

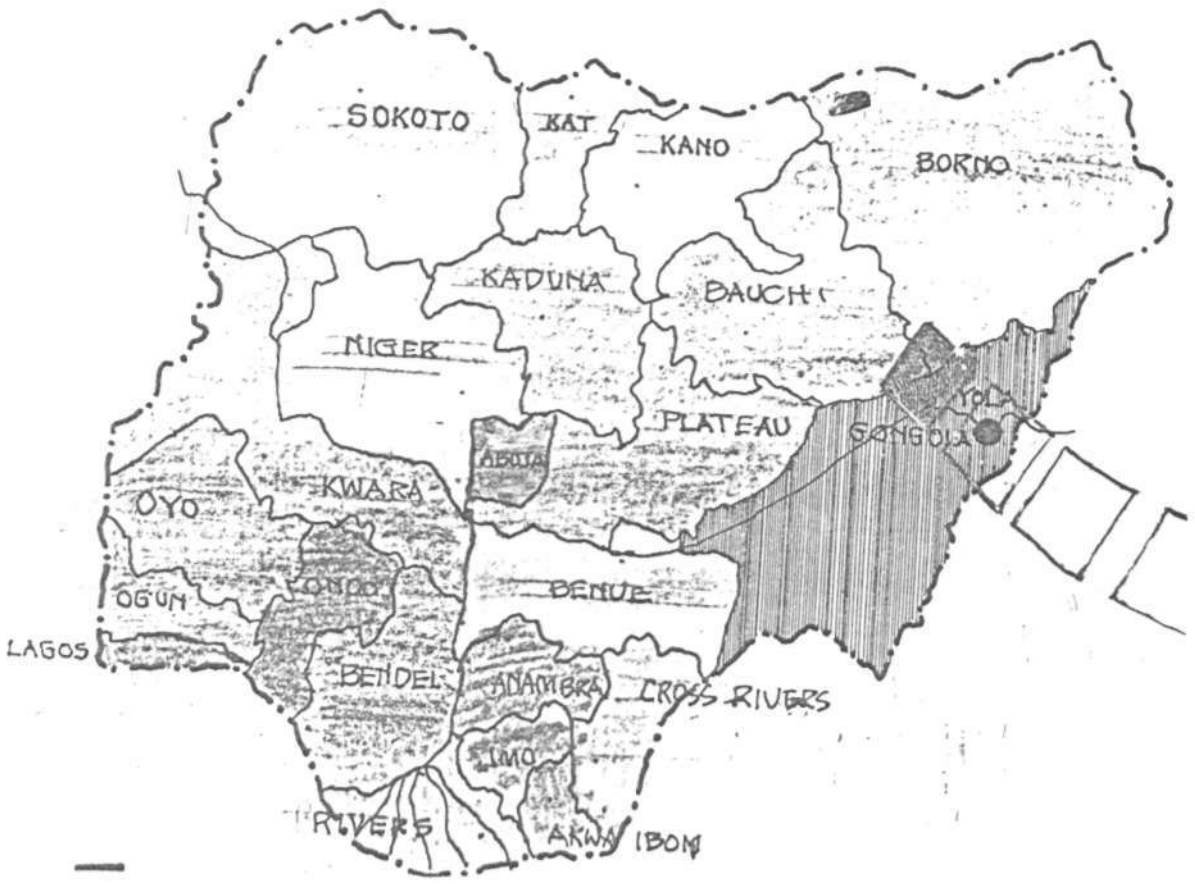
It is hoped that the airforce base would further strengthen Nigeria's position and re-affirm her leadership role within the scheme of things particularly in Africa while providing reassurance on the home front in handling all forms of military emergencies which breed political and economic turbulence leading to social insecurity and ultimately giving credence to the concept of defence for development.

PART ONE

- THE AIRFORCE SET-UP -



Map 1 :- Map of Africa showing the position of Nigeria



Map 2 :- Map of Nigeria showing the position of Yola

CHAPTER ONE

1.00 INTRODUCTION

Within the last century or so, there has been a greater metamorphosis in terms of military sophistication than perhaps the whole period preceding it. This sophistication both in military tactics and weaponry has also affected the ways of life of people, especially in Africa. Premodernization of the army,warriors used to live side by side with the other members of their respective communities, but today it has become necessary to provide specialised housing in terms of barracks, cantonments, bases,etc for members of the military community. The priority of most world governments has also shifted from the provision of food and shelter for their people to defence. This can be seen clearly by the huge amount allocated to defence in different budget allocations of countries. Although a good part of these defence allocations are spent on aquiring arms, buildings and allied works also take a substantial part. These buildings and allied works take the form of barracks, hospitals, school, offices ,etc all of which constitute a base or barracks either for the airforce, navy or army. This work aims at providing an architectural solution to the problem of airforce

base planning with a view to designing a model base for the Nigerian Airforce. To achieve this goal, it is necessary to have a good idea of the military setup and its historical background.

1.10 HISTORY AND DEVELOPMENT OF THE MILITARY

According to the Guiness book of records 1988 edition, the oldest conventional army in the world is the eighty-three strong Swiss Guard at the Vatican City with a regular foundation dating back to the 21st of January 1506. Its origin however goes back before 1400. The largest numerical armed force in the world is that of the Peoples Republic of China with four million, seven hundred and fifty thousand (4,750,000) members. Her para-military forces of armed and unarmed militas has also been estimated by the International Institute of Strategic Studies (I.I.S.S) based in London at twelve million (12,000,000) plus. Their mid-1981 estimates for the two principal world powers are three million, six hundred and seventy-three thousand (3,673,000) for the Union of Soviet Socialist Republics (USSR) and two million and forty-nine thousand (2,049,000) for the United States of America (U.S.A). In Africa the largest armed force is that of Egypt with eight hundred and fifty thousand (850,000) men. It is followed by Racist South Africa (R.S.A) with three

hundred and forty five thousand (345,000) and Nigeria with about two hundred and thirty two thousand, five hundred (232,500) men. Nigeria however is the largest in "Black" Africa.

The earliest autonomous airforce is the Royal Airforce of Britain whose origin began with the Royal Flying Corps (created on the 13th day of May 1912). The air battalion of the Royal Engineers began on the 1st of April 1911 and the Corps of Royal Engineers Baloon section in 1878 although it was first operational in Botswana (then Bechuanaland) in 1844. The Prussian Army was also known to have used a baloon at Strasbourg, France as early as 24th September 1870. The largest airforce of all time was the United States Airforce (now the US Airforce, "USAF") which had seventy-eighty thousand, nine hundred and eight (78,908) aircraft as of July 1944 and two million, four hundred and eleven thousand, two hundred and ninety-four (2,411,244) personel in March 1944. The US Airforce including its Strategic Wing had five hundred and fifty five thousand, one hundred (555,100) personel and three seven hundred (3,700) combat aircraft in mid 1980. The U.S.S.R Airforce including Air Defence Forces had in mid - 1980 one million and seventy thousand (1,070,000) men and five thousand, eight hundred and fifty (5,850) combat aircraft. The strength of the Royal Airforce

was eighty nine thousand, seven hundred and fourteen (89,714) with combat aircraft in mid - 1980. Coming back home to Africa, Egypt had twenty five thousand (25,000) personel, Racist South Africa, eight thousand, five hundred (8,500) and Nigeria Six thousand as of 1978. These figures and those of other countries can be seen on table I. Africa as a continent can now be said to have three races or peoples; the negros or black race, the arabs and the whites. A look at table II clearly shows that "Black" Africa of which Nigeria is often considered the giant, lags behind when the ratio of the personel to the population is considered. This is a thing of great concern especially to the black man who has been oppressed through out history.

The time has therefore come for African's especially blacks to reassert themselves by developing a sophisticated army, which would be able to defend the territorial integrity of Africa and also protect its people.

1.20 HISTORICAL DEVELOPMENT OF THE NIGERIAN AIRFORCE

The Nigerian Airforce (NAF) is the youngest of the three arms of the military i.e. army, navy and airforce. It (ie the Nigerian Airforce) was established by an Act of Parliament by the Government of the Late Alhaji Sir Abubakar Tafawa-Balewa in April 1964 and the

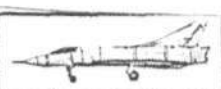
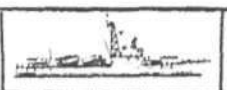
Table I:- Personnel Strength of armeds forces of all African Countries

PERSONNEL STRENGTH

Country	Air Force	Army	Reserves	Navy	Para-Military	Total
Algeria	5,000	67,000	100,000	3,800	10,000	185,800
Angola	800	30,000		700		31,500
Benin	150	2,100			2,100	3,250
Burundi		7,000			2,000	9,000
Cameroon	300	5,500		200	7,000	13,000
Central African Empire	100	1,100			1,400	2,600
Chad	200	5,000			6,000	11,200
Congo	300	6,500		200	2,900	9,900
Egypt	25,000	300,000	500,000	20,000	50,000	895,000
Ethiopia	2,000	50,000	20,000	1,500	84,000	157,500
Gabon	200	950		100	1,600	2,850
Ghana	1,400	15,000		1,300	3,000	20,700
Guinea	500	5,000		350	8,000	13,850
Ivory Coast	200	4,500		250	3,000	7,950
Kenya	800	6,500		400	1,800	9,500
Liberia		5,220			21,300	26,520
Libya	4,500	22,000		2,700		29,200
Madagascar	350	9,550		250	7,000	17,150
Malawi		2,400			460	2,860
Mali		4,200			5,700	9,900
Mauritania	150	7,000		300	6,000	13,450
Morocco	5,650	75,000		4,000	30,000	114,650
Mozambique		19,000				19,000
Niger	50	2,000			1,800	3,850
Nigeria	6,000	221,000	2,000	3,500		232,500
Rhodesia	2,300	8,250	55,000		44,000	109,550
Rwanda		3,750			1,200	4,950
Senegal	200	5,500		250	1,600	7,550
Sierra Leone		2,200			2,500	4,700
Somalia	1,000	30,000		500	12,000	43,500
South Africa	8,500	41,000	165,000	5,500	125,000	345,000
Sudan	1,500	50,000		600	3,500	55,600
Tanzania	1,000	13,000		600	36,400	51,000
Togo		2,500			1,400	3,900
Tunisia	1,700	18,000		2,500	9,000	31,200
Uganda	1,000	20,000				21,000
Upper Volta		8,070			1,850	9,920
Zaire	3,000	30,000		400	30,000	63,400
Zambia	1,500	7,000			700	9,200

Source: IISS: The Military Balance 1977-1978

Table II:- Personnel Strength and equipment of Black, Arab and White Africa

AREA	PERSONNEL				POP.
BLACK AFRICA	780,200	314	597*	237	279,832,000
ARAB AFRICA *African Members of the Arab League*	1,368,400	853	4,310	229	107,292,000
WHITE AFRICA	454,550	410	170	16	4,689,000**
			*excluding Nigeria		**excluding Africans

service was charged with responsibilities which include:-

(a) To achieve a full compliment to the military defence system of the Federal Republic of Nigeria both in the air and on the ground.

(b) To ensure fast versatile mobility of the armed forces.

(c) To provide close support for the ground forces in all phases of operation and to ensure the territorial integrity of a united Nigeria.

The first airforce base to be established in Nigeria was the Ground Training Group (G.T.G) base at Kaduna in 1964. This was the brainchild of the German assistance group that was invited to set up the base. Nigerian Airforce bases therefore have their origin from Germany (ie the Federal Republic of Germany otherwise known as West Germany). The G.T.G base was designed as a mixed flying and ground training base.

Successive governments have continued to add to the roles of the Nigerian Airforce. These roles include:-

(a) To defend the territorial integrity of Nigeria

(b) To deter any attack by any nation and should deterrence fail to bring any war to a conclusion favourable to Nigeria to attack the nation.

(c) To provide aid to civil power.

(d) To aid the Organisation of African Unity (O.A.U), the United Nations Organisation (U.N), the Economic Community of West African States (ECOWAS) and support any other arrangement or agreement that may be entered into from time to time by the Federal Government of Nigeria.

Because of the nature of the functions to be performed by the Nigerian Airforce, it has become necessary to acquire sophisticated equipment and weapons. The NAF is a highly technical service with obvious bias for personnel who have a science or technological background. It is on top of this academic background in its personnel that military discipline is incalcated into its men and women. There exist basically two category of personnel in the Nigerian Airforce:-

(a) The commissioned officers

(b) The non-commissioned officers.

The Nigerian Airforce is therefore made of enlightened personnel comparable to any airforce in the world.

1.30 THE NIGERIAN AIRFORCE TODAY

The Nigerian Airforce today ranks as one of the safest not only in Africa but in the world. This is due to the calibre of personnel it has as well as the high level of training the personnel receive both at home and abroad. Although the Nigerian Airforce might

not have as many personnel as that of countries like U.S.A., U.S.S.R., Britain, Egypt, Racist South Africa (R.S.A), etc, airforces of countries like Isreal whose personnel are few in number have shown that the quality of the personnel is more important. This was demonstrated by Isreal in the six days war with Egypt. This however does not mean that a large airforce is more disadvantaged compared to a small one. A large airforce with well trained personnel would of course perform better and within a shorter time than a smaller one with equally good personnel. What however is important is the quality of the personnel and not the quantity.

According to the Nigerian Airforce Public Relation Directorate, the present organisational structure of the Nigerian Airforce is as detailed below:-

(a) HEADQUARTERS OF THE NIGERIAN AIRFORCE (HQ. NAF)

The Nigerian Airforce Headquarters (HQ NAF) comprises four main staff branches:- Operations, Administration, Logistics and Inspection. Each branch is headed by an Air Officer who is responsible directly to the Chief of Air Staff (C.A.S). The Directorates of Finance and Accounts (D.F.A) and the NAF Tenders Board (NAFTB) also come under the C.A.S's office.

(b) HEADQUARTERS NAF OPERATION STAFF BRANCH

This branch is responsible for policies and directives for daily operations as well as training on land and air in the Nigerian Airforce. It comprises the directorates of Operations, Training, Communication and Electronics, Plan, Intelligence, Air Traffic, Signals and Inspectorate of Regiment.

(c) HEADQUARTERS NAF ADMINISTRATION STAFF BRANCH

This branch is the nerve centre of most of the Nigerian Airforce Administration and Personnel Matters. It deals with the organisation of the NAF in accordance with operational policy and requirements. It is served by the following directorates:- Administration, Personnel, Air Police, Education, Public Relation and Information and Medical Services.

(d) HEADQUARTERS NAF LOGISTICS STAFF BRANCH

This branch is responsible for policies on provisioning, procurement and maintenance of all equipment and infrastructure in the NAF. Directorates under it are:- Engineering, Supply, Works and Armaments.

(e) HEADQUARTERS NAF INSPECTION STAFF BRANCH

The Inspection Branch is a new branch set up to ensure standardization between formation and units and to ensure proper maintenance of standards in the service and to facilitate full time research into problem areas in the service to avoid waste in human and material resources. It is served by the directorates of Manuals, Inspections and Safety.

1.40 COMMANDS

Apart from the above mentioned staff branches, the Nigerian Airforce also has four commands and each of these commands is headed by an "Air Officer Commanding" (A.O.C) who is an equivalent of the army's "General Officer Commanding" (G.O.C) and the navy's "Flag Officer Commanding" (F.O.C). The chain of command of the NAF is shown in Fig 1. The four commands are:- The NAF Tactical Air Command (T.A.C) the NAF Training Command (T.C), the NAF Logistics Command (L.C) and the recently created NAF Military Airlift Command (M.A.C). These Commands have special Airforce bases under them. The functions of these commands are discussed below.

(a) NAF TACTICAL AIR COMMAND (TAC)

This is a command established for the purpose of centralisation of command with a view to providing joint operation doctrine for the use of the tactical forces. Formations and units under it include the Strike Group, Air Transport Group, an Air Centre and Advanced Weapon School.

(b) NAF TRAINING COMMAND (T.C)

This command is established for the purpose of planning and coordinating the administrative and operational command of all training activities in the NAF. The training command consist of six (6) groups namely:- three Flying Schools each of group status, the Technical Training Group, Military Training Group and the Base Services Organisation (BSO).

(c) NAF LOGISTICS COMMAND (L.C)

The NAF Logistics Command has been established to supply and maintain the material as well as infrastructural facilities required for the accomplishment of NAF assigned tasks. The logistics command consists of a command headquarters and four (4) depots namely:- two (2) Aircraft Maintenance Depots, a Communications and Electronics Maintenance Depot and an Equipment Supply Depot.

(d) NAF MILITARY AIRLIFT COMMAND (M.A.C)

This is a new command created in May 1988 to suppliment the Logistics Command in terms of airlifting of the military. A full list of its functions are yet to be officially released. But it is worth noting that its main preoccupation is mainly to airlift personnel and equipment.

In addition to the above mentioned commands and staff branches, there are four (4) additional formations or units which are directly answerable to the headquarters of the Nigerian Airforce. These formations are the Pay and Accounting Group, the Personnel Management Centre, the Aero Medical Centre and the Airforce Military School.

At present there are about fourteen (14) airforce bases in Nigeria. These bases are directly under the commands although specific airforce bases are under specific commands as has been clearly shown in Fig 1. The bases are manned by base commanders. These base commanders are equivalents of brigade commanders that are present in army cantonments and they are responsible directly to the Air Officer Commanding (A.O.C) under which their respective bases fall. They are usually of the ranks of Wing Commander or Group Captain.

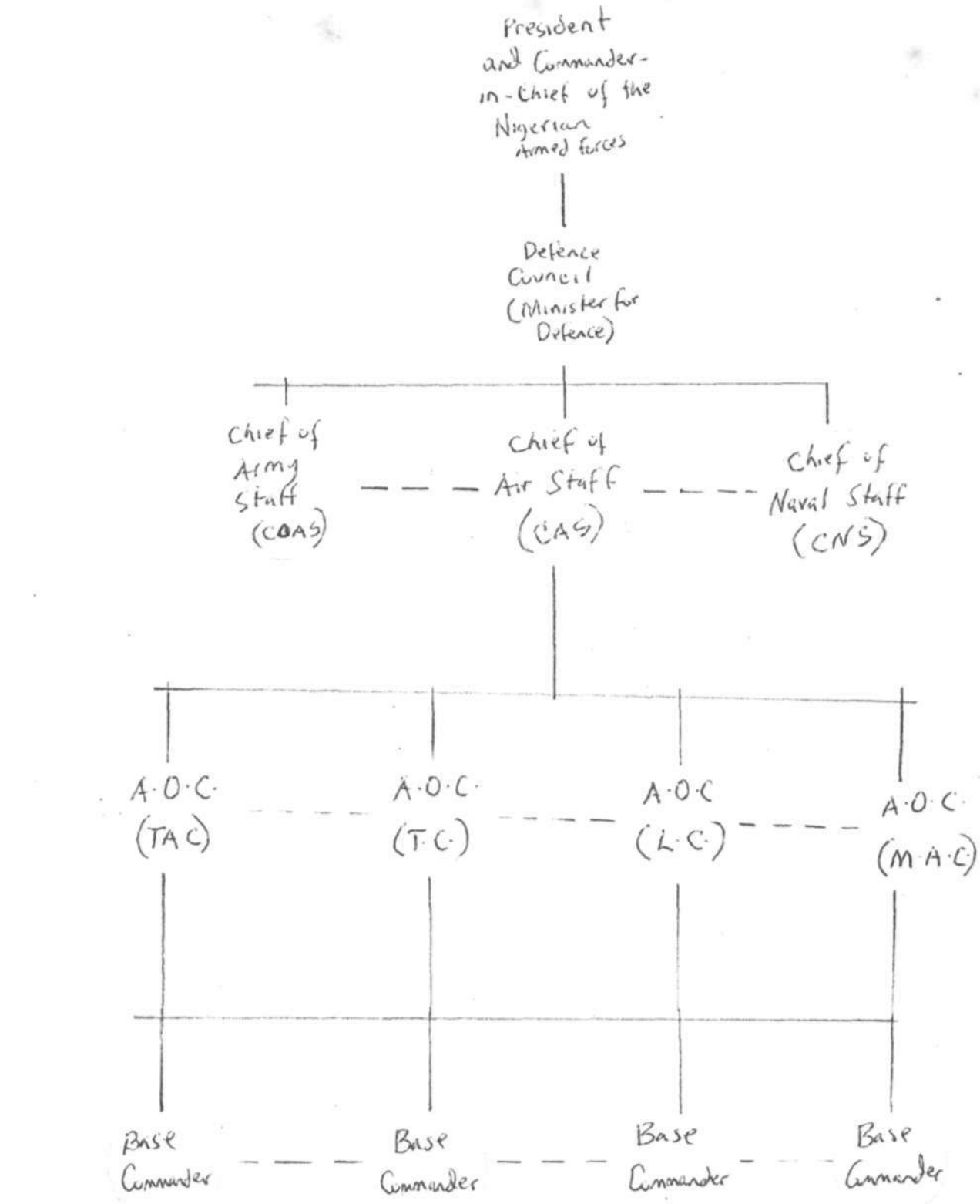


Fig 1:- Chain of Command of the Nigerian Airforce

1.50 THE NAF AND CONTAINMENT OF EXTERNAL THREAT

The role of the Nigerian Armed Forces to carry out its task effectively is based on the weapons it can aquire and this is dependent to a large extent on the nation's perception of the likely threats to its territorial integrity.

In view of the nations foreign relations which puts Africa as the centre piece and pivotal point of its foreign policy, coupled with its size and abundant human and natural resources, countries bordering Nigeria and within the sub-region tend to be suspicious of her intentions. This has sometimes resulted in minor border conflicts eg. Cameroun/Nigeria and on the other hand some countries have intentionally provided a base for clandestine operations for nations which are considered enemies of this country. A very good example is the recent South African presence in Equitorial Guinea which is less than an hour's flight from Nigeria.

The issue here is that the foreign policy objectives of Nigeria are dramatically opposed to the very existence of the Racist South African regime. In view of our foreign policy objectives therefore, there is a threat to internal destabilisation and external agression.

Air Vice Marshal A.D. Yahaya of the Nigerian Airforce in a paper entitled:- "The NAF and the Development of Air Power" sees three possible sources of threat to Nigerian on the African continent. These three sources are:- Our immediate neighbours, South Africa and North Africa. The reasons he advances are as follows:-

(a) "Our Immediate Neighbours

Nigerian is surrounded almost entirely by Franco-phone countries. The Niger Republic on the north, the Republic of the Camerouns on the east, the Republic of Benin on the west and the Chad Republic to the north-east. The military and economic strength of these countries within the West African sub-region could be generally described as weak. Nevertheless the weakness could pose a threat to our national security because they could be used as bases to try and destabilise Nigeria. Some hostile military actions by the Republic of Camerouns, especially the killing of five Nigerian soldiers deserve special attention. Also worth mentioning, is the occupation of some part of Sokoto State by soldiers from the Republic of Benin some time in 1981. Although these happenings might be of small nature, they need to be given serious thought to as possible threats that could lead to war.

(b) South Africa

Nigeria's present foreign policy, which makes Africa the centre piece, is a great challenge to the political system of the Racist South Africa (R.S.A) regime. Nigeria's objective and total commitment to the liberation of the black race and the promotion of equality of races is contrary to the R.S.A regime. With this type of cold hostile relationship existing between Nigeria and R.S.A., the latter could wish that Nigeria should not have existed on the map at all,

and would look for any possible means to either destabilise or humilate Nigeria. Also an evaluation of R.S.A. military strength would reveal that it is second only to Egypt in the continent of Africa. She also has a large military industrial complex which manufactures a considerable proportion of her war needs. She spends about seventy (70%) percent of her defence expenditure for the manufacture of her defence needs since the United Nations (U.N) partial arms embargo on her. All these are of great threat to Nigeria and Nigeria must therefore develop a credible deterrent force to ward off any aggression from Racist South Africa.

(c) North Africa

Another region of potential threat to Nigeria is the activity of some North African arab countries. Libya, for instance, has been known to be sponsoring extreme radical Islamic religious sects in a number of countries. Should it do so in Nigeria, it could undermine the hitherto relatively peaceful religious atmosphere within the country. Besides, the country's military adventures in the Chad Republic constitutes serious cause for concern. Nigeria therefore needs to watch Libya carefully."

Having identified and analysed some of the likely threats Nigeria faces which could undermine the country's national interest and objectives, it becomes imperative that she adopts some measure of defence strategy to counteract these threats. The Nigerian Airforce is assigned the responsibility of the defence of the nation's airspace. To achieve this task the airforce must be very effective in fire power and weapons delivery. In modern warfare, at least two services of the armed forces are needed to successfully persecute

a war. These services could either be the airforce and the army or the airforce and the navy. Whichever way one looks at, the airforce must be included. Airpower therefore becomes of paramount importance in modern warfare and for the airforce to be effective and in a position to give the other two services adequate air cover and support, it must possess the following capabilities:-

(a) Strike capability
(b) Air defence capability
(c) Close air support and ground attack capability
(d) Air lift capability
(e) Maintain patrol capability
(f) Effective logistics backing
(g) Communication services.

Any weakness in any of these capabilities would seriously affect the operational effectiveness of the Nigerian Airforce. A good look at these capabilities is therefore necessary. These capabilities are therefore discussed briefly below:-

(a) NAF STRIKE CAPABILITY

The strike element of the airforce is the main offence force whose primary duty is deep penetration of enemy war making potentials. Therefore without a good strike capability, the enemy could penetrate Nigeria's air defence system and attack vital installations.

(b) NAF AIR DEFENCE CAPABILITY

The main purpose of any air defence is to detect and destroy the enemy before he reaches his target. In a nation's defence network, the three arms of the armed forces and the civil aviation have roles to play. Here, the airforce has more responsibilities, and therefore in most cases is responsible for the entire development of the system.

(c) NAF CLOSE SUPPORT AND GROUND ATTACK CAPABILITY

The amount of fire power that can be brought to bear on the enemy in modern warfare, will be a determining factor for victory or defeat in the battle field. Thus, in developing close support/ground attack capability the airforce's main pre-occupation is to be able to fight in close support of the army and the navy in the battle field.

(d) NAF AIR TRANSPORT CAPABILITY

The ability of a nation to move its troops and equipment within the shortest possible time enhances the overall defence posture of the country. Furthermore, in warfare, victory or defeat would depend, to a large extent, on the mobility of the forces and the relevant logistics support.

(e) NAF MARITIME AIR CAPABILITY

It is a well known fact that a good part of Nigeria's foreign exchange earnings comes from off-shore oil exploration. She also has a coastline that is about eight hundred (800) kilometre long with an extended coastal economy zone of about three hundred and twenty (320) kilometres off-shore. At the moment the Nigerian Navy (NN) is not in a position to effectively patrol these areas so the airforces has to supplement the efforts of the navy.

(f) LOGISTICS BACKING IN THE NAF

For any successful air operation to take place, there must be a sound and effective logistics backing. Such logistics backing calls for sound planning in terms of provision of well-trained manpower, well equipped maintenance facilities with corresponding aero and auto ground equipment, and adequate storage facilities.

(g) COMMUNICATION SERVICES IN THE NAF

In order to achieve a high degree of effectiveness and preparedness, NAF must have a sound communication system.

All the above discussed factors influence to a great degree the ability of an airforce to perform. For an airforce to achieve its goals, it must possess

all these factors to a satisfactory level. In modern warfare, no single arm of the armed forces can achieve victory single handedly. At least two of them; the airforce and the army or the airforce and the navy have to go it together. The Nigerian Airforce therefore has a vital role to play in the Nigerian defence system.

1.60 AIRCRAFT IN USE BY THE MILITARY

Today, there are hundreds of different aircraft in use by the different armed forces of the world. At present the fastest combat aircraft in the world is the USSR Mikojan MIG - 25 fighter (code named "the bat") which moves at three thousand, three hundred and ninety-five (3395 km/h) kilometres per hour. There are also planes like the F - 16, F - 14, B - 1B bomber, B - 526 Stratofortress strategic bomber, F - 111 fighter - bomber, the Mirage series, etc. All these military aircraft are at present being used by air-forces of different countries and also by the other services.

At the moment, the Nigerian Airforce has a good collection of aircraft although she hopes to purchase more in the near future. Some of the aircraft in the Nigerian Airforce fleet include:-

(i) MB 339
(ii) Jaguar
(iii) Alpha Jet
(iv) MIG 21
(v) Delfin L 29

(iv) C 130 H
(vii) Dornier Sky Servant
(viii) BO - 105 Helicopter
(ix) Chinook
(x) L 39

These above mentioned aircraft vary from light attack aircraft to transport aircraft to reconnaissance and interceptor aircraft. In the near future, the airforce would acquire new and better planes while the outdated ones would be gradually phased out. Despite its relatively young age, the Nigerian Airforce has undergone a great metamophosis. It has grown from a relatively small airforce with six or so planes to a large one with about a hundred or more planes within a very short time. Its has also grown from a formation of about 80 men in 1964 to over 10,000 today. Bases also have increased from the original one to about fourteen. These are clear indications of a bright and positive future for the Nigerian Airforce. It is a force to reckon with because everyday it is growing from strength to strength. Afterall to the airforceman, the sky is no limit; it is the starting point. That is to say for the Nigerian Airforce, there is no limit.

CHAPTER TWO

2.00 THE TYPICAL AIRFORCE BASE

As has already been mentioned, the first airforce base to be established in Nigeria, is the Ground Training Group Airforce Base located in Kaduna. An airforce base is a place from which the operational activities of the force is conducted. The airforce base also provides for residential, administrative, recreational, educational, health, work and training activities of personnel of the Nigerian Airforce. It is the equivalent of an army Cantonment or a naval base. The airforce base is therefore an all embracing community patterned after the military way of life to provide the airforce personnel with a place to work and live in with his/her family. The different activities that take place in a base have intrinsic linkages to one another ie. the residential, recreational and other activities are linked to each other.

There are basically two main zones in a typical airforce base namely; the Operational zone and the Non-operational or Barracks zone. Their respective components and functions are hereby discussed.

2.10 THE OPERATIONAL ZONE

As the name implies, this is the zone where all military operations relating to the flying and training aspects of the airforce take place. It is therefore considered the nerve centre of the airforce base. It is also a kind of military airport. Apart from other differences that would be mentioned later on in this chapter, the main difference between a civil airport and a military airport or the operational zone is that of security. The operational zone is restricted and does not have commercial passengers whereas the civil airport has passengers and is open to all. Most of the facilities that are present in conventional civil airports are also present in this operational zone: These include

(i) Runways and taxiways
(ii) Aircraft shelters (hangars)
(iii) Parking aprons
(iv) Workshops
(v) Warehouses
(vi) Control tower and administration block
(vii) Fire service station
(viii) Fuel depots, etc.

In addition to these facilities it, things like bunkers for the commander, pilots and aircraft as well as guard houses are present in a base. It is also worth noting that the operational zone is fenced with high

rised barbed wire and in some cases with high walls. The operational zone is also clearly demarcated from the barracks zone also with a high fence or wall.

2.20 THE BARRACKS ZONE

This is the part of the base that houses the personnel of the airforce that work in the base and their families. However, unlike the army where the cantonment has seperate offices outside the barracks zone for the commander and other officers, the barracks zone in the base also houses the commander's office and other major offices. This is due to the sentitive nature of the operational zone. Visitors or outsiders who might want to transact business with the airforce are not allowed into the operational zone and hence all their business transactions can be done in the offices in the barracks. Apart from the offices, all the other welfare facilities are provided in this zone. The barracks is also surrounded by high barbed wire fence and is also clearly demarcated from the operational zone. One point to note in the housing sector is that four main zones exist. These are:- The officers quarters, the senior non-commissional officers quarters, the junior non-commissional officers quarters and the trainee quarters. The officers quarters is further zoned into senior, intermediate and junior officers.

Basically the units that exist in the barracks zone are:-

(a) The quarters for the officers and men

(b) The base commander's and other offices

(c) Welfare offices and facilities

(d) Messes for the officers' and men

(e) Sports and other recreational facilities

(f) Religious buildings (ie Mosques and Churches)

(g) Schools

(h) Medical Reception Station (M.R.S)

(i) Parade ground

(j) Mammy market

(k) Super market

(l) Motor maintenance workshop

(m) Warehouses

(n) Guardhouses.

All these functions however have links which are quite strong and influence the planning of the base to a great extent. The barracks zone is usually planned in the grid-iron style to potray the orderly nature of the military and also to ensure fast and versatile movement of the military personnel in event of any outbreak of war or any civil unrest. The personnel therefore have to be housed in an atmosphere that is conducive to them.

2.30 TYPES OF BASES

There are basically three types of airforce bases namely:- Ground training base, Flight training base and Mixed ground/flight training base. These bases though different in nature have a few things in common; runways for military aircraft. All base types also provide for residential, work and training, administration, recreation and other uses. In a case where a barracks or non-operational zone does not exist in a base, it is usually referred to as a Nigerian Airforce Station.

The three types of bases are briefly discussed below to give an insight to what the set-up looks like.

(a) GROUND TRAINING BASE

This is the type of base where the training of ground officers is conducted. These officers are usually the personnel of the Nigerian Airforce who do not make it in the flying sector of the force or for university graduates or university cadets.

(b) FLIGHT TRAINING BASE

Like the name implies, this is the base where the flying is done. This is where the pilots and other flight related training and other flight operations are done. The personnel in the flight training base are mainly pilots and here hangars, control towers, etc are present.

(c) MIXED FLIGHT TRAINING/GROUND

This is the kind of base where both ground training and flight operations are done. It is a kind of synthesis between the flight training and ground training base.

2.40 FACTORS THAT INFLUENCE THE SITING OF AIRFORCE BASES

As has already been said, the Nigerian Airforce is assigned the responsibility of the defence of the nations airspace. To do this the airforce has to have places from which to perform this function. These places are the ones we refer to as either bases or stations. However, in order to site an airforce base or station at a place, many factors have to be taken into consideration and these factors that influece the siting range from one reason to another. These include:-

(a) The geographical location of the area and the source or sources of threat to the nation around these areas. For this very important reason, most bases are sited in states that border other countries not only in Nigeria but the world over.

(b) The importance of economic installations that may be present in the location. These economic installations could be industries, dams, etc on which the nation depends to a great extent.

(c) They could also be sited in certain location for political reasons by the government and these political reasons vary from government to government.

(d) A base can also be sited in an area to supplement and give aid to civil power ie to support a civil government or to support civil aviation operations and to link remote areas.

(e) An airforce base can also be sited in place due to the presence of certain infrastructure present eg. an airport that has been put out of use due to the building of a new airport. The airforce in such cases would take over or acquire such a project since it would to a certain extent lie fallow or idle.

(f) An airforce base normally has to be sited in the capital city of the country in order to defend the seat of government.

(g) Bases can be sited in a particular place for security reasons in order to forestall disturbances or to supplement either the army or navy's function.

2.50 MILITARY PLANNING - THE AIRFORCE EXPERIENCE

Planning for the military especially the Nigerian Airforce poses quite a big challenge to the planner or designer who might not be familiar with the military way of life ie ethics and rules and regulations governing their life. Planning of airforce bases also differs from that of the army or navy because, while a cantonment for the army or a naval base can just be built anywhere, an airforce base has to be located within the vicinity of either a civil airport or a military airport. This might pose problems for the planner who has to consider amongst other things the effects of fast and noisy aircrafts, on adjacent buildings and people.

Another problem the planner/designer is faced with is that of planning two major zones - the operational zone and the barracks zone - both of which require expertise and a lot of analysis. Due to the sensitive nature of matters relating to the military, there has not been much documentation in respect of planning in the airforce and the little data that exists about it is normally limited and restricted in circulation.

The first Nigerian Airforce Base was designed in 1964 by members of a special task force of the German Airforce and this base was designed for mixed flying/ground training. After the Nigerian Civil War in 1970, another task force, this time of the young Nigerian Airforce were given the task of designing/ planning the first indeginous full fledged military base. After that the Nigerian Airforce started to aquire old airports from the Nigerian Airports Authority who had started to move to new airports, e.g. Kaduna. However, since these airports were not originally designed as airforce bases, certain problems emerged that were bound to hamper the effective functioning of the base. There came the problem of either under-utilization or over-utilization of certain facilities, utilities and services or the spatial location of non-conforming land-uses. It was also discovered

KASHIM IBRAHIM LIBRARY
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA.

that the residential area or barracks zone was unable to cater for all personnel working or training in the base. This further necessitated the aquisition of houses for servicing personnel in civilian urban areas. This subsequently led to the problem of transportation of such personnel from their homes to and from their places of work or training. Furthermore, the provision of training, educational and recreational facilities were grossly inadequate.

Due to this fact the Nigerian Airforce decided to acquire land in some parts and to build full fledged bases which are supposed to be self sufficient in terms of infrastructure. As already mentioned earlier the airforce base can be divided into two main zones:

(a) The operational zone

(b) The barracks zone

Although these zones have been discussed before, a more comprehensive assessment as regards planning in the airforce is discussed below.

(a) <u>The Operational Zone</u>

This is the part of the base which serves the same functions as an airport only that it does not serve commercial purposes. It is also here that pilots are trained. It consists of runways, taxiways, parking aprons, aircraft shelters/hangers, warehouses,

control tower, fire service, fuel supplying. In a nutshell it is a military airport restricted to military activities.

It can be seen here that in order to design this zone, a very good knowledge of airport design requirements as well as the military way of life is very essential. In order to be able to design this zone a good knowledge of the types of aircraft to be used is essential. You must also understand the airport master-plan, airport requirements, airport site selection, land-use planning, environmental study, ground access, vehicle parking, economic and financial feasibility, obstruction clearance requirements, evaluation of noise, airport runway configuration, etc. Aspects such as wind direction and airport drainage are also very essential. Since this operational zone is also a military zone, it should be well shielded from the enemy. This can be done with the help of good camouflage, e.g., trees. Also only one access into the base should be allowed and very high barbed wire fences should be used to surround the entire site and also the same barbed wire should be used to clearly demarcate the operational zone from the barracks.

(b) The Barracks Zone

This is the part of the base that houses the officers and members of the base. Apart from the housing scheme, it also contains messes for the officers and men, the medical centre, schools, sports and recreational facilities, religious buildings, super-markets/mammy markets, etc. It is interesting to note also that unlike in the other cases, i.e., army and navy, the commander's office, parade ground, etc. are located within the barracks.

One other interesting point is that there are four main housing zones in the barracks. These are:

i. Officers quarters

ii. Senior non-commissioned officer (N.C.O) (Sgt. and above)

iii. Junior non-commissioned officer (Corporals and below)

iv. Trainee quarters.

Usually the officers live in three bedroom bungalows, Senior non-commissioned officers in two bedroom, junior non-commissioned officers in one bedroom and trainees in single row buildings. Individual officers' dwelling unit is directly connected with the main residential sheet. However, the circulation is usually peripheral to the corporal and below residential schemes. Residential area planning

in airforce bases refers to the planning of a housing environment that is technically sound, environmentally healthy, professionally adequate and functional, efficient and effective to the attainment or achievement of their military roles. The whole concept of military residential area is to achieve despatch in the out-break of eventualities. In other words, residential area in military cantonment should be concise, adhering very rigidly to the grid iron pattern of circulation system. Landscaping should serve first as camouflage and as a cover to structure on ground. The concept of specialized residential planning in the airforce is to achieve a distinct self sufficient, healthy living environment, provided by government, effectively and efficiently linked with the civilian urban area, but separated and segregated as a unit, and interably by rank.

It would be seen from all that has been discussed that the overall design/plan of an airforce base should be aggressive, rigid, massive yet at the same time neat and orderly. It is for this reason that the bases usually conform with gridded or modular designs. This does not mean however, that irregular or non-modular plans cannot or have not been used. However, due to its practicality and simplicity, most military plans for either cantonments, naval bases or airforce bases or stations adhere strictly to this orderly method of planning.

However, as time goes by, more and more practical concepts and ideas would begin to emerge. Concepts like that of the Japanese, i.e. Metabolism should be tried out in military planning on a large scale as would be attempted in this thesis. This is because the growth of the airforce is continuous and so the base should be able to grow systematically. Planning for the military as regards their housing is often referred to as specialised housing and the planners should thus, have good knowledge of the military way of life. This is necessary if justice is to be done to planning for them. The most important fact to note in this case is the hierachy and segregation in the armed forces. Officers and men are zoned according to rank and this can be seen clearly in all military barracks.

2.60 DIFFERENCES BETWEEN MILITARY AND CIVIL AIRPORT AND AIRCRAFT

An airport whether for civil or military functions remains or is basically an airport. They differ however is a number of ways and so do the aircraft. The main difference between an airforce base or station and a civil airport is that of their modes of operation. The civil airport is used for commercial purposes and is open to all whereas that of the military is restricted and it performs mainly military functions.

The civil airports also place a lot of emphasis on the terminal building which is supposed to be a kind of transit zone for the passengers whereas in the military it is de-emphasised due to the absence of commercial passengers.

A lot of emphasis is placed on the provision of bunkers (ie underground shelter) for airforce bases due to their nature of operations in addition to hangers but in most commercial airports these are de-emphasised and it is only in rare cases that hangers are even provided.

Military aircraft travelat much higher speeds than normal aircraft and hence they are a source of very high noise pollution compared to the civil aircraft and therefore normally require longer runways than those of civil airports.

Military airports also are placed very far out of town mainly due to security reasons and also because of the noise problem but civil airports are usually located a bit out of town but at a reasonable distance so that it is easily accessible by very good transportation system.

There are also very many installations of military importance in bases that are not at all available in local airports. These range from plane bunkers to pilot bunkers, etc.

By and large, the most important difference between airports and airforce bases is that apart from the security aspect of airforce bases which bordens on its inaccessible nature to outsiders, the airforce base or military airport is an airport without passengers ie it does not serve commercial purposes. The bases also provide housing units for their personnel and this is hardly found in airports.

In the case of the aircraft, military aircraft, except for the transport planes, usually have no extra seats for passengers except for the pilot and co-pilot whereas most civil aircraft are commercially oriented and hence have room for many passengers.

Civil aircraft are also more bulky in nature e.g the DC 10, Boeing 747, etc whereas military aircraft like the F-16, the Mirage 200, Jaguar, Mig 21, etc are slick and small in nature. Military aircraft also have the tendencies to land even in the worst of places. This is due to their ruggedness. They are usually also fitted with armaments such as missiles, bombs, etc, things not found in civil aircraft.

These factors therefore make the mode of operation of the two types of airports different. It is easier for a military aircraft to adapt to worse conditions than for civil aircraft. While any military aircraft can just land anywhere even on a dirt road, a DC 10 would find it impossible. This is like has been said before, due to the ruggedness of the military aircraft.

PART TWO

- THE DESIGN ANALYSIS -

CHAPTER THREE

3.00 AIRPORT PLANNING

The operational zone or in other words the air-station (or airdrome) as has already been mentioned could be considered as a military airport differing from a conventional airport mainly because of the lack of passengers. Apart from the security aspect of the operational zone and other already mentioned factors, this zone generally could be seen as an airport. Because of this reason, most if not all factors that influence the design and planning of airports have to be taken into consideration when designing an airforce base operational zone.

Airport planning in itself is such a complex process that inadequate analysis of activities without regard to one another would not provide the desired results. The activities that take place in an airport are interdependent to each other yet they are of a wide range with different and often conflicting requirements. Activities related to the "airport system" can be already seen in fig 2. There are basically two sides as can be seen :- The "airside" and the "landside". It is important and worthy to note that whereas in the conventional airport the terminal building plays a vital role, it

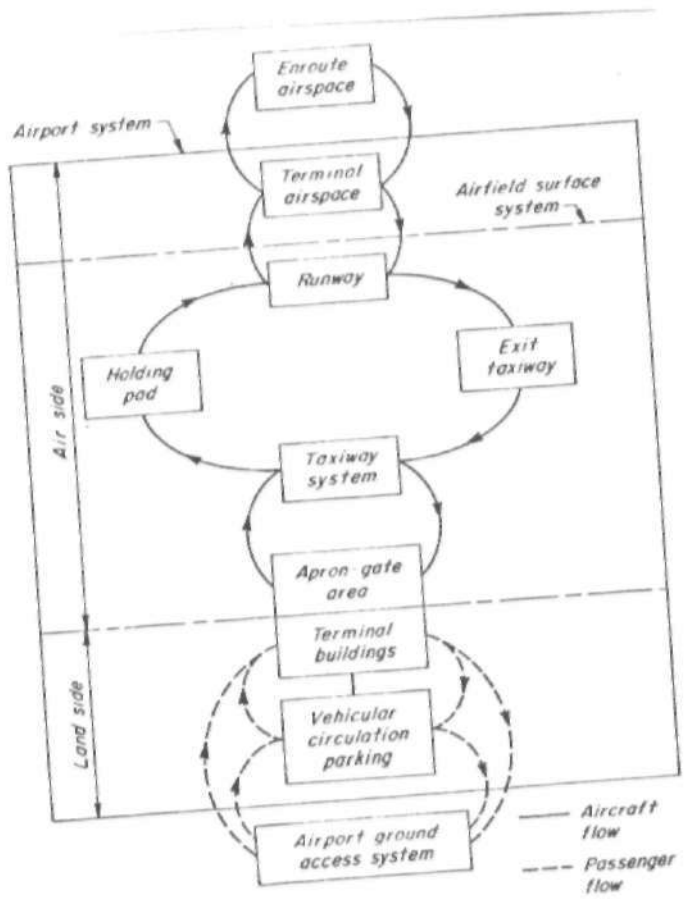


Fig 2:- Airport systems

is normally not required in an airforce base. This is due to the fact that the operational zone is normally an airport with no passengers and the terminal building plays a very important part in that it is the major public - use facility inside the airport and includes the passenger-handling system, the baggage-handling facilities and airline and airport operations facilities. Airports are at present classified on the basis of their runway length. Based on this, we have the five types of airports namely:-

(a) International airports

These are airports whose runway length are 4,000m (13,000 ft) or more.

(b) Principal domestic airports

These type of airports have lengths equal to or greater than 3,500m (11,500ft) but less than 4;000m (13,000 ft).

(c) Domestic airports

Domestic airports are airports whose runway lengths are about 3, 000m (10,000ft) or more but which are less than 3,500m (11,500ft).

(d) Local airports

These airports have runways of about 2,200m (7,000ft) long or more but which are less than 3,000m (10,000ft) and

(e) Secondary airports

These type of airports have runway lengths of about 1,500m (5,000ft).

When planning an airport, many factors ranging from airport site selection to evaluation of noise to aircraft characteristics related to design, etc have to be taken into consideration. These factors are discussed fully below.

3.10 THE AIRPORT MASTER-PLAN

Robert Horonjeff defines an "Airport Master-Plan" as "a concept of the ultimate development of an airport". The term development includes the entire airport area, both for aviation and non-aviation purposes or uses, and use of land adjacent to the airport. Horonjeff goes on to say that

> "The overall objectives of the airport masterplan is to provide guidelines for future development which will satisfy aviation demand and be compatible with the environment, community development, and other modes of transportation. More specifically, it is a guide for (a) developing physical facilities of an airport, (b) developing land in and adjacent to the airport, (c) determining the environmental effects of airport construction and operation, (d) establishing access requirements, (e) establishing the economic and financial feasibility of proposed developments, and (f) establishing a schedule of priorities and phasing for the improvements proposed in the plan."

The masterplan, is a compromise among many diverse physical and non-physical requirements. The content of a masterplan varies but it usually includes forecast of demand, development of alternative solutions to reasonably satisfied forecasted demands, determination of cost-effectiveness of alternative solutions, financial feasibility and environmental impact of alternative solutions.

It has been suggested that when the masterplan is being drawn up, interested parties (ie private citizens, community organisations, airport users, etc) should be brought in early in the development of the plan and given access to all relevant information.

3.20 AIRPORT REQUIREMENTS

Some basic requirements have to be highlited if a good airport masterplan/design is to be effective. These requirements include:- initial inventory, reliable forecasts, analysis of capacity and delay, facility requirements and environmental impact. These factors or requirements are discussed briefly below.

(a) Inventory:-

This is the initial phase in the preparation of the masterplan and it involves the collection of data on existing airport facilities and also the collection of socio economic data (ie population, economic

activity, land use, etc) for the region or zone the airport is supposed to serve. Analysis of the financing available to help in airport improvements and maintenance is also necessary for the development of a financial plan.

(b) Forecasts:-

An airport masterplan is usually developed based on initial forecasts. It is based on these forecasts that various facilities of the airport can be established. Forecasts are usually required for short, intermediate and long terms planning and it is worthy knowing that the longer the forecast terms, the less accurate. There is no easy way of forecasting because too many factors have to be considered.

(c) Analysis of capacity and delay:-

Capacity could be defined as "the number of aircraft operations during a specified interval of time corresponding to a tolerable level of average delay" or as "the maximum number of aircraft operations that an airfield can accommodate during a specified interval of time when there is a continuous demand for service."

The determination of capacity and delay of alternative schemes for the improvement of an existing airport or the development of a new one is an essential

step in master planning. There are many factors that however, influence the capacity of an airfield, but in general the capacity depends on the configuration of the airport or airfield, the environment in which the aircraft operate, and the availability of navigational and control facilities. The standard factors according to Horonjeff are about fourteen in number and they all in one way or another could be classified under one of the three already mentioned factors. However, a brief run down of the factors would not be out of place. These factor are:-

(a) The configuration of the runways, namely number, spacing and orientation.

(b) The configuration and number of taxways.

(c) The arrangement, size and number of gates

(d) For mixed operations (eg, landings and takeoffs), occupancy time on the runway

(e) The various sizes of aircraft using the facility.

(f) Wealther, particularly visibility, since the air traffic rules in good visibility are different than in bad visibility.

(g) Wind conditions vary preclude the use of all available runway.

(h) Noise abatement procedures vary limit the type of operations (eg, landings, takeoffs) on the available runways.

(i) Within the constraints of wind and noise abatement, the way the controllers choose to operate the runways (eg arrivals only mixed operations, etc). This is refered to as strategy.

(j) The number of arrivals relative to the number of departures.

(k) Wake vortices. Air traffic rules require the seperation when a light aircraft follows a heavy aircraft be larger then when a heavy follows a light.

(l) Aids to navigation such as the availability of ILS, VOR, DME and radar

(m) The availability of airspace for establishing arrival and departure routes

(n) The nature and extent of the traffic control facilities (eg tower, approach and departure control).

The first four items pertain to airfield configuration, the middle seven to the environment in which the aircraft operate and the last three indicate the availability of air to navigation and airtraffic control facilities.

The most significant factor which affects runway capacity is spacing between successive aircraft. The spacing in turn is dependent on appropriate air traffic rules. The air traffic rules are dependant on weather and aircraft size.

(d) Facility Requirements:-

The requirements for such things as the runways, taxiways, aprons etc are developed by analysing the demand and capacity and from geometric and other standard governing the design of airport components. This would give the number of required functions eg runways, taxiways, etc. Having found out these facts, it helps the designer/planner in his task of approximating the form and overall expansion of the airport.

(e) Environmental Impact:-

The emphasis on preservation of the environment requires the airport planner to spend time on this subject and to also consult other specialists who have an understanding of environmental problems.

3.30 AIRPORT SITE SELECTION

When the selection of a suitable site for a new airport has been made, certain criteria which would serve as a guide in the determination of its proper size and location must be established. The location or siting of an airport is usually influenced by nine factors namely:- type of development of the surrounding area, atmospheric conditions, accessibility to ground transport, availability of land for expansion, presence of other airports in the general area, surrounding obstruction, economy of construction, availability of utilities and proximity to aeronautical demand. These

factors are taken one after the other in order to fully grasp them.

(a) Type of development of the surrounding area.

This is an important factor because with the arrival and departure of aircraft every now and then, the noise would be a great source of disturbance to the airports neighbours. It is for this reason that sites which offers the closest compatibility with airport activities should be given priority. Proximity to schools and residential areas should however be avoided whenever possible except in a case where the resident make up the staff of the airport (eg Airforce Bases). It is desirable to provide a buffer zone between the runways; taxiways, aprons, etc, and the boundaries of the airport property, in order that nuisances created by activities of the airport be at least partially attenuated.

(b) Atmospheric Condition.

This has to do with the normal weather conditions. The presence of haze or smoke or duststorms affect the visibility and thereby has the effect of lowering possible number of flights to the airport or airfield. The presence of smoke and haze can be mostly noticed within the vicinity of large industrial layouts.

(c) Accessibility to ground Transport.

This is most important for conventional airports whose passengers have to move. In the case of the Military or Airforce Bases however, this could be a

a disadvantage. The haze should be as far away from the urban areas as possible. In the case of the conventional airports however, a good transportation network with the urban setting is important. This is because transit time from the passengers point of departure to the origin is a matter of major concern.

(d) Availability of Land for expansion.

In a field so dynamic as aviation, it is necessary to aquire a land in advance that would be sufficient to accommodate any future expansion projects that might become necessary by the airport. This is because as the size of aircraft and volume of traffic continues to increase, runways would have to be lengthened and widened, terminal facilities expanded and additional support facilities provided.

(e) Presence of other airports in the general area.

When another airport exists in the general area, the new one should be located at a sufficient distance from the old one or existing one so as to prevent aircraft which are manouvering for a landing at one airport from interfering with the movement of aircraft at the other airport of the two airports which might be located too close to each other pose some problems in that they can hinder the smooth operation of each other to the extent that the two airport will have no more capacity during IFR weather within a single airport.

(f) Surrounding obstructions.

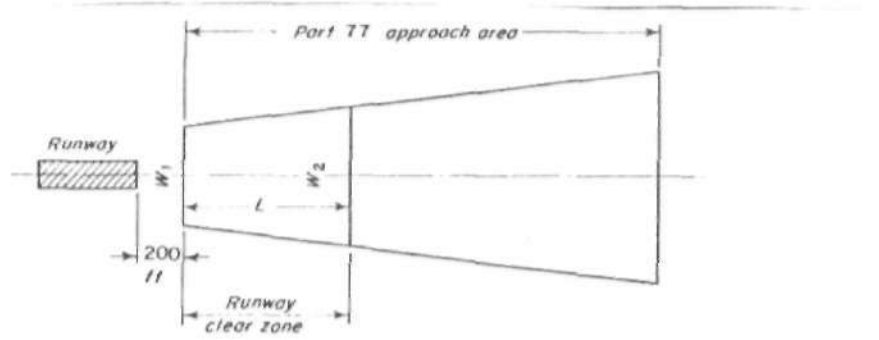
The sites to be used for airport should be so selected that approaches necessary for the ultimate development of the site are free of obstructions or can be cleared if obstructions exist. Measures should also be taken to safeguard against erecting future obstructions especially in airport turning zones and in line with the runways. Clear zones are required at the ends of runways and are supposed to be provided by the airport operators (eg the Nigerian Airports Authority N.A.A, the Nigerian Airforce, etc). Runway clear zones are areas comprising the innermost portions of the runway approach areas. The dimensions of the clear zones are shown in Fig 3. Provision of adequate approaches very near the ends of runways is essential in the interest of safety although difficult to maintain.

(g) Economy of Construction.

In a case where a number of sites of equally satisfactory area are available, the site which is more economical to construction should be used. A dry flat site is usually more economical to develop than a damp irregular one. In such a case, therefore, the flat dry site is more suitable.

(h) Availability of Utilities.

The provision of such utilities like water, electricity supply, and other related things should be given thought when siting an airport. This is because



Category*	W_1	W_2	L†
1. Precision instrument	1,000	1,750	2,500
2. Nonprecision instrument for larger than utility with visibility minimums as low as 3/4 mi	1,000	1,510	1,700
3. Nonprecision instrument for larger than utility with visibility minimum greater than 3/4 mi	500	1,000	1,700
4. Visual approach for larger than utility	500	700	1,000
5. Nonprecision approach for utility	500	800	1,000
6. Visual approach utility	250	450	1,000

SOURCE: Federal Aviation Administration.

* For description of categories see heading "Obstruction Clearance Requirements" in this chapter.

† Length of clear zone is determined by distance required to reach a height of 50 ft for the appropriate approach surface.

Fig 3:- Dimensions of runway clear zones

most of those things like aircraft fuel have to be transported. Others like electricity and water have to be connected from the mains and this should be done as economically as possible. One other important factor is the disposal of waste. It is therefore necessary to have a sewage disposal plant within the vicinity.

(i) Proximity to Aeronautical Demand.

Another important factor to be taken into consideration is the selection of a site that would result to the shortest ground access time possible. It should be located where there is demand for air travel.

It is worth mentioning that one of the major factors that influence the size of an airport is the performance characteristics and size of aircraft expected to use the airport. Others are the anticipated volume of traffic, the meteorological conditions (wind and temperature) and the elevation of the site. The performance charateristics of aircraft are the principal factors that determine the length and thickness of runways.

3.40 LAND-USE PLANNING

.It is necessary to have a land-use plan for property or functions both within and outside the airport boundary. This is an essential part of the airport masterplan. The airport land-use plan encompasses such diverse

factors as projection of the extent of aircraft wise that will be generated by airport operations in the future to the coordination of the areawide comprehensive planning program with the objectives, policies, and program for the area which the airport is to serve. Although zoning is used as a method for controlling land-use adjacent to an airport, it is not effective in areas which are already built-up because it is not retroactive. Airport generally are involved in two types of zoning.

One type is the height and hazard zoning, which is mainly to protect the approaches to the airport from obstructions. This involves buildings and trees mainly within the vicinity of the airport complex. Base on these we have high, medium and low obstructions and normally certain standards are provided to aid the planning. The zoning is such that as one approaches the airfield or airport from the air, the obstructions decrease from high used structures from a very far distance to very low eg grass and shrubs when one is within the vicinity of the airport.

The other type of zoning is that based on the functions within the airport. These functions can be categorised as either those closely related to aviation and those remotely related to aviation. Those closely related to aviation use include the runways, taxiways, aprons, terminal buildings, parking, and maintenance

facilities. Non-aviation uses include space for recreation, industrial, commercial and residential activities. Care must be taken to ensure that these activities do not interfere with the aircraft operations.

The principal objective of the land-use plan for areas outside the airport boundary is to minimize the disturbing effects of noise. The delineation of noise contours as would be seen in due course is a promising approach for the establishment of noise-sensitive areas and this helps in defining areas which are or are not suitable for such function as residential, light industrial, commercial, or recreational activities. The land-use plan provided will greatly influence and assist the governing bodies in their task of establishing a very comprehensive land-use zoning.

3.50 ENVIRONMENTAL STUDY

This is an important factor that should be considered when either developing a new airport or expanding an existing one. The major problem that is usually considered in this study is the aircraft noise. A effective means of reducing noise is through proper planning of landuse for areas adjacent to the airport. Other important factors of environmental importance include air and water pollution, industrial waste and domestic sewage originating at the airport and the disturbance of natural environmental values. The study

must include how water and atmospheric pollution are to be overcome. In the course of preparation of an environmental study statement, most government require that the findings include the following items:-

(a) The environmental impact of the proposal development

(b) Any adverse environmental effects which cannot be avoided should the development be implemented.

(c) Alternatives to the proposed development.

(d) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long term productivity.

(e) Any irreversible environmental and irretrievable commitments of resources which would be involved in the proposed development should it be implemented.

(f) Growth-inducing impact

(g) Migitation measures to minimize impact.

The preparation of an environmental impact statement is an extremely important part of the airport planning process and so unless it is comprehensive, the entire airport development may be in jeopardy.

3.51 GROUND ACCESS AND VEHICLE PARKING

In commercial airports, these factors have to be taken up seriously. Access to airports is a necessity not only for passengers but also for the other users of the airport such as employees, visitors, business organisations, etc. It is therefore necessary to

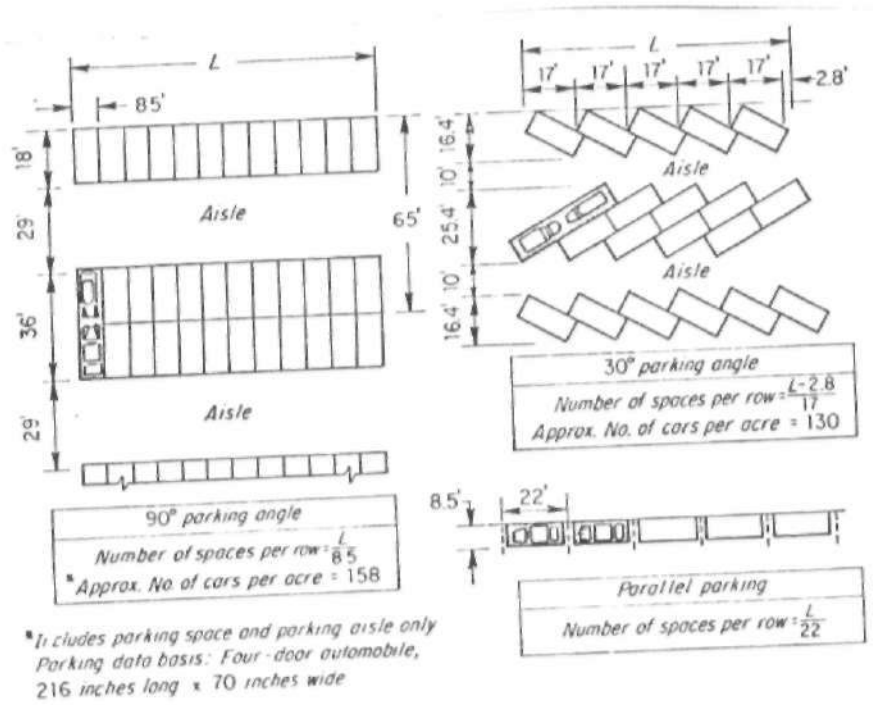
consider all modes of access. The circulation of traffic in an airport should generally be one-way and counter-clockwise.

The provision of adequate automobile parking is also essential in the case of the airports that are used for commercial purposes mainly due to the large number of passengers that use them. This is because despite the number of measures being taken to ensure sound transportation to the airports eg tubes and buses, a good number of passengers would continue to make use of private vehicles. Facilities required to satisfy automobile parking demand for major airports have grown to magnitude that they have become a dominant consideration in the planning of an airport. Parking at an airport must be provided for:- (a) Airline Passengers, (b) Visitors accompanying passengers, (c) Spectators, (d) People employed at the airport, (e) Rentals and (f) People having business with the airport tenants.

Various parking systems have been used and Fig 4 shows some of the parking systems that are in common use. They vary from airport to airport.

3.52 ECONOMIC AND FINANCIAL FEASIBILITY AND OBSTRUCTION CLEARANCE REQUIREMENTS

The economic and financial feasibility of alternative plans for either a new airport or for the expansion of an old one is very important and a



*Includes parking space and parking aisle only
Parking data basis: Four-door automobile, 216 inches long x 70 inches wide

Fig 1:- Passenger car parking systems

clear understanding must be demostrated by the planner. The reserve generating capacity of the airport must be determined for such stage of development scheduled in the master-plan. The economic criteria used in evaluating an aviation investment is the total cost of facilities, including quantifiable social costs, compared with the value of increased effectiveness measured in terms of total benifits. In the design, however, of an military airfield, since it is not a commercial venture, usually only the financial feasibility at the initial planning stage is actually considered.

Any object that protrudes along the imaginary surface within the vicinity of an airfield is considered as obstruction to air navigation.

Obstruction clearance requirements adjacent to airports are contained in the Federal Aviation Requirements (FAR) part 77 (Ref 7) and also in Part 4 of the International Civil Aviation Organisation (ICAO) Annex 14. These texts are hereby provided below.

FAR Part 77

In part 77 airports are classified as shown in Fig 5. "Visual runway" means a runway intended solely for the operation of aircraft using visual approach procedures. A "utility runway" means a runway that

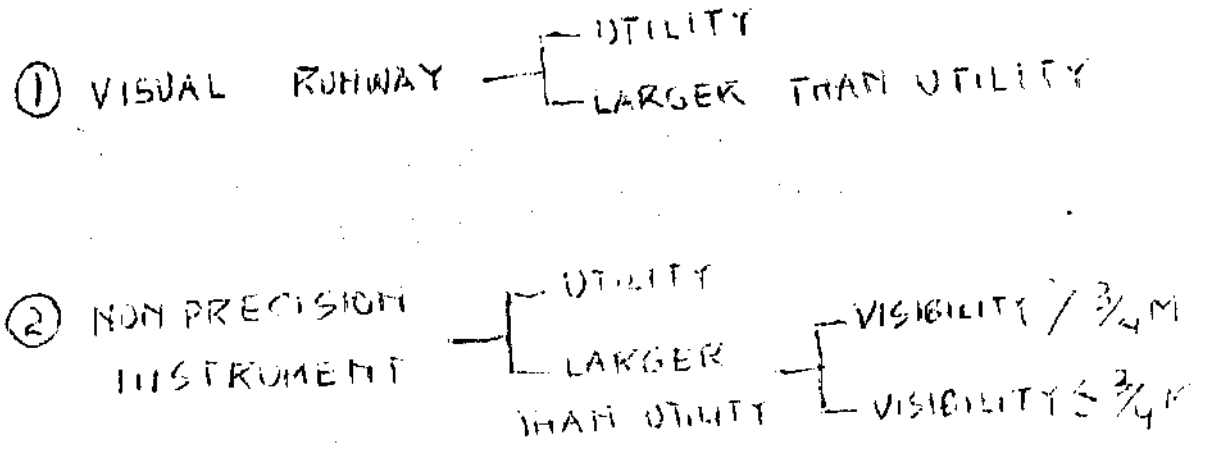


Fig 5:- F/R part 77 classification of airports

is constructed for and intended to be used by propeller-driven aircraft weighing 12,5001b or less. A "non-precussion instrument runway" means a runway having an instrument approach procedure with only horizontal guidance or area-type navigation equipment. A "precision instrument runway" means a runway having an existing instrument approach procedure utilizing an instrument landing system (ILS) or precision approach radar (PAR).

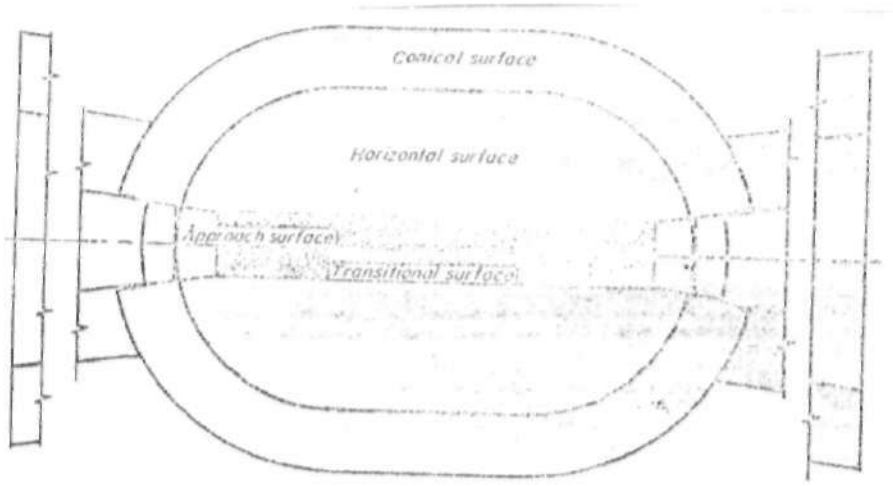
In order to determine whether an object is an obstruction to air navigation or not, several imaginary surfaces are established with relation to the airport and to each runway.

The size of the imaginary surfaces depend on the category of each runway (eg, utility) and on the type of approach planned for the runway(eg visual, non-precision instrument, precision instrument).

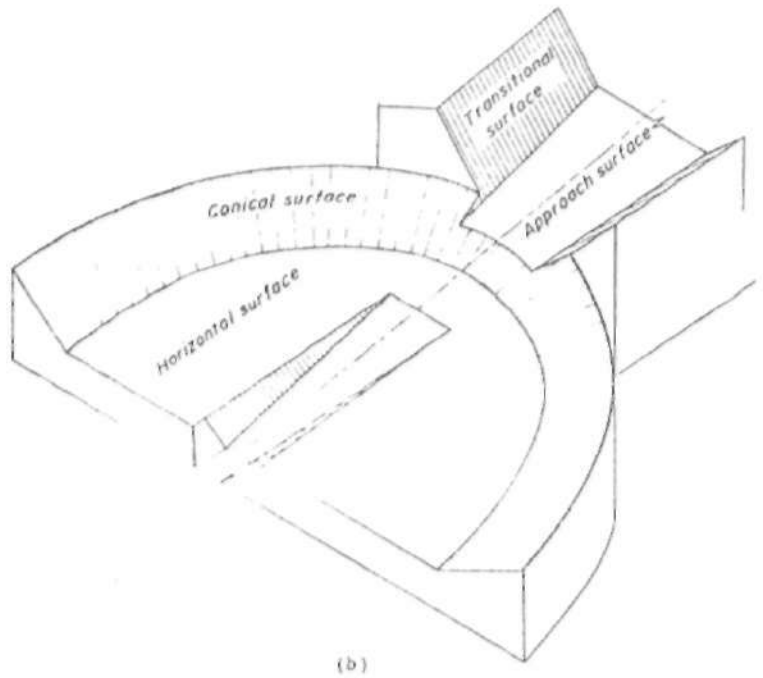
The principal imaginary surfaces are shown in Fig 6 and are described as below:-

(a) Primary Surface:-

A surface longitudinally centred on a runway is called a "primary surface". When the runway is paved the primary surface extends 200ft beyond each end of the runway.



(a)



(b)

Fig 6:- Principal Imaginary Surfaces

(b) Horizontal Surface:-

This is a horizontal plane 150ft above the established airport elevation, the perimeter of which is constructed by surveying airs of specified radii from the center of each end of the primary surface of each runway and connecting the adjacent arcs of lines tangential to those arcs.

(c) Conical Surface:-

A surface extending outward and upward from the periphery of the horizontal surface at a slope of 20 to 1 for a horizontal distance of 4,000ft is known as a "conical surface".

(d) Approach Surface:-

A surface longitudinally centred on the extended runway centreline and extending outward and upward from each end of the primary surface is called an "approach surface". It is applied to each end of a runway based on the type of available or planned approach.

(e) Transitional Surface:-

These surfaces extend outward and upward at right angles to the runway centreline plus the runway centre-line extended at a slope of 7 to 1 from the sides of the primary surface and from the sides of the approach surfaces. Dimensions of several imaginary surfaces are shown in table III.

Table III:- Imaginary surface dimensions FAR Part 77 (In Feet)

Item	Visual runway*		Nonprecision instrument runway†			Precision instrument runway
	A	B	A	B		
				C	D	
Width of primary surface and approach surface at inner end	250	500	500	500	1,000	1,000
Radius of horizontal surface	5,000	5,000	5,000	10,000	10,000	10,000
Approach surface width at outer end	1,250	1,500	2,000	3,500	4,000	16,000
Approach surface length	5,000	5,000	5,000	10,000	10,000	50,000‡
Approach slope	20:1	20:1	20:1	34:1	34:1	50:1§

SOURCE: Ref. 7.

* A — utility runways; B — runways larger than utility.

† C — visibility minimum greater than ¾ mi; D — visibility minimums as low as ¾ mi.

‡ Inner length, 10,000 ft; outer length, 40,000 ft.

§ Inner length, 50:1; outer length 40:1.

Runway category	Conical surface horizontal distance (ft)
A	7,000
B	7,000
C	5,000
D	3,600
E	2,300

* The center of the circle is the geographic center of the airport.

ICAO Annex 14

The ICAO requirements are similar to that of FAR part 77 with the following exceptions. The ICAO specifies dimensions for each category of runway coded A,B,C,D, and E. The meaning of these codes are shown clearly in Table IV. The approach surface defined in Part 77 is for both arriving and departing aircraft. The ICAO separates arrivals and specifies dimensions for approach surfaces for arrivals and "take-off climb surfaces" for departures. The horizontal surface specified by ICAO is a circle whose center is at the "airport reference point", whereas in Part 77 it is not a circle. The height of this surface is 150ft above the airport elevation, the same as in Part 77. In part 77 the conical surface extends horizontally 4,000ft at a slopes of 20 to 1 inespective of type of runway and visibility. In Annex 14 the slope of the conical surface is the same (20 to 1) but the horizontal distance varies depending on the runway category. This can be seen in Fig 7. In Part 77 the slope of the transitor surface is constant 7 to 1, whereas in Annex 14 this slope is specified only for category A,B, and C runways. For category D and E runways, the slope is 5 to 1. The dimensions of the imaginary surfaces specified by the ICAO in Annex 14 are summarized in table V.

Table IV :- Imaginary Surface dimension ICAO Annex 14 (In Feet)

Approach						
Item	Runway category*					Instrument approach
	A	B	C	D	E	
Radius of horizontal surface ..	13,000	13,000	13,000	8,300	6,500	—†
Width of primary surface and approach surface at inner end	500	500	500	260	200	1,000
Approach surface width at outer end	2,500	2,500	2,500	1,920	1,240	16,000
Approach surface length	10,000	10,000	10,000	8,300	5,200	50,000‡
Approach slope	40:1	40:1	30:1	25:1	20:1	50:1§

Climb				
	A, B, C			
	Main takeoff runways	Other runways	D	E
Width of takeoff climb surface at inner end.....	600	600	260	200
Width of takeoff climb surface at outer end	4,000¶	4,000¶	1,900	1,250
Length of climb surface ...	50,000	40,000	8,300	5,200
Climb surface slope	50:1	40:1	25:1	20:1

SOURCE: Ref. 13.

* For runway categories see Chap. 8. Dimensions are for visual approach.

† Runway category determines radius of horizontal surface.

‡ Inner length, 10,000 ft; outer length, 40,000 ft.

§ Inner length, 50:1; outer length, 40:1.

¶ Diverges to 4,000 ft in a distance of 13,600 ft. Then the width remains constant to the outer end of surface.

Fig 7:- ICAO Annex 14 slope of conical surfaces .

Table V :- Summary of dimensions of ICAO imaginary surfaces

3.60 EVALUATION OF NOISE

This is one very important factor that has to be tackled ie the effect of noise from aircraft operation since it seriously affects communities surrounding the airport. Quite a lot of data has been aquired as a result of the persistent study of the noise characteristics of aircraft and their corresponding effects on the general community. On the basis of this knowledge simplified procedures have been developed permitting the planner to estimate the magnitude and extent of noise from airport operation and to predict community response. Some of these procedures are briefly discussed below.

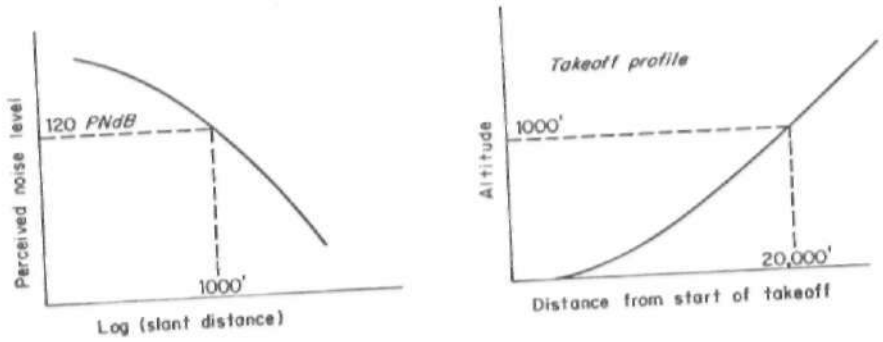
3.61 SOUND INTENSITY

The intensity of sound is usually expressed in decibels (dB). Commercial Jet operations can generate over 100dB, while average daytime ambient noise in residential areas vary from 55 to 65 dB. Frequency, however, is a more important factor in the evaluation of sound. It (ie frequency) is the rate of vibration of a sound source expressed in cycles per second (C/S). The faster the object vibrates the greater the number of cycles per second and hence the higher the frequency. For the purpose of wise analysis, the range of frequencies is divided into smaller ranges known as octave bands. The breakdown of noise into these bands

provides a useful and meanful way of describing the quantity and character of aircraft noise. The human ear can detect sounds over a wider range of frequencies. A loud roar has a low frequency while a siren (eg police, government, etc, siren) is a high frequency sound.

Noise is usually measured with the help of an instrument known as a "sound level meter " which reads in a unit known as the decibel. One of the readings that can be obtained with the sound-level meter indicates the total amount of sound present at any location and is described as the overall sound pressure.

On the basis of extensive measurements made on the ground during aircraft flyovers, one can determine the relationship between the maximum noise level observed, on the ground and the distance to the aircraft. This relationship can be expressed by plotting a graph as shown in Fig 8a. From this graph one can determine the maximum noise level at any distance from the aircraft, whether it be passing overhead or passing to one side. Next, the flight profiles for landings and takeoffs must be estimated. As an example, for takeoffs this can be deduced by a generalized take-off profile for a specific type of aircraft, such as is shown in the upper right-hand corner of Fig 8b. If we assume that these two curves are associated with



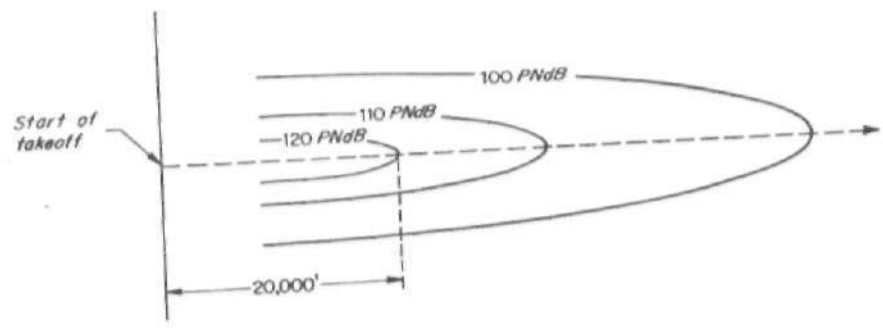


Fig 8 a,b,c :- Graphs Showing Perceived noise level contours

a particular aircraft eg the C130H, one can now construct a set of noise contours representing the maximum noise levels on the ground during takeoffs for this aircraft, as shown on Fig. 8c. Noise contours of this type can then be used to describe the noise underneath either a takeoff or a landing path as far as several miles from the runway and several thousand feet to the side. These contours however represent the sound levels generated by a single flyover of one particular aircraft type (eg as already mentioned C130H). In order to evaluate response of listeners to aircraft noise, the cummulative effects of many flyovers of several types of aircraft must be considered.

Every investigation of aircraft noise has shown that the impact of aircraft operations on communities or neighbourhoods is a function of not only the intensity of a single flyover out also of the duration and number of operations occuring during the day and night. A number of methods combining the noise from individual aircraft flyovers into measures of cummulative noise exposure have been developed in America and other countries and would be discussed in due course. In the United States of America for example, we have the composite noise rating (CNR), or Noise exposure forecast (NEF), Community noise equivalent level (CNEL), Day - Night average level (Ldn), and Aircraft Sound description system (ASDS). In other countries in Europe we have

the noise and number index (NNI) in the United Kingdom, 150 pheric index (II) in France, mean annoyance level (Q) in Germany, total noise load (TNL) in the Netherlands, and weighted noise exposure level (WECPNL) used by the International Civil Aviation Organisation (ICAO). These methods while differing in technical detail, are conceptually very similar and correlate very well with each other. The primary difference is in the unit of measure of sound level. It has been suggested that to be effective, any method for predicting community reaction to noise must have a reasonable correlation between cummulative noise levels and community annoyance.

3.62 COMPOSITE NOISE RATING (CNR)

This is one of the earliest methods for evaluating land use around airports. Composite noise rating is equal to the perceived noise level expressed in PNdB adjusted for the number of aircraft operations, whether the operations occured in the day or night, and the present time the runway is utilized. This is expressed as CNR = PNdB $\pm$ Adjustments. These adjustments are applied in discrete steps of 5 PNdB. Aircraft are segregated into different groups, and air carriers and military aircraft are further grouped according to trip length. The CNR contour for each class and trip length is computed and drawn on a land use map. The

contour encompassing the largest area is considered. Although this method is relatively simple, very little use is made of it today.

3.63 NOISE EXPOSURE FORECASE (NEF)

This is an extension of the CNR concept. The main differences however are that (a) The perceived noise level is expressed in EPNdB instead of PNdB and (b) adjustments for number of operations are continous rather than in discrete steps. Mathematically NEF can be expressed as follows:-

$$NEF = EPNL + 10\log_{10}\left(\frac{N}{K}\right) - C$$

Where

EPNL = Effective perceived noise level expressed in EPNdB

N = Number of operations during the day or night

K = Constant and depends whether the operations are during the day or night, Kd = 20, Kn = 1.2

C = Normalization factor to make NEF numbers substantially different from CNR.

In this case day time operations are taken to occour from 0701 to 2200hrs and night time operations are considered to occur from 2201 to 0700hrs. The manual computation of NEF contours is cumbersome. As a result a number of computer programmes are available for developing NEF contours eg the computer ploted NEF contours for Chicago O'Hare Airport are shown in Fig. 9.

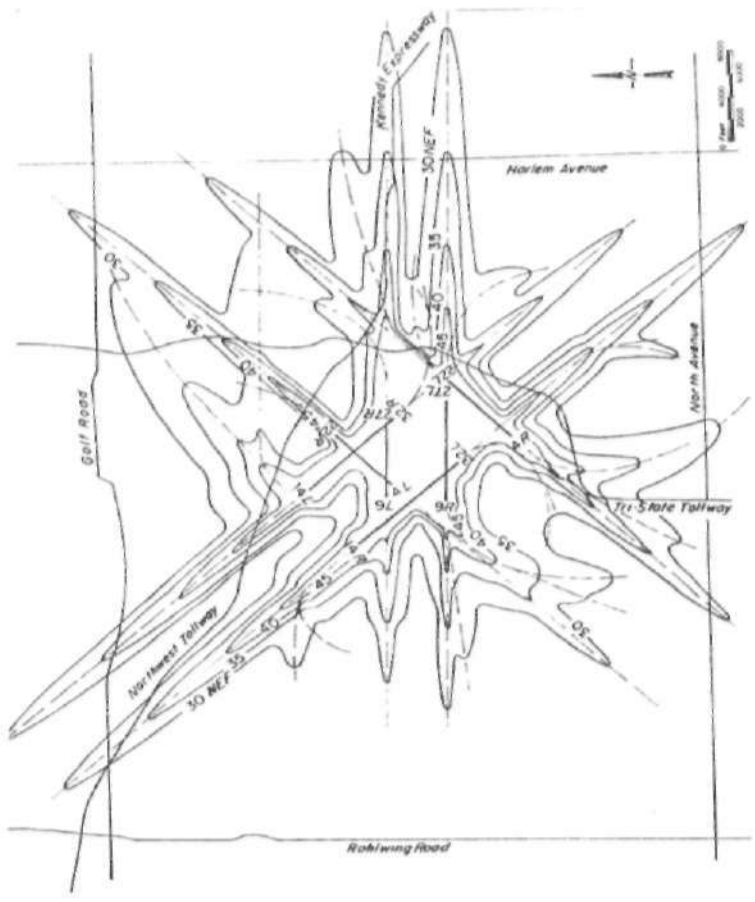


Fig 9 :- NEF Contours for Chicago O'Hare airport

Compartible land uses for various levels of NEF are briefly summarised in Table VI for illustrative purposes only the variation of EPNdB with distance from specific types of aircraft is shown in Fig 10a and Fig 10b.

3.64 COMMUNITY NOISE EQUIVALENT LEVEL (CNEL)

This was developed in America in the state of California to enforce noise standards enacted by the legislature. It can be used for predicting community reaction as well as for monitoring aircraft operations. The concept is similar to NEF except that dBA is used as the unit of measurement of noise. The mathematical expression for the day - night average CNEL, of aircraft type i following a path, is expressed as

$$CNELij = NELi + 10 \log_{10} Nc - 49.4 \text{ in dBA units}$$

Where

NELi = Single flyover noise level of aircraft i on flight path j corrected for the duration of sound

Nc = Equivalent number of daily operations, which is equal to Nd + 3Ne + 10Nn

Nd = total number of operations during the period 0701 - 1900hrs

Ne = total number of operations during the period 1901 - 2200hrs

Nn = total number of operations during the period 2201 - 0700hrs

Table VI :- Compartible Landuses for various levels of NEF

Noise exposure forecast areas	Land-use compatibility								
	Residential	Commercial	Hotel, motel	Offices, public buildings	Schools, hospitals, churches	Theaters, auditoriums	Outdoor amphi-theaters, theaters	Outdoor recreational nonspectator	Indust
Outside *NEF* 30	yes	yes	yes	yes	*	*, †	†	yes	yes
Between *NEF* 30 and 40 ..	‡	yes	*	*	no	no	no	yes	yes
Inside NEF 40	*no*	*	*no*	*no*	*no*	*no*	*no*	*yes*	*

SOURCE: Bolt, Beranek, and Newman.

* An analysis of building noise reduction requirements should be made and needed noise control features should be included in the build design.

† A detailed noise analysis should be undertaken by qualified personnel for all indoor or outdoor music auditoriums and all outdoor theat

‡ Case history experience indicates that individuals in private residences may complain, perhaps vigorously. Concerted group action is p sible. New single-dwelling construction should generally be avoided. For apartment construction, see *.

TABLE 6-7

Aircraft class	Number of operations		
	0700–1900	1900–2200	2200–0700
A	50	10	2
B	30	5	2
C	20	5	1

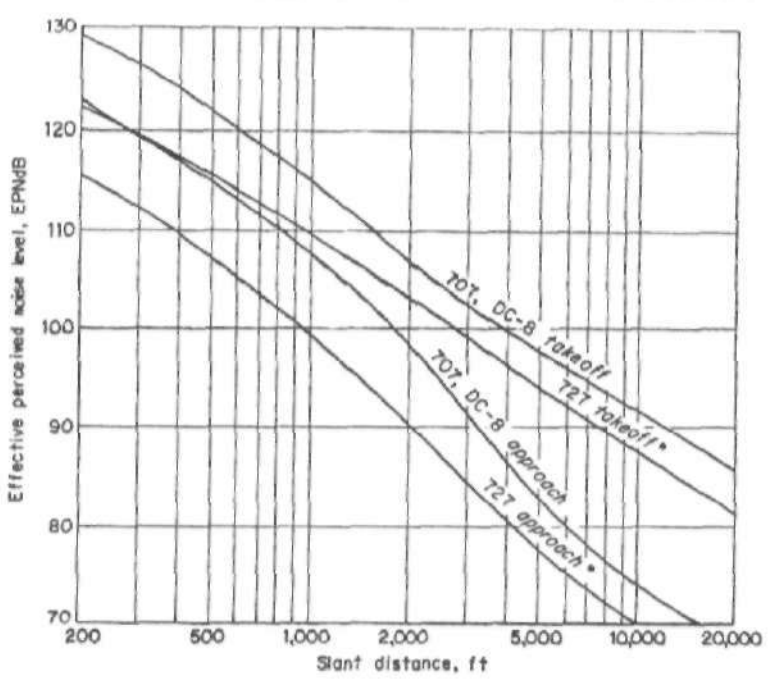


Fig 10 a & b :- Variation of EPNdB with distance for speficic types of aircraft

The total day - night average exposure for several classes of aircraft i at a point on the ground following the same flight path j is

$$CNELj = 10 \log_{10} \quad i \text{ antilog } \frac{CNELij}{10}$$

In California for example, CNEL 65 is considered acceptable for residents. CNEL is approximately equal to NEF - 35. This CNEL 65 is approximately equal to NEF 30.

3.65 DAY - NIGHT AVERAGE LEVEL (Ldn)

This is specified by the Environmental Protection Agency (EPA) for specifying community noise. It is nearly the same as CNEL except that the day is divided into two periods, night and day, instead of three periods. The approximate mathematical expression for Ldn is

$$Ldnij = NELi + 10 \log Ne - 49.4$$

Where

Ldn = day - night average noise level, dBA Units

NELi = Single flyover noise for aircraft i on flight path j corrected for the duration of sound.

Ne = Equivalent number of daily operations, which is equal to Nd + 10 Nn

Nd = Total number of operations between the hours of 0701 and 2200

Nn = Total number of operations between the hours of 2201 and 0700.

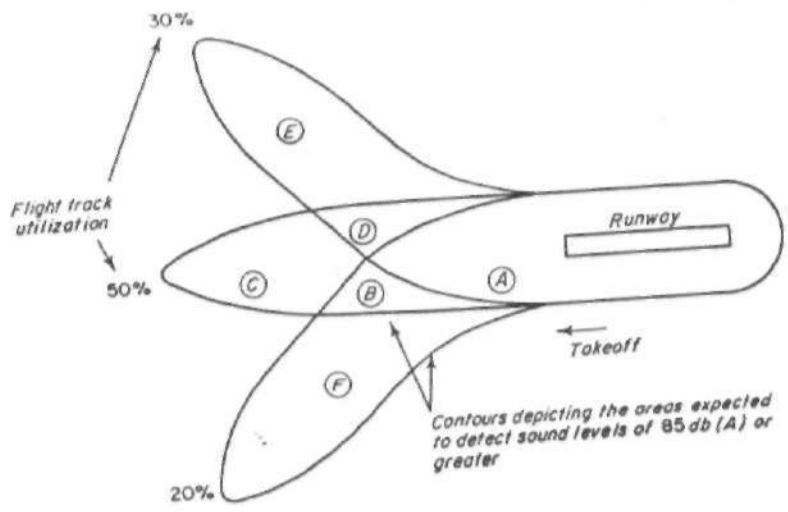
The Total day - night average exposure for several classes of aircraft i at a point on the ground following the same flight path j is

$$Ldnj = 10 \log_{10} \text{ i antilog } \frac{Ldnij}{10}$$

3.66 AIRCRAFT SOUND DESCRIPTION SYSTEM (ASDS)

This system was developed by the Federal Aviation Administration (F.A.A) and is refered to as ASDS. It is straight forward but differs substantially from the preceding procedures. At any point near the airport exposure to aircraft noise is described in terms of the total amount of time in minutes that sound levels exceed a threshold value of 85 dBA. While durations of sound levels above 85.dBA vary with the individual aircraft, average values of 15 seconds for takeoff and 10 seconds for landings are considered sufficiently accurate for estimating duration.

An analysis for a single runway airport with one aircraft type using three different departure flight paths is shown in Fig 11. The first step is to plot the 85 - dBA contour for the aircraft on a land use map. The next step is to divide the area into zones and determine the number of operations in each zone. The final step is to multiply the number of operations by the approximate duration, which results in noise exposure as shown in Fig 11. In a case that involves



Zone	Exposure
A	(100 %) = 180 events = 45 min
B	(70 %) = 126 events = 31.5 min
C	(50 %) = 90 events = 22.5 min
D	(80 %) = 144 events = 36 min
E	(30 %) = 54 events = 13.5 min
F	(20 %) = 36 events = 9 min

Fig 11 :- Analysis for a single runway airport with one aircraft type using departure flight paths.

a number of aircraft, the 85 - dBA contours of each aircraft must be superimposed on each other. From such a plot and with the knowledge of the number of aircraft operations one can determine the areas that will be exposed to more than 85 dBA during the fixed intervals of time (eg 0 to 5, 5 to 10; 10 to 15 minutes, etc).

In the end a composite single number, the "Situation Index" (SI), is defined as the total integrated value of the product of exposure time in minutes above 85 dBA and the area exposed in acres. The SI, in acre - minutes is an attempt to quantify the overall noise exposure into one number. The mathematical expression is given by

$$SI = \sum_{j=1}^{m} \sum_{j=1}^{n} Aij\ Nij\ T_c^{\,i}$$

Where

Aij = Area in Acres with the 85 - dBA contour for airplane type j for event of type i (ie event can be differentiated by takeoff or landing flight path, etc).

Nij = number of events of type i performed by airplane of type j

Tc = duration of noise for event of type i

m = total number of airplane types

n = total number of events for each airplane type j.

The procedures so far discussed approximate community response and are used for land-use planning and for assessment of impact by new airports or extension of existing ones. They lack the precision needed for litigation but are useful looks and their limitations must never be forgotten. From all that has been discussed, it would be seen that noise plays a very important role in the planning stage of the airport masterplan. A good airport masterplan would therefore only be acceptable if the noise factor is considered seriously in relation to the other land - use planning factors.

3.70 AIRPORT CONFIGURATION

Airport configuration is defined as the number and orientation of runways and the location of the terminal area relative to the runways. The number of runways depends on the volume of traffic, and the orientation depends on the direction of wind and sometimes on the size of the area available for the airport development.

In order to provide a guide for airport designs and a reasonable amount of uniformity in airport landing facilities, design criteria have been prepared by the ICAO and the FAA. Any criteria involving width and gradients of runways and other features of the landing area must necessarily incoporate wide

variations in aircraft performance, pilot technique and weather conditions. The ICAO strives towards uniformity and safety on an international level.

Six factors come under the configuration heading and these factors or functions are runways, taxiways, holding apron, holding bays, relationship of terminal area to the runways and the analysis of the wind. These factors would be discussed in the above mentioned sequence hereunder.

3.71 RUNWAYS

A runway is a specially prepared hard surface usually made of concrete or bitumen (Coal tar) in an airport along which aircraft take-off or land. In general, the runways and the correcting taxiways should be arranged so as to (i) Provide adequate seperation in the air traffic pattern; (ii)cause the least interference and delay in the landing, taxiing, and takeoff operation; (iii) provide the shortest taxi distance possible from terminal area to the ends of runways; and (iv) Promote adequate taxiways so that landing aircraft can leave the runways as quickly as possible and follow routes as short as possible to the terminal area. At busy airport it is necessary to have holding or run-up apron adjacent to the takeoff ends of runways. These apron should be designed to accomodate three or possible four aircraft of the maximum size anticipated, with sufficient space for aircraft to bypass one another.

RUNWAY CONFIGURATIONS

There are many types of runway configuration in existance today. Most of these configurations are combinations of several basic configuration. The basic configuration that exist are:-
(a) single runways; (b) parallel runways; (c) Dual-lane runway (d) Intersecting runways, and (e) Open "V" runways. These configuration are discussed below.

(a) Single Runway

This is the simplest of the runway configuration and is clearly shown in Fig 12a. It has been estimated that the hourly capacity of a single runway in Visual flight rules (VFR) conditions is somewhere between 45 and 100 operationsper hour, while in Instrument Flight rules (IFR) conditions the capacity is reduced to 40 or 50 operationsdepending on the composition of the aircraft mix and on the navigation aids available.

(b) Parallel Runways

The capacities of parallel runway system depend to a great extent on the number of runways and on the spacing between the runways. Two and four parallel runways are common. There are very few airports with three parallel runways. Airport with more than four parallel runways to the best of my knowledge do not exist as at now and the likelihood is rare that they would exist since few locations can generate the demand

Fig 12 a - i :- Runway Configurations

to match the capacity of five or more parallel runways. Furthermore, the ability of the airtraffic control system to supply five or more runways at the sametime becomes progressively more difficult, and the airspace requirements becomes very large. The spacing between runways varies widely. These spacing can be classified as being either close, intermediate or far. Close parallel runways are spaced from a minimum of 700ft to less than 3,500 ft, intermediate between 3,500 - 5,000ft and far 5,000ft or more. In IFR condition, the two runways can be operated independently for both arrivals and departures. Fig 12b shown a typical runway configuration that has two parallel runways with even threshold; Fig 12c two parallel runways with staggered threshold; and fig 12d four parallel runways. When there are four parallel runways as in the above mentioned fig 12d, each pair is spaced close but the pairs are spaced far apart to provide space for the terminal building. There are also time when it may be desirable to stagger the thresholds of parallel runways. The staggering (ie fig 12c) may be necessary because of the shape of the area available for runway construction, or it may be desirable for reducing the taxiing distance of takeoff and another for landing. In this case the terminal buildings are located between the runways so that the taxiing distance for each type of operation ie takeoff or landing is minimized.

(c) Dual-lane runway

A dual-lane runway consists of two close - spaced parallel runways with appropriate exit taxiways. Although both runways can be used for mixed operations, the desirable mode of operation is to dedicate the runway farthest from the terminal building (outer) for arrivals and the runway closest to the terminal building (inner) for departures. Estimates have shown that a dual-lane runway can handle at least 70 per cent more traffic than a single runway in VFR condition and about 60 per cent more traffic than a single runway in IFR conditions. The major benefit of a dual-lane runway is to provide an increase in IFR capacity with minimal acquisition of land.

(d) Intersecting runways

Two or more runways in different directions crossing each other are refered to as intersecting runways or patterns. Intersecting runways are necessary when relatively strong winds blow from more than one direction resulting in excessive cross-winds when only one runway is provided. If the winds are light relatively, both runways can be used simultaneously but when winds are showing only one runway can be used reducing the capacity of the airfield substantially. The way the runways are used or operated is referred to as strategy (eg takeoff or landing). This is clearly illustrated in figs 12e,f and g. For the strategy

shown in fig 12e, the hourly capacity is from 60 to 70 operations in IFR and 70 to 175 operation in VFR, in fig 12f it is 45 to 60 for IFR and 50 to 100 for VFR and that of fig 12g is 40 to 55 for IFR and 60 to 100 for VFR. It can thus be seen that the further the intersection is from the takeoff end of the runway and the landing threshold, the lower is the capacity (ie fig 12g).

Due to complication, however, intersecting runways should be avoided as much as possible.

(e) Open - V Runways

Runways in divergent directions which do not intersect are referred to as "Open - V runways". This configuration is shown in fig 12h and 12i like the intersecting runways, open - V runways event to a single runway when the winds are strong from one direction. When the winds are light both runways can be used simultaneously. The strategy which yields the highest capacity is when the operations are away from the V, fig 12h and it has an IFR capacity of 60 to 70 operations, and 80 to 200 for VFR. When the operations are towards the V ie fig 12i, the hourly capacity is reduced to 50 or 60 in IFR, and 50 to about 100 in VFR.

Having carefully gone through the various runway configuration and from the standpoint of capacity and air traffic control, a single - direction runway

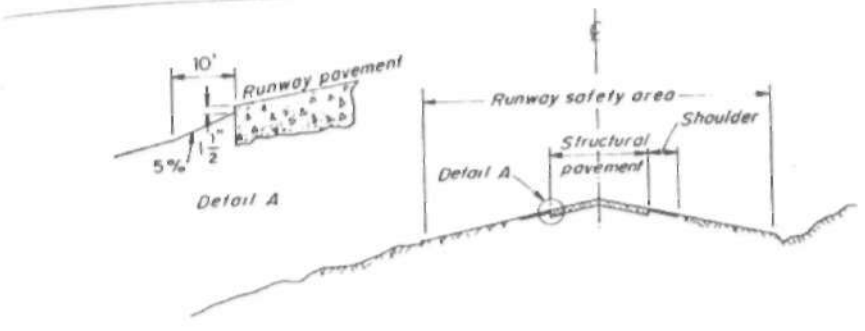
configuration is the most desirable. All things being equal, this configuration will yield the highest capacity compared with other configurations. For air traffic control the routing of aircraft in a single direction is less complex than routing in multiple directions.

Runway widths and slopes

Apart from the length, the "width" and "slope" of a runway are perhaps the most important structural/ design components of a runway. In order to provide a guide for airport designs and a reasonable amount of uniformity in airport landing facilities, design criteria have been prepared by the ICAO and FAA. Any criteria involving width and gradient of runways and other features of the landing area must necessarily incoporate wide variations in aircraft performance, pilot technique, and weather condition. The FAA standards are similar to that of the ICAO. The principal elements of a runway can be seen in figs 13a and 13b and these elements are:-

(i) The "structural pavement", which supports the aircraft load,

(ii) The "shoulders" adjacent to the structural pavement, which are designed to resist erosion due to jet blast and to accommodate maintenance equipment and patrol;



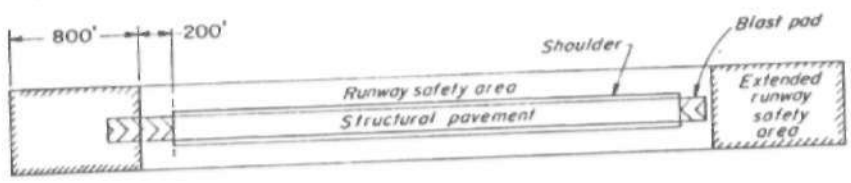


Fig 13 a & b :- Principal elements of runways

(iii) The runway "safety area" which includes the structural pavement, shoulders, and an area that is cleared, drained, and graded. This area should be capable of supporting fire, crash, and other equipment under normal conditions as well as provide support for aircraft in case they near off the pavement for one reason or another; and fig 13b indicates the extent of the safety area in a longitudinal direction.

(iv) The "blast pad" is an area designed to prevent erosion of surfaces adjacent to the ends of runways which are subjected to sustained or repeated jet blast; this area can be paved or planted with turf. Experience has it that it should be of the order of 60 meters, except for large, wide-boby aircraft where they may require as much as 120 metres or more in length.

(v) The "extended safety area", is an extension of the safety area. The extended safety area is provided whenever feasible, to reduce accidents from undershoots or overruns. It is desireable to have the length of the extended area as much as 250 metres beyond the normal safety area.

The ICAO and FAA runway standards related to width of structural pavement and safety area and longitudinal and transverse gradients are listed in table VII and table VIII respectively.

Table VII :- ICAO runway standard related to width of structural pavements

Airport category	Width of structural pavement	Width of[c] safety area	Width of shoulders	Structural pavement: Max. longitudinal slope	Structural pavement: Max. effective gradient	Structural pavement: Max. longitudinal slope change	Structural pavement: Slope change per 100 ft	Structural pavement: Max. transverse slope[d]	Safety area: Max. longitudinal slope	Safety area: Max. transv slop
ICAO										
A	150	500	..[e]	1.25	1.0	1.5	0.1	1.5	1.5	2.5
B	150	500	..	1.25	1.0	1.5	0.1	1.5	1.75	2.5
C	100	500	..	1.5	1.0	1.5	0.2	1.5	2.0	2.5
D	75	260	..	2.0	2.0	2.0	0.4	2.0	2.0	3.0
E	60	260	..	2.0	2.0	2.0	0.4	2.0	2.0	3.0
FAA—Air carrier										
B-727-100, B-737, DC-9	150	500	25	1.5	1.0	1.5	0.1	1.5	1.5	3.0
B-727-200, B-707, DC-8	150	500	25	1.5	1.0	1.5	0.1	1.5	1.5	3.0
B-747, DC-10, L-1011	150–200[f]	700	25–50[g]	1.5	1.0	1.5	0.1	1.5	1.5	3.

Table VIII :- FAA runway standard related to width of structural pavements

	FAA—General aviation									
Basic utility										
Stage I	50	100	..[d]	2.0	..[e]	2.0	0.33	2.0	2.0	5.0
Stage II	60	120	..	2.0	..	2.0	0.33	2.0	2.0	5.0
General utility	75	150	..	2.0	..	2.0	0.33	2.0	2.0	5.0
Basic transport	75–100[h]	300[g]	..	2.0	..	2.0	0.33	2.0	2.0	3.0
General transport	100[i]	300[f]	..	2.0	..	2.0	0.33	2.0	2.0	3.0

SOURCE: Ref. 1; also FAA advisory circulars.

[a] All dimensions in feet.
[b] All slopes in percent.
[c] For instrument runways, 1,000 ft.
[d] It is desirable to make the slope not less than 1 percent to ensure proper drainage.
[e] Not specified.
[f] For airplanes weighing more than 700,000 lb, 200 ft.
[g] For 150-ft wide runway, 50 ft.
[h] For instrument runway, 150 ft.
[i] For instrument runway, 500 ft.

Sight Distance and Longitudinal Profile

In addition to the information shown in Tables VII and VIII, there are other factors that must be considered when establishing the longitudinal profile. One is sight distance and the other is the minimum permissible distance between vertical curves.

With respect to sight distance, the ICAO requires that there should be an unobstructed line of sight from any point 3.5 metres above the runway to all other points 3.5 metres above the runway within a distance of at least one - half the length when the runway category is between 5000 to 7000 ft (ie category A,B & C) and 2.5 inches above the runway where the runway category is 3,600 or less (ie category D and E). The FAA has no requirement for sight distance at airports with control towers since the standards for longitudinal gradients at these airports provide an adequate line of sight.

In regard to longitudinal profile, it is desirable to minimize longitudinal grade changes as much as possible for reasons of economy; therefore both ICAO and FAA allow changes in grade but limit their number and size. The maximum longitudinal slope changes that are permitted are listed in Tables VII and VIII. Slope changes are accomplished by means of vertical curves.

The length of a vertical curve is determined by the size of the change in slope and the maximum allowable change in slope per 35 metres of runway. These are listed in the above mentioned tables (ie VII and VIII). Vertical curves are not normally necessary if the change in slope is not more than 0.4 percent.

Fig 14 shows a typical runway profile. This is necessary in explaining the rules which limit the number of slope changes. The ICAO requires that the distance between the points of intersection of two successive curves should not be less than the sum of the absolute numerical values of change in slope multiplied by the appropriate value as follows: 33,300 metres for category A and B runways; 17,000 metres for category C runway; and 5,600 metres for category D and E runways. The FAA requires 33,000 metres for airports serving air carriers; 8,500 metres for basic transport, general transport, and utility airports.

Tables VII and VIII list the maximum longitudinal slope. In addition, for runways that are equipped to be used in bad weather, the slope of the first and last quarter of the length of the runway must be very flat for reason of safety. The ICAO requires that the slope should not exceed 0.8 percent for airport categories A and B. The FAA limits the gradient to 0.5 percent.

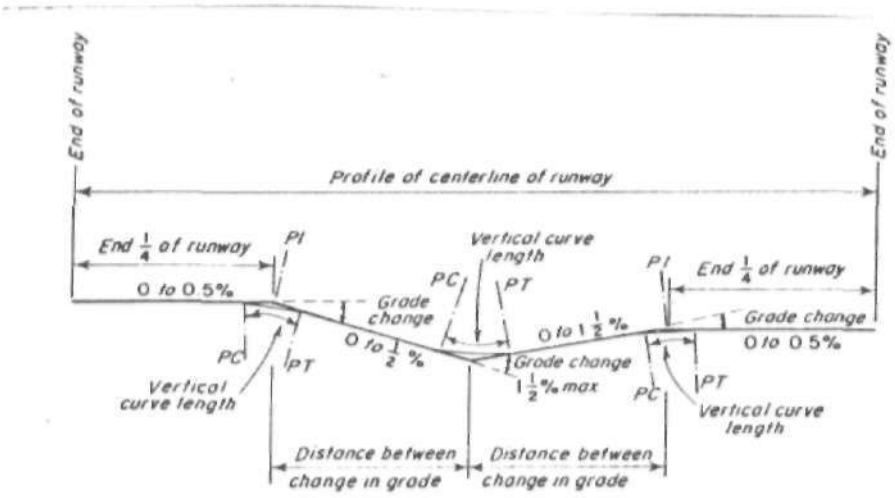


Fig 14 :- Typical runway profile

One last factor concerning the longitudinal profile is the "effective gradient" shown in Tables VII and VIII. The effective gradient is defined as the slope computed by dividing the difference between the maximum and minimum elevation along the runway centerline by the entire length of the runway.

Runway length

It is actually very difficult to specify runway length for different classes of airports because length depends on many factors. Although most of these factors would be discussed under the heading "Aircraft Characteristics related to airport design" in this part, it is worth mentioning that some of the important factors are performance characteristics of a particular type of plane or aircraft, length of the tip, and altitude and temperature at the airport. As a guide to planners concerned with airports, FAA has published the runway length for air-carrier and general aviation. The ICAO also has data on this but both the FAA and ICAO data is in the form of curves plotted on a graph which relate to runway length to takeoff or landing weight, temperature and altitude. The distance that aircraft normally travel for a specific take off weight is also given.

It should be noted however that the "runway" forms about the most important part of the airport. Its

design is therefore very essential and it should be designed such that it can accommodate the aircraft which possesses or requires the longest distance to land and takeoff and also that has the widest wing - tip width.

3.7.2 TAXIWAYS

The principal function of taxiways is to provide access from the runways to the terminal area and service hangars. Taxiways should be arranged so that the aircraft which have just landed do not interfere with the aircraft taxiing to takeoff. Usually in airports where taxiing traffic is expected to move simultaneously in both direction, parallel one way taxiways should be provided. Routes should be selected which will result in the shortest practicable distances from the terminal area to the ends of runways used for takeoff. Taxiways should be located at various point along runways, so landing aircraft can leave the runways as quickly as possible to clear them for use by other aircraft; these are commonly referred to as "exit taxiways" or "turnoffs". Taxiways should as much as possible be routed so as to avoid crossing of active runways. A taxiway designed to permit higher turnoff speeds reduces the length of time a landing aircraft occupies the runway. This is a case whereby the exit taxiways

are at angle of less than 45^{o} to the runway or runways. This permits succeeding landing aircraft to be more closely spaced, in terms of time, or it might allow a takeoff to be sandwiched in between two succssive landings.

Taxiway width and Slopes

Due to the fact that the speeds of aircraft on taxiways are considerably less than on runways criteria governing longitudinal slopes, vertical curves, and sight distance are not as stringent as for runways. Also the lower speeds permit the width of the taxiways to be less than that of the runway. From the cross section of a typical taxiway shown in Fig. 15 it would be noticed that it has basically the same structure as that of the runway shown in fig 13a. Just like the runways, the taxiway principal geometric design features of interest are listed in Tables IX and X. In table X the FAA classifies aircraft into three groups ie I,II, III and the basis for this classification is given in Table XI. The difference arises from the different wingspans, the undercarriage width and the wheelbase.

Sight Distance and Longitudinal Profile

As in the case of runways, the number of changes in longitudinal profile is limited by sight distance and minimum distance between vertical curves. With

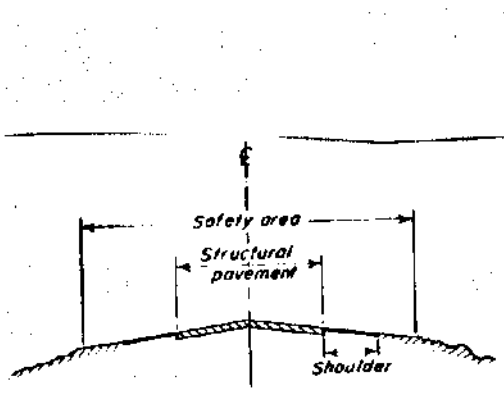


Fig 15 :- Cross Section of typical taxiway

Table IX :- ICAO taxiway standards related to width of structural pavement

Airport or aircraft category	Width of structural pavement	Width of safety area	Width of shoulders	Structural pavement: Max. longitudinal slope	Structural pavement: Max. effective gradient	Structural pavement: Max. longitudinal slope change	Structural pavement: Max. longitudinal slope change per 100 ft	Structural pavement: Max. transverse slope	Safety area: Max. longitudinal slope	Safety area: Max. transverse slope
ICAO										
A	75	..‡	..‡	1.5	..‡	..‡	1.0	1.5	..‡	..‡
B	75	..	..	1.5	..	..	1.0	1.5	..	..
C	50	..	..	3.0	..	..	1.0	1.5	..	..
D	33	..	..	3.0	..	..	1.2	2.0	..	..
E	25	..	..	3.0	..	..	1.2	2.0	..	..
FAA—Air carrier										
I B-727-100, B-737, DC-9 ..	50	110	20	1.5	..‡	3.0	1.0	2.0	1.5	3.0
II B-727-200, B-707, DC-8, DC-10, L-1011	75	165	25	1.5	..	3.0	1.0	2.0	1.5	3.0
III B-747	75	200	35	1.5	..	3.0	1.0	2.0	1.5	3.0

Table X :- FAA runway standard related to width of structural pavements

Basic utility											
Stage I.....	20	160	..‡	2.0	..‡	..‡	..‡	2.0	2.0	5.0	
Stage II.....	30	70	..	2.0	..	..	..	2.0	2.0	5.0	
General utility	40	80	..	2.0	..	..	..	2.0	2.0	5.0	
Basic transport	40§	90	..	2.0	..	..	..	2.0	2.0	3.0	
General transport ...	40§	90	..	2.0	..	..	..	2.0	2.0	3.0	

SOURCE: Ref. 1; also FAA advisory circulars.
* Dimensions in feet.
† Slope in percent.
‡ Not specified.
§ Width is 50 ft if wheel tread is over 25 ft.

Table XI :- FAA basis for classification of Taxiways

respect to sight distance, the ICAO requires that the surface of the taxiway should be for a distance of 330 metres from a point 3.3 metres above the taxiway for category A,B,and C airports. For category D and E airports the comparable dimensions are 275 metres and 2.3 metres. The FAA does, not specify sight distance for taxiways.

As for the longitudinal profile of taxiways, the ICAO does not specify the minimum distance between the point of intersection of vertical curves. The FAA however specifies that the minimum distance for air carrier airports should not be less than the product of 3,300 metres multiplied by the sum of the absolute numerical values of change in slope.

Exit Taxiway Geometry

The function of exit taxiways, on turnoffs as they are sometimes referred to, is to minimize runway occupancy by landing aircraft. Exit taxiways can be placed at right angles to the runway or at some angle to the runway. When the angle is in the order of 30^{o}, the term "high-speed exits" is often used to denote that it is designed for higher speeds than other exit taxiway configurations. Specific dimension for high-speed and right-angle exit taxiways are presented later in this chapter. The dimension for the high-speed exit taxiways are the result of exhaustive tests conducted for the Airways Modernization Board (AMB).

A very significant finding of the tests was that at high speeds a compound curve was necessary to minimize tyre wear on the nose gear. That is, the central or main curve Ri should be preceded by a much larger radius curve R1. Aircraft path in the test approximated a spiral. A compound curve is relatively easy to establish in the field and begins to approach the shape of a spiral, thus the reason for suggesting a compound curve.

As a result of the tests conducted for the AMB, the following pertinent conclusions were reached mainly:-

(1) Transport category and military aircraft can safely and comfortably turn off runways at speeds on the order of 100 to 110 km/h on wet and dry pavements.

(ii) The most significant factor affecting the turning radius is speed, not the total angle of turn nor passenger comfort.

(iii) Passenger comfort was not critical in any of the movements.

(iv) The computed lateral forces developed in the tests were substantially below the maximum lateral forces for which the landing gear was designed.

(v) In so far as the shape of the taxiway is concerned, a slightly widened entrance (30 metres) gradually tapering to the normal width of taxiway is preferred. The widened entrance gives the pilot more latitude in using the exit taxiway.

(vi) Total angles of turn of 30^{o} to 45^{o} can be negotiated satisfactorily; the smaller angle seems to be preferable because the length of the curved path is reduced, sight distance is improved, and less concentration is required on the part of the pilots.

(vii) The relation of turning radius versus speed expressed by the formula $R_2 = \frac{V^2}{15f}$, where V is the velocity, will yield a smooth, comfortable turn on a wet or dry pavement when f is a constant made equal to 0.13.

(viii) The curve expressed by the equation for R_2 should be preceded by a larger radius curve R_1 at high turn-off speeds of 80 - 100 km/h. The larger radius curve is necessary, to provide a gradual transition from a straight ahead direction to a curved path. If the transition curve is not provided, tyre wear on large jet transports can be excessive. The following radii were found experimentally to be satisfactory:-

Speed (km/h)	Radius (R_1 metres)
65	570
80	800
100	1040

(ix) The length of the transition curve can be roughly approximated by the relation $L_1 = \frac{V^3}{CR_2}$, where V is in feet per second and R_2 is in feet. C was found experimentally to be equal to 0.13. The length in feet can then be converted to the metric unit metres after the calculation.

(x) Sufficient distance must be provided to comfortably accelerate an aircraft after it leaves the runway. It is suggested that for the present this distance be based on an average rate of deceleration of 1 metre per second per second. This applies only to transport category aircraft. Until more experience is gained with this type of operation the stopping distances should be measured from the edge of the runway.

A chart showing clearly the relationship of exit speed to radiu R_1 and R_2 and the length of transition curve Li is shown in Fig 16. A configuration for an exit speed of 60mi/h (ie 100km/h) is shown in Fig 17.

Right-angle or 90° exit taxiways, although not desireable from the stand point of minimizing runway occupancy, are often constructed for other reasons. The configuration for a 90° is shown in Fig. 18a . and taxiway intersection details are shown in Fig 18b.

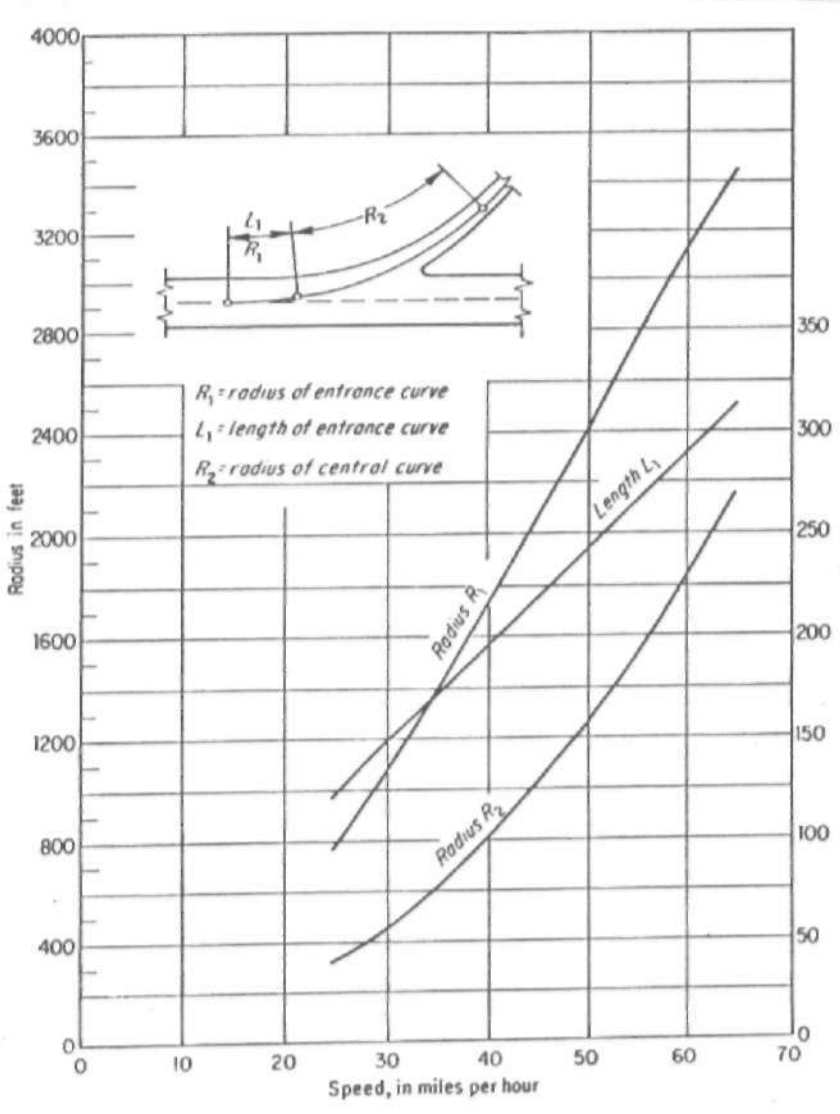


Fig 16 :- Radii of curvative for taxiways

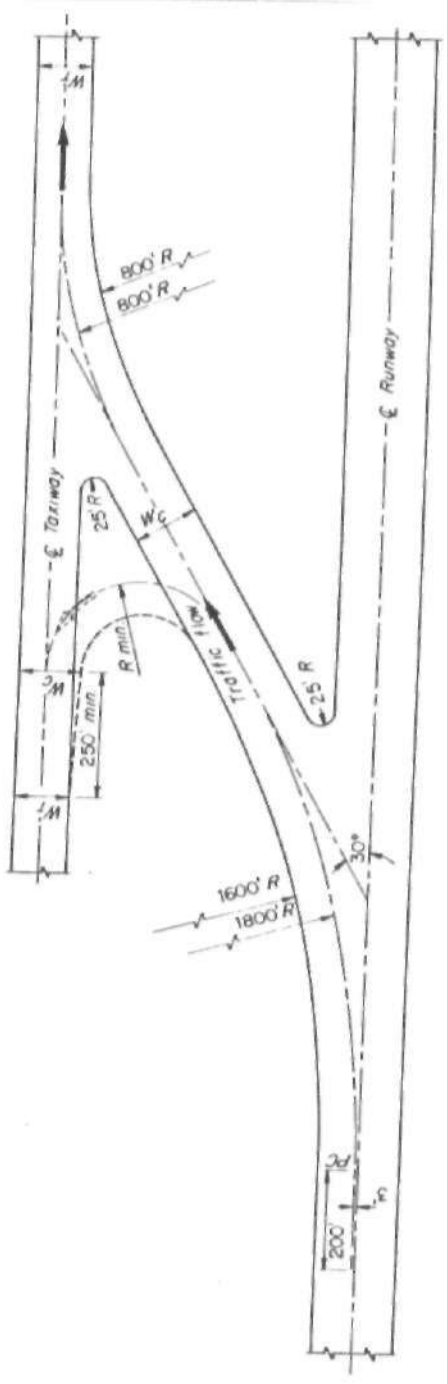


Fig 17 :- High exit taxiways

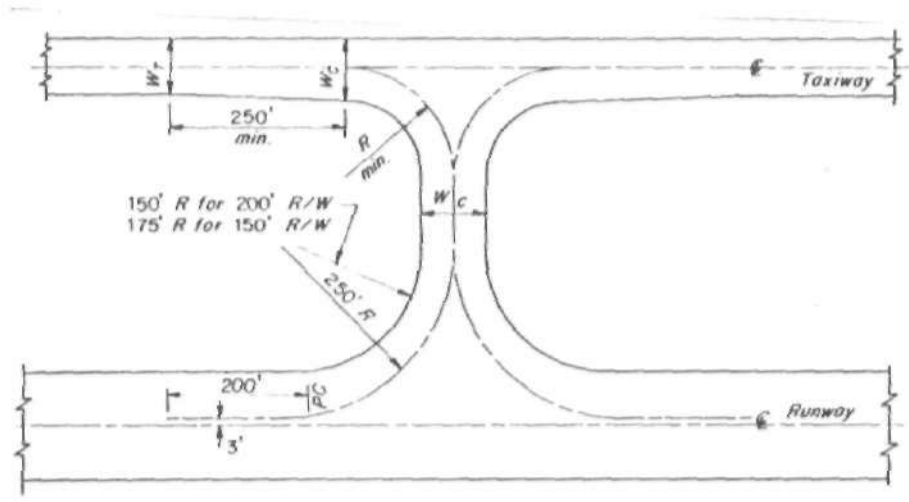


Fig 18 a :- 90° exit taxiways

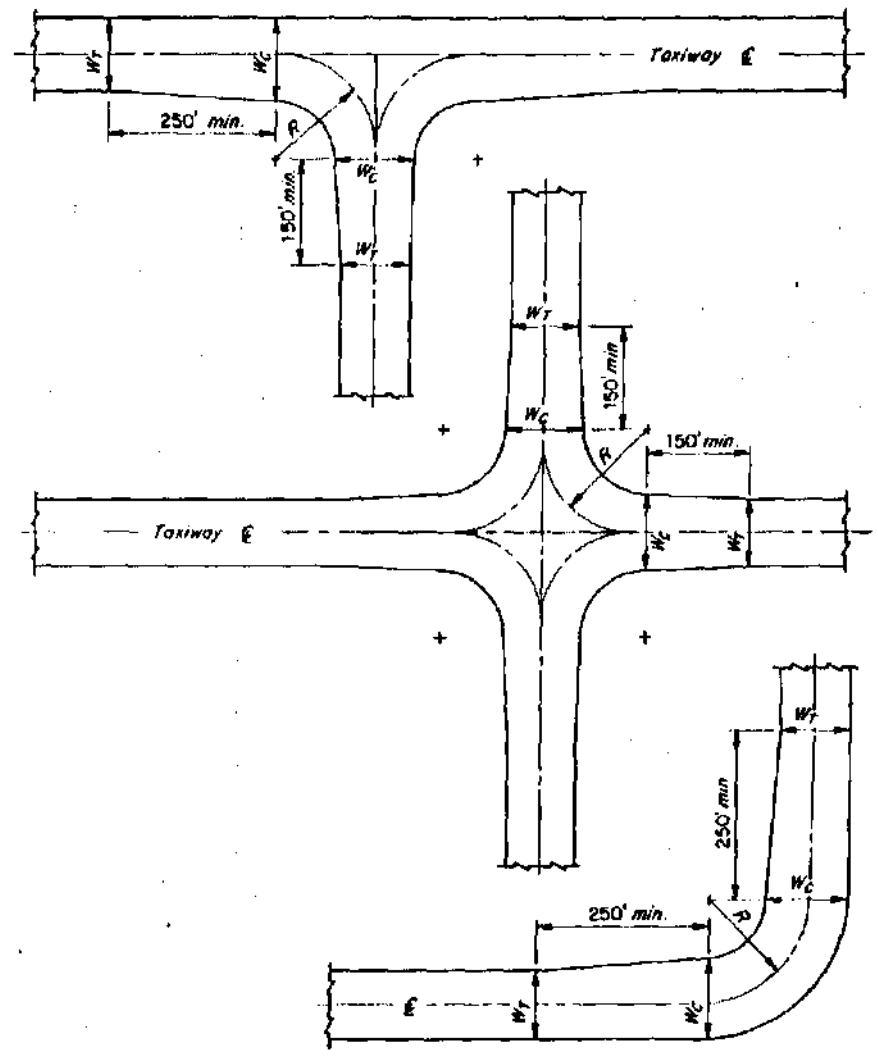


Fig 18 b :- Taxiway intersection details

Location of Exit Taxiways

The location of exit taxiways depend to a large extent on (a) The types of aircraft, (b) The approach and touchdown speeds, (c) The exit speed, (d) The rate of deceleration, which in turn depends on the condition of the pavement surface, ie whether dry or wet, and (e) the number of exit.

Mathematical analysis or models have been developed for optimizing exit location. The models make things much easier to determine these points of exit. The location for the exit taxiways are derived using standard sea-level conditions. Altitude and temperature also affect the location of exit taxiways. Altitude increases distance on the order of 3% for each 330 metres above sea level and temperature 1½% for each $10^{o}F$ above $59^{o}F$.

When locating exits it is important to recognize local conditions such as frequency of wet pavement or dusty winds.

Design of Fillets

The basic designs of fillets for three of the most common types of taxiway intersections have been developed by the FAA. These designs can be seen in Fig 19.. ICAO Annex 14 specifies minimum radii of fillets, which are given in table XII. The radii are dependent on the angle of intersection of the taxiways and the aircraft's wheelbase.

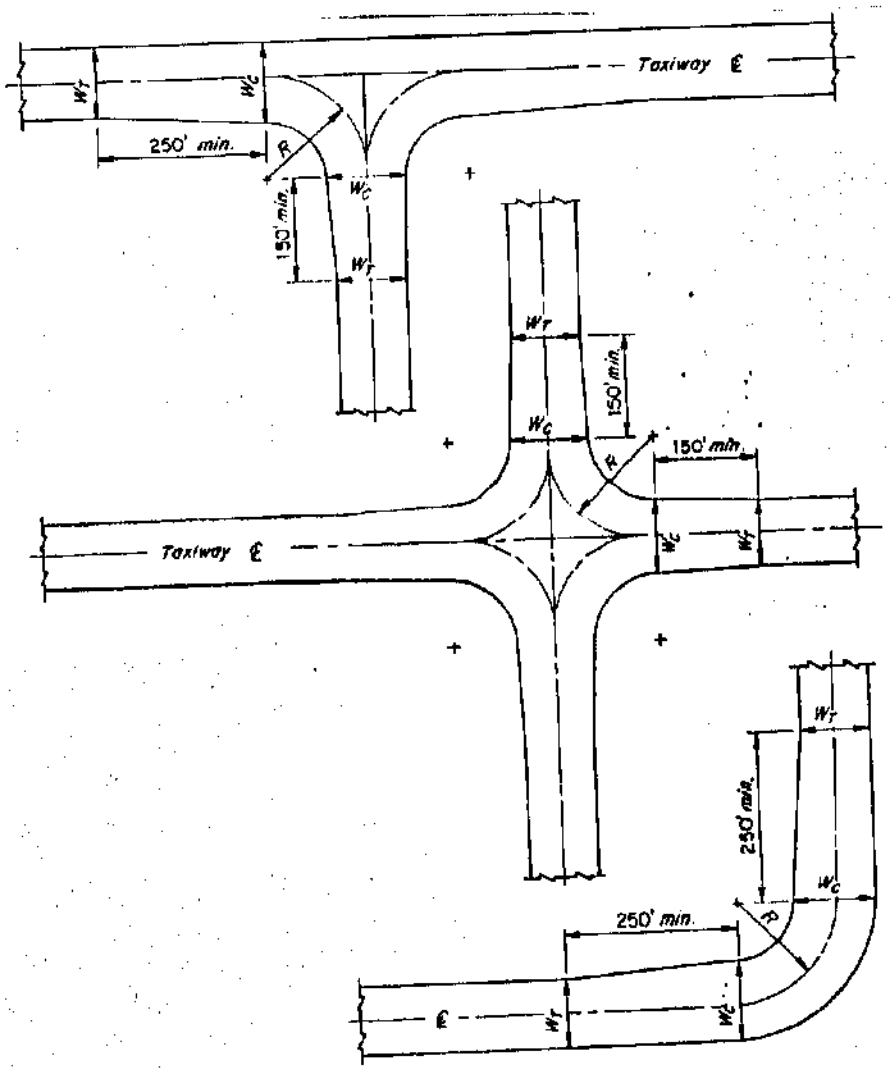


Fig 19 :- Design of fillets for three most common types of taxiway intersections

Table XII :- Minimum fillet radii recommended by ICAO

Wheelbase (ft)	Intersection angle of taxiway		
	Less than 45°	45–135°	More than 135°
Greater than 66	*	*	*
50–66	75	100	200
33–50	25	50	200
Less than 33	20	35	100

* Not specified—must be designed for critical aircraft.

3.7.3 SEPERATION CLEARANCE

Certain standards have beenhandeddown both by the ICAO and FAA regarding seperation distance between runways, taxiways and other fixed obstructions. These are discussed below.

Taxiways

In order to provide a margin of safety in the airport operating areas, the traffic ways must be seperated sufficiently from each other and from adjacent obstructions. Table XII surmmarizes the minimum clearances between a taxiway and a runway, between two parallel taxiways, and between a taxiway and a fixed obstruction.

Parallel Runway Spacing

The spacing of parallel runways depends on a number of factors such as whether the operations are in VFR or IFR and, if in IFR, whether it is desired to have the capability of accommodating simultaneous arrival and departure. In summary, however, the ICAO has given the minimum seperation between two parallel runways as 150 metres.

Wing Tip Clearance

When taxiing, the pilot of a jet transport aircraft in particular cannot see his wing tips so a sufficient amount of clearance must be provided to account for it in case of deviation from the intended path. The

amount of clearance is dependent on wingspan and the amount of guidance provided to the pilot for manouvering his aircraft. Clearance recommended by the FAA are listed in table XIII. A terminal taxiline is a taxiway on an apron used for access to gate positions. An apron taxiway is a taxiway located usually on the periphery of an apron. ICAO Annex 14 does not specify wing tip clearances.

3.7.4 HOLDING APRONS

Holding aprons or "run-up" or "warm up" pads as they are commonly referred to, are placed adjacent to the ends or near the ends of runways. These aprons are used as storage areas for aircraft prior to take-off. They are designed such that one aircraft can bypass the other whenever it becomes necessary. The apron also provides for a trailing aircraft to bypass a leading aircraft in case the latters takeoff clearance must be delayed for one reason or another or if it experiences some malfunction. A holding apron should be designed usually to accommodate two to four aircraft. Whenever possible, holding aprons should be so located as to permit aircraft departing therefrom to enter the runway at an angle of less than 90^{o}. There are quite a number of considerations for holding aprons. The important design criteria are to provide (a) adequate space for aircraft to manouvre

Table XIII :- Minimum Clearance between two wing tips on a wing tip and fixed obstacle

Airplane type	Terminal taxilane	Apron taxiway and taxiway	Dual parallel taxiway
Twin-engine turboprop	20	40	50
Two- and three-engine turbojet* ..	25	50	60
Three- and four-engine turbojet ..	30	60	70
Four-engine wide-body turbojet	35	70	80

SOURCE: Ref. 2.
* Does not include wide-body aircraft.

easily onto the runway irrespective of the position of adjacent aircraft on the apron and (b) sufficient room for an aircraft to bypass parked aircraft on the apron. Even when the holding apron is provided, aircraft must often queue on the taxiway leading to the end of the runway since it is not practical to construct aprons large enough to accommodate peak demands.

Apron Surface Gradients

For fueling, ease of towing, and taxiing, apron slopes or grades should be kept to the minimum consistent with good drainage requirements. Slopes should not in any case exceed 1.0 percent. At gates where the aircraft are being fueled every effort should be made to keep the apron slope within 0.5 percent.

3.7.5 HOLDING BAYS

Holding bays are relatively small aprons placed at a convenient location in the airport for the temporary storage of aircraft. At airports the number of gates may be insufficient to handle the demand during a busy period of the day. If this is the case, the aircraft are routed by air traffic control to a holding bay and are held there until a gate becomes available. Holding bays are not required if capacity matches demand; however, fluctuation in future demand are difficult to predict so that a temporary storage facility may be necessary.

3.7.6 TERMINAL AREA/RUNWAY RELATIONSHIP

The key to a desirable airport is to provide the shortest taxiing distances from the terminal area to the takeoff ends of runways and to shorten the taxiing distance for landing aircraft as much as possible or practicable. This can be illustrated schematically by the sketches shown in Fig 20. The terminal building is the transit zone between the airside and landside as was discussed earlier in this chapter. It is made use of mainly by the passengers and those friends or relatives of theirs who either come to the airport to receive them or to see them off. Since this thesis is a military base, however, commercial passengers are absent and hence it would not be necessary to provide a terminal building as is the practice in conventional airports. More important factors however would be discussed that relate more to the thesis.

3.7.7 ANALYSIS OF WIND

An analysis of wind directions is also important and essential for planning the runways. As a general rule, the principal traffic runway at an airport should be oriented as closely as practicable in the direction of the wind . In Nigeria, we have two main wind directions; the North-East trade winds and the South-West monsoon. Since these winds are along the same plane only that they are opposite in direction

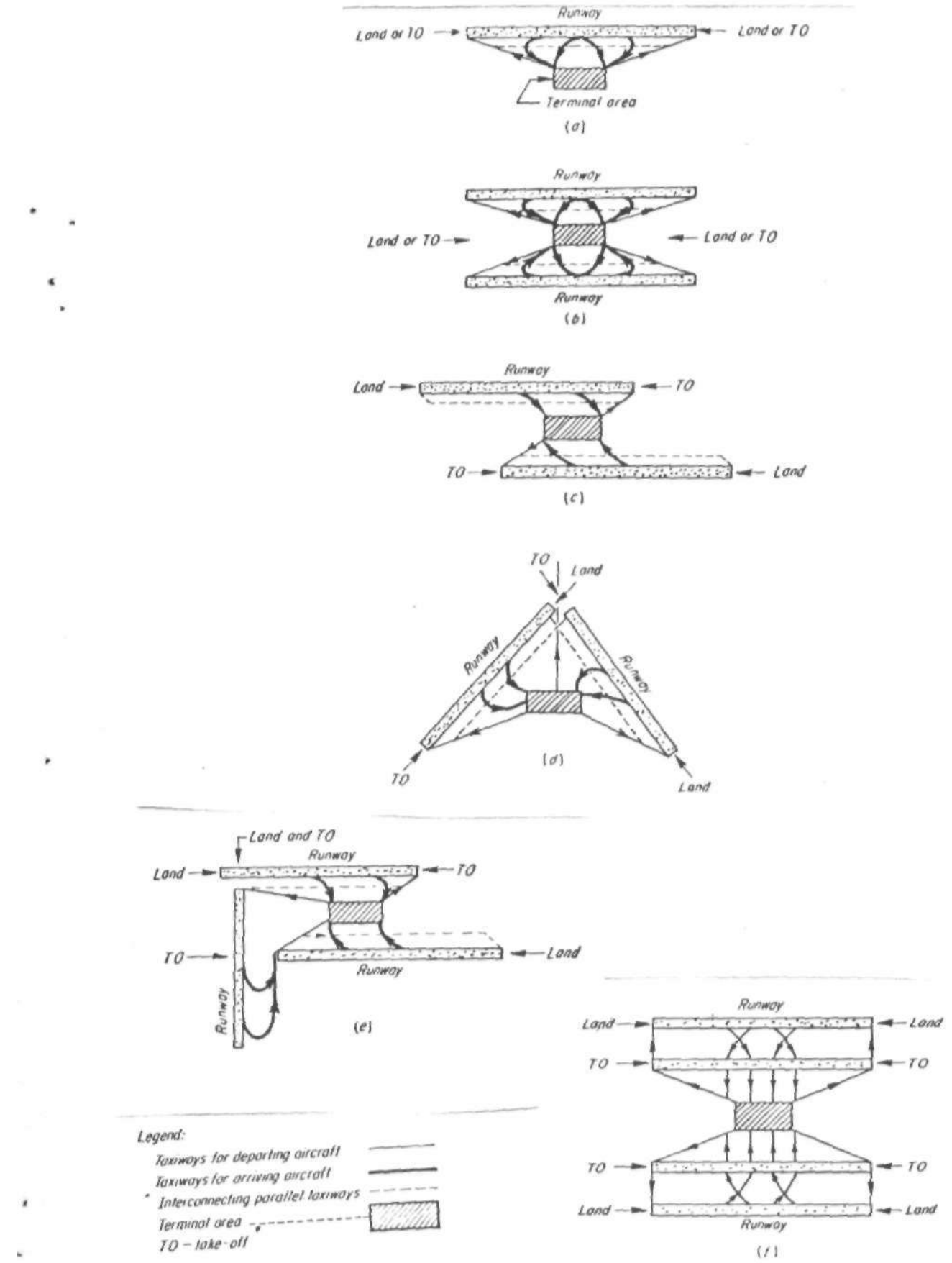


Fig 20 :- Terminal building/runway configurations

we can assume that it is along one plane hence the run way should as much as possible be aligned along NE - SW Direction. In climates where wind directions are in several different directions, certain computations have to be done and this makes the planning of the runway more difficult.

3.7.8 STRUCTURAL DESIGN OF AIRPORT PAVEMENTS

This aspect of the airport design is considered essentially a structural problem which is usually done by structural engineers. However it is worth mentioning that materials that are used in the construction of pavements are materials such as bitumen (coal tar), asphalt, concrete, portland cement concrete mixes, etc. These pavements should be designed so that the impact weight of takeoff, landing or taxiing of the aircraft are sufficiently taken care of. A section through a typical structural pavement section can be seen in Fig 21.

3.7.9 AIRPORT DRAINAGE

A good or adequate drainage system for the removal of surface and subsurface water is vital for the safety of aircraft and for the longevity of the pavements. Improper drainage results in the formation of puddles on the pavement surface which can be hazardous to the aircraft taking off and landing. Poor drainage can

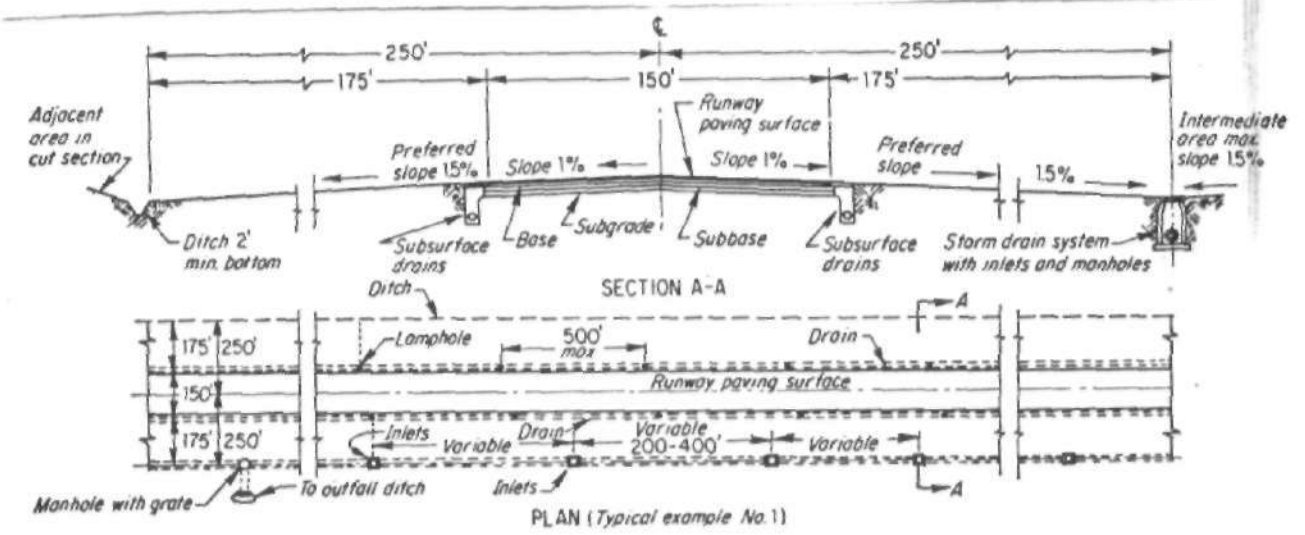


Fig 21 :- Typical structural pavement section

also result in the early determination of pavements. Flat longitudinal and tranverse grades and wide pavement surfaces often pose difficulties in making provision for adequate drainage at airports.

The main functions of an airport drainage systems are mentioned here below:-

(i) Interception and diversion of surface and groundwater from originating from lands adjacent to the airport.

(ii) Removal of surface runoff from the airport

(iii) Removal of subsurfaces flow from the airport.

Unless the airport site is slanting which in most cases is not possible, natural drainage becomes a problem hence artificial drainage systems are usually employed to help in such cases (ie relatively flat sites). These artificial methods appear in the form of partially or wholly covered gutters, underground mechanical systems and other forms available. Recommended pavement drainage system section can be seen in Figs 22, 23 and 24.

3.8.0 AIRCRAFT CHARACTERISTICS RELATED TO AIRPORT DESIGNS.

. Airports are basically to accommodate aircraft (ie their operations eg landings, takeoffs, etc) and this factor make aircraft characteristics about the most important factor in designing and planning

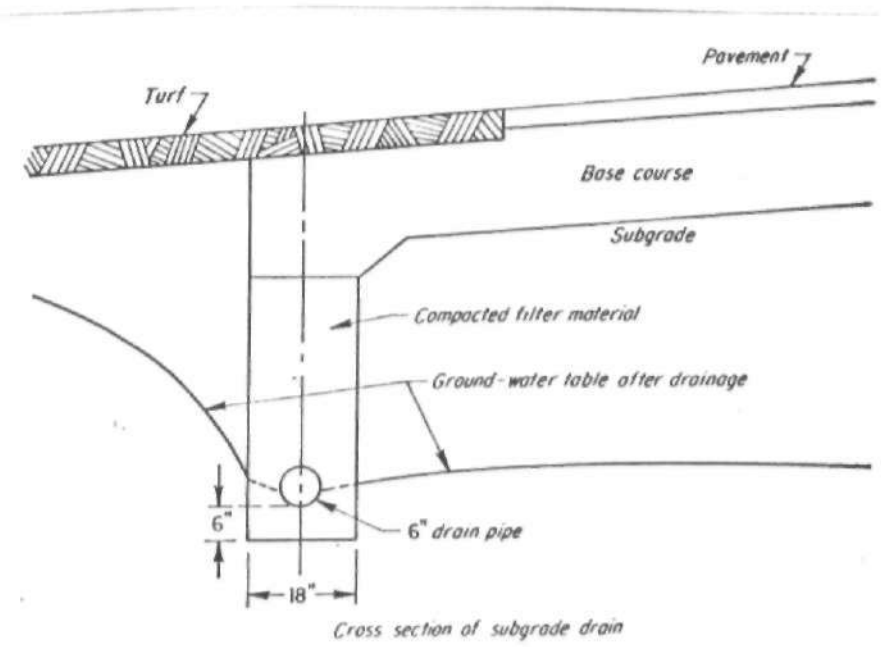
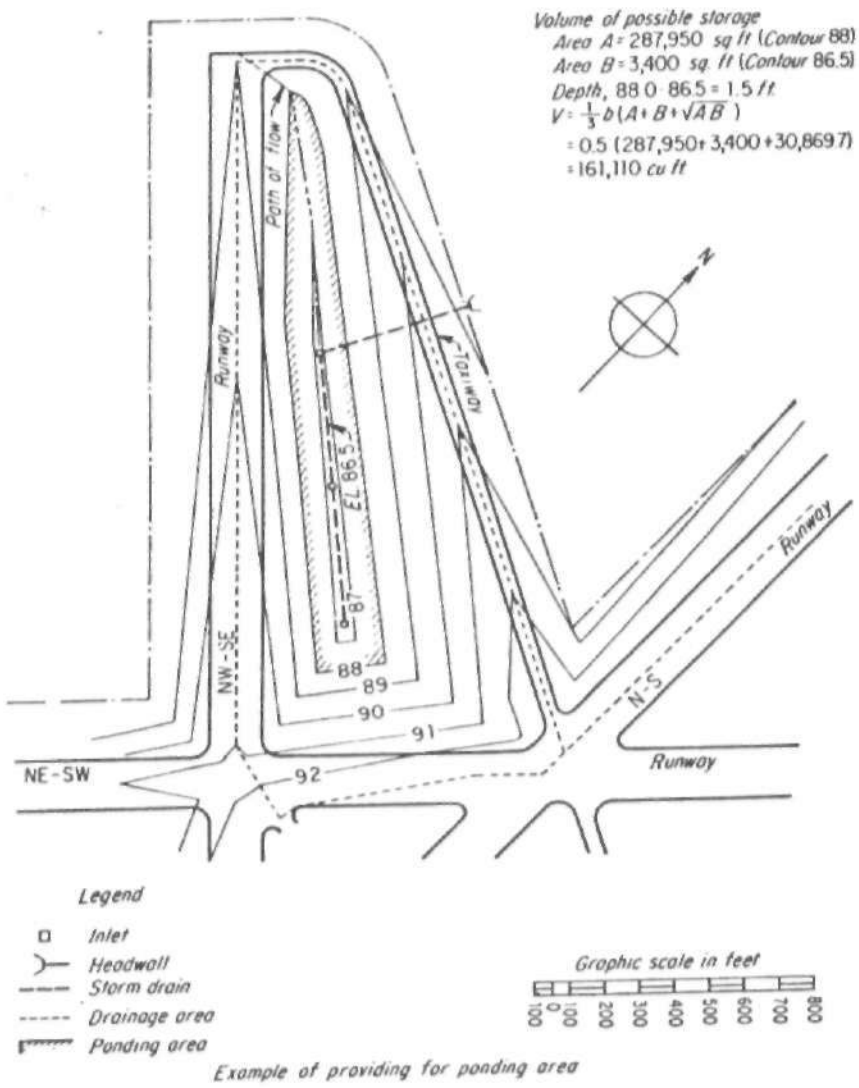


Fig 22 :- Subgrade subdrainage details



Example of providing for ponding area

Fig 23 :- Layout of drainage for ponding

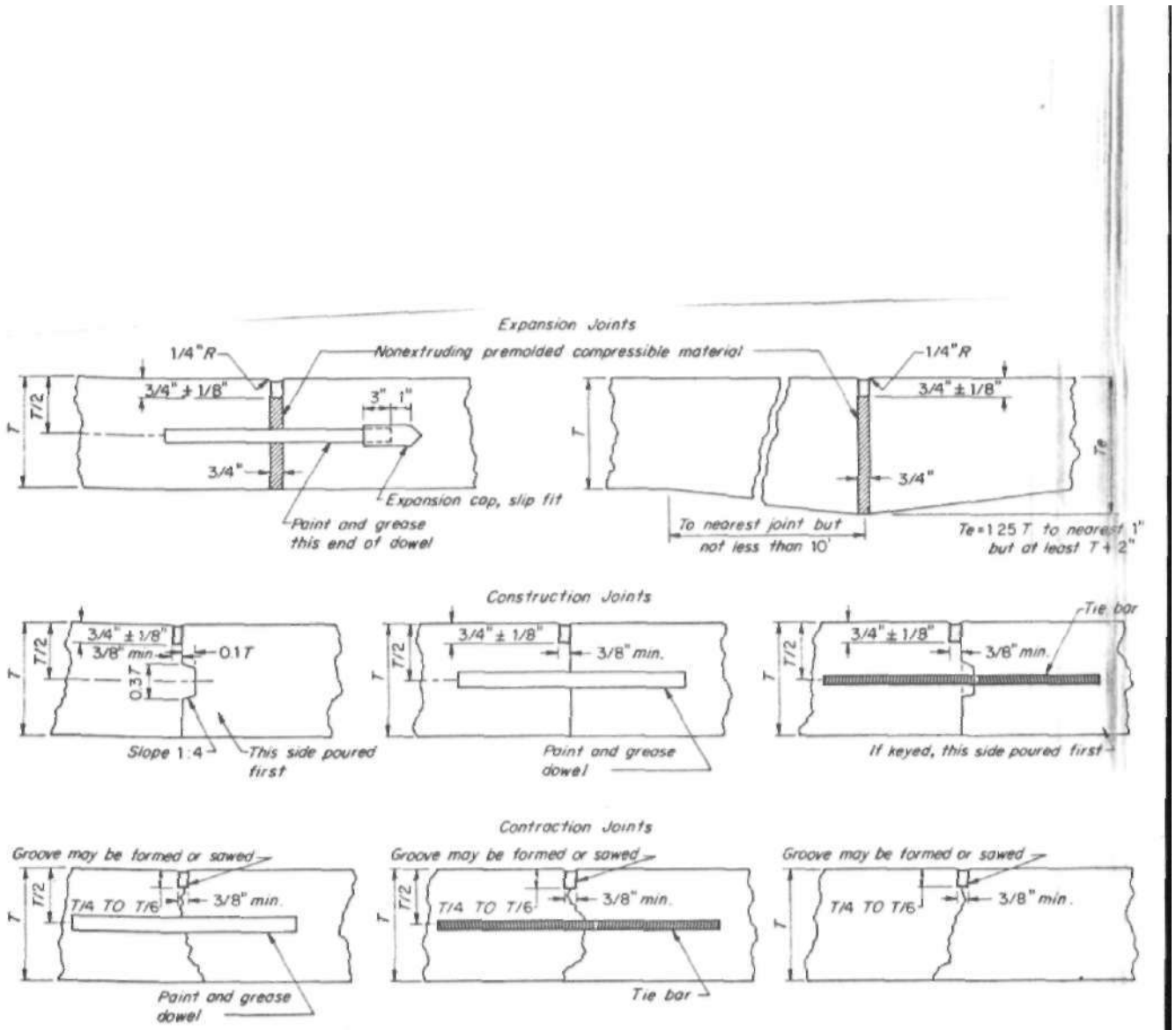


Fig 24 :- Details of joints in rigid pavements

airports generally. Just like a train terminus or railway station is to be able to accommodate trains on the rails and not bicycles or cars, the airport too has as its first prerequisite the accommodation of the aircraft. Some of the most important characteristics of aircraft which influence the design of airports are as follows:-

(a) Weight

Aircraft weight is important for determining the thickness of runway, taxiway, and apron pavements.

(b) Size

The wingspan and the fuelage length influence the size of the parking aprons which in turn influences the configuration of the terminal buildings. Size also dictates width of runways and taxiways as well as distances between these traffic.

(c) Capacity

The passenger capacity has an important bearing on facilities within and adjacent to the terminal building.

(d) Takeoff and Landing Speeds and the aircrafts ability to Shoot off or ston

This greatly influences the length of the runway that is to be provided in the airport. Usually, provision is made for the aircraft with the greatest characteristics that are billed to use the airport.

(e) Wing Span

This influences the width of both the runway and taxiway as well as parking aprons, hangars, bunkers, etc. Fig. 25 shows basic aircraft dimensions that are usually taken into consideration.

(f) Characteristics of Jet Engines

This deals mainly with the noise aspect and this has already been discussed in this chapter under the evaluation of noise aspect.

(g) Turning Radii

For determining aircraft position on the apron adjacent to the terminal building and establishing the paths of aircraft at the other locations on the airport, it is important to understand the geometry of movement of an aircraft or turning radii. This is a function of the nose-gear steering angle. The larger the angle, the greater the radii would be. From the center of rotation the distances to the various parts of the aircraft, such as the wing tips, the nose, or the tail result in a radii number or a number of radii. The minimum turning radiis corresponds to the maximum nose-gear steering angle specified by the aircraft manufacturer. The maximum angles vary from 60 to 80°. The centre of location can be easily determined by drawing a line through the axis of the nose gear at whatever steering angle is desired. The intersection of this line with a line drawn

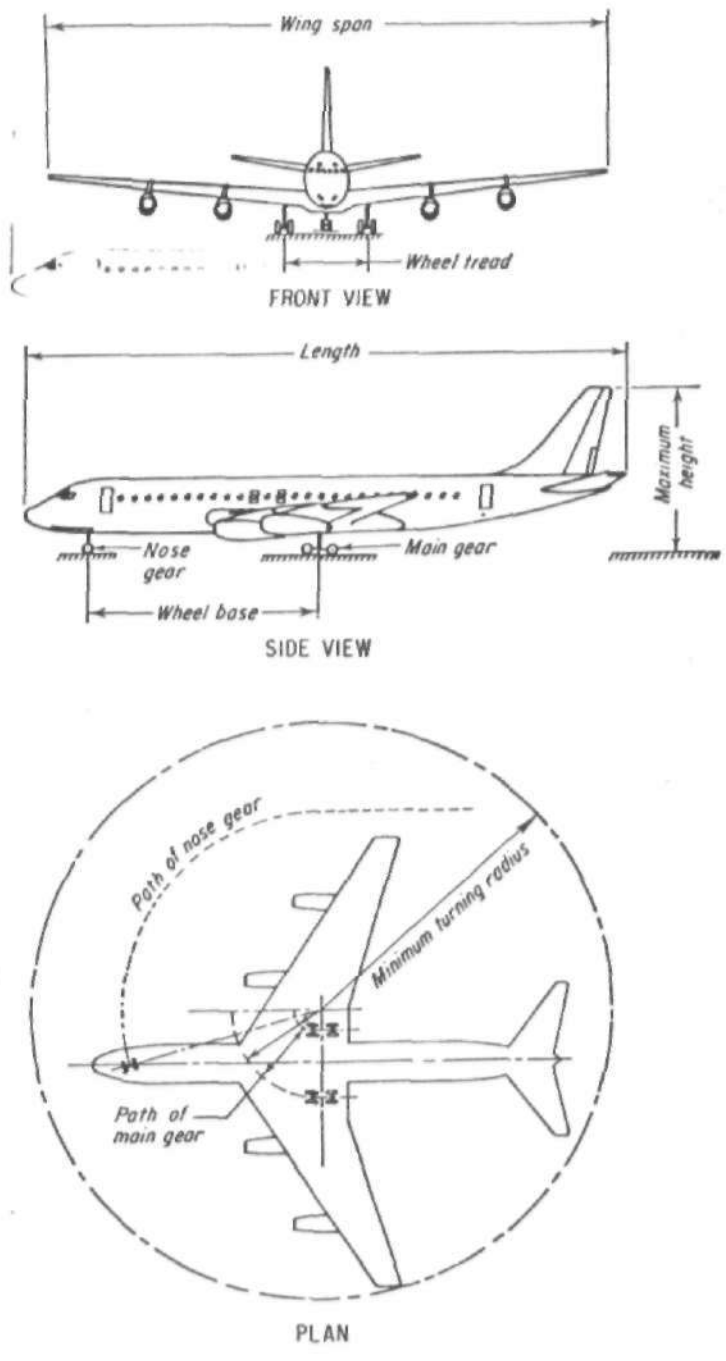


Fig 25 :- Aircraft dimensions

through the axes of the two main gear is the center and this is shown in the already mentioned fig 25. Some new aircraft have the capability of swiveling (ie turning round a ring and prove or ring with a linked hook to a chain or attachment joining two parts of the wing body so that one can turn round without the other eg aircraft) the main gear when making sharp turns. The effect of the swivel is to reduce the turning radiis. This is a very critical consideration when planning for or designing an airport.

(A) Wing Tip Vortices

Whenever the wings lift an aircraft, vortices form near the ends of the wings. Vortices are masses of whirling fluids or winds especially wind pools which form in this case around aircraft wings. The vortices are made up of two counterotating cylindrical air masses about a wingspan apart, extending along the flight path. The velocity of the wind within these cylinders can be very hazardous to aircraft encountering them in flight. The vortices encountering an aircraft when there is no wind and when there is a cross wind are shown in fig 26[a] and b respectively. These vortices influence the distances therefore between successive runways and also between runways and terminal buildings and other possible physically related obstructions.

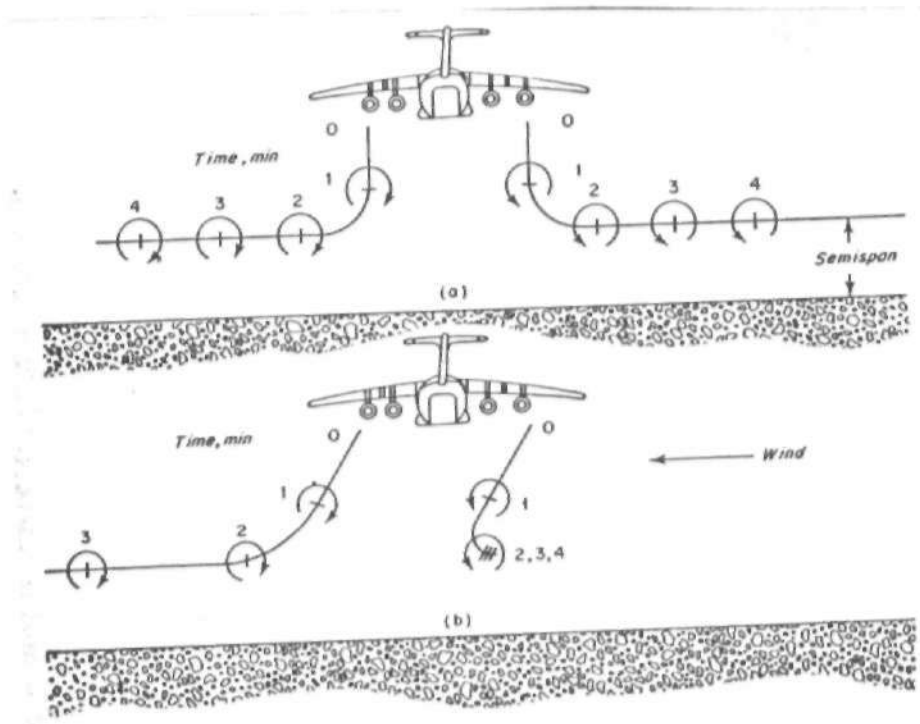


Fig 26 a & b :- Vortex movement near the ground

(B) <u>The effect of Aircraft performance on runway length</u>.

Although this important factor has already been mentioned, it is worth mentioning that factors which have a bearing on runway length may be grouped into three general categories namely:-

(a) Performance requirements imposed by the government on aircraft manufacturers and operations;
(b) Environment at the airport, and
(c) Those items which establish the operating takeoff and landing gross weights of each aircraft type.

All these factors actually in one way or the other influence the length and type of the runway to be provided in a particular airport.

One comforting factor, however, that is comforting is that aircraft manufacturers have been able to provide data regarding their various aircraft performances. All these factors are listed in " Janes All the World Aircraft Manual" which is an annual publication; thanks to the Jane Organisations that the aircraft for which one is to design for are included. This greatly reduces the task of having to go to various manufacturers as would be seen in the third and final part of the thesis write-up.

3.9.0 HELIPORTS AND SHORT TAKEOFF AND LANDING (STOL) PORTS.

All that has been discussed in the parts preceding this one with regards to airport design has been on the assumption that the aircraft in mind are conventional carrier/military aircraft which require relatively long runways for landing and takeoff. However, in the past twenty years or so, research and development have been going on in a number of different types of aircraft or vehicles which in effect can stand still while flyin_ or taking-off or landing within the smallest available space. The best known of this family of aircraft is the helicopter. This is an aircraft or better still a vehicle which essentially can lift-off the ground in a rearly vertical direction. There are also conventional military aircraft apart from this class of aircraft called the helicopter which can also perform this fete. The best known of this non-helicopter family is tomcat - harrier (ie a British product). Aircraft which aquire these "helicopter- like" characteristics (ie aircraft which can lift off the ground nearly or in a vertical direction and which can stand still while flying) are referred to vertical takéoff and landing (VTOL) aircraft. In the past years it is worth mentioning that considerable research and development effortshas been devoted to investigating the potentials of short takeoff and landing (STOL)

aircraft for intercity transportation. Though these aircraft may not be able to rise vertically, they are designed to kind of takeoff and land on very short runways. The term "short runways" however is relative. However for discussions relating to STOL aircraft, a runway of distance of not up to 900 metres would be taken as a short runway hence aircraft that do not require runways of up to 900 metres would be referred to as STOL aircraft. Since the helicopter is by far the most advanced aircraft in this class, facilities for helicopters (ie their landing taking off, parking and other facilities) otherwise known as heliports would be discussed. Usually, in the design of heliports, STOL aircraft are usually considered although VTOL aircraft atimes are considered. The reasons why the STOL aircraft are usually used are that they are less noisy and less costly to operate than VTOL, and they require less land for runways than conventional aircraft. Hence the runways at normal airports may be adequate for STOL whereas conventional aircraft may not be accommodated at heliports. One other important factor to note is that perhaps apart from the Clinook Military helicopter, no other STOL or VTOL aircraft can accommodate up to fifty (50) passengers or more. Certain factors are usually considered in the design or planning stages of heliports and as usual these factors are discussed below.

3.9.1 NATURE OF HELICOPTER TRANSPORT

Generally, transport by helicopter can be classified into three main categories namely, private operations, common-carrier operations and military operations. Though these operations differ in character, it is worth mentioning that the helicopters used in all cases basically operate on the same principles. Usually helicopters are used to get to naturally impossible areas eg mountains, jungles etc and these might by short, medium or long distances. The main advantage of helicopters is its ability to land at very rugged places. However, in a case where a good number exist (eg in the Nigerian Airforce fleet) it becomes necessary to provide specialized heliports to accommodate them.

3.9.2 CHARACTERISTICS AND DIMENSIONS OF HELIPORTS

A helicopter is basically a powered aircraft which gains its lift from the rotary motion of airfoil surfaces. The distinctive feature of a helicopter is its ability to hover through application of power to the rotating airfoils. While helicopters can ascend vertically from the ground, prolonged vertical ascents severely restrict load-carrying capacities. Just before touch down, the helicopter hovers momentarily two to

three metres above the landing pad. From safety point of view, the operation of single-engine helicopters requires that emmergency landing areas be available from anypoint in the flight path. Twin-engine helicopters are designed on the other hand to permit continuation of flight and even a moderate rate of climb in the event one engine fails and for these type of helicopters its is necessary from a safety point of view to have available space for landing along the entire route.

The principal dimension of representative helicopters in use today are given in the table shown in fig 27.

3.9.3 FACTORS RELATED TO SITE SELECTION

The most important factors considered in site selection for heliports are:-

(i) Best location to serve potential traffic;

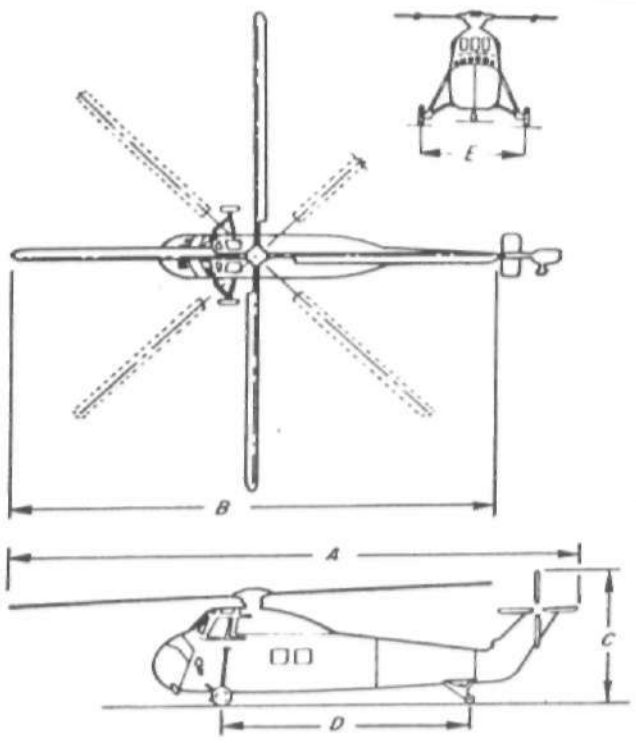
(ii) Minimum obstructions in the approach and departure areas;

(iii) Minimum disturbance from wide and desirable location with regard to adjacent land use;

(iv) Good access to surface transport and

(v) Minimum cost to aquire and develop.

Usually final selection of a heliport site will require a compromise among these various goals.



Company	Model Designation	A Overall Length	B Rotor Diameter	C Height	D Wheelbase	E Tread	Max. Gross Wt.	No. of Engines	No. of Passengers	No. of Main Rotors
Bell	205A	57.1	48.0	14.4	..	9.0	9,500	1	14	1
Bell	206A	39.1	33.3	9.5	..	6.3	3,350	1	4	1
Bell	47G	43.2	37.1	9.3	..	7.5	2,950	1	2	1
Sikorsky	S-58	72.8	65.8	15.9	28.3	12.0	13,000	1	16	1
Sikorsky	S-61L	62.0	56.0	17.0	23.5	13.0	19,000	2	30	1
Hughes	300	28.9	25.3	8.2	..	6.3	1,670	1	2	1
Vertol	107-II	83.3	50.0	16.9	24.8	12.9	19,000	2	25	2

All dimensions are in feet; all weights are in pounds.

Fig 27 :- Helicopter data

Factors like obstruction clearance and other related considerations also play a very important role in the design and Fig 28 gives the basic obstruction clearance requirements for heliports.

3.9.4 PHYSICAL CHARACTERISTICS OF HELIPORTS.

A heliport as has already been said is a facility which is intended to be used for the landing and takeoff of helicopters and may include space for helicopter parking, buildings, servicingfacilities, and vehicular parking. The takeoff and landing area is where the helicopter actually takes off and lands. The FAA classifies heliports according to use as follows:-

Class I - Private

Class II - Public (small)

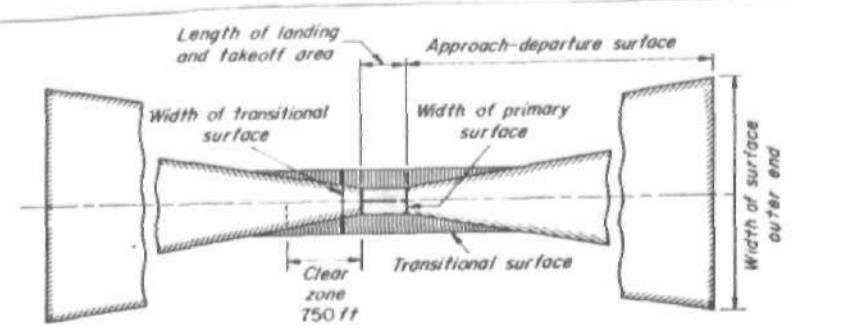
Class III - Public (large)

and this can be seen in table that is attached to fig 28. They are also further sub-classified according to their available support facilities and these are:-

Subclass A - Minimum support facilities - no buildings, maintenance or fueling.

Subclass B - Limited support facilities - no maintenance or fueling

Subclass C - Complete support facilities, including maintenance and fueling.



Item	VFR			IFR
	Private I	Small public II	Large public III	
Width of Primary Surface	1.5L*	1.5L	1.5L	300
Width of Approach-Departure Surface—Inner End	1.5L	1.5L	1.5L	300
Width of Approach-Departure Surface—Outer End	500	500	500	3,400
Length of Approach-Departure Surface	4,000	4,000	4,000	10,000
Slope of Approach-Departure Surface	8:1	8:1	8:1	15:1
Slope of Transition Surface	2:1	2:1	2:1	4:1
Width of Transitional Surface	500	500	500	700
Minimum distance prior to beginning of curved path	300	300	400	†
Radius of curved path	700	700	1,500	†

All dimensions in feet.
* L is the overall length of helicopter.
† Not permitted in IFR.

Fig 28 :- Obstruction Clearance requirements for heliports

The first subclass includes small heliports, the second medium and the third subclass large heliports. It should not be forgotten that the principal components of a heliport are the landing and takeoff area, the touchdown area, and for large heliports, taxiways and building or terminal areas. These and other related functions are discussed below.

(a) Landing and Takeoff Area

This is the surface from which the helicopter can takeoff or land. Its size depends primarily on the overall length of the largest helicopter to be accommodated by the heliport. Usually because of the dust that is created by the rotor of a helicopter, it is necessary to prepare the surface of the landing and takeoff area so that it would be free of dust hence it usually is paved. The dimensions of the landing and takeoff area are listed in Table XIV. The overall length of the helicopter and the rotor diameter represented by "A" and "B" respective in the table can be seen in a clearly illustrated diagram in the already discussed Fig 27.

(b) Touchdown Area

Within the landing and takeoff area, an area is designated for the normal everyday landing of helicopters. The touchdown area is usually designated or defined

Table XIV :- Geometric Design Standard for Heliport

Item	Design criteria		
	Class I	Class II	Class III
Length of landing area ..	1.5*A**	2.0*A*	2.0*A*
Width of landing area ...	1.5*A*	1.5*A*	1.5*A*
Size of touchdown area ..	*B*†	*B*	*B*
Taxiway width, ft	20	20	40
Shoulder width, ft	–	10	20
Max. pavement slope, %.	2.0	2.0	2.0
Shoulder slope, %	3.0‡	3.0	3.0

SOURCE: FAA.

* *A* overall length of helicopter; see Fig. 11-4.

† *B* rotor diameter; see Fig. 11-4.

‡ For first 10 ft, 5.0%.



clearly by a solid border painted on the pavement surface as is shown in fig 29. The dimensions of the touchdown area are also clearly listed in Table XIV.

(c) Peripheral Area

As an obstruction-free safety zone, it is normally recommended that a peripheral area surrounding the landing and takeoff area with a minimum width of one-fourth the overall length of the helicopter usually not less than 3.0 metres is provided. This area should be kept free of objects hazardous to the operation of helicopters as much as possible.

(d) Effects of Wind

Despite the fact that helicopters possess the ability to maneuver in much higher cross-wind than conventional aircraft, the takeoff and landing area should preferably be oriented to permit operation into the wind as rearly as possible.

(e) Terminal Area

This is normally very small in relation to that of conventional airports and this is mainly due to the fact that helicopters usually carry very few passengers in comparison to conventional aircraft that use conventional airports.

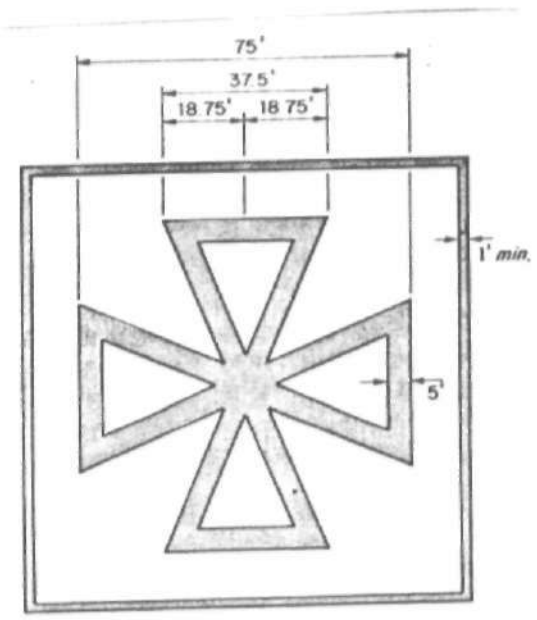


Fig 29 :- Recommended heliport Marking

(f) Marking of Heliports

The primary purpose for marking heliports is to identify the area clearly as a facility for the use of helicopters. Requirements for markings are specified by both the ICAO and FAA. These requirements essentially consist of painting a maltese cross in the centre of the touchdown area as shown in Fig 29. The marking(s) should be oriented in such a way that one exit of the cross is in line with the primary direction of approach. Marking on the takeoff and landing area should be white while that on the taxiway andservice area markings should be yellow.

(g) Structural Design of Heliports

Helicopters using facilities on land are usually supported on skids or wheels equippied with rubber tyres. Helicopters equippied with conventional landing gear wheels are normally supported by two main wheels and one tail or noise wheel. For the larger helicopters each main landing gear consists of two wheels. These are very common in military helicopters. Each main gear supports 40 to 45 percent of the weight of the helicopter, and the tail or nose wheel the remainder, approximately 10 to 20 per cent. If the helicopter is supported by skids, 50 percent of the weight is supported by each skid. The strength requirements for the landing and takeoff area are determined by considering the

helicopters dynamic and static wheel loads and the landing gear configuration. For pavements, only the static load is considered. The landing surface should be designed to support a concentrated load equal to 75 percent of the gross weight of the helicopter at each main landing gear. It is usually assumed that each main landing gear will strike the surface simultaneously. The landing area should therefore be able to withstand the forces that would be exerted on them at all times.

At present only very few STOL aircraft are available and these are mostly in use in the very developed countries. There are quite a number of restrictions in the performances of these aircraft but it is worth mentioning that these aircraft can use the conventional runways and taxiways used by conventional aircraft without causing any inconveniences.

3.95 SUMMARY

Very many factors have to be taken into consideration when planning and designing an airport. This chapter has briefly tried to touch on these factors with a view to showing how each of these intricate details influence the design. The exclusion of any of these factors in the planning/design stage would only produce an airport which would not only be defficient in certain things but also a hazardous

airport. The reason why all things have to be considered seriously is that a functional and safe airport is the ultimate aim of any government or organisation. It would be seen, therefore, that the planning/design of airports is a big project that requires all members of the design team; ie the Architect, Structural/Civil Engineer, Urban/Regional Planners, the Quantity Surveyor and the builder as well as other allies. The architect as usual being the master of the design team is the "main man" (or woman in some cases). All things revolve round the architect.

In the design of the airforce base, therefore, all things factors would be taken into consideration in relation to other aspects like that of security which is vital to the military. Because of its sensitivity, the security aspect of the Airforce base would not be discussed in this part but consideration would be given to it when designing the Model "Airforce Base" for the Nigerian Airforce.

CHAPTER FOUR

4.00 CASE STUDIES

This is one very vital aspect of the design/ planning process of any project. It is useful to not only the architect who is the head of the design team but also to the client. This is so because as Hugh Stubbins puts it; "The case study approach educates the architects and clients alike."

For this purpose three practical or live case studies and four studies (extracted from Journals and books) were undertaken. The case studies are divided into three major categories namely full fledged airforce bases, hangars and bunkers. Three of the case studies are situated in Nigeria, two of the studies in Italy, one in East Germany and the other in Pakistan. However, due to the sensitive nature of the military, the case studies undertaken have been code named Base "A" and "B" and some things of security importance have been deliberately left out in the write-up but these factors have in no way affected the critque nor the final outcome of this research.

4.10 CASE STUDY 1: NIGERIAN AIRFORCE BASE "A"

This base (fig 30) was designed and built by a special task force constituted by the Federal Military Government after the Nigerian Civil War. It happens to be the first full fledge airforce base built in this country. Being a typical airforce base therefore, it is divided into two; the barracks and the operational zone. The barracks zone consists of a total of two hundred and two (202) houses made up of the Commanders house and his guest house, five (5) senior officers quarters, thirty (30) squadron leaders and Wing Commanders quarters, thirty (30) Pilot Officers, Flying Officers and Flight Lieutenants quarters, ninty (90) senior non-commissioned officers quarters and forty-five (45) junior non-commissioned officers quarters. There also exist recreational facilities which are central in location such as the sports ground, offices and airmen's mess, green parks, etc. Other centrally located facilities include religious buildings, the medical reception station (hospital), a junior school and shops. The parade ground, the administrative building, the maintenance yard and workshops, the welfare centre and the signals building also are found in this base. This zone (ie the barracks) is separated from the operational zone by a very high security barbed wire fence.

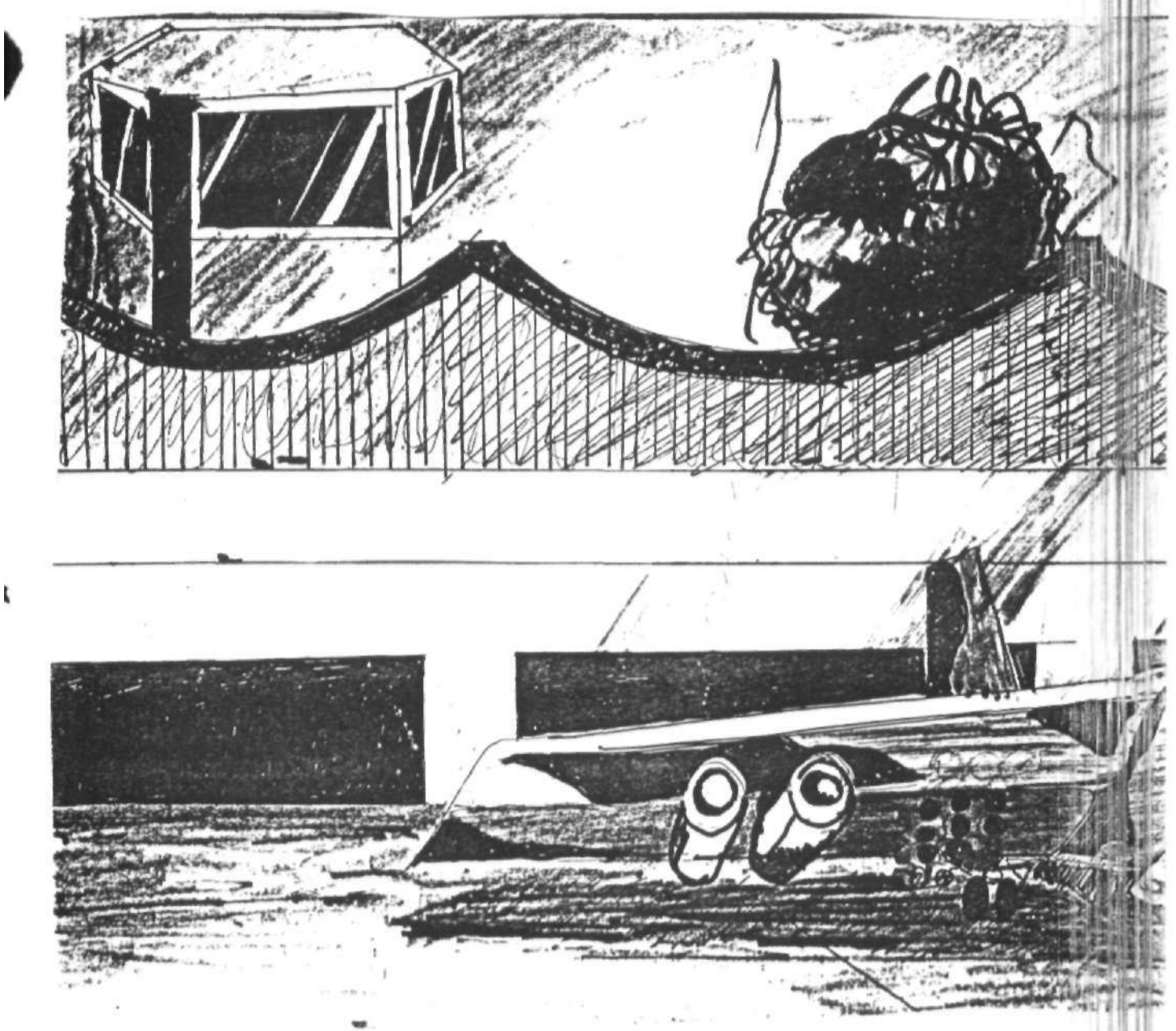


Fig 30 :- NAF Base A

The operational zone is made up of the runway and taxiways, an operational building, one apron, a fire station, a hangar and bunker, a fuel farm, a meteorological radar, a missiles bunker, a transformer station and a pumping station. Certain other installations are restricted in circulation and cannot be mentioned here but have been taken into consideration for the purpose of the critique. This base can cater for all aircraft.

Critique:-

The provision of bunkers for both the aircraft and personnel is a right step in the right direction. Most of the vital installations are underground and hence are very well protected. The use of concrete for both the hangars and the bunkers also makes the base a bit more bomb proof than if aluminium claddings were used. The orderly planning of the operational and barracks zones also conforms with military planning techniques.

The barracks zone however lacks ample space for expansion and this is one very important shortcoming. The operational zone is also visible from the main road and this is a big threat to national security. The officers and men's zone is not well segregated and some of the recreational facilities are too one sided. There is also the absence of a mini-market

for the personnel and this has further compounded their problem of transportation to town and back thus causing traffic jams.

Generally, the base serves it function quite adequately.

4.20 CASE STUDY 2: NIGERIAN AIRFORCE BASE "B"

This base (fig 31) was designed by the Directorate of Works of the Nigerian Airforce. It is at the moment perhaps the best and most modern airforce base in Black Africa. It is also about the largest within the same sphere. This base is about the most complete as it has almost all the necessary facilities a base needs. There is the presence of a very high barbed wire fence round the base and it is clearly divided into the operational and barracks zone by a equally high fence.

When fully completed, the barracks would have a total of two thousand, two hundred and sixty (2260) quarters for the personnel made up of the Commanders house and guest house, nine (9) Group Captain's quarters, eighty-six (86) for Squadron Leaders and Wing Commanders, one hundred and twelve (112) for Flying Officers one hundred and two (102) for single officers, five hundred and eighty nine (589) for senior non-commissioned officers and one thousand, three hundred and sixty (1360) for junior non-commissioned officers. There are centrally

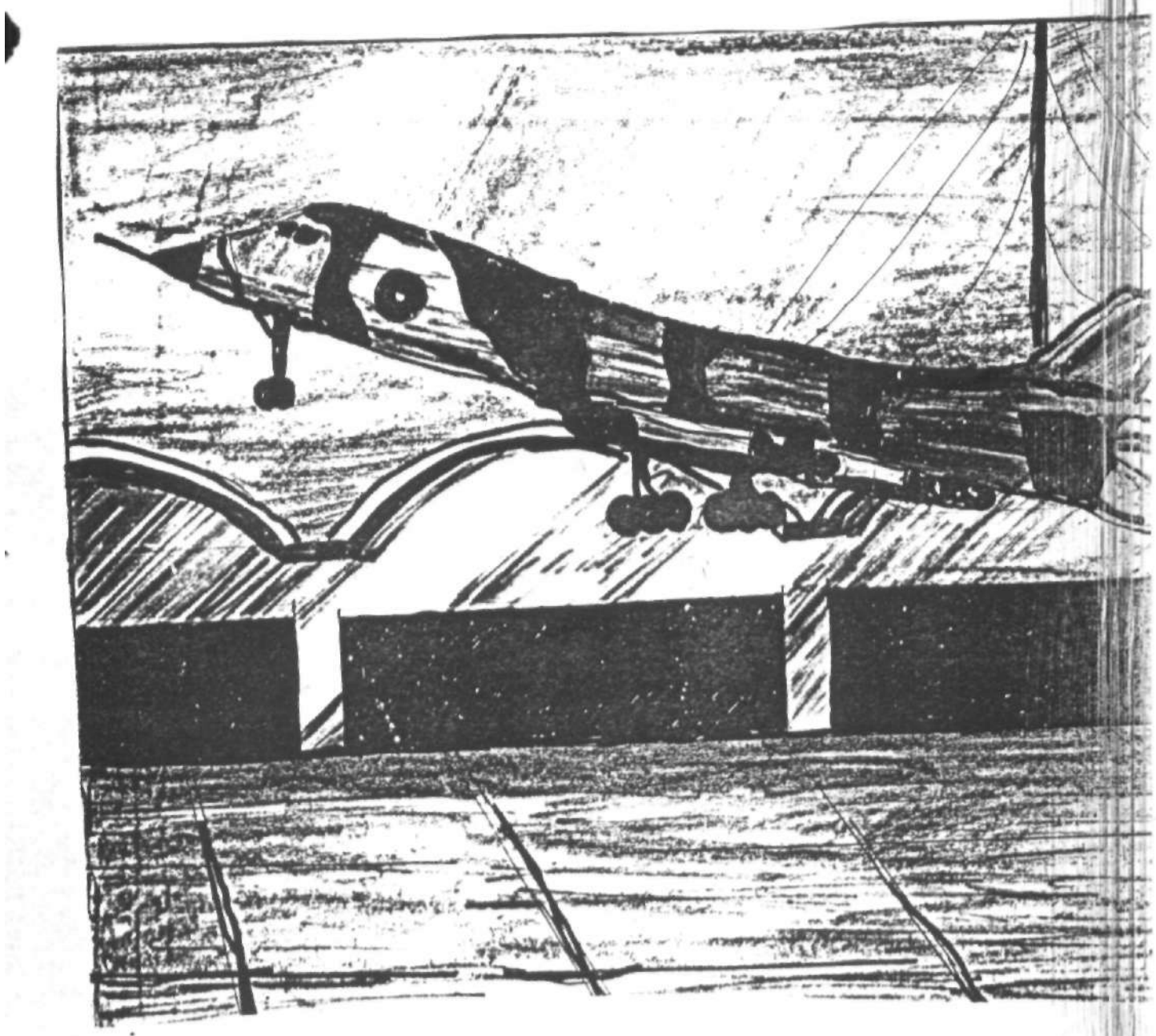


Fig 31 :- NAF Base B

located recreational facilities such as a school, the medical reception station (or hospital), a church and a mosque. Other facilities like the mammy market, etc are near the non-commissioned officers quarters while the super market is near the officers quarters. There is also one officers mess and two messes for the senior and the junior non-commissioned officers (N.C.O.'s). The fire station is centrally located. The warehouses, the maintenance workshops, the parade ground, the officer commanding's (O.C) station and the armoury are located closer to the N.C.O.'s quarters. This is due to the fact that most of the N.C.O.'s lack means of transportation in comparison to the officers and hence they have to walk to work. There also exists a guard house in the barracks.

The operational zone is highly sophisticated in terms of construction and planning. It is made up of a runway and taxiway, a fuel station, a heliport, two aprons, three hangars, a bunker, a motor transport yard, workshops and warehouses. There also exist a power house, squadron offices, operational buildings, fire station, logistics building and guard house. Also present in the base are the Wing Commanders bunker and an underground water reserviour. There is also a training wing for the personnel of the airforce.

Critique:-

This base has the advantage of being organised and has ample space for future development. It is also a well zoned base and it possess adequate security coverage. The presence of bunkers for both personnel and equipment is also worthy of commendation. The barracks zone is well segregated as regards the military hierachy but I must say the planning of the road network is not in conformity with urban planning laws.

There are too many cross-junctions in the barracks zone and usually it is difficult to tell who actually has right to the move. The road pattern looks kind of hap-hazardly done. The underground installations in some cases are too far away from other functions that are directly related to it.

The base, especially the operational zone, has however been able to function quite well and this is what planning is all about. The installations have also contributed to making it a successful design.

4.30 CASE STUDY 3: NIGERIAN COLLEGE OF AVIATION TECHNOLOGY HANGARS, ZARIA.

The new hangar (fig 32) was designed by an Ibadan based architectural consultancy group by name of Enplar Nigeria Limited. It measures about 110 x 60 metres and is situated infront of an older and smaller hangar.

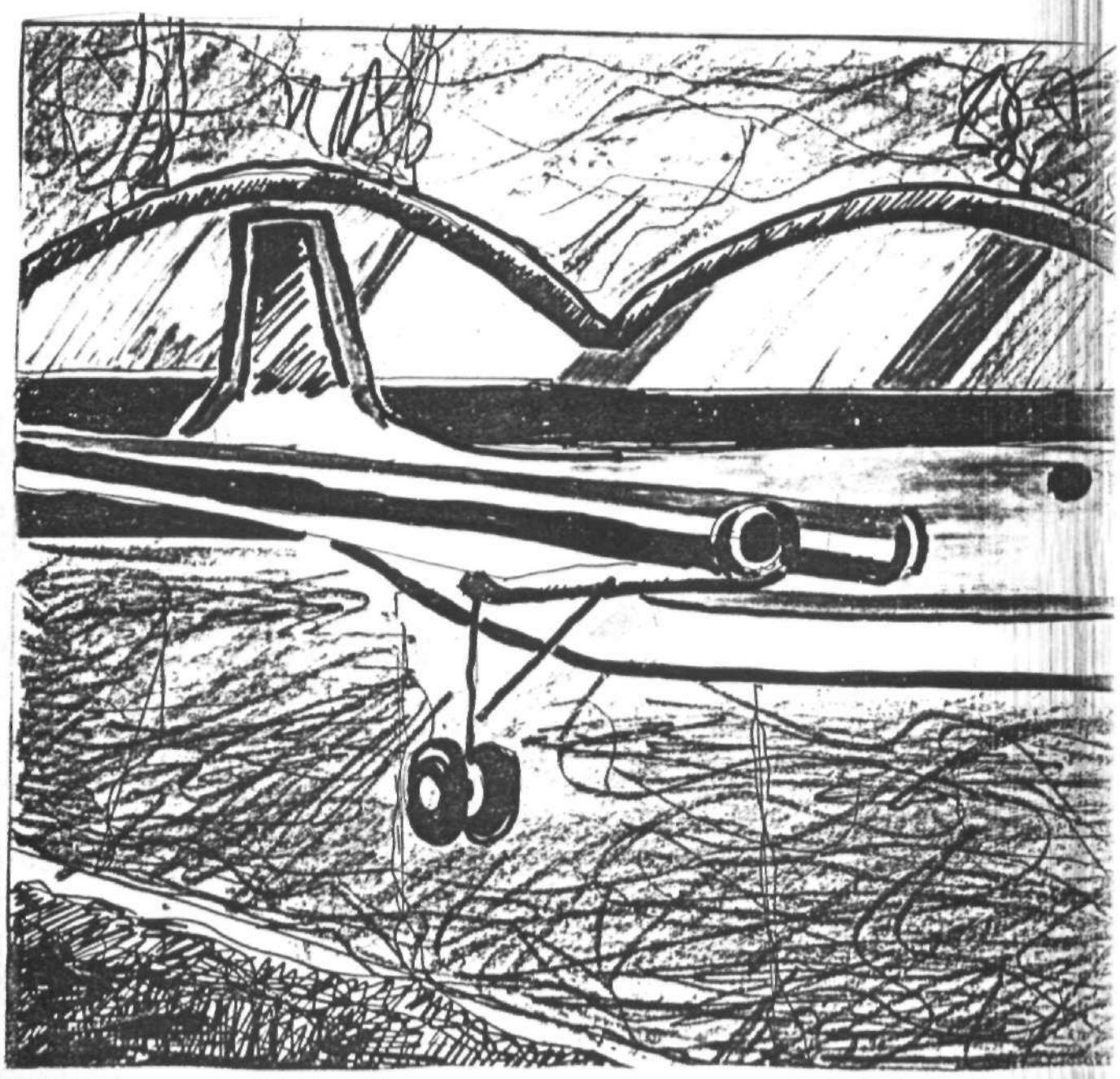


Fig 32 :- NCAT Hangars

It is designed to accommodate all existing aircraft present in the school. The parking space for the planes measures about 110 x 50 metres and has two large openings at the two ends. The workshops and offices are arranged on the third side of the hangar and are two storeyshigh with the heavy machinery workshop and stores on the ground floor. Relatively less heavy machinery workshops are on the first floor in addition to offices, changing rooms stores etc. The second floor consist mainly of an emergency workshop, staff canteens, offices and changing rooms for the staff. These floors are connected to the aircraft parking space by a set of four staircases. The fourth side of the hangar is walled and only has a strip of fixed windows panes. The material used for the construction is mainly concrete and the roofing consist of a set of barrel vaults covered with aluminium sheets. The entire structure is about twelve metres high. The aircraft enter the hangar from the two open ends which are fitted with gigantic sliding doors.

Critique:-

This hangar happens to be the first real hangar to be erected with total indigenous technology. The principle material used is concrete and it happens to be the most economical at the moment when compared to

aluminium claddings. There also happens to be adequate space for all the functions thus making it very functional. The technological know-how implored in both the design by Enplar and the construction work by Jagal Nig. Ltd and the barrel vault roofing structure is something worthy of commendation. Its asthetic appeal is unparalleled in Nigeria. The finishes are superb and I see it as at the moment the ultimate in civil aircraft hangars in Nigeria.

The major problem I encountered was that of entry. The Zaria hangar has only two major entrances at the two ends and this hampers the entry of more than two aircraft at the same time and hence their exit. Militarily this should not happen because in times of war, there should be despatch. However as a civil hangar, it is a real masterpiece.

4.40 STUDY 4: PAKISTANI AIR FORCE BASE, SARGADO

Apart from the U.S.A/U.S.S.R arms race, the next most competitive arms race in the world is probably that of India and Pakistan. The priorities of these two countries is naturally therefore defence oriented. This had led to the aquisition of many new and sophisticated equipment and the aquisition of nuclear power by the two countries. Installation of military significance therefore have to be as hidden and as safe as possible.

The Pakistani Airforce base (fig 33) in Sargoda happens to one such installation. It is considered by military experts that have had the priviledge of visiting it as perhaps the best base in the world. It was designed and constructed jointly by the Pakistani Airforce and a Pakistani Government owned construction company. The base is situated in the hills of the town of Sargoda and it is very difficult to tell which of these rocks or hills actually house the personnel as well as the aircraft even when flying at a relatively low altitude. The hills in one way or the other are similar and the camouflage is so intense that one finds it hard to tell even where the entrance to the base is and there are no visible runways or taxiways. What actually happens is that when an aircraft of the PAF is about to land, messages are relayed to the control tower in the base and then the gate opens up and the plane lands inside. The codes used by them vary from time to time as the need arises and so it is not very possible for the enemy to pick it up. The thick granitic rocks also make it almost totally bomb proof. Military personnel that have been to Sargoda consider it as one of the modern wonders of the world.

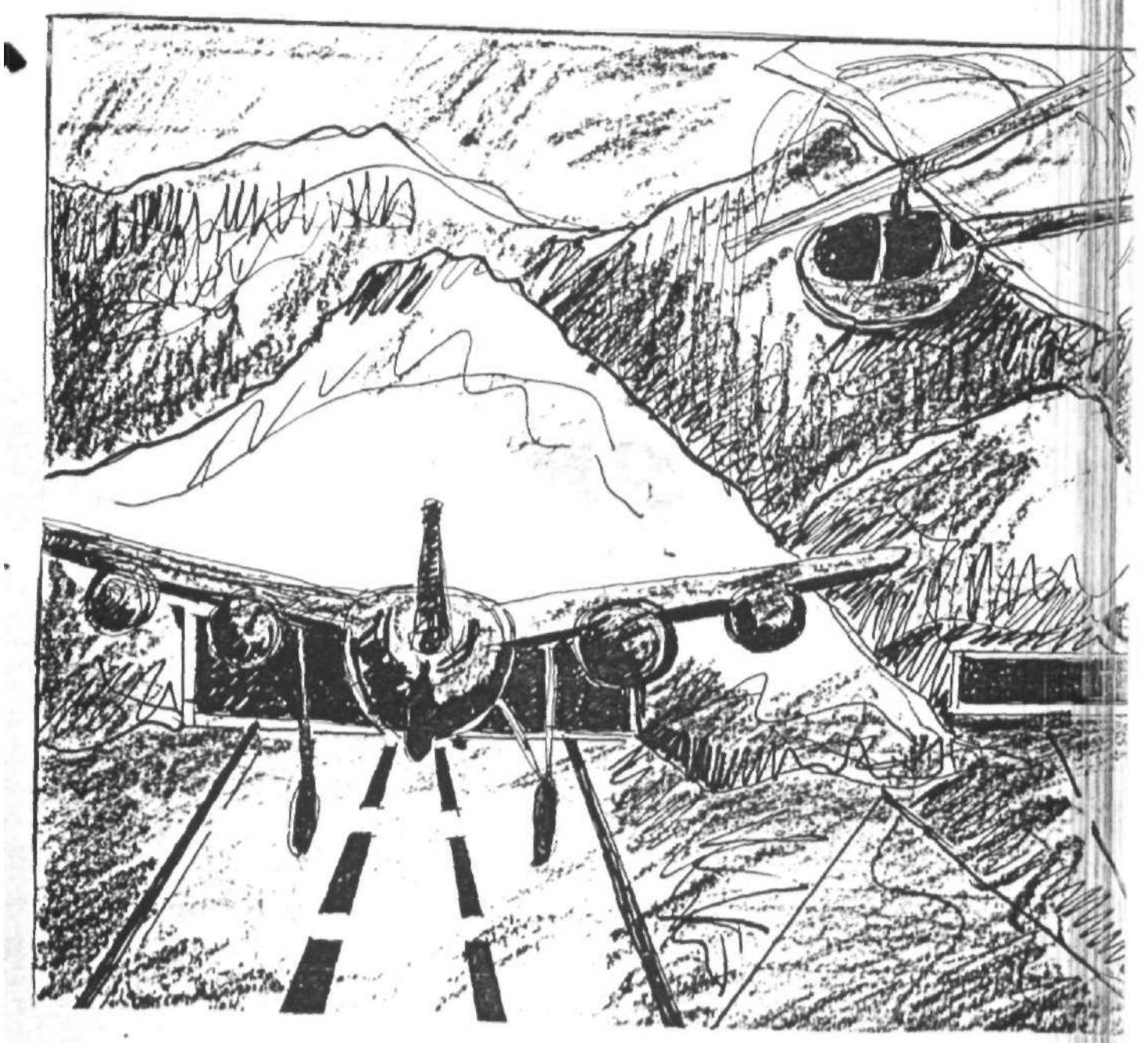


Fig 33 :- PAF Base, Sargoda

Critique:-

This base is almost totally bomb proof and very well camouflaged such that from the air it is hard to spot it. Its installations, aircraft and personnel are also well housed in the caves or rocks that make up the base. It is also almost totally unaccessible by unwanted persons and it is thus a very secure military zone. The use of natural materials like stone is very commendable and encouraging.

I must however say that the excavation and hewning works must have been very difficult and expensive even though money is a very little price to pay for defence and security. The base in Sargoda sounds like its a myth, but then, its for real.

4.50 STUDY 5: ITALIAN AIRFORCE HANGAR 1, ORTEBELLO

These hangars (fig 34 and 35) were designed during World War two for the Italian Airforce by the legendary master structural engineer/architect Pier Luigi Newi. It was built in 1936 for the Italian Airforce after a competition to which many specialized Italian Firms had been invited and of which Pier Luigi Newi's Construction Company won. The free interior dimensions for these hangars were 131 feet by 328 feet, with one side composed of two openings, 164 feet wide and 26 feet high, for large movable doors. In these hangars the

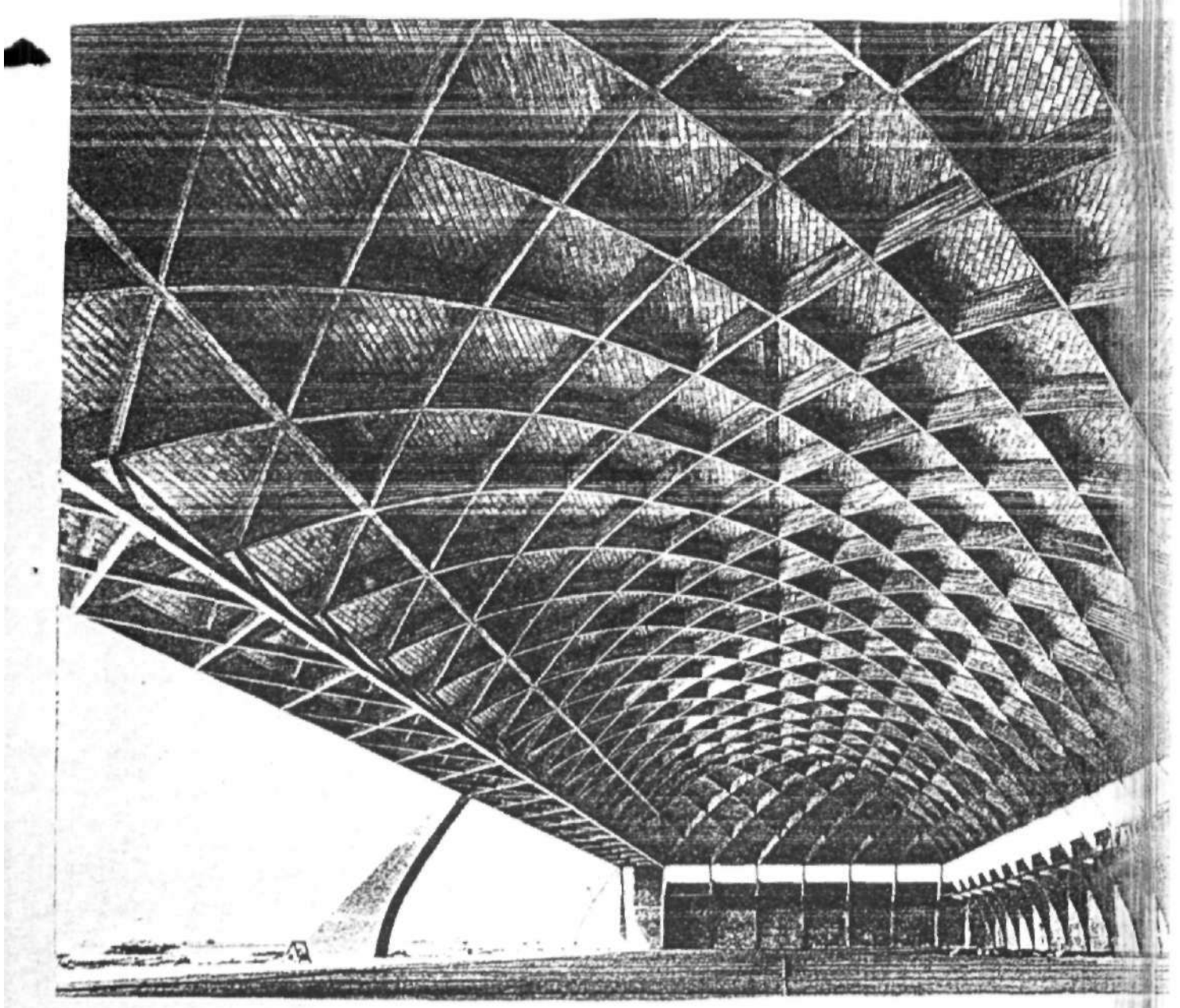


Fig 3 :- ITAF Hangars, Ortebello I

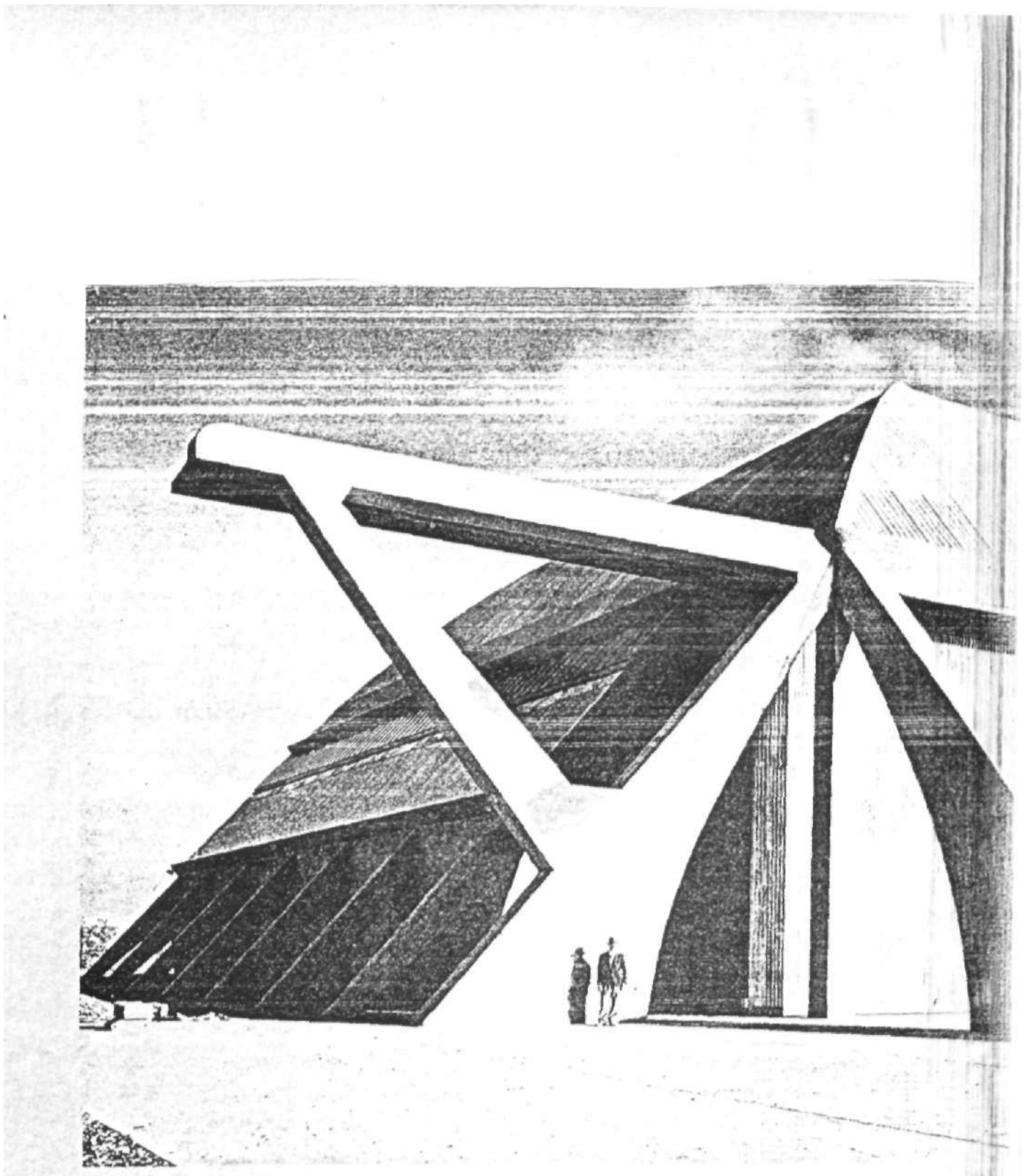


Fig 35 :- ITAF Hangars, Ortebello I

traditional combination of trusses and beams give way to a single resisting organism where the stresses due to its own weight and the external forces of wind and snow could be spontaneously diffused until they reached the supports placed on the three sides and the central column on the side of the doors. The assymetry of the supports made inevitable the presence of great flexural disturbances. Therefore instead of a thin shell, even one that could be made more rigid where needed, the architect turned to a discontinous structure formed by a double series of ribs and completed by a large horizontal truss placed at the opening of the doors. The horizontal truss was intended to take the horizontal components of the loads acting on the external edge of the structure. The external surface continuity was given by a light layer of reinforced tiles and a covering of corrugated cement asbestos. The hangar was constructed almost fully with reinforced concrete. They were however destroyed by the retreating German army in 1944.

Critique:-

The layer of reinforced tile placed over the reinforced concrete frame to form a surface continuity had the defect, due to changes of season, of breaking up. Bits of tile large enough to damage men or machines started to fall. This was due to the difference in

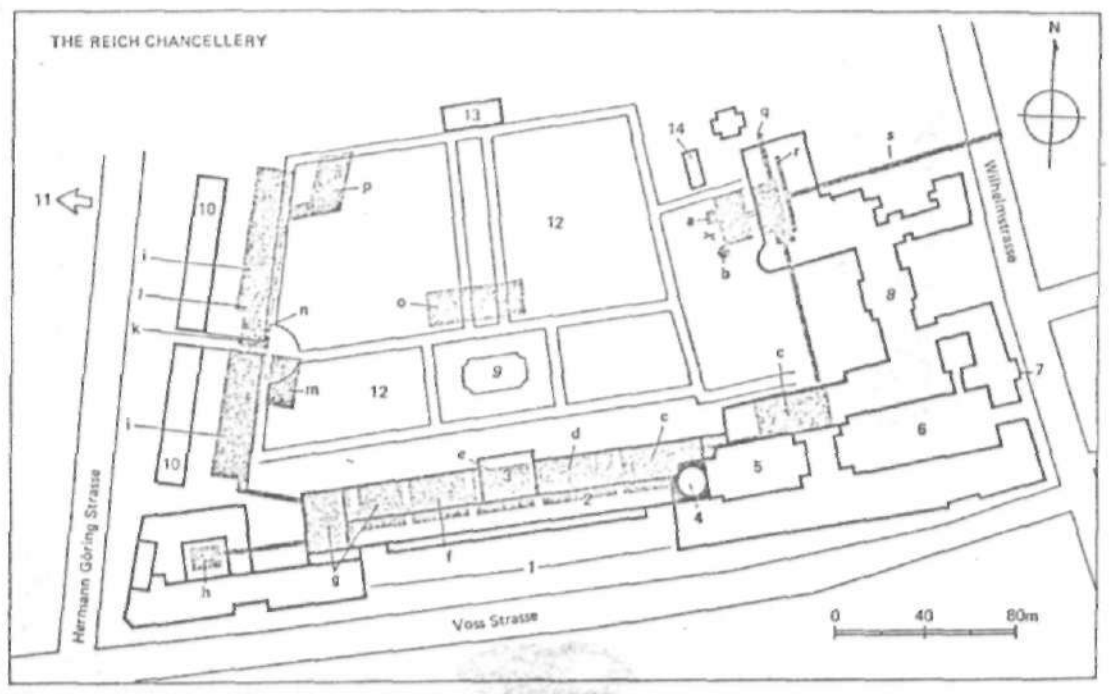
thermal expansion between the structure and the covering, which with changes in temperature underwent unforeseen stresses. Expansion joits were therefore necessary.

The hangars were able to accommodate a reasonable number of aircraft and they were able to leave them with despatch. There was also adequate parking and working space for both the aircraft and the engineers and mechanics. Here we see the master experimenting into methods that proved to be successful in the years that followed.

The hangars were successful to a reasonable extent since they were able to perform their function quite well.

4.60 STUDY 6: THE BERLIN BUNKER

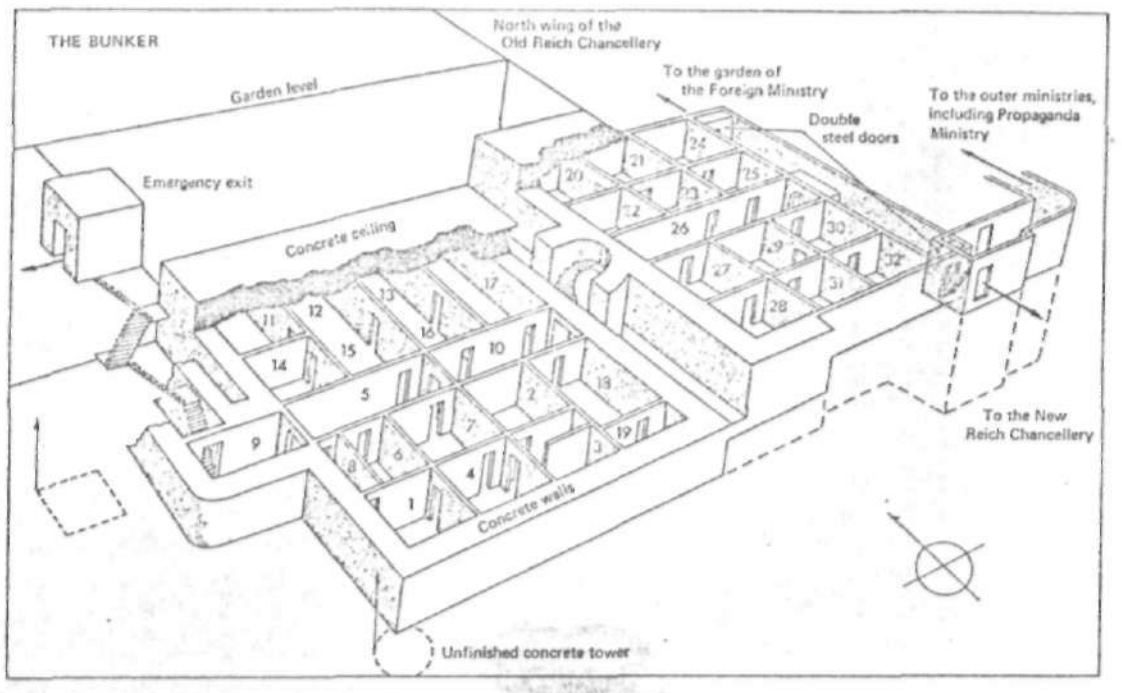
The conversion design process was undertaken by Hitler's great wartime architect, Albert Speer. The Berlin Bunker (fig 36 and 37) was Hitler's thirteenth major Fuehrer Headquarters (FHQ), the last in a trail of command posts that wound back and forth across the map of wartime Europe. This bunker was beneath the Reich Chancellery, and it looked like an air-raid shelter in which perhaps a dozen people could spend a rather uncomfortable night, or day, under steady



1 Reich Chancellery
2 Marble Galley
3 Hitler's workroom
4 *Round room*
5 Mosaic Room
6 Court of Honour
7 Balcony
8 Old Reich Chancellery
9 Fountain
10 Sentries' quarters
11 To the Zoo (secret store of driving materials and garages for 12 vehicles)
12 Garden
13 Greenhouse
14 Officers' quarters and Kempka's living quarters
✕ Site of cremation of corpses of Hitler and Eva Braun

a) Fuehrerbunker
b) Unfinished concrete tower
c) Adjutants quarters
d) Bunker for civilian personnel
e) First Aid station, operation room and dentist room
f) Office personnel
g) Living rooms and canteen
h) 2 autos and 2 armoured personnel carriers
i) Underground garage
k) Chauffeurs
l) Hitler's Mercedes
m) Bunker for 80 drivers
n) Kempka's office
o) Shelter for 10 vehicles
p) Workshop
q) To the gardens of the Foreign Ministry
r) Corridor to outside ministries
s) Corridor to Propaganda Ministry

Fig 36 :- The Berlin Bunker



The private rooms of Hitler and Eva Braun

1 Hitler's bedroom
2 Eva Braun's bed-sitting room
3 Bath and dressing room
4 Hitler's living room

Offices

5 Corridor and conference room
6 Small conference room
7 Hitler's office
8 Wardrobe
9 Ante room
10 Corridor
11, 12 Dr Stumpfegger's room and surgery
13 Emergency switchboard
14 Goebbel's bed-sitting room, earlier, Dr Morell's quarters
15 Dressing room
16 Telephone and sentry post
17 Machine room
18 Toilet
19 Power switches
20, 21, 22, 23 Goebbel's family suite
24, 25 Personnel
26 Communal dining room
27, 28 Storeroom and wine cellar
29 etc. Kitchens

Fig 37 :- The Berlin Bunker

bombardment. The Berlin Bunker was built in successive stages. The first bunker air-raid shelter that was built was a rather modest affair, with walls less than one metre thick. It was about nine metres underground and was dug early in 1936. This bunker was to serve the Old Reich Chancellery, since the new one had then not been built. This is why at the end one finds the "upper bunker" so close to the surface, only about four metres below the cellar level, just under the Old Chancellery garden.

One entered the first or upper bunker not through any tunnel but by descending a staircase from the cellar of the west wing of the Old Chancellery, and then through a short twenty five metre tunnel. When the New Reich Chancellery was built in 1938, it did not have a bunker but Albert Speer designed the cellar in such a fashion that it could easily be converted into one and that is what happened in 1943. A tunnel about one hundred (100) metres long, but only one and a half (1½) metres underground, was bored to connect the New Reich Chancellery to the upper bunker of the Old Reich Chancellery. The construction work was undertaken by a Berlin private-construction firm Hochief.

. The lower bunker or Fuehrerbunker as it was called was where Hitler stayed. Its roof was more than 4.5m thick, the walls at least 1.8m. Tons of

earth were piled on top of it all. It terms of permanent facilities, the lower bunker was never fully completed. The lower bunker was however safer.

The upper and the lower bunker were connected by a wrought-iron staircase, ten to twelve steep special steps. A bulkhead and a steel door on the lower level seperated the two areas. There were always two armed sentries posted just before this bulkhead. With Hitler always in the lower bunker, the upper bunker became a kind of servants' quarters, with storage space for provisions. The kitchen, pantry, the baker-table, communal mess, the refridgerator, the wine cellar and other rooms were in the upper bunker. Water was piped from an extension well deep below the lower bunker. A sixty kilowatt generator supplied electricity for lighting, heating, the switch board, and the water pump. Food, drinks, medicine and candles were in plentiful supply both in the vast store-rooms of the New Reich Chancellery and in the narrow corridor that served as the butlers pantry.

The private room in the bunker were Hitler's bedroom, Hitler's living room, Eva Braun's bed-sitting room and the bath and dressing room. The offices and servants quarters consisted of the corridor and and conference room, a smaller conference room, Hitler's office, wardrobe, ante room and the doctor's room and surgery. Others include the emergency switchboard,

Goebbel's bed-sitting room, dressing room, telephone and sentry post, machine room, toilet, power switches and Goebbel's family suite. There were also rooms for the personnel, communal dining, stores, wine cellar and the kitchens, There was also an emergency exit. On the original plan a tower was to be built but it was never really completed. The entire bunker was ventilated with the help of a mechanical ventilator and all the walls were of solid reinforced concrete,

Critique:-

There are two main weakness in the bunker that even Albert Speer the architect conceded to. The first was that the tunnel from the New Reich Chancellery to the upper bunker was not really deep enough, only five feet from the surface. The shallow structure was directly hit by artillery in the last week of April 1945. He observed that, "you could look up and see daylight, on the night-time sky through two or three jagged gaping holes." The second weak link became, during the battle of Berlin, a matter of life and death. The casualty station set up in the cellar of the New Reich Chancellery had woefully inadequate ventilation for its 500-700 wounded soldier - patients.

The bunkers also had inadequate accommodation for the number of personnel that were to actually make use of it. This was one very serious error in the initial

planning stage. The bunker also was not situated in a very appropriate place. It should have been sited in a place less conspicious than the Reich Chancellery where most Government offices like the Foreign Ministry, Propaganda Ministry, etc were situated.

The bunker however had the advantage of an entirely underground link to all the various functions. One therefore did not have to come out before going to any of the rooms. There is a kind of continuity and it was spread over a great expanse of land hence it would be very difficult for the actual position of the rooms to be determined by enemy both on land and in the air.

It also has the advantage of a very inconspicious entrance. It would be very hard for an outside force to actually determine where the entrance to the bunker was. The solid concrete walls also were quite advantageous but when one looks at it from an economical point of view then the huge amount spent on it is not very justifiable.

I must however say that the bunker to a great extent was able to perform its function quite satisfactorily.

4.70 STUDY 7: ITALIAN AIRFORCE HANGAR II, OR TEBELLO

These hangars (fig 38 and 39), six in number, were also designed and constructed by the firm of Pier Luigi Newi after being selected in a competition. This was in 1939. The hangars were to be 328 ft by 132 ft, with openings 164 ft wide for 39 - foot - high doors. The problem was therefore the same as that of the competition in 1936 except for the increase in height of the doors and the greater economic considerations involved in the requirement of six hangars instead of two.

Prefabricated reinforced concrete elements were used in the construction of these hangars. It was noticed that both the reduction of the formwork and of the weight of the structure could be achieved by replacing the poured-in-place ribs with prefabricated elements which could be statically joined by welding the reinforcing steel that would be allowed to protrude from each element and pouring concrete in the joint. These joints would re-establish the necessary static continuity. The precast elements could be cast in the form of trusses without causing constructional difficulties and with a consequent economy in weight. Each of the hangars had six supports. The statically most important ribs were cast in place because of the

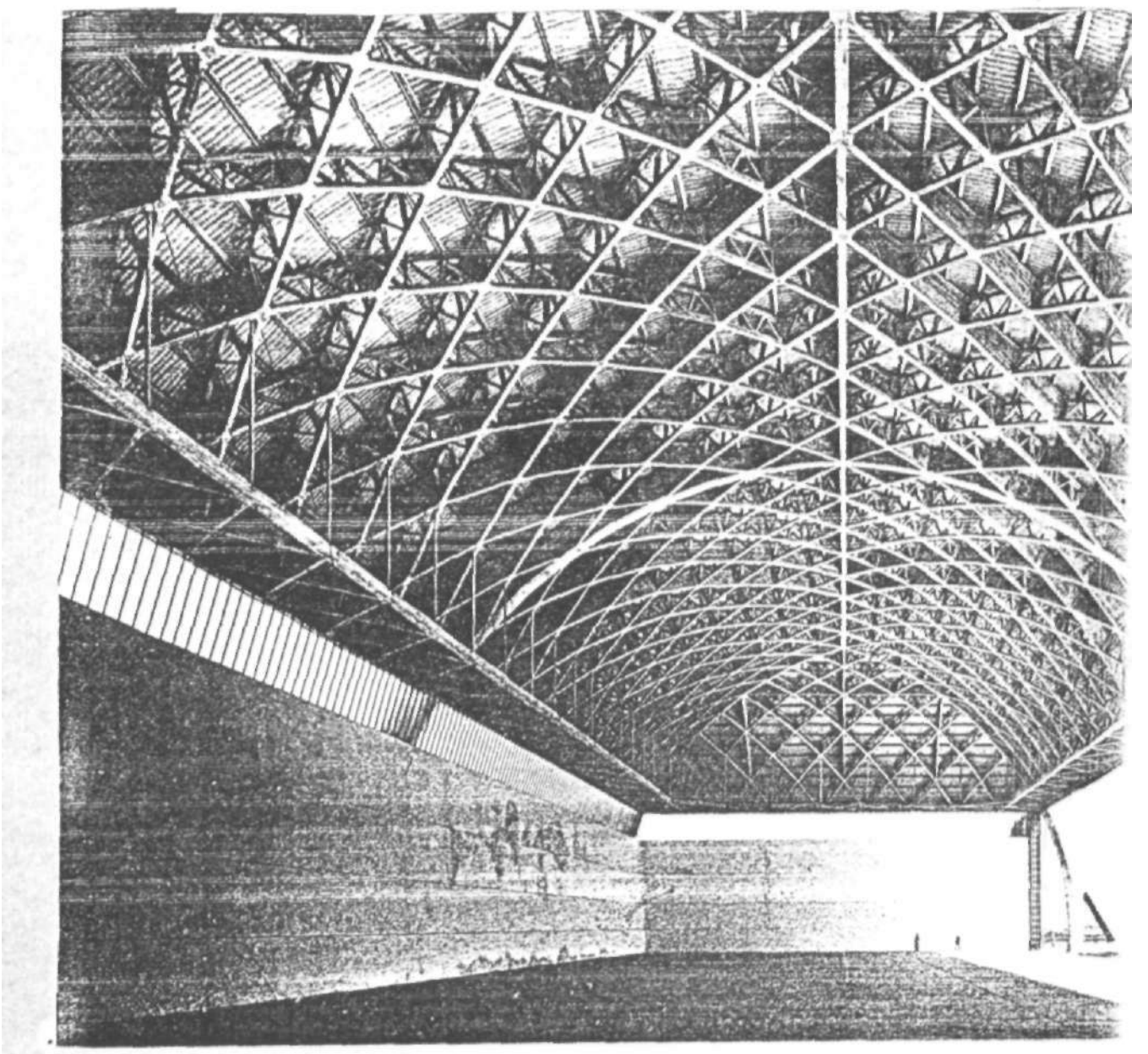


Fig 38 :- ITAF Hangars, Ortebello II

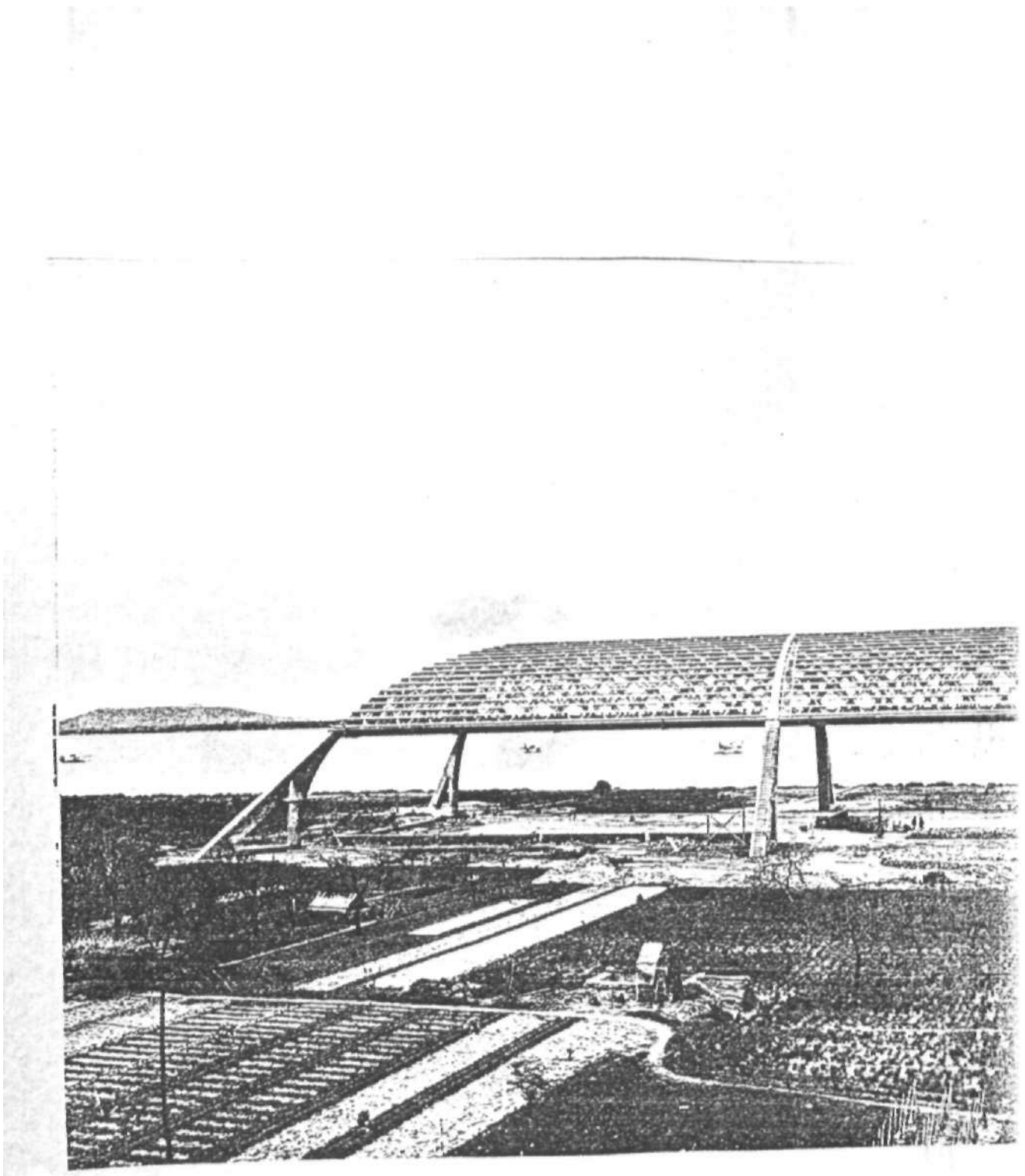


Fig 39 :- ITAF Hangars, Ortebello II

difficulty of transmitting the internal stresses through the joints. The six supports were made symmetrical (unlike the cast-in-place hangars of 1936) in order to equalize the stresses within the structure. These six hangars together with the other two earlier discussed were destroyed by the retreating Germans in 1944.

Critique:-

These hangars had openings in front which allowed the aircraft easy entry and exit from it which was a great advantage since it was during wartime. The free interior also provided maximum space for aircraft planning. The use of concrete also increased the resistance of the hangars. The sliding steel doors was also a great advantage in comparison to the vertical roller shutter doors since sliding doors just slide along the horizontal surface and are easier to pull or push.

The doors however were too high when viewed from an economical point of view. They could have been much lower and still been able to cater for the range of aircraft that were to use it. The hangars also lack any real source of natural light except for the doors. They had to therefore make use of artificial lighting sources ie electricity.

Here again, despite odds, we see the master at work.

4.80 DEDUCTIONS

After carefully analysing all the seven studies and case studies, I deduced that despite one or two short comings, they were to a certain extent able to function properly. Not one single design the world over is perfect. Even buildings considered to be masterpieces designed by the masters of modern architecture have in one way or another series of shortcomings.

The main aim of undertaking a case study is to analyse the merits and demerits of that study with a view to improving on it. The Nigerian Airforce base, Yola is one such base that has been able to a certain extent do that and this would be seen in subsequent chapters.

PART THREE

- THE THESIS -

CHAPTER FIVE

5.00 AIMS, OBJECTIVES AND SCOPE

An airforce base is a formation that encompasses a wide range of functions which have already been discussed in previous chapters. This thesis therefore aims at providing a realistic, functional and economical model base for the Nigerian Airforce taking into cognisance the latest technologically available materials and constructional methods adhering strictly to military planning laws already discussed. The base should therefore be able to function well for the present day users and also readily accommodate any future changes.

The scope of the thesis is the design of the hangars and bunkers in the operational zone and also detailed planning of the operational zone. A schematic but systematic planning of the functions in the barracks zone is also included. The scope can therefore be seen as the general planning of the base but with particular emphasis on the operational zone and better still, the design of the hangars and bunkers. Since generally these hangars and bunkers are supposed to serve two

different aircraft; the Jaguar and MB 339, both of which have very similar dimensions, only one prototype each (ie one hangar and one bunker) would be designed but their actual locations would be shown on both site plans provided in the design ie Figs 42 and 43. The macro-thesis can be therefore described as the overall planning of the Nigerian Airforce Base, Yola while the micro-thesis is the design of the hangars and bunkers.

5.10 SITE ANALYSIS AND SITE SELECTION CRITERIA

The actual selection of a suitable site for a project like an airforce base is a very difficult but essential part of the planning process. A wide range of factors ranging from the security aspects of the base to the soil types of the site have to be critically analysed. In the case of the Nigerian Airforce base, Yola, three alternative sites were provided. The sites code-named "A", "B" and "C" are shown in fig 40. After a critical analysis of all the three sites, site "C" was chosen. Many things were taken into consideration but it is worth noting that site "A" happens to be the present local Yola airport and at the moment it is situated in the heart of Jimeta town which is a mixed commercial/residential zone while site "B" happens to lie within NTA Yola frequency or wave transmission zone and this would affect the communication network of the airforce base and in addition to this the site

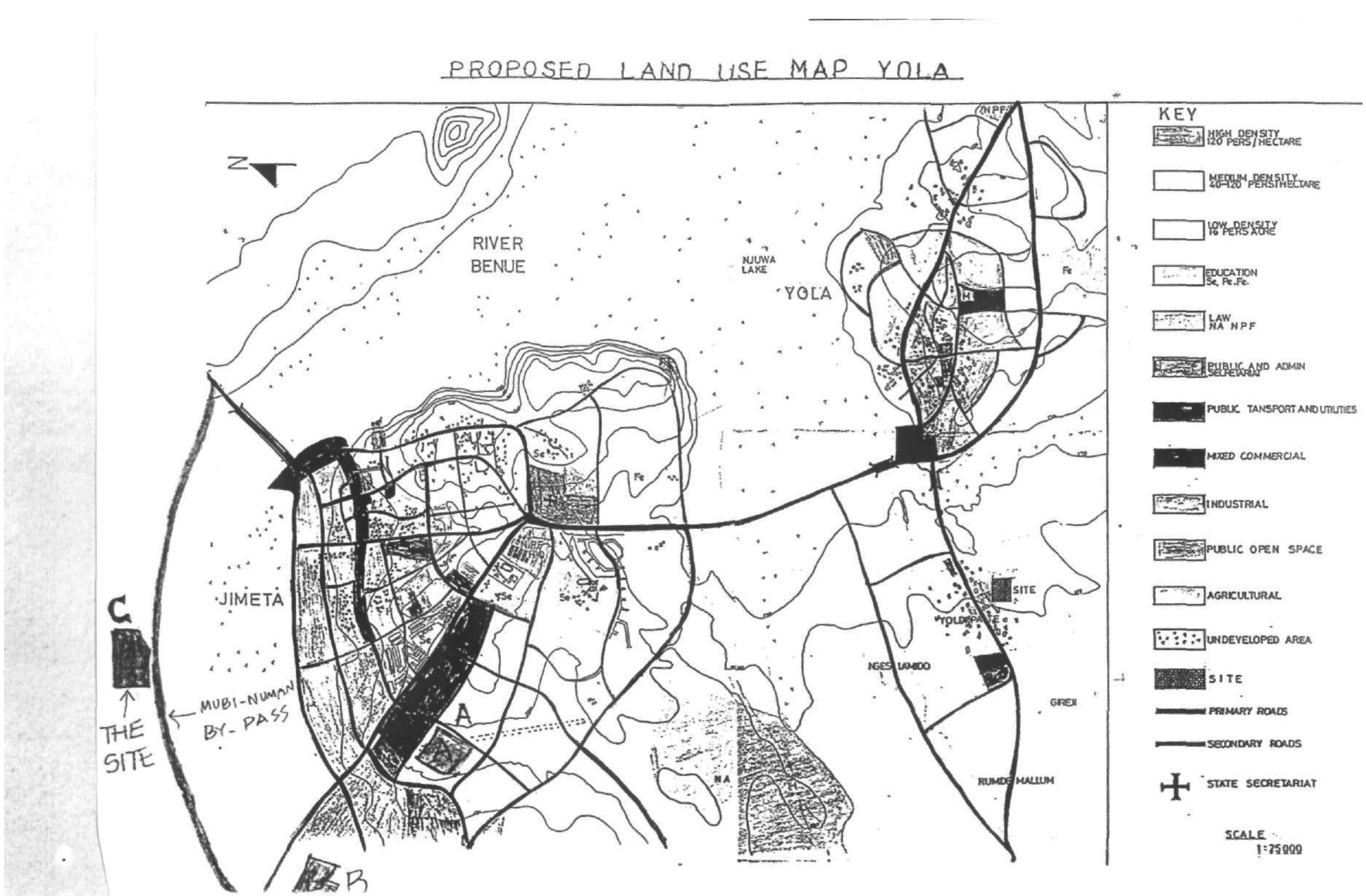


Fig 10 :- Greater Yola Plan

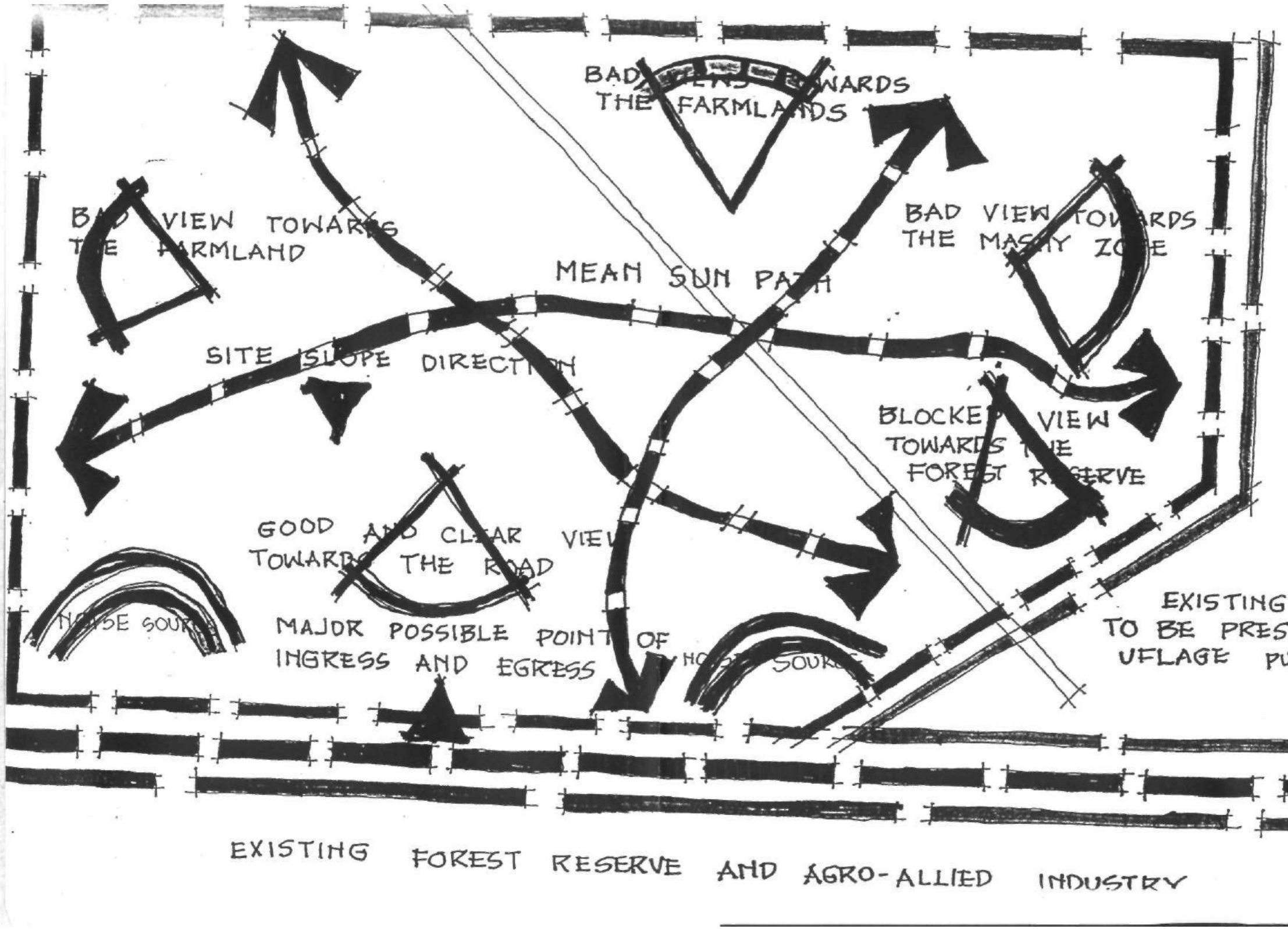


Fig 4.1 :- Site analysis

is at the moment very mashy. Also, both the sites have the military/security disadvantage of lying on major roads. Site "C" however happens to be on a bye pass which at the moment is not being utilised fully and also happens to be the one that the Federal Military Government deems fit (ie government policy or decision). These two main points in addition to the fact that the site happens to be adequate in terms of size and structure makes it the best suited for the purpose.

The total area of the site is about 596 hectares and this is sufficient for a medium sized airforce base. The long axis of the site lies along the NE - SW direction and this is a big advantage since the runway has to be aligned along the long axis and also along the prevailing wind direction or directions. The general climate of Jimeta is discussed below in addition to the physical characteristics of the site. A summary of these factors is clearly shown in fig 41.

(a) Climate:-

The climate of Yola is largely determined by relief and the inter-tropical convergence zone. The long dry season lasts from October to March and the wet season between April and September. Yola records higher temperatures than other parts of the north and even probably other parts of the country during the period December to March with about 78°F. The hottest

temperature is recorded in the pre-rain or early rain month of April, and this is about 90°F. There are basically two main wind directions namely the North - East trade winds during the harmattan period and the South - West monsoons during the raining season. Table XV shows the mean monthly temperature, rainfall and cloudy days.

(b) Vegetation:-

The site is relatively flat and a great part of it is at the moment being used for commercial farming. The trees on the site, mostly eucalyptus, are preserved in a scattered pattern save for the forest reserve on the periphery of the site along the Mubi - Numan bye-pass. On one side of the site ie towards the South - West direction which happens to be areas that are frequently cultivated, secondary growth and fire resistant shrubs and stunted thorny trees have taken over from the former vegetation.

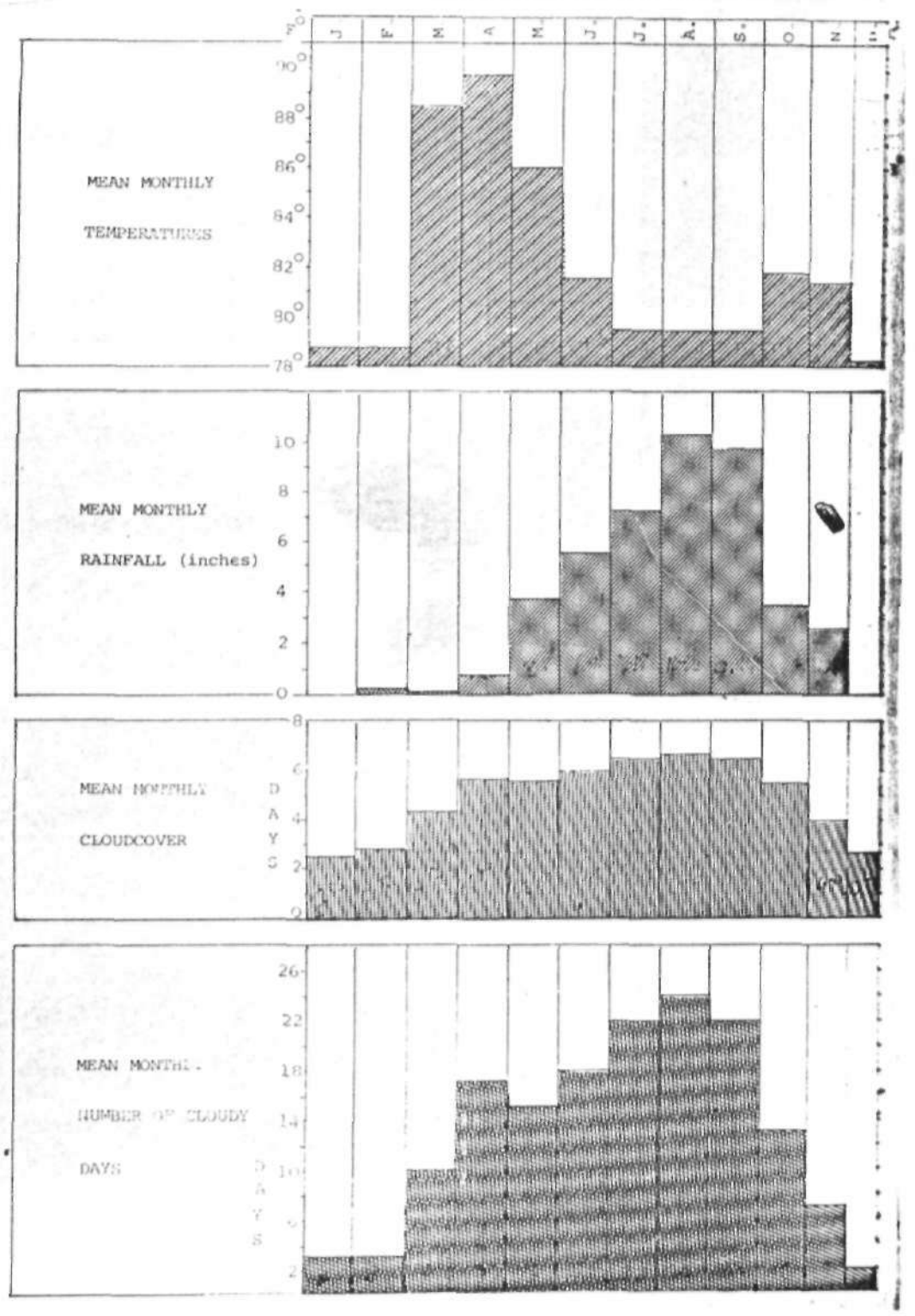
(c) Geology:-

The general rock types on the site happen to be those of sedimentary origin ie sedimentary rocks of crateceous origin.

(d) Soil:-

Basically the site consists of alluvial soils. The soil is weakly developed and hydromorphic in some areas varying from sandy and loamy to clayey soils

Table XV :- Bioclimatic data of Yola



which are often alkaline in nature.

The factors discussed above all a direct influence on the planning and design of the base. They affect the planning in terms of things like the orientation of the buildings, the building types and materials to be used, etc while at the same time influencing the foundation types and other related factors.

5.20 DESIGN CONCEPTS AND METHODS

In the design of a project like an airforce base, it is not usually possible to look at the "macro" and "micro" schemes as one because here one is dealing with a wide variety of functions each related to the other at different levels ie some are more intricately or intimately related than others. When therefore utilising a particular concept on a "marco" scale, it might not be very possible to employ it on a "micro" scale. The Nigerian Airforce base, Yola, however is one project in which the concept for the "marco" and "micro" schemes are in but one and the same as would be seen in due course but first I would like to discusse various architectural concepts or approaches before discussing the airforce base concept.

Various personalities view architecture in totality as different things. To be Le Corbusier, it is "the masterly, correct and magnificient play of masses brought together in light," and to Frank Lloyd Wright it is

"the triumph of human imagination over materials methods and men." Adolf Hitler described architecture as "stone documents ... an expression of the unity and power of a nation" and to Mies Vander Rohe it is "the will of an epoch translated into space." Which ever way one looks at it, these individuals are describing in their own special way or language the same thing only that their views are from different perspectives. It is like looking at a bottle; one person might when asked say it is a bottle that is before him, another might say the liquid inside and a third, glass. They are all looking at the same thing only from different perspectives.

In line with this, various approaches have been advanced over the years in form of styles. From the earliest times through to the Egyptian, Greek, Roman, Byzantine, Gothic, Rennassaince, Art Nouveau and even to present day modern or post-modern periods to mention a few, various approaches or concepts have at different times dominated the building scene.

After exploring various concepts such as primitivism, functionalism, ecclecticism, the catholic view, expressionism, metabolism, post-modernism and even High Tech (ie High technology), I came to the conclusion that for a project which such varied and dynamic functions like an airforce base, metabolism or what

I would prefer to describe as a concept of "Military Metabolism" be implored in the Yola design.

The initial concept of "Metabolism" was introduced in 1960 at the International Design Congress in Tokyo by a group of five Japanese architects namely Masato Otaka, Kiyonori Kikutake, Fumihiko Maki, Moriaki Kurokawa and a critic Noboru Kawazoe. Kenzo Tange and Arata Isozaki joined the movement later. According to Egon Tempel,

> "The notion of metabolism, derived from the Greek (meaning change or conversion) is intepreted as a process of continous or cyclic transformation. The metabolists insist that building for the community at large must be regarded as a metabolic process because, from a biological point of view, human society itself is in a continous process of renewal so that it defies any fixed or schematical design principles."

Changeability and flexibility were the key elements that the metabolist group siezed upon and explored. Metabolism as we know it, is the biological process by which life is maintained through the continous cycle of producing and destroying protoplasm. To the Japanese architects who adopted the name, it meant creating a dynamic environment that could live and grow by discarding its outdated parts and regenerating newer, more viable parts. Even the proponents of metabolism, different approaches were implored. To people like

Maki and Otaka, the approach was that of "Group Form" while "Unabara" comobining a project for a "Tower City" and a "Floating City" was adopted by Kikutake. Isozaki suggested that housing units be suspended from masts and Kurokawa proposed a "Wall City" project consisting of gigantic megastructures reduced in height at the periphery, with an integrated traffic system. All these to a certain extent have remained dreams and only Kenzo Tange's Communication Centre at Kofu, with its volumes suspended from a structure of sixteen reinforced concrete cylinder comes nearest to the vision of Metabolist urbanism. He too was a proponent of the Megastructure Scheme. Even though the Metabolist developed the Metabolism idea in different ways, it should be noted that the idea was brought about by a similar concern ie how to structure the rapid growth of Japanese cities.

In contrast to the space or land problems of Japan, Nigeria is a country with abundant land at the moment. However, as the years go by, land problems would start to arise with an increase in population. A project like an airforce base that is hard and expensive to develop and construct must have the ability to accommodate different functions or changes at different times. Airports, for example, in Nigeria have at various times have been converted to airforce bases and vice versa.

The in-ability of these airports/bases to perform a different function from that it was originally designed for satisfactorily has been a great source of concern for various governments and planners.

My concept of metabolism is for the base to be able to either increase or reduce without any visible changes (ie the hangars most especially). The ability of the base to grow or metamorphosize is in itself metabolism. At any point in time the base should be able to function and readily accommodate any changes. A building cannot be all things to all men at all times. Architecture and planning should not be divorced from nature. I hold Yinka Gbotosho's belief that; "there is an inherent logic in the nature and structure of organisms that inhabited this planet. Any architecture, urban design or social organisation devoid of this structure is self destructive hence untenable." Everything present today on this earth has its roots strongly embedded in nature. In the design of hangars, what I would like to term as "Military Metabolism" is used. The hangars have the ability to grow from the sides without necessarily causing much havoc. The "military" aspect of it lies in the brutalistic, aggressive, massive, repulsive but orderly or regimented nature of the hangars. "Hitlertarian architectural philosophical" ideas or concepts would perhaps be a

better phase to use. This is so because Hitler's definition of architecture is "power" oriented and it is generally believed the world over today that the power of a nation lies in the strength of it military and so his definition of architecture as "Stone documents ... an expression of the unity and power of a nation" is put into play here.

The aggressive and brutalistic nature of the hangars can be clearly seen in the scaling of the building and the thickness of the columns. Bare walls also add to the repulsive nature of the building. The design is supposed to be massive having been built of thick concrete walls. The idea of brutality in architecture is in the use of fable columns. In addition to the zoning aspect and also other security devices provided in the operational zone supposed to keep unwanted visitors away from the sensitive zone (ie hangars, bunkers, etc), I purposely decided to provide a kind of repealing structure in form of the hangars. This is because in nature I have observed that different species of living organisms have their own peculiar ways of keeping their respective enemies away. The tortoise for example has the ability to move back into its shell, the bee stings, certain varities of plants shrink or close up, birds fly away etc. All these are God - given gifts and these in one way or the other help these natural organisms in the struggle

to keep their enemies away. It is for this same reason that I introduced the brutalistic and aggressive elements into the hangars.

A more comprehensive description of the base and the hangars would be given in due course.

5.30 FORM AND FUNCTION IN ARCHITECTURE

Four schools of thought exist on the "form follows function" philosophy since the cry was voiced out by one of the first masters' of modern architecture in person of Louis Henri Sullivan. The first school of thought gives in line with that of Sullivan (ie it agrees that form follows function), the second; form and function are equal components of equal value, the third; function follows form and the fourth; form and function are not related.

I am of the view that Louis Henri Sullivan had a different interpretation or notion of his "form follows function" than what is used today. This is so because when one looks at Sullivans works like the Schwab and Selz house in Chicago and the Bradley house in Madison, Wisconsin, we see two buildings designed to suit two similar or same functions but possessing different forms in the present day definition of "form". I believe strongly that there exists more to be explained about this phase. I however hold the view

that in very few cases, the function of a thing may determine a certain form. Runways for aircraft, for example, the world over a straight in outlook, character, structure or we are decide to use the word "Form". They however differ in configuration ie in two modes of alignment. It is not possible as at this present day to have a curved runway due to the landing and taking off characteristics of aircraft. However, the same does not hold for houses, museums or even as Sanusi Daggash puts it, in airport terminal buildings. He goes on to say;

> "It is so taken for granted that function takes precedence over everything else when it comes to designing airports. It is hardly accepted that a style might derive from the functional requirement on the basis that form follows function. There is not one airport building the world over that resembles another, although they all have identical functions. This means therefore, that form is not derived from function, and this one dimensional approach is the result of functional planning ideology. Form and function are components of equal value, which in part are independent on eachother, and in part combine to provide a building with its characteristics and appearance. Not only is function conditional partly upon form; form is also contingent upon function. Function will at the very least be influenced by form in the same degree as the form is derived from the functional requirements. In the same way that the functional requirements, as at an airport for example, cannot be realised where there is too much concentration on abstract theory without reference to practical and constructional principles, a successful building form cannot be conceived unless the associated functions are taken into account at the time of conception".

The argument being put forward here is that it is accepted that form and function to a certain degree are related (ie they go hand in hand) but none takes precedence at all times ie form does not follow function because if it did, then since all airports the world over have the same or similar functions, then their respective terminal buildings should have the same form.

Airforce bases the world all have similar functions but planning methods used are different in outlook giving each one a distinctive feature. I hold Daggash's view that the conceptual aim in finding the simplest solution for the operation and organisation of an airport (or in this case an airforce base) is in itself abstract, analytical and formless. The disciplines of geometry have been applied as the basis of the airport (airforce base) design work, to act as a catalyst between form and function.

The concept of function in architecture is very relative ie functionalism varies from one school of thought to another and better still from one individual to another. Hangars also vary in form and structure from place to place having only free spanning interiors as a common feature. Different constructional techniques and design concepts used for different hangars have failed to give them a particular form or outlook hence further buthessing the point that form does not

necessarily follow function. If they did, then since hangars for aircraft the world over have similar or the same functions, then they should have similar or a characteristic form. I accept the fact that the function determines one or two things about the hangars, eg free spanning interiors but not the overall form of the hangars. I therefore stand by my argument that in the design of hangars, the function does not determine any specific form but that form and function in military architecture compliment each other but there is no universal law or laws that they follow or obey at all times. I like Hugh Stubbins believe that there is obviously "no blueprint for architecture". Certain guidelines however have been provided by him within which a building should at least be good and has the potential, if appropriate, to be great. He goes on to say;

> "I have deep respect for function. The planning problems must be solved. The building must not only work for the user but also, if possible, be flexible for the future. Structure is of great importance. It should be forthnight, logical and honest. It should have intergrity, which does not mean that structure should necessarily be expressed. A building should express in some way its purpose as well as have unity in itself. It must be a whole thing, rather than a lot of pieces stung together. Integration within the environment is important, for, if we are to avoid the physical chaos with which we are now surrounded, we must respect to some extent the existing fabric, be it natural or man made. In the long view, to be new and exciting may not be as important as to be courteous and restrained. But this does not mean that - within these

> parameters - we should not exploit fully the technology and materials we have at our command. Perhaps most of all it is important to realize that at any time we are only a link between the past and the future, and we must see ourselves as evolving from the one and leading to the other - despite the ever-present tempetation to deny our forebears. Since in the last analysis architecture reflects society's priorities and purposes, our architectural heritage is a unique expression of the history and progress of man. What moments we leave behind in the form of buildings reveal more clearly than anything else the value we place on the quality of life".

Different individuals have different approaches to problems but I strongly believe that the guidelines provided by Hugh Stubbins hold a lot of truth. Form and function are related differently to different functions but universallyI do not accept the notion that form follows function and my argument has already been put foward.

5.40 FUNCTIONAL ANALYSIS AND SCHEDULE OF ACCOMMODATION

A critical analysis of design synthesis is necessary and rids the architectural process of some of its mystery to an experienced architect, the solution to a certain problem or basic design concept may occur ever before all the data and programming information might have been assembled and weighed. The case however is not the same for a young or inexperienced architect or student. An analysis of the necessary

FUNCTION	NO.
RUNWAYS	2
TAXIWAYS	6 (1MN)
BAYS/APR.	5
HANGARS	3
BUNKERS	2
MISSILES BK.	2
OPS BLD.	1
LOGISTICS B.	1.
SQUADRON	1
FIRE STN.	1
ARMOURY	1
M.T. YARD	1
FUEL FARM	4
OFFICERS	230
N.C.O.s	840
MESSING	3
PARKS	2
MOSQUE	1
CHURCH	1
MARKET	1
SCHOOL	1
M.R.S.	1
ADMIN.C.O.	1
PARADE	1
GUARD HS.	4

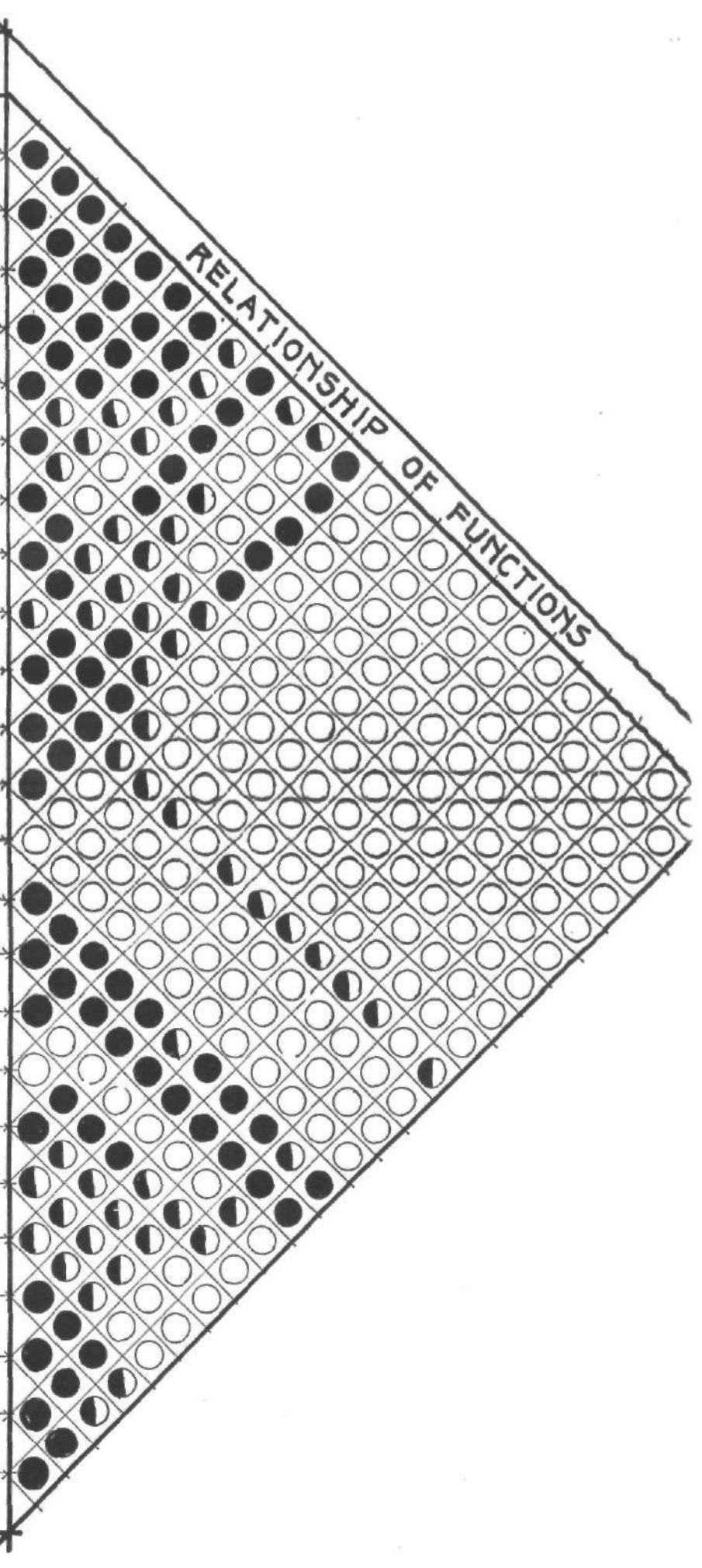
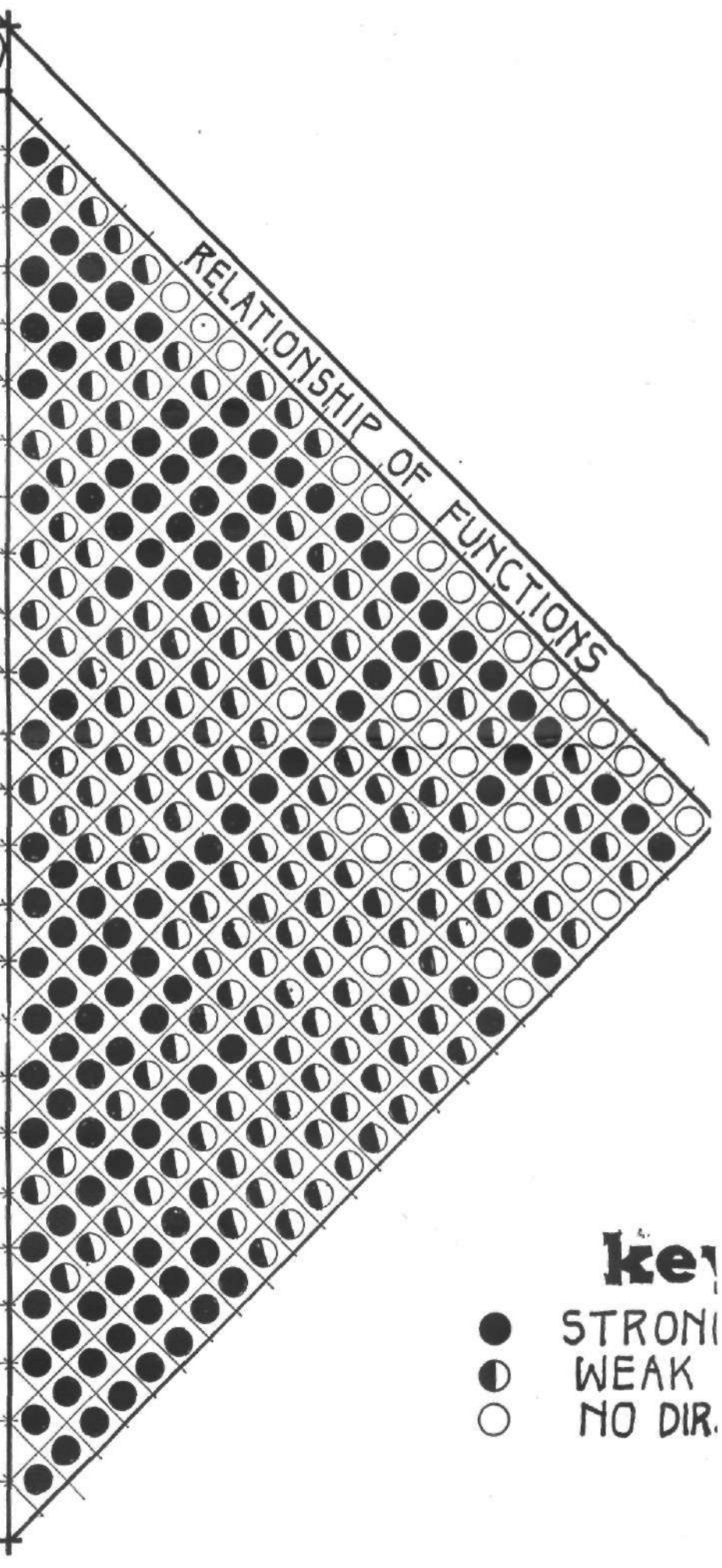


Table XVI :- Functional relationship table of the NAF Base, Yola

Table XVII :- Functional relationship table and schedule of accommodation of the hangars

FUNCTION	AREA(M²)
BAY|APR.	
HANGAR	4,000
MECH. WKS.	135
CRACK DET.	30
ENG. BUD.-UP	60
BATT. RM.	25
RECEPT'N	30
SWITCH RM.	50
CHANGING	100
TOOLS RM.	55
MAIN STORE	120
QUARRANT.	30
ELECTRICAL	85
ELECTRONICS	60
OVERHAUL	55
SOFT-WARE	95
CHIEF-ENGR.	50
INST. AVIONIC	60
RADIO NAV.	85
EMM. WKSH.	90
MECH./TECH.	60
SNACK BAR	80
P.A.E.	60
AIRCFT. ENG.	130
JUNIOR A.E.	55



data is essential in order to get a very appropriate and functional design. A functional analysis scheme is a very essential part of the design or planning process. Functions that are directly related to each other are usually zoned together. Table XVI gives the functional relationship of the functions on the base generally and table XVII that of the hangars.

From these two schemes, a design for the Nigerian Airforce Base, Yola has metamorphosized having undergone a painstaking functional analysis study of all the functions that abund in the base.

5.50 THE NIGERIAN AIRFORCE BASE, YOLA

The schemes for the Yola base can be seen in figs 42 to 50. The concept of ultimate development of the base is shown in Fig 42. It consists of a network of roads that are grouped into development stages or zones. They are arranged in such a way that as the development of the base continues the roads grow out or metamorphosize. This is itself is in line with the concept of metabolism ie the ability to adapt to changes.

The operational zone is equiped with a single runway and taxiway but provisions have been adequately made for the addition of one extra runway parallel in configuration to the existing one should the need

arise in future. All the installations both above and below ground level conforms with military or security requirements. All functions listed in the functional analysis/space requirements table have been adequately catered for.

The road network in the barracks zone also conforms to the metabolic concept. The houses for the personnel have been zoned according to status or rank ie there is requirementation. The focal point in the barracks are the recreational/welfare facilities eg like the medical reception station (MRS) Schools, messings, sports complex, etc. These functions are placed near the non-commissioned officers (NCO's) quarters because most of them lack means of transportation and they also have larger families who would make use of the facilities. The officer's however are more likely to be mobile. The planning in the barracks zone is simple, straightforward and flexible for future development or expansion.

My contributions to architecture or construction technology can be viewed from three different perspectives:-

(a) The general planning concept of the base,

(b) The hangars, and

(c) The runway/taxiways

These are discussed hereunder.

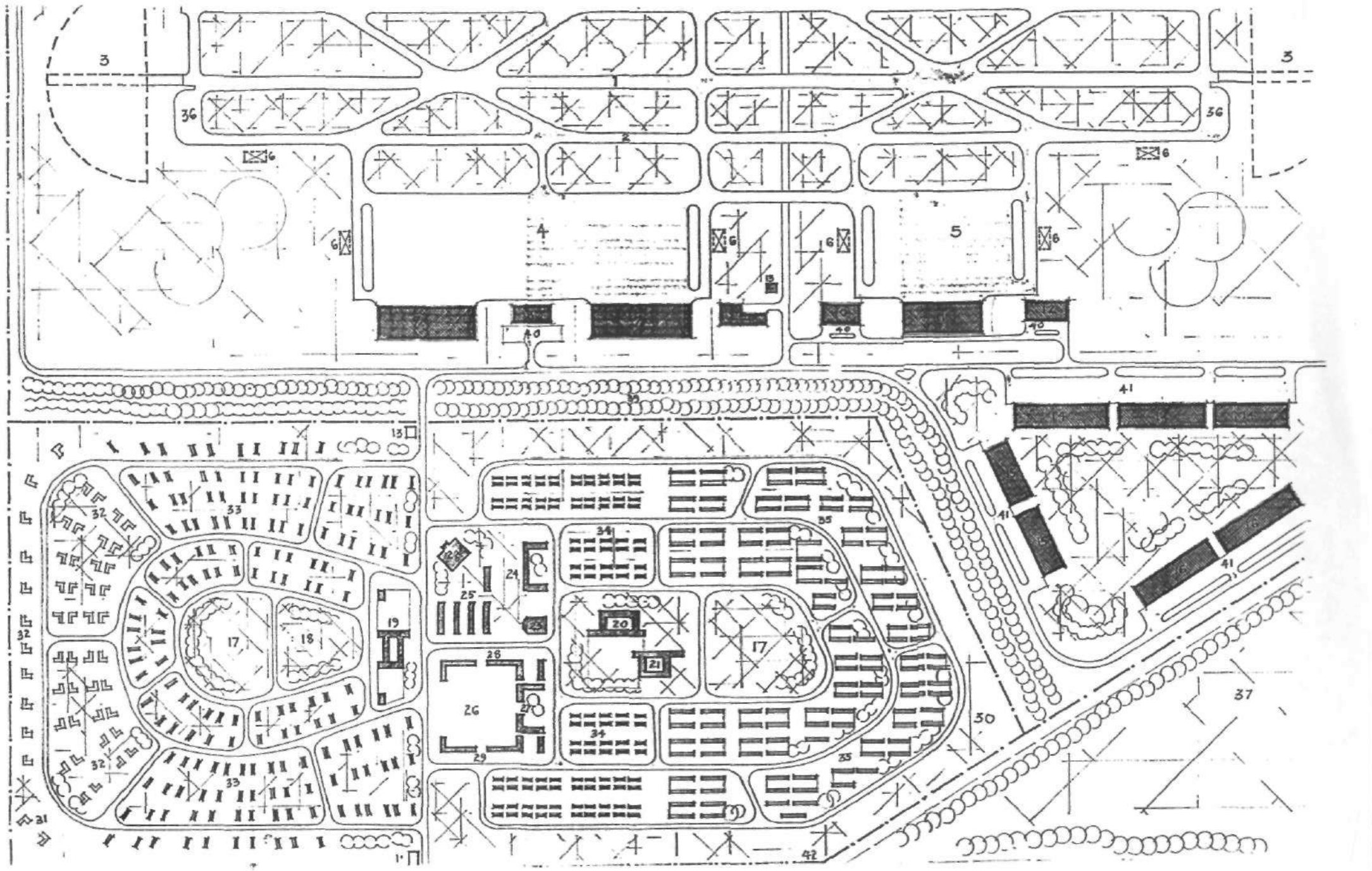


Fig 42 :- Concept of Ultimate development

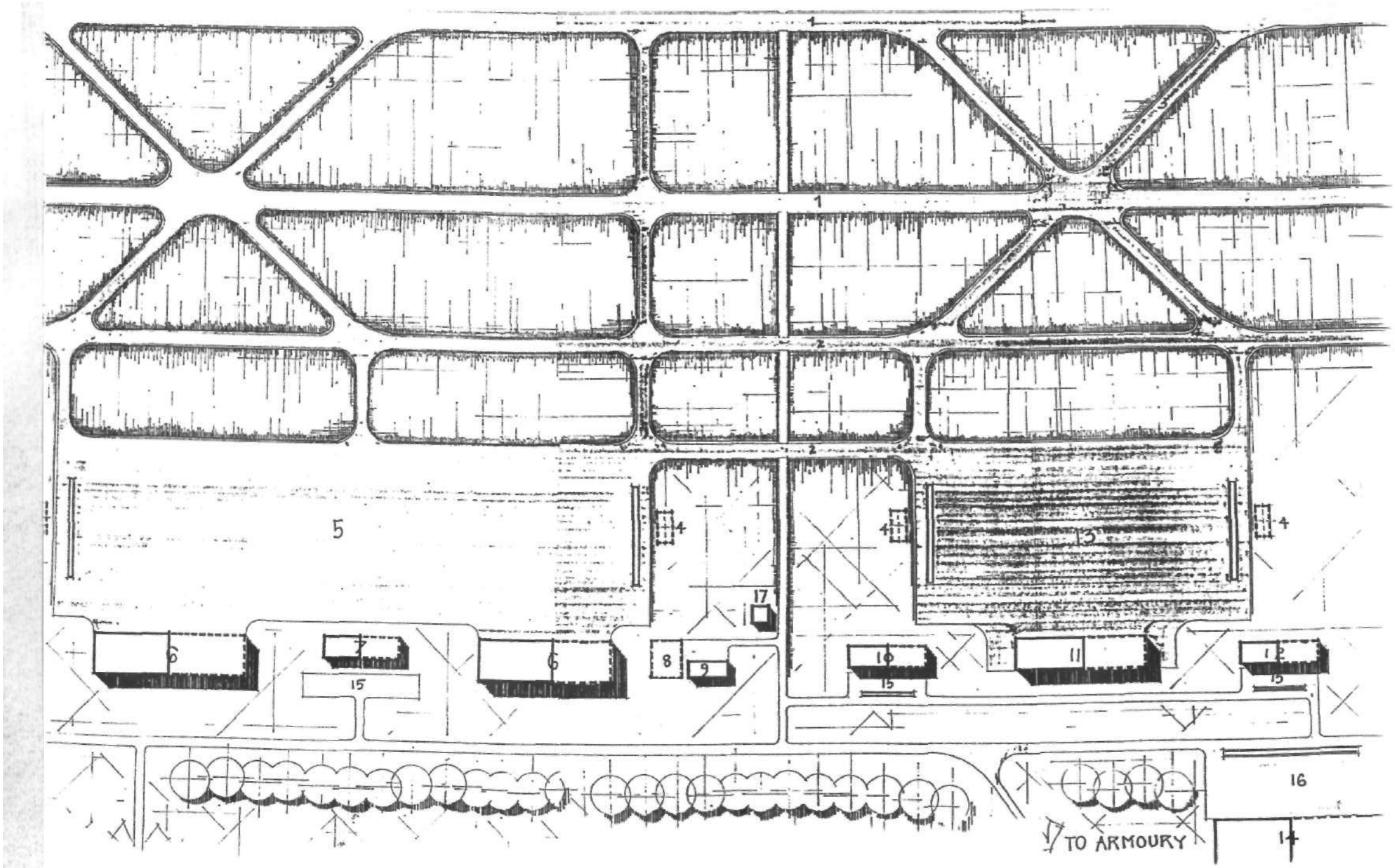


Fig 43 :- Site Plan

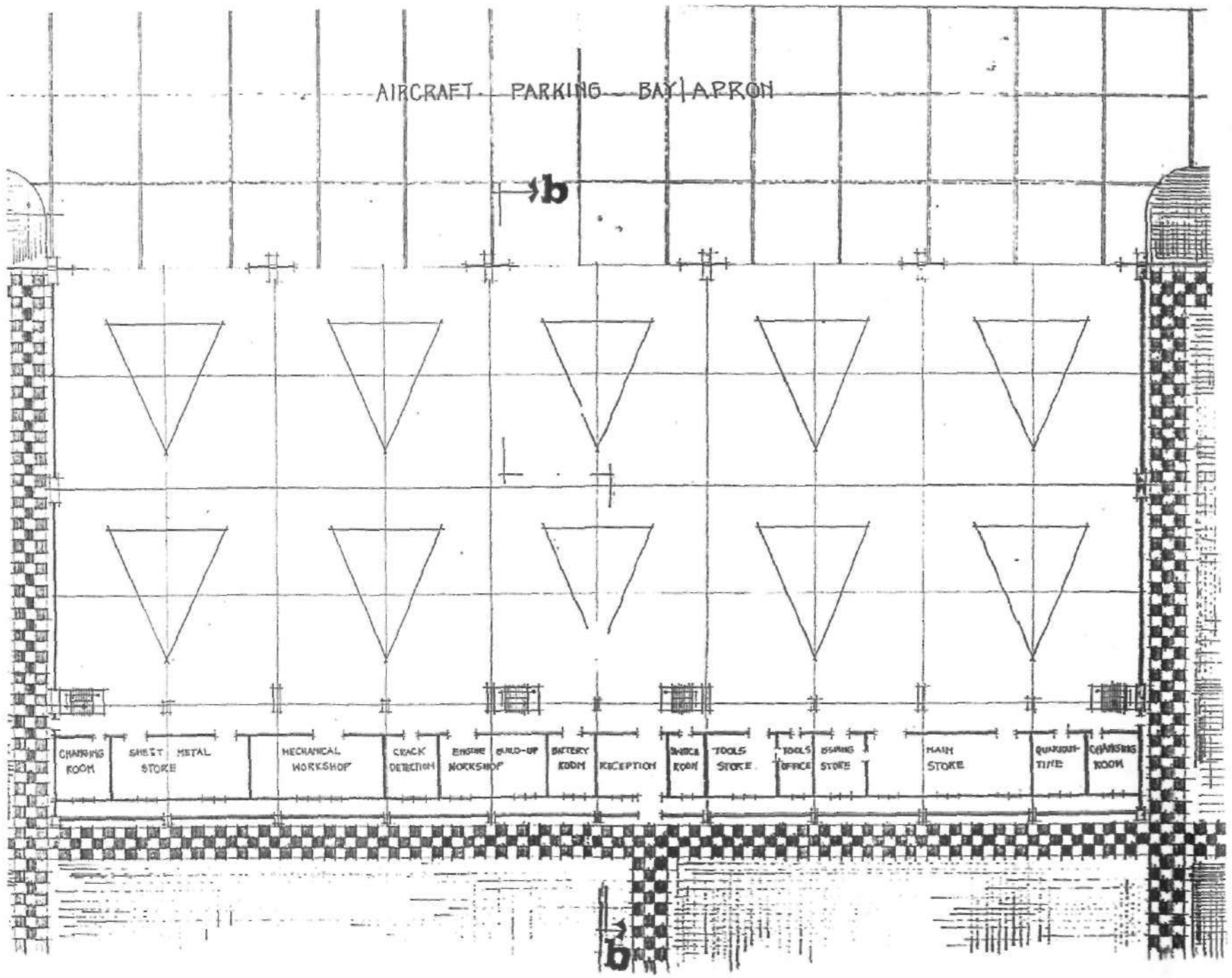
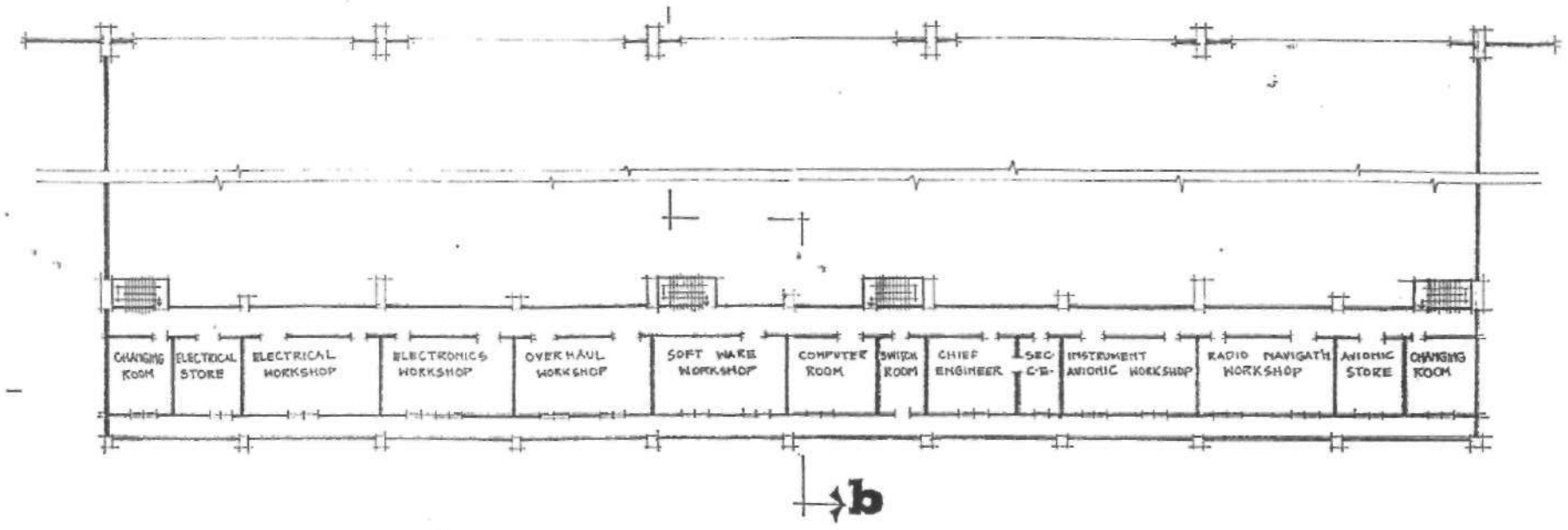
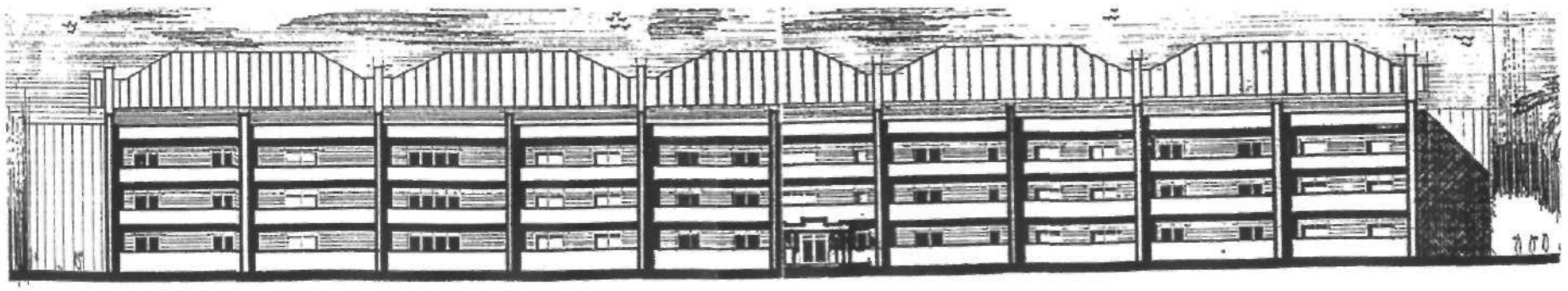


Fig 44 :- Ground Floor plan of the hangar

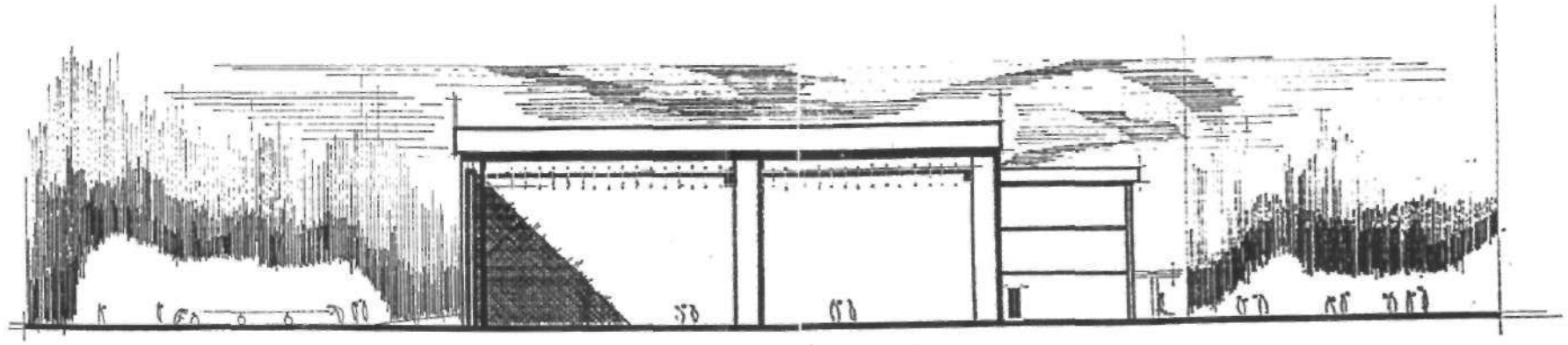


PLAN OF PART OF FIRST FLOOR

Fig 45 :- First and Second floor plans of the hangar



REAR ELEVATION



SIDE ELEVATION

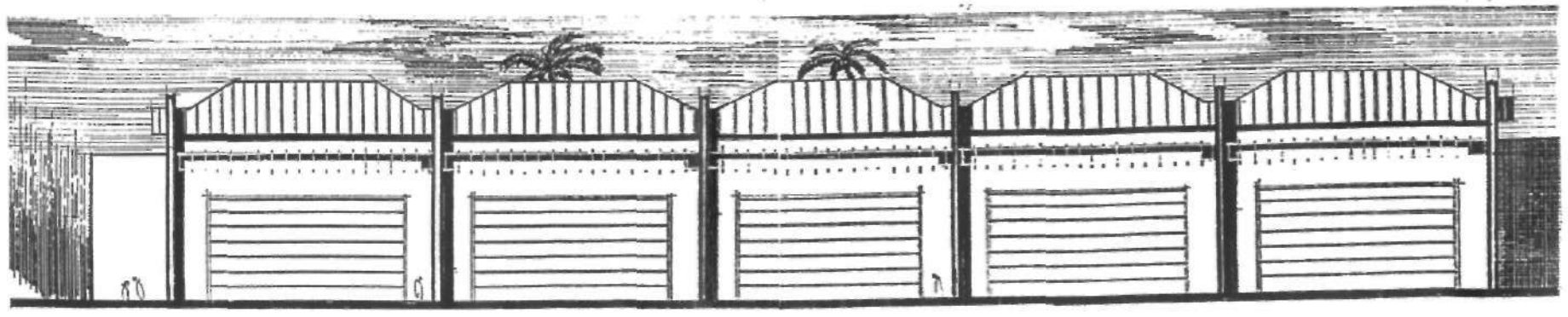


Fig 46 :- Elevations of the hangar

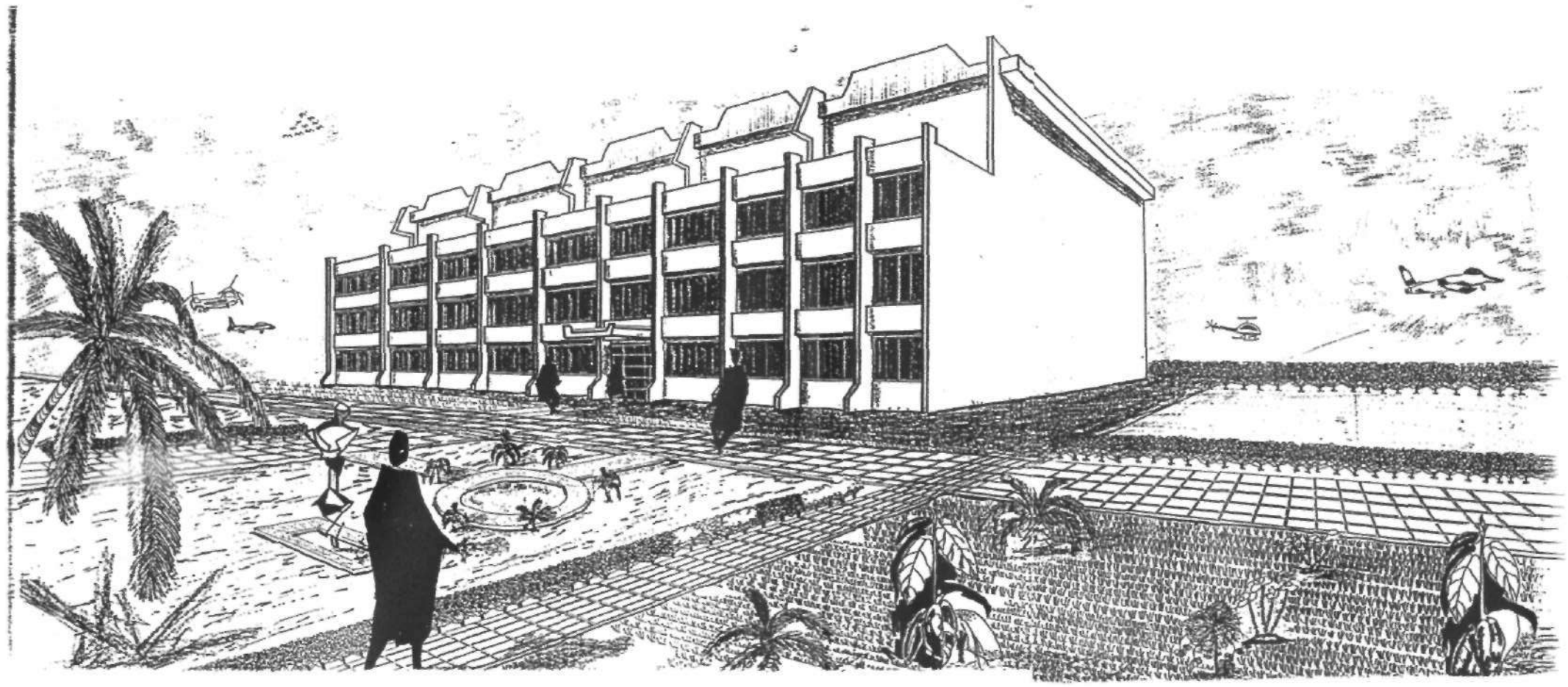


Fig 47 :- Sections of the hangar

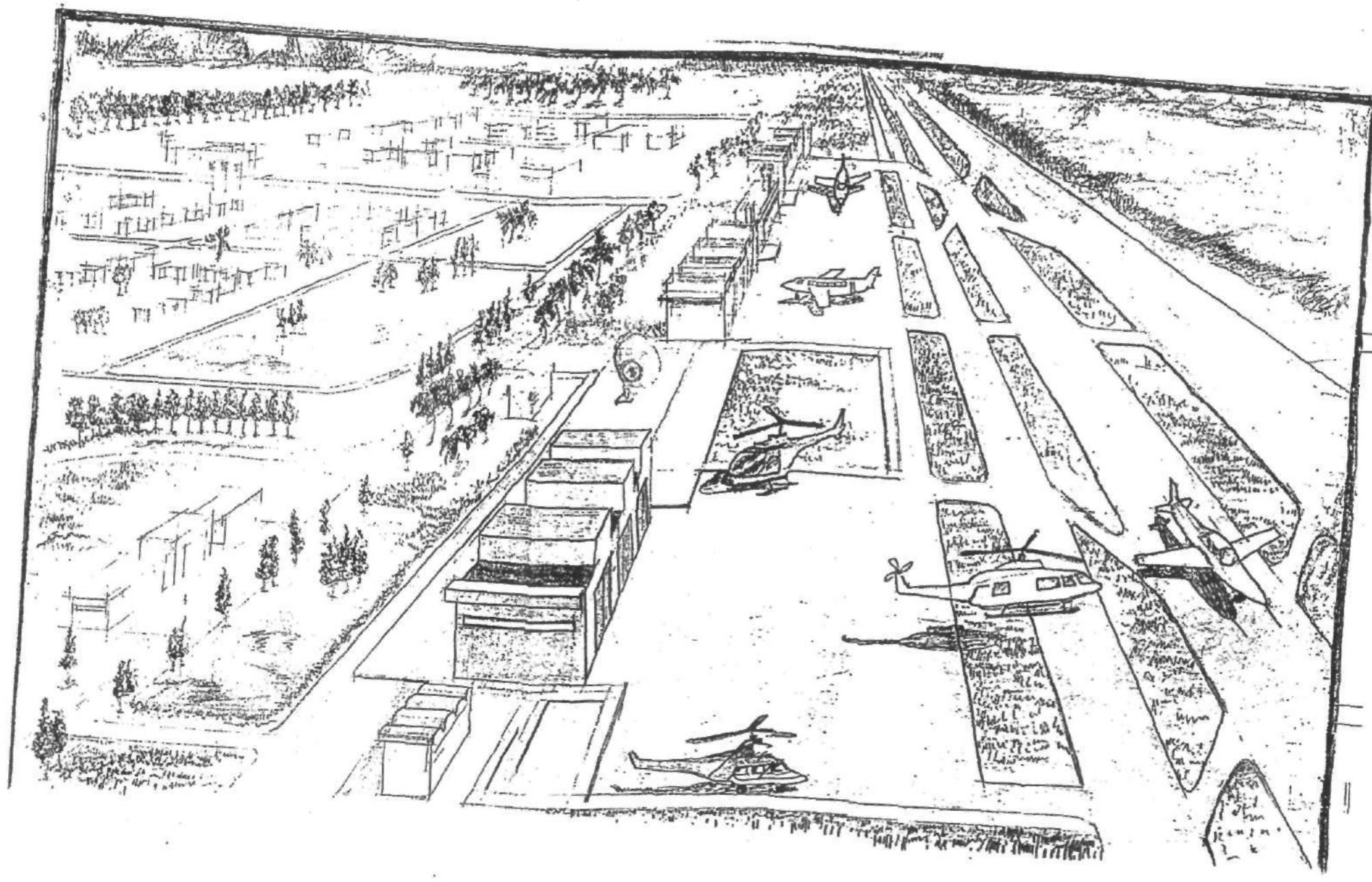
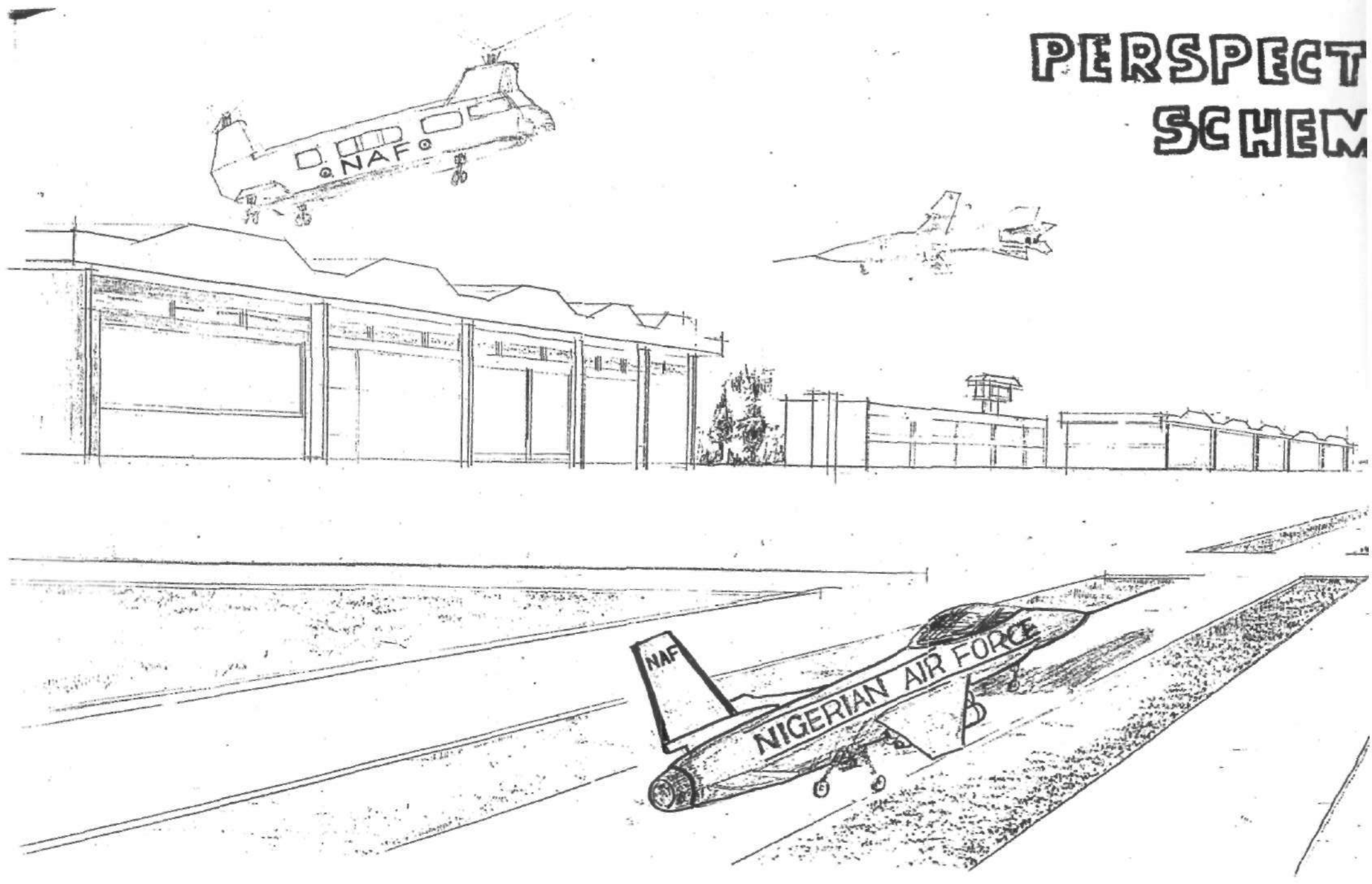


Fig 48 :- Perspective



PERSPECT
SCHEM

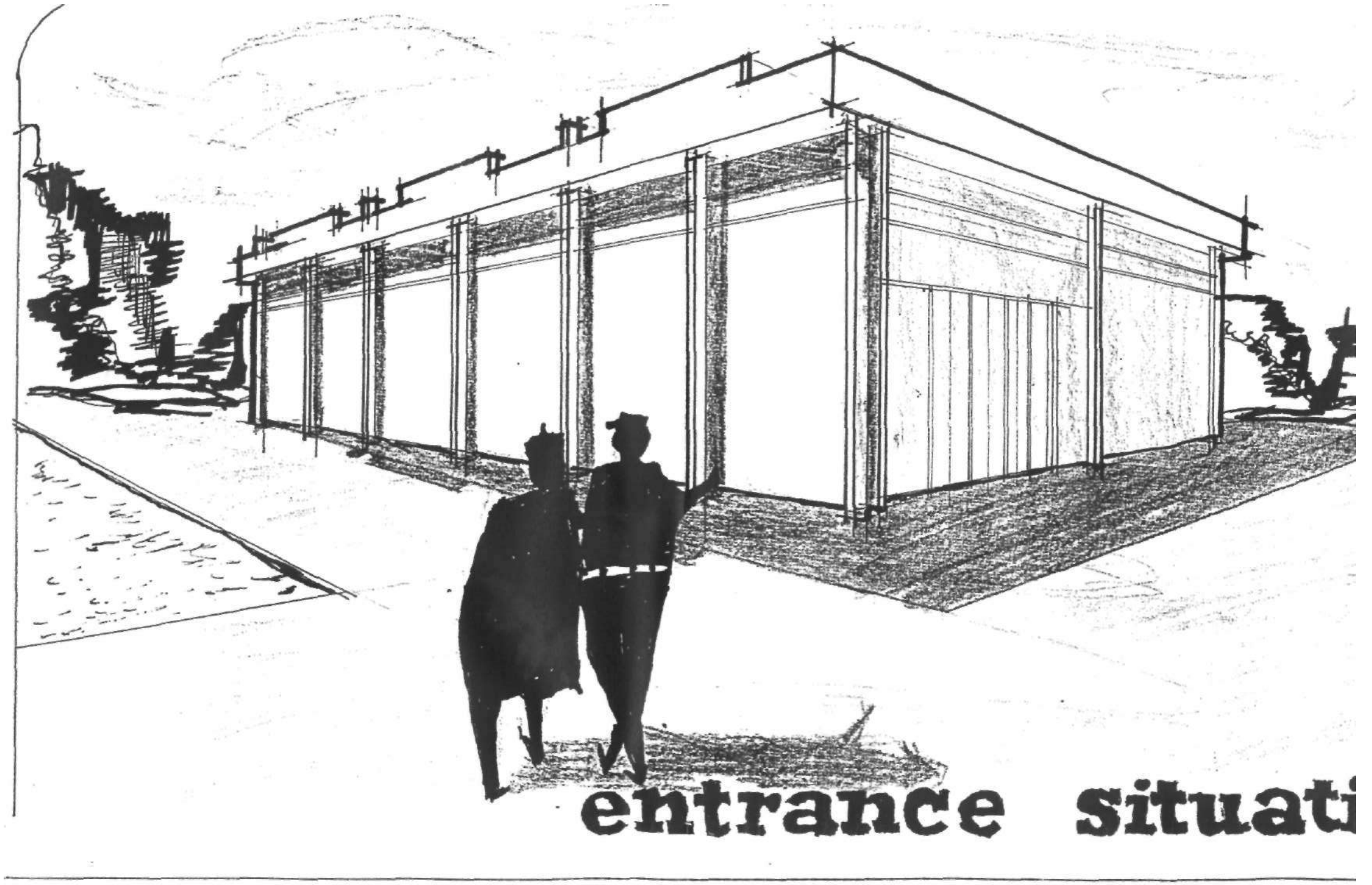
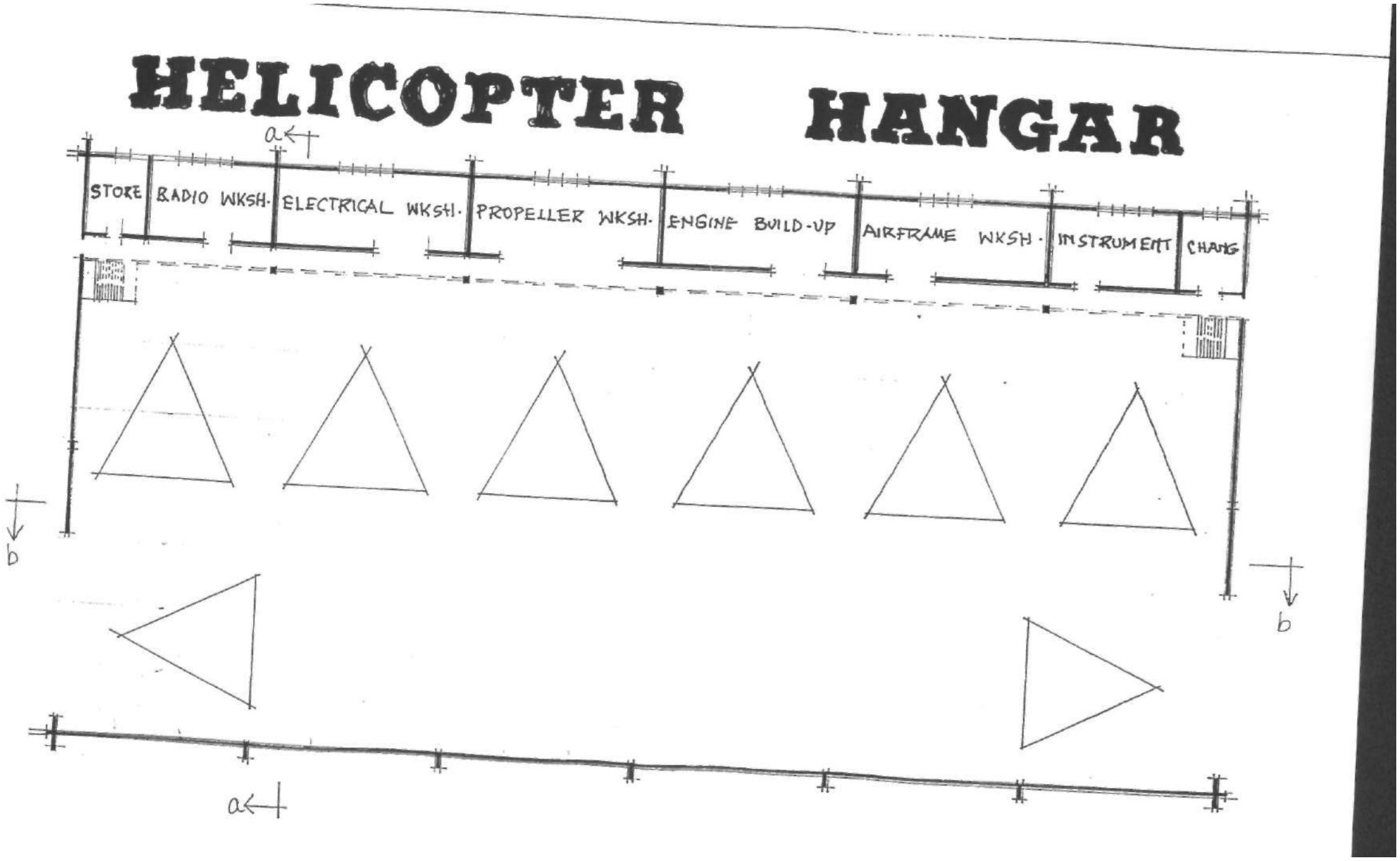
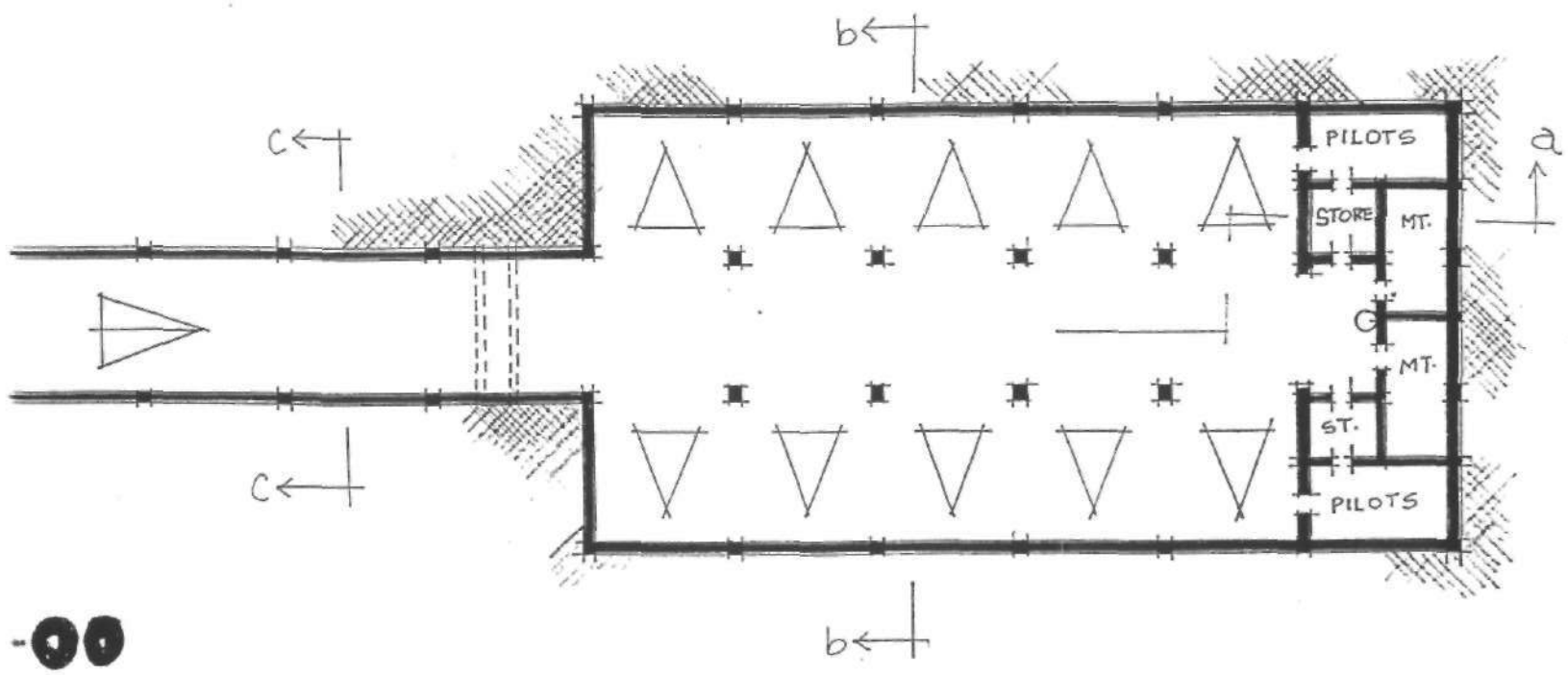


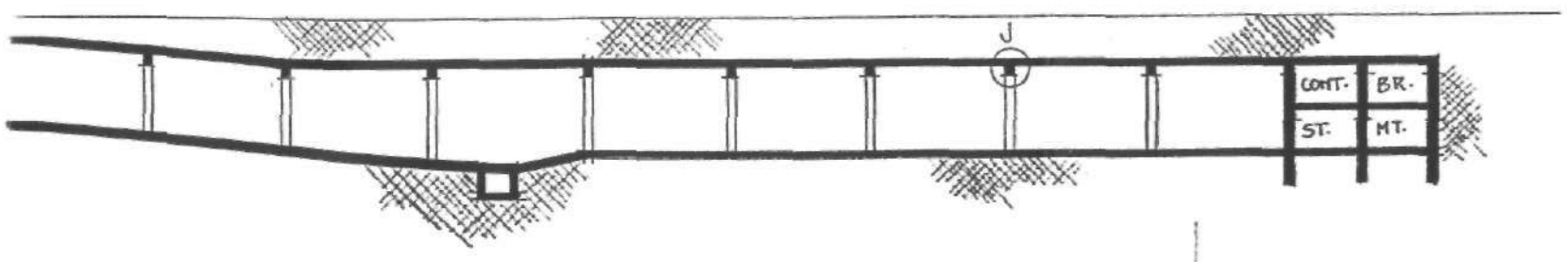
Fig 50 :- Model of the base

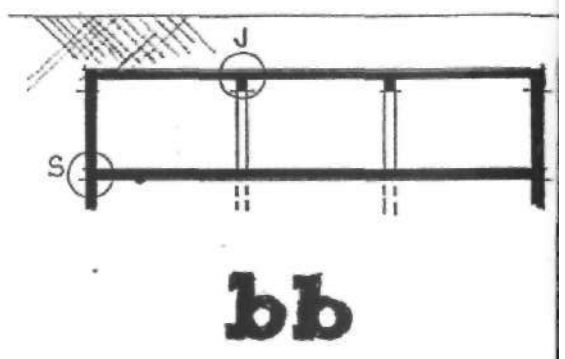
HELICOPTER HANGAR



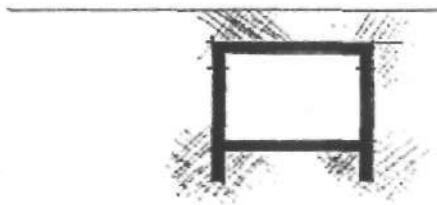


-00

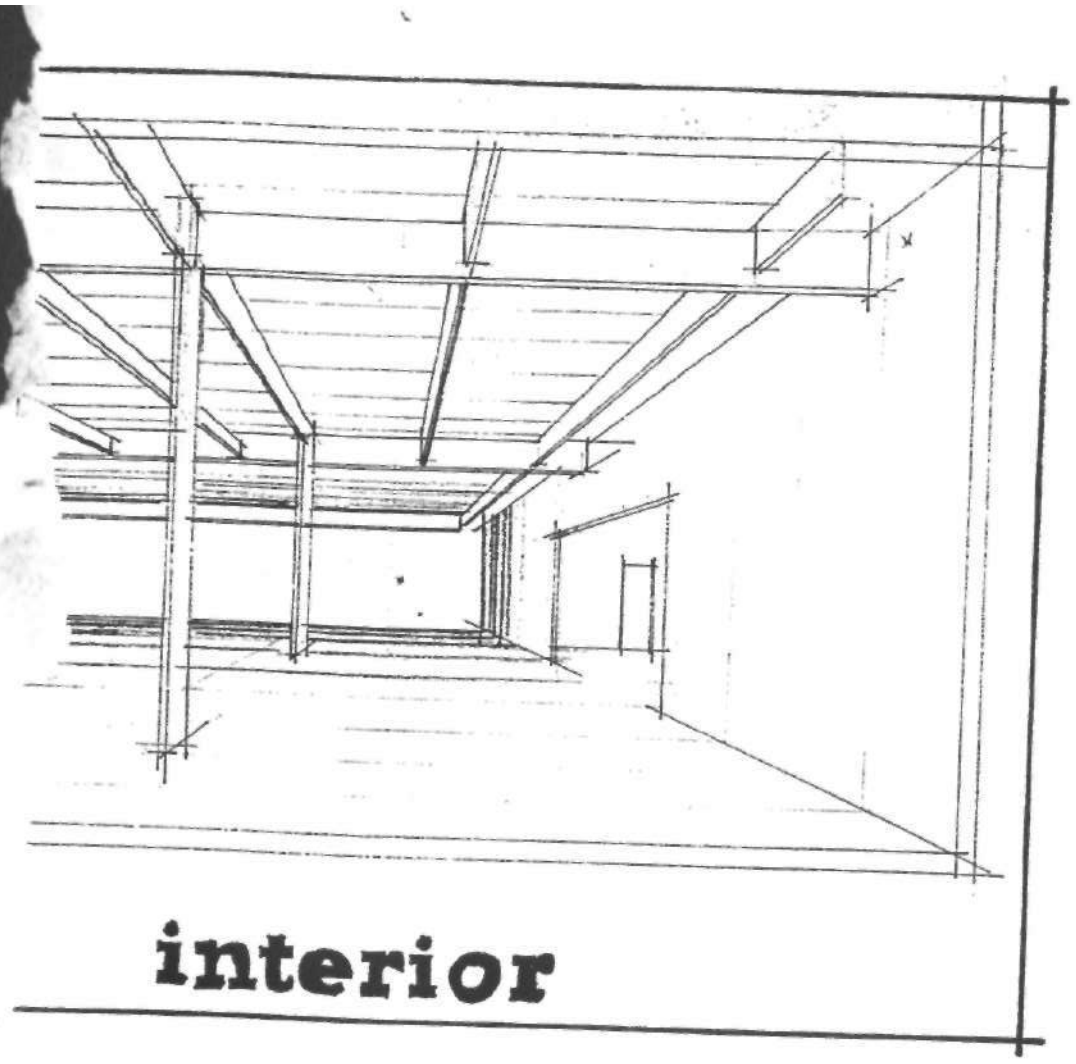




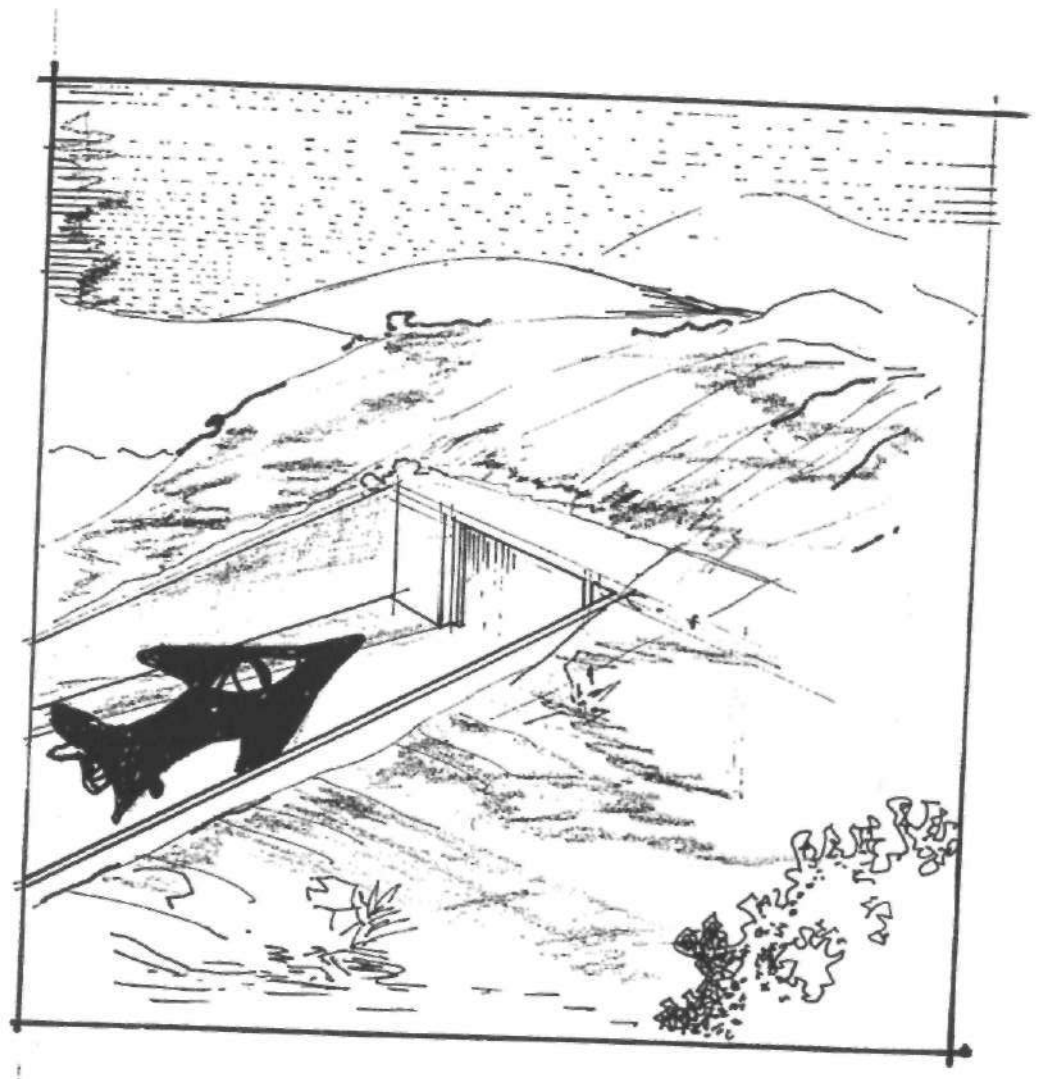
bb



cc



interior



entrance

SAGAR J.B.

(a) The general planning concept of the base

Metabolism has been used in the entire planning of the base with great success. There is therefore the possibility of gradual growth of the base without a ctually changing the set-up completely. It has also been used for the hangars.

(b) The hangars

The hangars has the ability to grow in two directions ie the aids without altering the structure. The use of prefabrication in the roof space frame structure is also a positive step. Research over the years have shown that prefabricated elements were found to withstand greater stresses than normal frames constructed on site.

(c) The Runways and Taxiways

Prefabricated concrete slabs have been used for the runways and taxiways. This is because in times of war, the enemies first point of call would be vital installations like the base and they would destroy the runways. When this happens, the airforce is rendered function since the planes cannot take-off on bad or pot-holed runways. When, therefore, small units or prefabricated slabs are used, all that is necessary is for the engineers or ground officers to remove the debris and put on new slabs

The Nigerian Airforce Base, Yola has therefore to a certain extent been able to employ new techniques of construction as well as planning. This is the end result of a painstacking analysis and study.

CHAPTER SIX

6.00 SUMMARY

The journey from the initial analysis stage down to the design and planning stage has been a tedious but rewarding process. Usually in the design of projects which are of security importance like the airforce base in Yola, a lot of sacrifices have to be made in order to achieve a functional and fully secure base. The Nigerian Airforce Base, Yola design speaks for itself. The design is an attempt at providing a functional, economical and genuine solution to the problem of airforce base planning in Nigeria. In a number of ways, this solution has been achieved to a very satisfactory level.

6.10 SUGGESTIONS

In the cause of my analysis and design, I came face to face with a lot of problems and I figured that a few suggestions would not be out of place. Those suggestions that are of security importance would be left out of this write-up.

The Nigerian airforce should have in its fleet only aircraft that are relatively easy to man and also economical but which have good performance levels.

It should also look into the possibilities of assembling and ultimately designing and manufacturing her aircraft. The awareness level in the Nigerian Airforce should be maintained. Training in future should be restricted to Nigeria and the planes used should be those present in our fleet.

The design and construction of all airforce projects should also be undertaken by the directorate of Works of the Nigerian Airforce instead of giving them to foreign "experts". This would provide greater security to installations that would constitute part of the base.

6.20 EPILOGUE

It is abundantly clear the world over that the security of any country lies in her defence strength. Of all the three arms of the military, the airforce is the most offensive. This is because of its ability to carry the war into its enemy's territory with despatch in comparison to the army or the navy. Projects, therefore, that have a relationship with the airforce should therefore be able to allow for despatch in event of any casuality. The Nigerian Airforce Base, Yola design is one such project that would comfortably be able to accommodate this great function, ie the despatch capability.

GLOSSARY

A

A.M.B.	-	Airways Modernization Board
A.O.C.	-	Air Officer Commanding
A.S.D.S	-	Aircraft Sound description system

C

C.A.S	-	Chief of Airstaff
C-in-C	-	Commander-in-Chief
C.N.E.L	-	Community Noise equivalent level
C.N.R.	-	Composite noise rating
C.N.S.	-	Chief of Naval Staff
C.O.A.S	-	Chief of Army Staff
c/s	-	Cycles per second

D

db	-	Decibels

F

F.A.A	-	Federal Aviation Authority
F.A.R	-	Federal Aviation Report
F.O.C	-	Flag Officer Commanding

G

GOC	-	General Officer Commanding

I

ICAO	-	International Civil Aviation Organisation
IFR	-	Instrument flight rules
ITAF	-	Italian Airforce

J

JHQ	-	Joint Headquarters

L

LC	-	Logistics Command
Ldn	-	Day and Night average level

M

MAC	-	Military Airlift Command

N

NA	-	Nigerian Army
NAA	-	Nigerian Airports Authority
NAF	-	Nigerian Airforce
NCAT	-	Nigerian College of Aviation Technology
NN	-	Nigerian Navy
NNI	-	Noise and Number index

P

PAF	-	Pakistani Airforce

Q

Q	-	Mean annoyance level

R

RAF	-	Royal Airforce (Britain)
RSA	-	Racist (Republic) South Africa

S

STOL	-	Short take-off and Landing

T

TAC - Tactical Air Command
TC - Training Command
TNL - Total noise load

U

USAF - United States Airforce

V

VFR - Visual flight rules
VTOL - Vertical take-off and landing

W

WECPNL - Weighted noise exposure level

BIBLIOGRAPHICAL ENTRIES

(A) BOOKS

Boyne, Walter J and Lopez, Donald S. (ed) (1979) The Jump Jet. (Forty Years of Jet Aviation). Washington: Smithsonian Institution Press.

De Chiara, Joseph and Koppelman, Lee E. (1978) Site Planning Standards New York: McGraw - Hill Book Company.

Engel, Heino (1977) Structure Systems Stuttgart: Deutshe Verlags-Anstalt Gmbtt.

Foster, Timothy R.V (1978) The Aircraft Owners Manval New York: Litton Educational Publishing Inc.

Gniadzik, J.S. (1984) Structural Systems in Architecture. Zaria: Ahmadu Bello University Press

Horenjeff, Robert (1975) Planning and Design of Airports New York: McGraw-Hill Book Company.

Imobighe, T.A (Ed) (1987) Nigerian Defence and Security Issues and Options for Policy Lagos: Macmillan Press.

Le Corbusier (1976) Towards a New Architecture trans. Friederick Etchells. London: The Architectural Press.

Martin, Lawrence (1973) Arms and Strategy (The World Power Structure Today) New York: David McKay Company Inc.

Mondey, David (Ed) (1978) The Illustrated Encyclopedia of Aircraft. Middtesex: Hamlyn Publishing Group Limited.

Myles, Bruce (1978) Jump Jet (The Revolutionary V/STOL Fighter) London! Presidio Press.

Nervi, Pier Luigi (1966) Aesthetics and Technology in Building (The Charles Eliot Norton Lectures, 1961-62) trans. Robert Einaudi. Massachussets: Howards University Press.

Neufert, Ernst (1982) Neufert Architects Data New York: Halsted Press John Wiley and Sons, Inc.

O'Donnel, James P. (1979) The Berlin Bunker London: Arrow Books Limited.

Peusner, Nikolaus Fleming, John and Honour, Hugh (1975) A Dictionary of Architects London: Penguin Books.

Ross, Michael Franklin (1978) Beyond Metabolism (The New Japanese Architecture) New York: McGraw - Hill Books Limited,

Stubbins, Hugh (1976) Architecture: The Design Experience New York: John Wiley and Sons, I

Taylor, John W.R(Ed) (1984) Janes All the World's Aircraft 1984 London: Macdonald and Janes Publishing Company

(B) PERIODICALS

Abu, Sully and Cammack Diana "South-Africa (Strong but Vulnerable, " The African Guardian, Dec 18, 1986, pp 8 - 15.

Gutteridge, William "The Military Equation - Black Africa Lags Behind", Africa, No 82, June 1978, pp 14 - 23.

Howe, John "Libya Moves In ", Africa, No 112, Dec 1980, pp 23 - 24.

Komba, Marcelino — "Amin's Pillage in the Kagera", Africa, No 89 Jan 79, pp 12 - 17

Matatu, Godwin — "Machel's New War, "Africa, No 105, May 1980, pp 14 - 20.

Special Report — "The War is on," Newsweek, May 10, 1982.

(C) ESSAYS AND ARTICLES IN COLLECTION

MARTIN, Laurence (1973) "The Arms Trade with the Third World," Arms and Strategy The World Power Structure Today New York: David McKay Company Inc. pp 253 - 267

Yahaya, M. (1987) "The Nigerian Airforce and the Development of Air Power, "Nigerian Defence and Security Issues and Options for Policy. Lagos: Macmillan Publishers Limited pp 86 - 104.

(D) UNPUBLISHED MATERIALS

Atere, P.M. (1985) "Residential Area Planning in Military Cantonments" (Unpublished M.Sc. thesis, Dept of Urban and Regional Planning, A.B.U., Zaria)

Bayi, Abdullahi Ibrahim (1981) "Kano Airforce Base" (Unpublished M.Sc thesis, Dept of Architecture, A.B.U., Zaria)

Daggash, Sanusi Mohammed (1984) "Abuja International Airport - A Modular Design Approach, "(Unpublished M.Sc thesis, Dept. of Architecture, A.B.U. Zaria).

Gbotosho, Olayinka Johnson (1984) "An Architect's Utopia" (Unpublished M.Sc thesis, Dept of Architecture, A.B.U., Zaria).

Kurfi, Gambo (1986) "Planning for the Nigerian Airforce Ground Training Base", (Unpublished M.Sc thesis, Dept. of Urban and Regional Planning, A.B.U. Zaria).

(E) NEWSPAPERS

Concord
Democrat Weekly
Guardian
New Nigerian
Nigeria Standard