DETERMINATION OF SERVICEABILITY RATING OF INTERNATIONAL AIRPORT RUNWAY PAVEMENTS IN NIGERIA; CASE STUDY PORT-HARCOURT INTERNATIONAL AIRPORT RUNWAY.

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CERTIFICATION

(a) BY STUDENT: This work to the best of my knowledge has not been presented elsewhere for the award of a degree or other purpose.

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(b)BY SUPERVISOR: This is to certify that the research work was carried out by Godwin Uzodinma Anukwa in the Department of Civil Engineering of the Federal University of Technology, Akure, Ondo State, Nigeria.

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ABSRACT

The serviceability rating of selected Airport runways in Nigeria have been determined with focus on Port Harcourt International Airport. A visual inspection of the runway pavements were first undertaken to determine the nature and types of deterioration. Thereafter the pavement condition index was determined for each runway. The dynamic cone penetration test was also conducted to provide geo-technical information for the design of the pavement rehabilitation/upgrading work.

The visual inspection revealed the pavement distresses; while the pavement condition index (PCI) showed their magnitude. The ratings of the airports using standard scale of measurement were: Kano 94; Abuja 57; Port-Harcourt 36; and Lagos 23 with 100 being perfect PCI; implying that Lagos international airport was considered as very poor, Abuja as good and Kano as excellent. The result of the Dynamic Penetration Test also showed that the water table was low, while the subgrade and other underlying formation meet required standards of CBR. The results of the tests conducted on the runways were used to evolve appropriate procedure and methodology for their rehabilitation and upgrading.

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May the Almighty God protect and guide you all.

CHAPTER ONE

INTRODUCTION

1.0 Background

As aviation industry develops gradually in Nigeria what used to be the main objective of patronizing an airport in the past that is to fly in and out from one location to the other is now expanding to several other activities. Airports are seen as a centre of interest and national pride which caters for the need of travelers, visitors, friends, relations and other airport work users such as the concessionaires. An airport is like a total city devoted to dynamic movements.

The aviation community has a large investment in airport pavements, therefore the objective in the design and construction of these pavements is to provide adequate load carrying capacity and to provide good ride-quality, permitting safe operation of aircraft under all weather conditions. Statistics on world record of Aircraft/passenger movement has shown that there is always one takeoff or landing of an aircraft in every two seconds in the world, 45,000 flights and three million passengers daily. In Nigeria, there is always one takeoff or landing of an aircraft every six minutes, 500 flights daily and 25,000 passengers daily. (Source from Aviation Line Vol. 3 issue No. 02 2007). With this statistics as published in 2007 one can begin to imagine the rapid development of Aviation business in Nigeria with twenty one government owned Airports.

Upon completion of construction, airport pavements begin a gradual deterioration which is attributed to several factors, normal distresses in the pavement structure resulting from surface weathering, fatigue effect, poor drainage and differential movement in the underlying sub-base and sub-grade over a period of years, in addition faulty construction techniques, substandard materials or workmanship can accelerate the pavement deterioration process, consequently, there is a continual requirement to perform routine maintenance, rehabilitation and upgrading of existing airport pavements.

Furthermore, many pavements were not designed for servicing today's aircraft, which impose loads much greater than those initially considered for design. Also there may have been a considerable increase in the frequency of take – offs and landings. Both of these factors result in accelerated deterioration of the pavement structure.

1.1 Aviation in Nigeria

The first flight into Nigeria was recorded in 1925. Commercial aviation however commenced in 1935 when Imperial Airlines started regular flight between the United Kingdom and Nigeria. The development of one of the supporting infrastructure, aerodromes was boosted with the advent of the Second World War. At the end of the war, the British Overseas Airways Corporation [BOAC] replaced Imperial Airlines to serve the British West African colonies. In 1946, West African Airways Corporation [WAAC] took over from BOAC but broke up in 1957 when Ghana gained independence and formed its own airline. The Nigerian government British Overseas Airways Corporation and Elder Dempster then formed the West African airways corporation Nig. Ltd, which later renamed Nigerian Airways Limited [NAL] after the Federal government bought over the shares of BOAC and Elder Dempster.

In the early days of aviation in Nigeria, the control and administration of civil aviation was vested in the director of public works, who applied the British air navigation order [ANO] as the legislative instrument. Rapid growth in air transport activities in the country necessitated the establishment of a Nigerian Civil Aviation Department [CAD]

The CAD remained a separate entity until it was integrated into the federal ministry of transport in 1965. The CAD was later to be a Department in the Ministry of Aviation. The ministry remained the organ of government responsibility for the formation of policies, regulation of the industry and provision of services including aeronautical facilities, air traffic control services etc. however, with the creation of the Federal Civil Aviation Authority [FCAA] in 1990 the regulatory functions and the provision of services were transferred to FCAA.

The creation of the FCAA as a regulatory authority was based on the recommendation of the Air Commodore Kola Falope Committee's report. The committee formulated the first National Civil Aviation Policy for Nigeria in 1989. The FCAA was responsible for safety and economic regulation of the industry as well as provision of air traffic services, aeronautical information services and aero telecommunication services.

The aviation reforms of 1995, however, scrapped the Federal Civil Aviation Authority [FCAA] and re – aligned some of its functions with those of the ministry of aviation and former Nigerian Airports Authority [NAA]. The realignment of functions led to the establishment of the Directorate of Safety Regulation and Monitoring [DESRAM] a Directorate of Economic Regulation and Monitoring [DERAM] in the ministry and the creation of the Federal Airports Authority of Nigeria [FAAN] as a Agency of the ministry.

The structure created by the 1995 aviation reforms turned out to be at variance with the approved aviation policy as well as the recommendation of International Civil Aviation Organization [ICAO] and other international organizations. This coupled with some developments in the domestic and international aviation such as the increasing activities of handling companies, cargo consolidators, tour organizers and the implementation of a new African Air Transport Policy [Yamoussoukro Declaration] created the need for the review of the 1989 civil aviation policy in 1998.

The major highlights of the reviewed 1998 policy were the recommendations for the creation of the Nigerian civil aviation authority [NCAA] out of DSRAM and part of DERAM in the ministry for the safety and economic regulation of the aviation industry. The Nigerian Airspace Management Agency [NAMA] was also carved out of the Federal Airports Authority of Nigeria [FAAN] to provide navigational facilities, air traffic services, aeronautical information services among others, while a restructured FAAN continued to be responsible for the development and management of the nation's airports.

The 1998 reviewed policy, like the 1989 policy was expected to last for ten [10] years however, certain developments in the industry including government privatization and liberalization policies, the unified insurance liability scheme [the 1999 Montreal convention] the Yamoussoukro decision of 14th November 1999, the Banjul accord group agreement to liberalize air transport in west Africa, the open skies agreement Nigeria signed with the United States of America and the desire of foreign carriers to operate into multiple points in Nigeria, necessitated the review of the 1998 civil aviation policy in July 2001.The overall objective of the 2001 review was to ensure that developments in the international and domestic aviation were incorporated in the new policy.

1.2 Aviation Agencies

The ministry, together with five [5] Agencies under it namely Nigerian Civil Aviation Authority [NCAA] Nigeria Airspace Management Agency [NAMA] Federal Airport Authority of Nigeria [FAAN] Nigerian College Of Aviation Technology [NCAT] Nigerian Meteorological Agency[NIMET] constitute the core of the aviation industry in Nigeria.

- The Nigerian Civil Aviation Authority [NCAA] is vested with the safety and economic regulation of the industry. The authority ensures compliance of the industry with government policies and ICAO Standards And Recommended Practices [SARP's]
- The Nigerian Airspace Management Agency [NAMA] is responsible for the provision of navigational facilities, air traffic services; aeronautical information services [AIS] and aeronautical search and rescue.
- The Federal Airports Authority of Nigerian [FAAN] is responsible for the development and management of the nation's airports.
- The Nigerian College of Aviation Technology [NCAT] is responsible for various aviation professional training for skilled personnel required in the industry.

- The Nigerian Meteorological Agency [NIMET] is responsible for the provision of weather reports to flights through the air traffic services of NAMA.

Presently, aviation activities in Nigeria have undergone tremendous expansions and explosion in the area of airports development – there are twenty one (21) functional airports in Nigeria today.

This increase in flying activities in Nigeria has placed a lot of stress on the facilities of the airports, thus justifying the need for the determination of the level of serviceability rating(s) of this important component of the airport, termed runway.

1.3 Aim of The study

The aim of this Study is to develop a comprehensive and coordinated data base for surface condition evaluation of Port-Harcourt international airport pavements.

1.4 Objectives of The study

The objectives of the study are to:-

i assess the operational surface condition of the selected runway pavements and determine the serviceability rating (s)

ii evaluate the magnitude of distresses and proffer remedies.

iii provide rational basis for runway rehabilitation projects in Nigeria.

1.5 Justification for the Study

Upon completion of construction, Airport pavements begin a gradual deterioration which is attributed to several factors such as distresses and depressions in the pavement structure resulting from surface weathering, fatigue effect, faulty construction techniques, sub standard materials and differential movements in the underlying sub-base; sub-grade over the years can accelerate the runway pavement deterioration. These runway pavements including Port –Harcourt Airport runway pavement which is the case study were initially designed for small and medium aircrafts, but the modern heavier aircrafts such as Boeing 747-400/800 series, A380 and the hosts of others are being introduced in the air transportation system and this will no doubt have adverse effect on the existing Airport runway pavements which would result to rapid deterioration or failure of the runway pavement.

Also, the frequency in the landing and take-off of aircrafts on the runway pavement as a result of increase in air transportation has also contributed to the deterioration of runway pavement.

With the new development in the transportation system, sufficient material has not been generated that would lead to a cost effective approach to maintenance of Airport runway pavements within the context of International Civil Aviation Organization (ICAO) engineering standard. It is on this premise therefore that this research is aimed to determine serviceability rating of the International airport runway pavements in Nigeria.

1.6 SITE DESCRIPTION

Port Harcourt international airport is located around the sleeping village of Omagwa in Ikwere local government area of Rivers state.

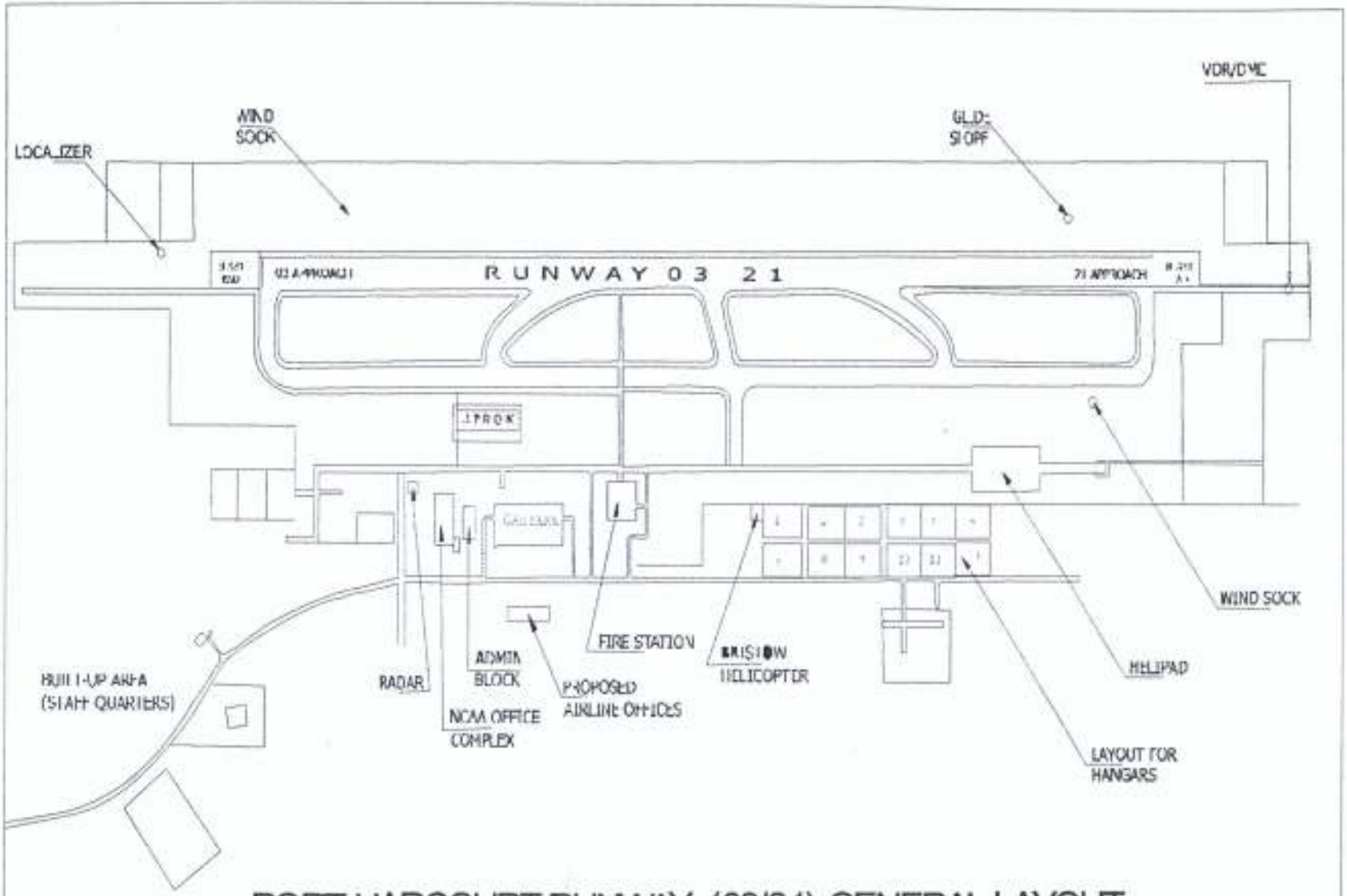
Good road network right from Rumokoro all through to Igwurita and from Owerri through Omagwa leads to the airport. Access can also be achieved from any part of the world through aircraft. The area has a wide expense of land being dotted by FAAN staff quarters and temporary air force and military settlements [for security at the airport].

On approaching the airport through Owerri – Port Harcourt by Omagwa at the airport gate, it is about five minutes (5min.) drive from the gate of the airport to arrival area.

The site proper is the major runway code-named 03-21 which measures about 3126m x 67m of asphalt / concrete with five(5) taxiways consisting of three (3) exit taxiways and two (2) rapid exit taxiways coded A, C, E, B and D respectively (Fig.1)

The area investigated falls within the tertiary Niger delta which occurs at the southern end of Nigeria bordering the Atlantic Ocean and extends from about longitude $3^0 - 9^0$E and latitude $4^0 30^1 - 5^0 20^1$ N.

The fast developing airport as a result of oil exploration and other industrial activities in the region was commissioned in 1981. The airport is located approximately $05^0 50^1 52^{11}$ N and $06^0 57^1 01^{11}$E and is about 32km west from Port Harcourt city. It has one runway whose orientation and dimension are 03 / 21 and 3000 x 60 sq. meters, respectively



PORT HARCOURT RUNWAY (03/21) GENERAL LAYOUT

FIG. .1.

2.0 The Federal Airports Authority of Nigeria [FAAN]the official operator of government- owned airports in Nigeria manages twenty one[21] airports, five of them international, making it one of the largest airport groups in the world, in terms of number of airports managed. These international airports are as shown in the Table 1 below.

In 2005, the federal airports authority of Nigeria enjoyed 18.8% growth in passenger movement with a total of 8,310,515 passengers compared to 8,157,152 recorded in 2004 Table 2 and 3 below [FAAN 2006]

Aircraft movement recorded a 14. % growth from 137,277 in 2004 to 143,323 in 2005. Cargo fared better rising by 23 % from 77,286,924 in 2004 to 99,411,126 million in 2005[FAAN 2006]

The above records attested to the fact that the runways are subjected to more pressures than was experienced when they were commissioned some years back. For example, records of outbound and inbound passenger's traffic at the Ikeja and Kano airports [1959-1969] as shown in Table 6 below are quite low when compared with the figures above and Table 4-8.

TABLE 1: CLASSIFICATION OF AIRPORTS IN NIGERIA

S/N	NAME OF AIRPORT	DIMENSIONS/M RUNWAY	ORIENTATION DEGREE	CLASSIFICATION
1	ABUJA	3600 X 60	04/22	INTERNATIONAL
2	CALABAR	2450 X 45	03/21	DOMESTIC
3	ILORIN	3100 X 60	05/23	DOMESTIC
4	KADUNA	3000 X 60	05/23	DOMESTIC
5	KANO	3000 X 60	06/24	INTERNATIONAL
6	KANO	2600 X 45	05/23	DOMESTIC
7	LAGOS	3900 X 60	18R/36L	INTERNATIONAL
8	MADUGIRI	3900 X 60	05/23	INTERNATIONAL
9	PORTHARCOURT	3000 X 60	03/21	INTERNATIONAL
10	SOKOTO	3000 X 60	08/26	DOMESTIC
11	AKURE	3000 X 60	03/21	DOMESTIC
12	BENIN	2800 X 45	05/23	DOMESTIC
13	ENUGU	2400 X 45	08/26	DOMESTIC
14	IBANDAN	2400 X 45	05/23	DOMESTIC
15	JOS	3000 X 45	10/28	DOMESTIC
16	YOLA	2400 X 45	17/35	DOMESTIC
17	ZARIA	1646 X 46	06/24	DOMESTIC
18	MINNA	3400 X 45	05/23	DOMESTIC
19	OWERRI	2700 X 45	17/35	DOMESTIC
20	OSUBI			
21	KATSINA			

SOURCE: FAAN 2006

TABLE 2 PASSENGER MOVEMENTS IN NIGERIA AIRPORTS

S/N	AIRPORTS	2005 TOTAL	2004 TOTAL	% DIFFERENCE
1	ABUJA INT'L	221,186	300,398	(26.37)
2	ABUJA DOMESTIC	1,905,459	1,894,114	0.60
3	AKURE	2,671	2,952	(9.52)
4	BENIN	53,315	77,039	(30.79)
5	CALABAR INT'L	289	1,263	(77.12)
6	CALABAR DOMESTIC	135,864	141,160	(3.75)
7	ENUGU	197,783	205,768	(3.88)
8	IBADAN	13,778	12,517	10.07
9	ILORIN	13,632	13,243	2.94
10	JOS	51,683	54,214	(4.67)
11	KADUNA	126,267	134,716	7.3
12	KANO INT'L	159,930	137,065	16.68
13	KANO DOMESTIC	142,087	155,790	(8.80)
14	MAKURDI	1,452	1,783	(18.56)
15	MAIDUGURI INT'L	12,629	11,612	8.76
16	MAIDUGURI DOMESTIC	52,258	70,459	(25.83)
17	MMA DOMESTIC	2,255,903	2,220,568	1.59
18	MMA INT'L	1,561,435	1,355,621	15.18
19	PORT HARCOURT INT'L	106,771	107,468	(0.65)
20	PORTHARCOURT DOM	810,380	762,817	6.24
21	SOKOTO INT'L	27,380	23,338	17.32
22	SOKOTO DOMESTIC	26,319	34,818	(24.41)
23	YOLA	70,466	52,228	124.25
24	MINNA	2,261	4,250	(46.80)
25	KATSINA	4,142	2,886	43.52
26	OWERRI	66,093	59,518	11.05
27	OSUBI	287,899	313,527	(8.17)

SOURCE FAAN 2006

TABLE 3: AIRCRAFTS MOVEMENT IN NIGERIA AIRPORTS

S/N	AIRPORTS	2005 TOTAL	2004 TOTAL	% DIFFERENCE
1	ABUJA INT'L	4,980	2,094	138
2	ABUJA DOMESTIC	37,885	46,280	(18)
3	AKURE	512	596	(9)
4	BENIN	3,997	6,138	(35)
5	CALABAR INT'L	436	96	(63)
6	CALABAR DOMESTIC	4,172	3,608	16
7	ENUGU	4,202	5,724	(27)
8	IBADAN	1,565	1,597	(27)
9	ILORIN	1,608	1,390	1
10	JOS	1,102	1,434	(23)
11	KADUNA	1,712	1,799	115
12	KANO INT'L	1,692	1,466	15
13	KANO DOMESTIC	218	3,611	(9)
14	MAKURDI	104	247	58
15	MAIDUGURI INT'L	122	94	30
16	MAIDUGURI DOMESTIC	1,256	1,378	(9)
17	MMA DOMESTIC	50,945	52,629	(3)
18	MMA INT'L	19,948	14,579	37
19	PORT HARCOURT INT'L	12,462	891	1,299
20	PORTHARCOURT DOM	11,709	18,102	(35)
21	SOKOTO INT'L	152	136	12
22	SOKOTO DOMESTIC	833	957	(13)
23	YOLA	1,500	1,303	73
24	MINNA	470	518	(9)
25	KATSINA	196	190	3
26	OWERRI	2,406	2,010	20
27	OSUBI	20,028	24,254	(17)

SOURCE FAAN 2006

TABLE 4: PASSENGER TRAFFIC AT THE IKEJA AND KANO AIRPORTS

[1959-1969]

YEAR	IKEJA AIPROT		KANO AIRPORT	
	IN/OUT BOUND	TRANSIT	IN/OUT BOUND	TRANSIT
1959/60	92,785	1,028	51,723	84,349
1960/61	91,741	7,418	52,195	93,460
1961/62	115,076	29,872	50,233	142,371
1962/63	146,082	70,317	53,189	169,529
1963/64	187,546	64,271	51,929	139,496
1964/65	211,448	90,828	54,103	126,891
1965/66	226,585	94,135	56,331	108,225
1966/67	219,223	95,469	53,119	97,620
1967/68	159,382	81,466	48,975	68,765
1968/69	265,061	90,492	64,200	76,698

SOURCE: [FAAN, 1981]

TABLE 5 : 2004 AIRCRAFT MOVEMENT IN INTERNATIONAL AIRPORTS.

	FIRST QUARTER		SECOND QUARTER		THIRD QUARTER		FOURTH QUARTER		TOTAL		GRAND TOTAL
AIRPORTS	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	
ABUJA											
DOM	4,509	4,505	5,326	5,328	6,946	6,946	6,360	6,360	23,141	23,139	46,280
INT'L	317	321	226	226	225	225	277	277	1045	1049	2094
KANO											
DOM	413	418	454	460	490	484	444	448	1771	1810	3581
INT'L	278	265	118	125	154	156	180	190	730	736	1466
MMA											
DOM	5,957	5,985	7,022	7,069	6,522	6,445	6,909	6,720	26,410	26,219	52629
INT'L	2,372	2,361	1,416	1,414	2,284	2,274	1,233	1,225	7305	7274	14579
PHC											
DOM	3,424	3,424	2,618	2,613	1,526	1,516	1,492	1,489	9060	9042	18102
INT'L	169	169	93	93	82	91	97	97	441	450	891
CAL											
DOM	439	439	423	423	459	459	483	480	1804	1801	3605
INT'L	11	11	6	6	16	16	15	15	48	48	96

TABLE 6: 2005AIRCRAFT MOVEMENT IN INTERNATIONAL AIRPORTS.

	FIRST QUARTER		SECOND QUARTER		THIRD QUARTER		FOURTH QUARTER		TOTAL		GRAND TOTAL
AIRPORTS	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	
ABUJA											
DOM	4,999	4,999	4,683	4,691	4,456	4,442	5,654	2,761	19792	16893	36685
INT'L	611	611	418	407	373	380	345	431	1747	1829	3576
KANO								271			
DOM	407	399	393	388	476	458	448	124	1724	1516	3240
INT'L	253	288	133	130	194	208	407		987	750	1737
MMA											
DOM	6,293	6,331	6,518	6,530	6,771	6,777	7,933	5,433	27,515	25071	52586
INT'L	1,525	1,527	2,265	2,265	2,136	2,136	3,026	319	8952	6247	15,199
PHC											
DOM	1,317	1,299	2,854	2,839	2,687	2,670	2,639	558	9497	7366	16863
INT'L	68	68	333	520	178	178	811	651	1390	1417	2807
CAL											
DOM	524	524	526	902	464	464	671	473	2185	2363	4548
INT'L	11	11	6	6	1	1	0	0	18	18	36

SOURCE: FAAN STATISTICAL DATA 2006

TABLE 7: 2004 PASSENGER MOVEMENT IN INTERNATIONAL AIRPORTS.

	FIRST QUARTER		SECOND QUARTER		THIRD QUARTER		FOURTH QUARTER		TOTAL		GRAND TOTAL
ORTS	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	
A	223,508 84,741	206,510 86,373	229,146 16,777	230,092 18,438	250,162 21,427	245,548 23,427	247,731 25,395	261,417 24,009	950,547 148,151	943,567 152,247	**1894114** **300,398**
O	16,580 27,376	17,953 13,787	20,833 10,830	19,214 6,640	22,300 10,547	22,327 18,522	18,995 16,717	17,588 32,646	78,708 65,470	77,082 71,595	**155,790** **137,065**
	236,942 152,372	248,310 168,437	353,629 151,719	216,005 161,502	302,484 180,919	316,402 196,834	254,820 174,193	291,976 169,645	1147875 659203	1072693 696418	**2220568** **1355621**
	100,675 12,306	105,042 29,485	99,913 8,383	100,560 9,266	88,488 11,210	91,611 10,338	89,209 14,204	87,319 12,276	378285 46103	384532 61365	**762817** **107,468**
	15,589 244	16,586 333	18,557 37	17,458 87	18,830 116	18,554 220	18,671 128	16,915 98	71647 525	69513 738	**141,160** **1263**

SOURCE: FAAN STATISTICALDATA2006

TABLE8:2005 PASSENGERMOVEMENT IN INTERNATIONAL AIRPORTS.

	FIRST QUARTER		SECOND QUARTER		THIRD QUARTER		FOURTH QUARTER		TOTAL		GRAND TOTAL
AIRPORTS	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	LAND	T/OFF	
ABUJA OOM NT'L	217,141 27,612	216,804 32,857	160,995 29,463	256,017 23,596	253,556 108,904	271,137 105,234	224,158 27,093	218,313 26,084	855850 193072	962271 187,771	**1818121** **380,843**
KANO OOM NT'L	15,975 28,771	16,160 20,541	18,109 12,032	16,809 9,914	20,344 12,285	19,321 16,369	14,464 19,851	14,676 35,167	68,892 72939	66946 81991	**135838** **154930**
MMA OOM NT'L	249,193 178,171	269,777 196,942	289,992 182,923	303,861 197,443	317,820 145,848	325,425 213,606	247,175 197,815	252,660 196,402	1104180 704757	1130723 804393	**2234903** **1509150**
PHC OOM NT'L	89,394 13,954	86,919 13,111	100,401 9,295	98,640 9,579	114,057 14,312	112,066 15,378	110,356 17,204	103,172 13,941	414208 54765	400797 52009	**815005** **106774**
CAL OOM NT'L	14,805 102	15,250 113	17,192 27	16,799 44	17,393 0	17,530 0	19,076 0	18059 0	68466 129	67638 157	**136104** **286**

SOURCE: FAAN STATISTICALDATA2006

2.1 Runways

A runway is a paved strip located in the central portion of the landing strip and provided specifically for landings and take- offs of aircrafts [ICAO, 1983]. Runways are normally identified by the following principal elements.

the structural pavement, which supports the airplane load.

the shoulders adjacent to the structural pavement which are designed to resist erosion due to jet blast and to accommodate maintenance equipment and patrol.

the runway strip, which includes the structural pavement, shoulders and an area that is cleared drained and graded.

Runway End and Safety Area (**RESA**) An extended runway centre line and adjacent to the end of the strip primarily intended to reduce the risk of damage to an aeroplane undershooting or overshooting the runway.

The runway is so important that its length or surface condition significantly affects the landing and take – off of the aircraft. Evidence from airplane overrun and runoff accidents indicate that in many cases, in adequate runway friction characteristics was the primary cause or at least, a contributing factor. A part from this safety related aspect, the regularity and efficiency of aero plane operations can become impaired significantly as a result of poor runway characteristics [ICAO 1983]

The Nigerian air transport sector has witnessed series of accidents within the last thirty years [Table 9] and the cause of most of these accidents is not far from the runway conditions.

TABLE 9: AN UPDATE OF PLANE CRASES IN NIGERIA [1968 -2006]

DATE	DETAIL
July 13, 1968	Boeing 707, reg. 005jk Sabena airline at Lagos, 7 dead.
Nov 1983	Nigerian Airways F28 at Enugu, 53 dead
Aug. 6 1986	Kabo Airline at Calabar Airport
1990	Okada Air at Sokoto 4 dead.
1992	C130 Military Hercules At Ejigbo Near Lagos 163 military officers dead
June 1995	Harka Air in Lagos 15 dead [Cause over shooting of runway- slippery due to rain]
Nov 1995	Nigerian Airways Boeing 707 at Kaduna Airport, 9 dead [Cause over shooting the runway]
Jan 1996	Presidential Jet at Kaduna 3 dead
June 20, 1996	Private Jet at Jos, 13 dead
Feb 24, 1997	Air force Jet at Kaduna 3 dead
Oct 27, 1999	Air force Jet at Mayama Village Brini Kebbi, 1 dead
Jan 7, 2000	Sky power Express EMB110 at Abuja 3 dead
May 4, 2001	EAS plane about 100 people dead at Kano
Oct, 22 2005	Bellview aircraft crashed in Lisa Village, in IFO in Ogun state, 117 people on board and no survivors. Nov.28 2005 Private aircraft [EAS] crashed in Kaduna Airport. The two [2] crew died.
Dec. 10 2005	Sosoliso aircraft crashed in Port Harcourt International airport 110 people on board 7persons rescued.
Oct. 29 2006	ADC Aircraft Boeing 737 crashed in Abuja two minutes after take off 105 passengers on board with 7 survivors [Cause yet to be determined]
Nov. 2006	DHL cargo DC 10 aircraft over short the runway as a result of port holes and water logged runway.

SOURCE: NCAT 2003

2.2 Evaluation of Runway Pavement

Pavement evaluation includes many different activities, such as distress or condition surveys, material testing, deflection testing and other specialized types of data collection. Pavement evaluation is commonly performed prior to the project design phase, and the information that is collected is an important part of the design process. However, routine evaluation of a pavement network maybe carried as part of a monitoring programme [PCI 1997]

Runways are evaluated for several reasons. Evaluations are needed to establish load carrying capacity for expected operations to assess ability of pavements to support significant changes from expected volumes or types of traffic and to determine the condition of existing pavements for use in the planning or design of improvements which may be required to upgrade the facility [FAA1978]

2.3 Pavement Evaluation Methods

Generally, there are three basic means of evaluating pavements, these are – destructive, non destructive and surface evaluation testing method.

2.4 Evaluations using non – Destructive Testing Method

One of the most widely used in non – destructive testing [NDT] is the falling weight deflectometer.

The falling weight deflectometer is the state of the art in non – destructive deflection test equipment. It is an impulse loading device that was developed to apply a load to the pavement that simulates a moving wheel load, and measure pavement response with the

applied load. The equipment operates by lifting a series of weights to a pre – determined height and then gradually dropping the weights. The "falling weights'' strike a specially designed plate, imparting an impulse force to the pavement. The load magnitude and characteristics can be varied by changing the drop height, the number of weights or the load plate size.

Velocity transducers are used to measure pavements response to load [deflection]. These transducers are mounted on a bar and automatically lowered to the pavement surface along with load plate. The measured deflections and their distance from the applied load defined as deflection basin. A computer located in the tow vehicle controls the entire operation and records the data measured by the load pressure cell and the velocity transducers.

The strength of each pavement layer [surface, base, sub-base and sub grade] will be estimated using the deflection data collected with the falling weight deflectometer and pavement layer information obtained from airport records. The pavement layer strength in terms of dynamic elastic modules will be estimated by imputing the field – measured falling weight deflectometer, deflection basin and pavement layer thickness in the ELMOND computer program. This program estimates the elastic modules of each pavement layer by matching the program – predicted deflection basin to the field measured deflection basin. The material properties for each pavement section are thus gotten and summarized.

2.5 Evaluation Using Destructive Testing Method

Naturally as it implies, it is a test that causes damage to the structure in the process of evaluation.

This is done by performing series of tests upon the various components of the pavement. The values can be used with the design criteria to determine the magnitude of load, which the pavement will sustain [Yoder, 1959] for rigid pavements, the evaluation requires the determination of the thickness, the flexural strength of the concrete, and the modules of sub grade reaction.

The thickness of the component layer is usually available from construction records. Where information is not available or of questionable accuracy, thickness may be determined by borings or test pits in the pavement.

The flexural strength of the concrete is most accurately determined from test beams sawed from the existing pavement and tested. Sawed beams are expensive to obtain and costs incurred in obtaining sufficient numbers may be prohibitive. Construction records maybe used as a source of concrete flexural strength data if available.

Tensile splitting tests can be used to determine an approximate value for flexural strength.

The modulus of subgrade reaction is determined by plate bearing tests performed on the subgrade.

These tests should be made in accordance with the procedures established in AASHTO T 222. an important part of the test procedure for determining the subgrade reaction modulus is the correction for soil saturation.

For flexible pavements, tests are performed upon each of the components of the pavement either in the insitu condition or upon undisturbed samples.

As a general rule, field tests such as CBR can be made with reliance after a period of several years.

However, testing and evaluation are done using undisturbed samples. The samples are soaked and tested. The evaluation in addition to including strength test will indicate the condition of the pavement at the time of evaluation [Yoder 1959].

2.6 Visual Condition Survey

The airport pavement condition survey and the determination of the pavement condition index [PCI] are the primary means of obtaining and recording vital airport pavement performance data. The condition survey for both rigid and flexible pavement facilities consists principally of a visual inspection of the pavement surfaces for signs of pavement distresses resulting from the influence of aircraft traffic and environment.

The first step in the condition survey is the designation of pavement features. Each facility such as a runway, taxi way etc is divided into segments. All pavements in a given feature are such that they can be considered uniform.

The minimum number of sample units that must be surveyed, to obtain an adequate estimate of the PCI of a feature is selected from fig 5(the curve). Once the number of sample unit's n has been determined the spacing interval of the units is computed from:

$$i = \frac{N}{n}$$

Where:

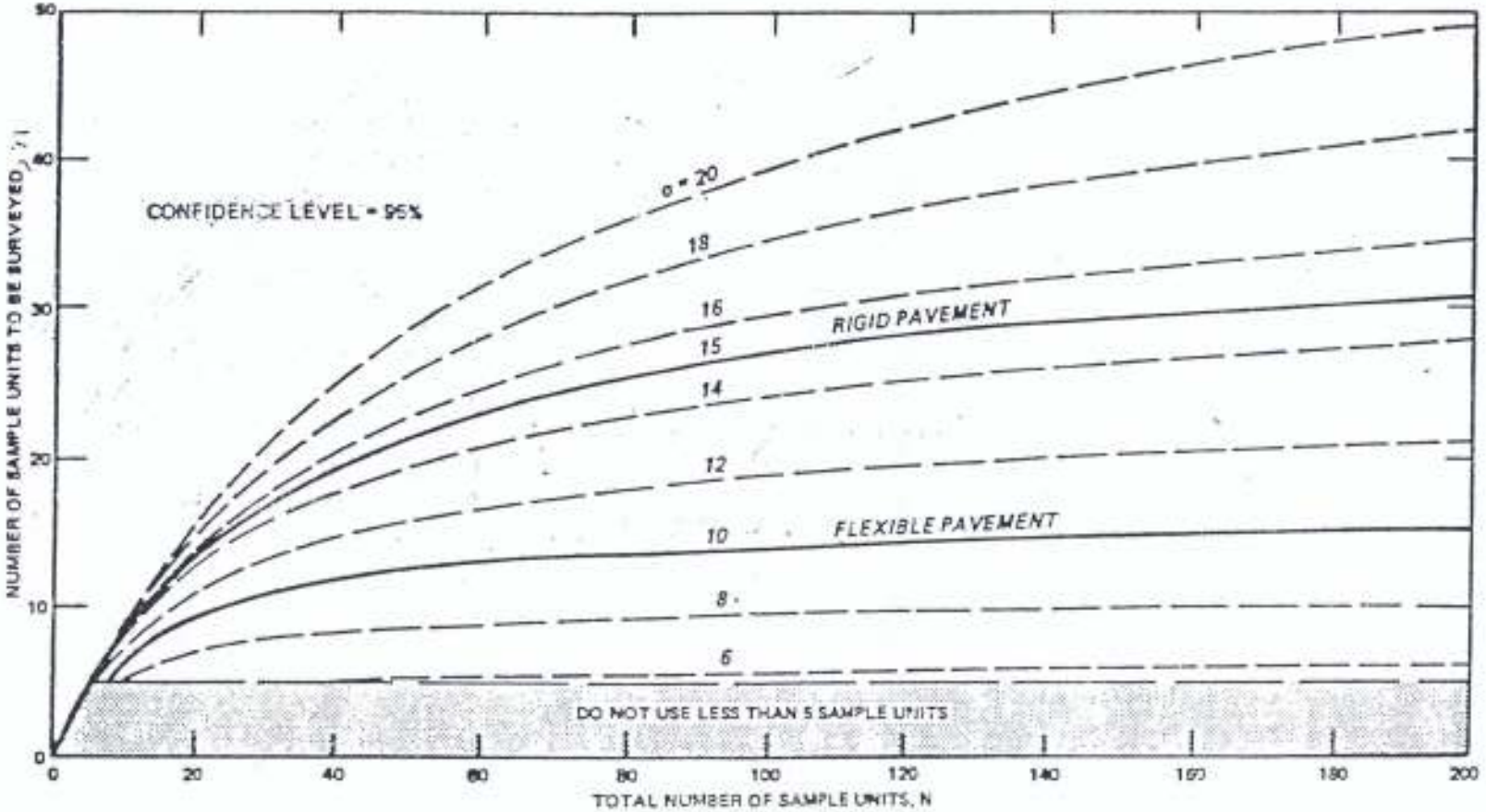


Figure .5. Selection of minimum number of sample units

Source : (FAA, 1982)

i = spacing interval of units to be sampled

N = total number of sample units in the feature.

n = number of sample units to be inspected.

All the sample numbers within a feature are numbered and those that are multiples of the interval i are selected for inspection. The first sample unit to be inspected is selected at random between 1 and i. Sample unit size should be 450sqm [generally 15 x 30m] for flexible pavement.

Each sample unit is numbered so that it can be relocated for future inspections, maintenance needs, or statistical sample purposes. Each of the selected sample units must be inspected and its PCI determined. The mean PCI of a pavement feature is determined by averaging of the PCI of each sample unit inspected within this feature.

2.7 The Adopted Evaluation Method

Each of the methods has advantages and short comings. The major advantages of non – destructive testing are: –

The pavement is tested in place under actual conditions of moisture and density.

The disruption of traffic is minimal and the need for destructive tests minimized.

Falling weight deflectometer are often preferred over destructive method because they are much faster than destructive tests and do not entail the removal of pavement materials.

In addition the testing apparatus is easily transportable.

Disadvantages

In the peculiar Nigerian situation, the non- destructive testing equipment can not be used because they are not available as a result of the poor economic status of the country.

Disadvantages of destructive test are that-;

(a) One could not also use the destructive method because the airport authorities felt it is a safety and security risk.

(b)The pavements will be affected while trying to get cores or some other samples thereby creating the need for repairs or rehabilitation hence it is not economical.

The only available method therefore is the condition survey. It is cost effective and simple to use.

2.8 Pavement Distresses

The deterioration of a pavement be it runway or highway, manifests itself by various external signs or indicators which can be associated with the probable causes of the failure or imperfection. This chapter provides a detailed discussion and description of the type of pavement distress relating them to the likely causal factors.

2.9 Distress Manifestations

The discussions of problems related to pavement distress are generally based on the pavement type, concrete or bituminous. However, while each possesses its own particular characteristics the various pavement distress manifestations for bituminous and concrete pavements generally fall into one of the following broad Categories.

Cracking, Distortion, Disintegration and Skid resistance

2.10 Bituminous Pavement

Cracking – Cracks in bituminous pavements are caused by deflection of the surface over an unstable foundation, shrinkage of the surface, poorly constructed lane joints or reflection cracking.

Longitudinal and Transverse Cracks – Longitudinal and transverse Cracks are caused by shrinkage of the bituminous concrete surface. Longitudinal cracks are also caused by poorly constructed lane joints.

Alligator or Fatigue Cracking – Alligator Cracks are interconnected Cracks that form a series of small blocks resembling an alligator skin. They may be caused by fatigue failure of the bituminous surface under repeated loading or excessive deflection of the surface over an unstable foundation. The unstable support is usually the result of water saturation of the bases or sub grade.

Slippage Cracks – Slippage cracks are caused by braking or turning wheels causing the pavement surface to slide and deform. This usually occurs when there is a low-strength surface mix or poor bond between the surface and the next layer of pavement structure. These cracks are crescent or half moon-shapes cracks having two ends pointed away from the direction of traffic.

Reflection Cracking – Reflection cracks are caused by vertical or horizontal movement in the pavement beneath an overlay, brought on by expansion and contraction with temperature and moisture changes. These cracks in asphalt overlays reflect the cracks pattern in the underlying Pavement. They occur most frequently in asphalt overlays on Portland cement concrete pavements. However, they may also occur on overlays of asphalt pavement wherever cracks in the old pavement have not been properly repaired.

Disintegration – Disintegration in a bituminous pavement is caused by insufficient compaction of the surface, insufficient asphalt in the mix or overheating of the mix.

Raveling – Raveling is the wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. As the reveling continues, larger pieces are broken free, and the pavement takes on a rough and jagged appearance.

Distortion:- Distortion in bituminous pavement is caused by foundation settlement, insufficient compaction of the pavement courses, lack of stability in the bituminous mix, poor bond between the surface and the underlying layer of the pavement structure, or swelling soils or frost action in the sub grade.

Rutting – A rut is characterized as a surface depression in the wheel path. In many instances ruts are noticeable only after a rainfall when the wheel paths are filled with water. This type of distress is caused by a permanent deformation in any of the pavement layers or sub grade and is caused by consolidation of the materials due to traffic loads.

Depression – Depressions are localized low areas of limited size. In many instances, light depressions are not noticeable until after a rain, when ponding creates "birdbaths" areas. Depressions can be caused by traffic heavier than that for which the pavement was designed, by localized settlement of the underlying pavement layers, or by poor construction methods.

Swelling – Swelling is characterized by an upward bulge in the pavement's surface. It may occur sharply over a small area or as a longer gradual wave. Both types of swell may be accompanied by surface cracking. A swell is usually caused by frost action in the sub grade or by swelling soil.

Skid Resistance – Factors which decrease the skid resistance of a pavement surface and can lead to hydroplaning include: too much asphalt in the bituminous mix, too heavy a prime coat; poor aggregate subject to wear and build up of contaminants.

Bleeding – Bleeding is characterized by a film of bituminous material that usually becomes quite sticky. It is caused by excessive amounts of asphalt cement or tars in the mix and / or low air-void content and occurs when asphalt fills the voids of the mix

during hot weather and then expands out onto the surface of the pavement. Since the bleeding process is not reversible during cold weather, asphalt or tar will accumulate on the surface. Extensive bleeding may cause a severe reduction in skid resistance

Fuel Spillage – Continuous fuel spillage on a bituminous surface will soften the asphalt. Areas subject to only minor fuel spillage will usually heal without repairs, and only minor damage will result.

2.11 AIRPORT PAVEMENTS: COMPOSITION AND FUNCTION

.Airport pavements are designed, constructed, and maintained to support the critical loads imposed on the pavement and to produce a smooth and safe riding surface. The pavement must be of such quality and thickness that it will not fail under the loads imposed and is sufficiently durable to withstand the abrasive action of traffic, adverse weather conditions, and other deteriorating influences. In order to ensure the necessary strength of the pavement and to prevent unmanageable distresses from developing, various design, construction, and material-related parameters must be considered. To assess such parameters, this chapter provides information on the composition of pavement sections and the functional aspects of flexible and rigid pavement components.

Classification: Generally, pavements may be divided into the following three classes: Rigid pavements, Flexible pavement, and Overlays

Combinations of different pavement types and stabilized layers constitute complex pavements which can be classified as variations of the normal rigid and flexible types.

2.11.1Rigid Pavements; Rigid pavements normally involve the use of Portland cement concrete (PCC) as the prime structure element. Depending upon conditions, the pavement slab may be designed with plain, lightly reinforced, continuously reinforced, prestressed, or fibrous concrete. The concrete slab is usually placed on a compacted granular or treated sub base which, in turn, is supported by a compacted sub grade. The sub base provides uniform stable support and may also provide subsurface drainage.

The concrete slab has considerable flexural strength and spreads the applied loads over a large area. Rigid pavements possess a high degree of rigidity. This rigidity and resulting beam action enables rigid pavements to distribute loads over large areas of the subgrade. For better pavement performance, it is important that support for the concrete slab is uniform. Rigid pavement construction strength is most economically built into the concrete slab itself with optimum use of low-cost materials under the slab.

2.11.2 Concrete Slab (Surface Layer): The purpose of the concrete slab is to provide a skid-resistant surface, prevent the infiltration of surface water, and provide structural support to the aircraft.

2.11.3 Flexible Pavements: Flexible pavements support loads through bearing rather than flexural action. They are comprised of several layers of carefully selected materials designed to gradually distribute loads from the pavement surface to the layers underneath. The design is such that the load transmitted to each successive layer does not exceed the layer's load-bearing capacity. The various layers comprising a flexible pavement and the functions they perform are described below:

.2.11.4(a) Bituminous Surface (Wearing Course):_The bituminous surface, or wearing course, is comprised of a mixture of various selected aggregates bound together with asphalt cement, heavy grades of tars, or other bituminous binders. Its function is to prevent the penetration of surface water to the base course, provide a smooth, well-bonded surface free from loose particles (which might endanger aircraft or persons), resist the stresses developed as a result of aircraft loads and furnish a skid-resistant surface without causing undue wear on tires.

2.11.5(b) Base Course: The base course is the principal structural component of the flexible pavement. Its functions are to distribute the imposed wheel load to the pavement foundation, the subbase and / or subgrade. The base course must be designed

f a quality and thickness to prevent failure in the subgrade and / or subbase, withstand he stresses produced in the base itself, and resist vertical pressures that tend to produce onsolidation and result in distortion of the surface course, and resist volume changes aused by fluctuations in its moisture content. The materials comprising the base course re select hard and durable aggregates which generally fall into two main classes: tabilized and granular. The stabilized bases normally consist of crushed or uncrushed ggregate that has been bound with a stabilizer such as cement or bitumen. The quality f the base course is a function of its composition, physical properties, and compaction f the material.

2.11.6 (c) Subbase: This layer is used in areas where frost action is severe or in ocations where the subgrade soil is extremely weak. The function of the subbase course s similar to the base course. The material requirements for the subbase are not as strict s those for the base course since the subbase is subjected to lower load stresses. The ubbase consists of stabilized or granular material properly compacted. Other functions re; to provide a sub-surface drainage which will in turn control swell of subgrade soils hereby preventing mud pumping of fine grained soil and thereafter provide uniform table support for the pavement slab.

.11.7(d) Stabilized Subbase: A stabilized subbase is required for all new rigid avements designed to accommodate aircraft weighing 45 350 kg or more. The tructural benefit imparted to a pavement section by stabilized subbase is reflected in the nodulus of subgrade reaction assigned to the foundation.

.11.8(e) Subgrade: The subgrade is the compacted soil layer which forms the oundation for the pavement system. Subgrade soils are subjected to lower stresses than he surface and subbase courses. These stresses decrease with depth, and the controlling ubgrade stress is usually at the top of the subgrade unless unusual conditions exist.

Unusual conditions, such as a layered subgrade or sharply varying water content or densities, may change the locations of the controlling stress. These conditions are checked during the soils investigation. The pavement above the subgrade must be capable of reducing stresses imposed on the subgrade to values which are sufficiently low to prevent excessive distortion or displacement of the subgrade soil layer. Since subgrade soils vary considerably, the interrelationship or texture, density, moisture content, and strength of subgrade material is complex. The ability of a particular soil to resist shear and deformation will vary with its density and moisture content. In this regard, the soil profile of the subgrade requires careful examination. The soil profile is the vertical arrangement of layers of soils, each of which may possess different properties and conditions. Soil conditions are related to the ground water level, presence of water-bearing strata, and the properties of the soil, including soil density, moisture content, and frost penetration. Since the subgrade soil supports the pavement and the loads imposed on the pavement surface, it is critical to investigate soil conditions to determine their effect on grading and paving operations, and the necessity for under drains.

2.11.9 Airport Pavement Overlays; Airport pavement overlays are usually undertaken to correct deteriorating pavement surfaces, to improve ride quality or surface drainage, to maintain the structural integrity, or to increase pavement strength. For instance, a pavement may have been damaged by overload; it may require strengthening to serve heavier aircraft; uneven settling may have caused severe pudding; or the original pavement simply may have served its design life and is worn out. Generally, airport pavement overlays consist of either Portland cement concrete or bituminous concrete.

Overlay is usually required if;

Pavement damaged by overloading that it cannot be maintained satisfactorily for service

Pavement in good condition may require strengthening to serve Aircraft Heavier than those for which pavement was originally designed.

Design life of original pavement has been reached.

Overlays also provide a solution for increased safety that is improved skid resistance and reduced danger of hydroplanning.

CHAPTER THREE

METHODOLOGY

3.0 To facilitate the objective attainment of this study, visual assessment of the Airport runway pavement was first of all carried out. The areas assessed were the runway 03/21 as well as the associated taxiway; this is to determine the extent of damage on the runway pavement. This inspection revealed the presence of alligator cracks, aging cracks, open longitudinal lane joints, local shear failure, as well as rubber deposits at the touch down zone area and this was followed by the pavement condition index (PCI).

The Airport pavement condition survey and the determination of the PCI was the primary means of obtaining and recording vital airport pavement performance data. The condition survey for both rigid and flexible pavement facilities consists principally of a visual inspection of the pavement surfaces for signs of pavement distress resulting from the influence of aircraft traffic and environment. The pavement condition survey in conjunction with the pavement condition index [PCI] may be used to develop pavement performance data. The PCI is a rating of the surface condition of pavement and is a measure of functional performance with implications of structural performance.

A pavement condition survey was performed on the four International Airport runways namely; Mallam Aminu Kano International Airport, Nnamdi Azikwe International Airport Abuja, Port-Harcourt International Airport and Murtala Mohammad International Airport Lagos. The decision to perform the PCI in other international Airports was for comparison since the primary purpose of PCI condition is to determine the rate of deterioration of pavement features and to justify pavement

evaluations and maintenance and repair projects. It therefore becomes imperative that this be also carried out in other Airports and the results be used to determine the rate at which each Airport runway deteriorates including that of Port-Harcourt.

The survey was performed using the pavement condition index [PCI] methodology developed by the US Army CORPS of engineers. This defines distress types, severity levels and methods for measuring and recording distresses. The PCI procedure provides engineers and management with a numerical value indicating overall pavement condition and which would reflect both pavement structural integrity and operational surface condition.

Load related distresses exist where the pavement has been over stressed by loads applied to its surface. The steps used for performing the condition survey and determining the PCI is described below:-

- The airport pavements were marked off in [30m] increments.

  The overall airport pavement was first divided into features based on the pavement design, construction history and traffic area. A designated pavement feature therefore has consistent structural thickness and materials constructed at the same time and is located in one airport facility, that is runway, taxiway etc. After initially designating the features in the airport, preliminary survey was made. The survey entailed a brief but complete visual survey of all the airport pavements. By

observing distress in an individual feature, it was determined whether there were varying degrees of distress in different areas which may necessitate sub division of the feature into two or more features.

- The pavement feature was divided into sample units. A sample unit for flexible pavement is an area of approximately 450 meter square.
- The sample units were inspected and distress types, severity levels and densities were measured on a survey data sheet. - Fig.3.1

FLEXIBLE PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRPORT		DATE	
WORLD INTERNATIONAL		5/26/1979	
FACILITY	FEATURE	SAMPLE UNIT	
TXYE	T-11	4	
SURVEYED BY		AREA OF SAMPLE	
JH/DE		450 SQ M	

DISTRESS TYPES

1. ALLIGATOR CRACKING
2. BLEEDING
3. BLOCK CRACKING
4. CORRUGATION
5. DEPRESSION
6. JET BLAST
7. JT. REFLECTION (PCC)
8. LONG. & TRANS. CRACKING
9. OIL SPILLAGE
10. PATCHING
11. POLISHED AGGREGATE
12. RAVELING/WEATHERING
13. RUTTING
14. SHOVING FROM PCC
15. SLIPPAGE CRACKING
16. SWELL

SKETCH:

EXISTING DISTRESS TYPES

	1	5	8	12			
	4 x 4M	6 x 4L	10L	3 x 10M			
	2 x 3L		5L				
			15L				
			5M				
			10L				
			5M				
			40FT				
TOTAL SEVERITY			10FT	30 SQ M			

PCI CALCULATION

DISTRESS TYPE	SEVERITY	DENSITY %	DEDUCT VALUE
1	L	0.12	7
1	M	0.32	19
5	L	0.48	2
8	L	0.8	5
8	M	0.2	5
12	M	0.6	7
DEDUCT TOTOAL			45
CORRECTED DEDUCT VALUE (CDV)			25

PCI = 100 - CDV = 75

RATING = VERY GOOD

Figure 3.1 Flexible pavements - condition survey data sheet

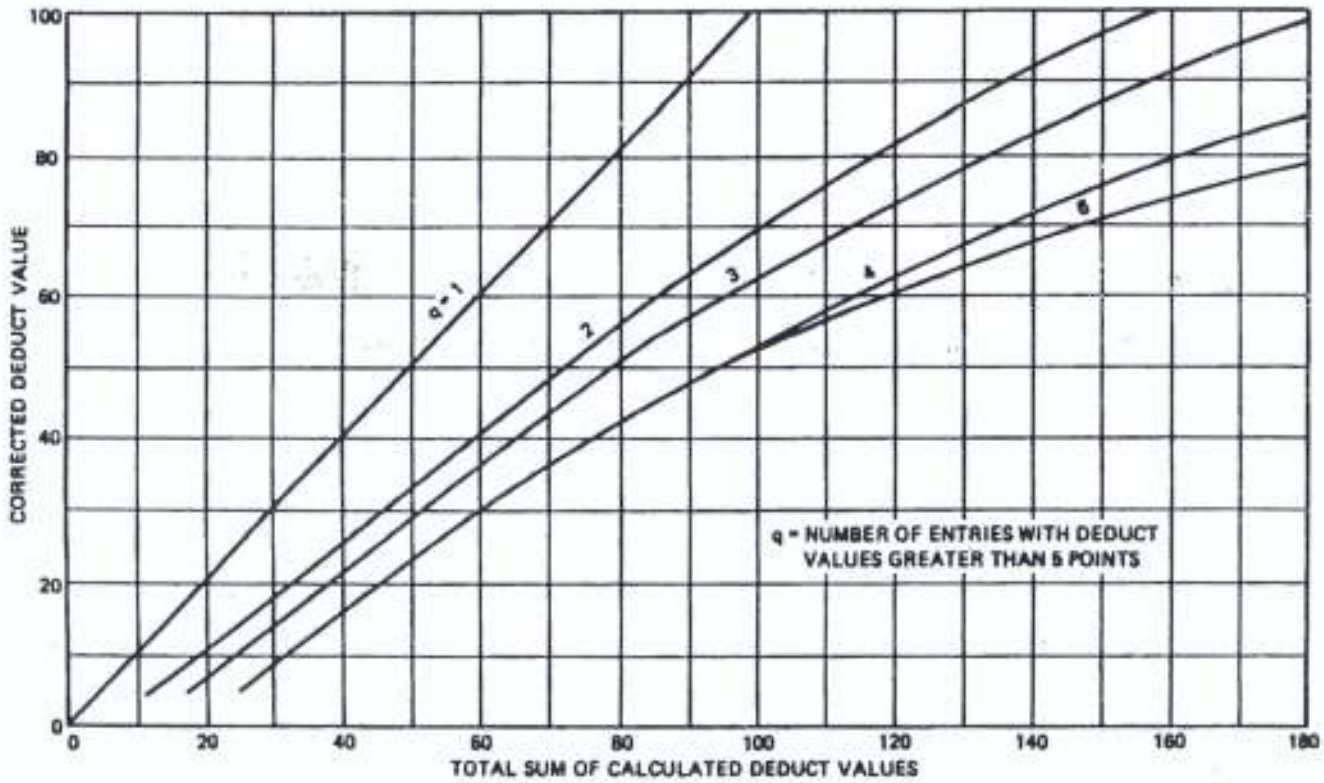


Figure 3-1.1 Corrected deduct values for flexible pavements.

A hand odometer was used in the measurement of distress severity also a three meter straight edge and a 300mm scale were used for the measurement of depths of the ruts or depressions. Each column on the data sheet is used to represent a distress type and the amount and severity of each distress located are listed in the column. For example, distress number five (5) (depression) was recorded as 6 x 4L, which indicates that the depression was 600mm x 400mm and of low severity. Depression type number eight (8) (Longitudinal and Transverse Cracking) was measured in linear meter, thus 10L indicates 10m of light cracking. This method was very convenient for recording data in the field, each distress type and severity level was summed up either in square meter or linear meter depending on the type of distress. One data sheet was used for each Airport,

- For each distress type, density and severity level within a sample unit, a deduct value was determined from the appropriate curve.-
- The total deducts value [TDV] for each sample unit was determined by adding all deduct values for each distress condition observed.

  A corrected deduct value [CDV] was determined using appropriate section for jointed rigid or flexible pavements.
- The PCI for each sample unit inspected was calculated as follows:-

  PCI = 100 – CDV (100 was regarded as a perfect PCI which was used as a standard of measurement).see fig 3.2

- The PCI of the entire feature was the average of the PCIs from all sample units inspected.

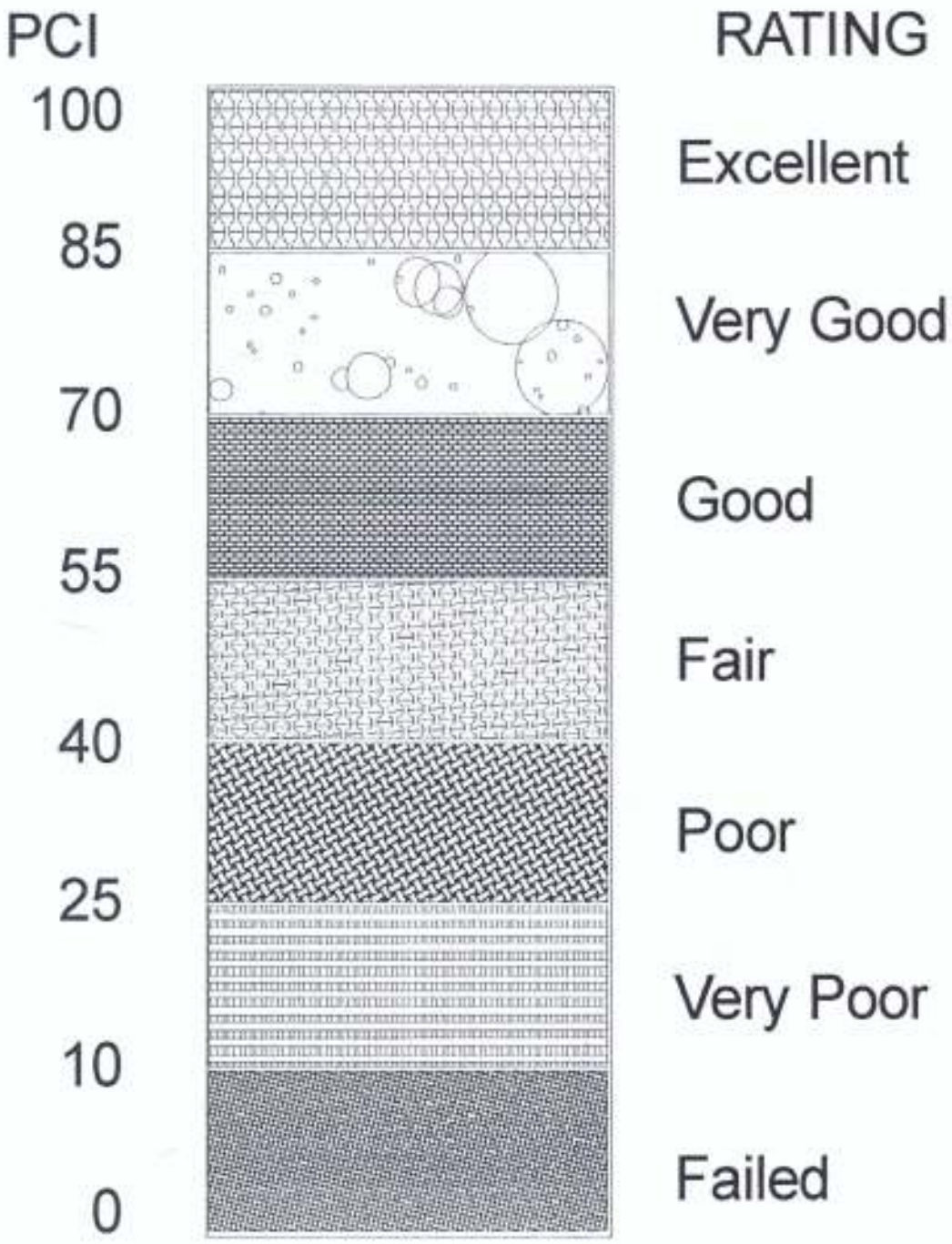


Fig.3.2 Airport Pavement Condition Index (PCI) and Rating Soruce (FAA1982)

This was followed by Dynamic Cone Penetration Test which consists of

- 18 core borings in the pavement from different points on the runway.(see Fig.3.3)
- Dynamic cone penetration [DCP] tests up to 3m
- Laboratory test on the core samples

This report therefore, presents a description of the field activities and results of both in-situ and laboratory tests carried out at the site and in the laboratory respectively, with a view of providing geo technical information for the design of the rehabilitation work.

The coring was executed using CRM drilling machine from the asphalt surface to a depth of 1.0m beneath the asphalt surface see appendix 4. Both wet and dry coring methods were adopted so as to recover good quality cores. Wet coring was applied for the asphalt layer whereas dry coring was applied to retrieve the cement treated / compacted sub – grades.

The dynamic cone penetration tests [DCPT] were executed using a 2.5 tons dinastar light dynamic self-anchoring penetrometer manufactured by techno test. The machine is equipped with a drop hammer weighing 8kg and dropping a height of about 0.58m. Complete accessories were provided to a depth of 2.00m below the asphalt/ pavement level.

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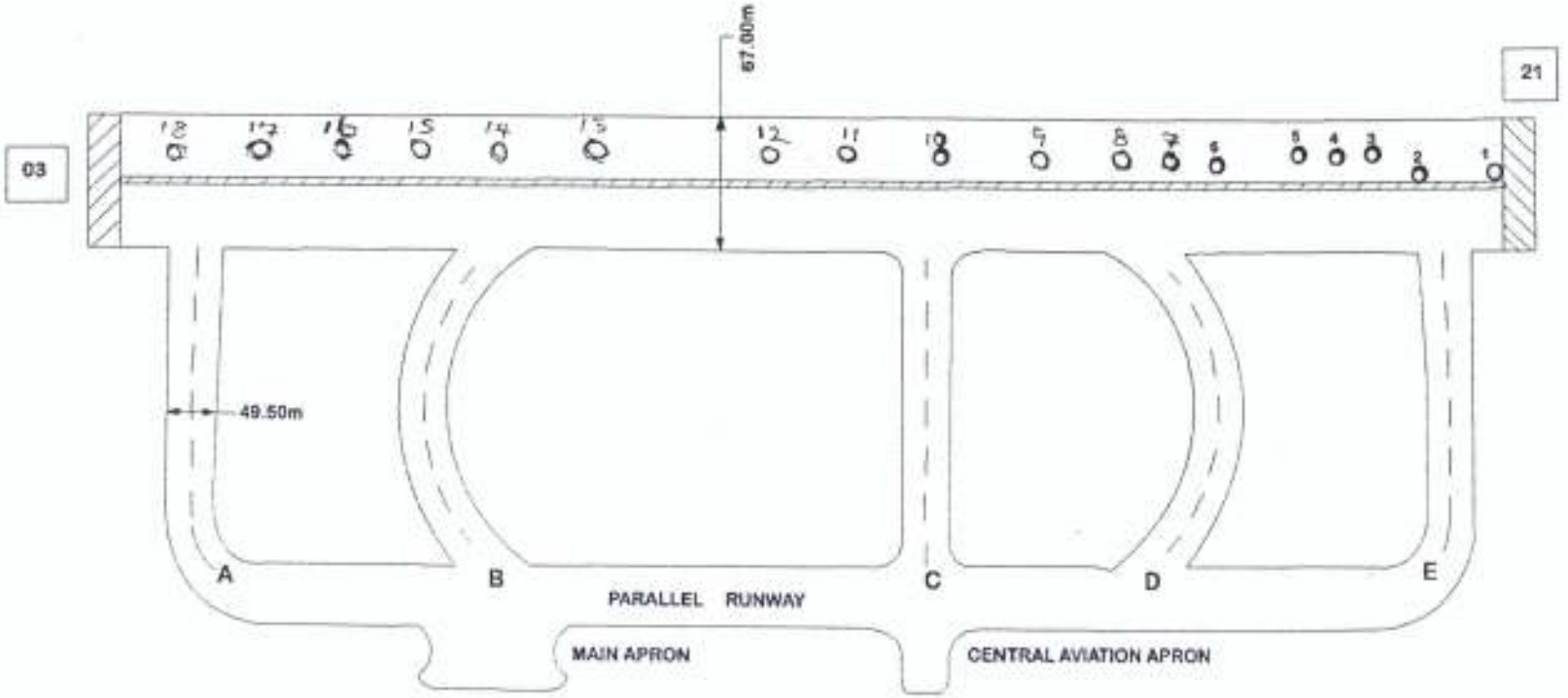
The summary of the result of the coring and DCPT tests are provided in fig. 4.2 and the tests are in Appendix 1.



LEGEND:

- BOREHOLE LOCATIONS (7 Nos)
- CENTRE LINE (EXITS)
- CENTRE LINE (RUNWAY)

FIG. 3.3

3.1 CRM procedure

The CRM operation is carried out by rotary drilling method after completely assembling the machine with its accessories; the machine is put on and checked for stability and balance. The drill rotates a hollow rod [drill string] and at the same time exerts a controlled axial thrust. At the bottom of the drill string is a core barrel with diamond or vidium bit. The core bit depends on the hardness and type of the rock to be cored. The bit used is of 101mm diameter with core barrel of 1.2m long.

The flushing medium is water, which is being supplied through triplex pump. The pump is of positive acting pump of high pressure sufficient enough to clear blockages in the cutting bit in order to avoid burning – up in extreme cases. The machine pumps sufficiently fast for the rock cuttings to be washed up the hole and prevent them from falling back and jamming the core barrel. The relative diameter of the drill rods, hole diameter together with the pumping rates determine the velocity of the hole. The pumping rate is varied to tally with different formations.

In broken formations [soil strata], dry coring is employed viz – a viz [coring without air or water thrust system]. The bit cuts an annular section of the rock as it descends; the cored rock enters the core barrel where it is retained by a core spring. When a core barrel is full or a run is finished, the core is broken off and the rods and core are lifted out from the core hole using the appropriate lever on the machine.

At the end of the operation, the core barrel is dismantled using the spanner of 101mm size or corresponding size depending on the size of the barrel. After which the core is removed and stored in a core box for examinations.

3.2 The Dynamic Penetration Test Procedure

After a complete assembly of the testing equipment, connect a cone shaped dynamic point to the sounding tube. Then screw the cone shaped element for tube connection to the free top of the tube after having inserted the 28mm diameter center square, the top vice and the knurled metal ring

Position the tube and lower the driving head. Screw the knurled ring to the anvil.

Before operation, the hammer rate is adjusted to approximately 60blows/minute; it may be reduced by decreasing motor speed.

The data to note in dynamic sounding is just the number of blows necessary for each 10cm subsequent driving: the guide holes, spaced 10cm can be taken as reference.

When the point [or one rod] is completely down to add a new sounding tube rod, then;

- Completely unscrew the knurled metal ring
- Raise the driving head helping with the winch
- Unscrew the cone – shaped element for anvil / sounding tube connection
- Screw a new tube and tighten strongly.
- Screw the knurled metal ring

- Continue the operation as before
- To end, when it becomes impossible to go on with the dynamic driving of the point, it is recommended to interrupt the sounding operation. In fact, in this case, the point has met an obstacle that cannot be overcome.

At the end of operation, open the rod stop vice adjusting the relevant closing motion for rod extraction. Restore the anvil – sounding battery coupling. The rods are extracted using the winch or the piston device. All the core holes [100mm diameter] were back filled with concrete mix made of sand, chipping, cement and water mixed in excellent good proportion so as to give room for the immediate use of the runway

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Site/Visual Inspection- Runway 03/21 and associated taxiway exits were inspected and the principal distress types observed in the order of importance and extent were as follows

Alligator cracks: These cracks were due to fatigue failure; load associated and indicated the end of the life of pavement at specific locations. These cracks were extensive near the entrance to runway 03 along the wheel tracks at a distance of 7.10m on either side of the runway centre line and at taxiway exist.

This distress was not surprising at Port Harcourt Airport Runway as the asphalt layer was more than 20years old and fatigue failure at locations of stress concentration was normal, especially at curve entrances and exits

Aging cracks and Open Lane Joints- The wearing course had aged and showed closely spaced block cracks in addition lane joints had opened due to shrinkage.

These were to be expected due to the age of the pavement (>20years). Although the surface layer of the existing pavement can be considered as a base layer during the upgrading

Local Shear Failures excessive horizontal shear stresses-At specific locations, such as near runway end 21 and on the apron taxiway, local shear failure had occurred in the wearing course. These were concentric cracks due to aircraft movement and braking.

Such failure was an indication of low stability, low interface bonding and low compaction of the surface layer.

Rubber Deposits at touchdown areas -Extensive rubber deposits had occurred at runway 03 Touch Down Zone area and to a lesser extent at the touch down zone area of runway 21.

a rubber deposit prevents proper adhesion when an overlay is placed and could lead to shear failure. At Touch Down Zone areas, braking aircraft introduces extensive horizontal shear stresses

4.2 ESTIMATION OF THE PAVEMENT CONDITION INDEX [PCI]

. The PCI of each sample was calculated and recorded as shown in feature summary sheet Table. 14. The average of the PCI for the feature was calculated by adding all the PCI's of the twenty six (26) sample unit for Port-Harcourt runway pavement then divide the total PCI by the total number of the sample unit which is (26). To obtain the rating condition the calculation is;-

Total unit sample = 26

Total PCI = 936

Average PCI = 936/ 26 = 36

Perfect PCI= 100, from the bar chart in fig.3.2, 25-40, 36 represents poor condition and the average PCI got for Port-Harcourt was 36 which showed that the condition of the runway rating is poor. See Table 15 for the percentage summary of pavement condition index and rating which can also be represented in a bar chart form in fig.4.1 for Port-Harcourt International Airport while other Airports are in appendix.2

TABLE 14: SUMMARY OF FEATURE RUNWAY 03/21, PORT-HARCOURT

Airport: Port Harcourt

Airport Facility: Runway 03/21

Total No. of sample units: 26

Sample Unit No.	Sample Unit Area, sq.	PCI	Sample Unit No.	Sample Unit Area, sq.	PCI
1	450	45	14	440	27
2	450	43	15	450	32
3	450	22	16	450	29
4	450	48	17	450	42
5	450	35	18	450	35
6	450	43	19	450	36
7	450	36	20	450	27
8	450	39	21	450	36
9	450	47	22	450	33
10	450	26	23	450	39
11	450	41	24	450	23
12	450	33	25	450	44
13	450	28	26	450	43
		486			446

Average PCI for feature: 36

Rating Condition: poor

TABLE 15: SUMMARY OF PAVEMNT CONDITION PERCENTAGE INDEX AND RATINGS

PCI/Rating	Airport Runway Rating, %			
	Lagos 01L/19R	Abuja 04/22	Kano 06/24	Port-Harcourt 03/21
85-100 (Excellent)			92.30	
70-85 (very Good)			7.70	
55-70 (Good)		53.60		
40-55 (Fair)		46.40		34.60
25-40 (Poor)	30			53.80
10-25 (Very Poor)	70			11.50
0-10 (Failed)				

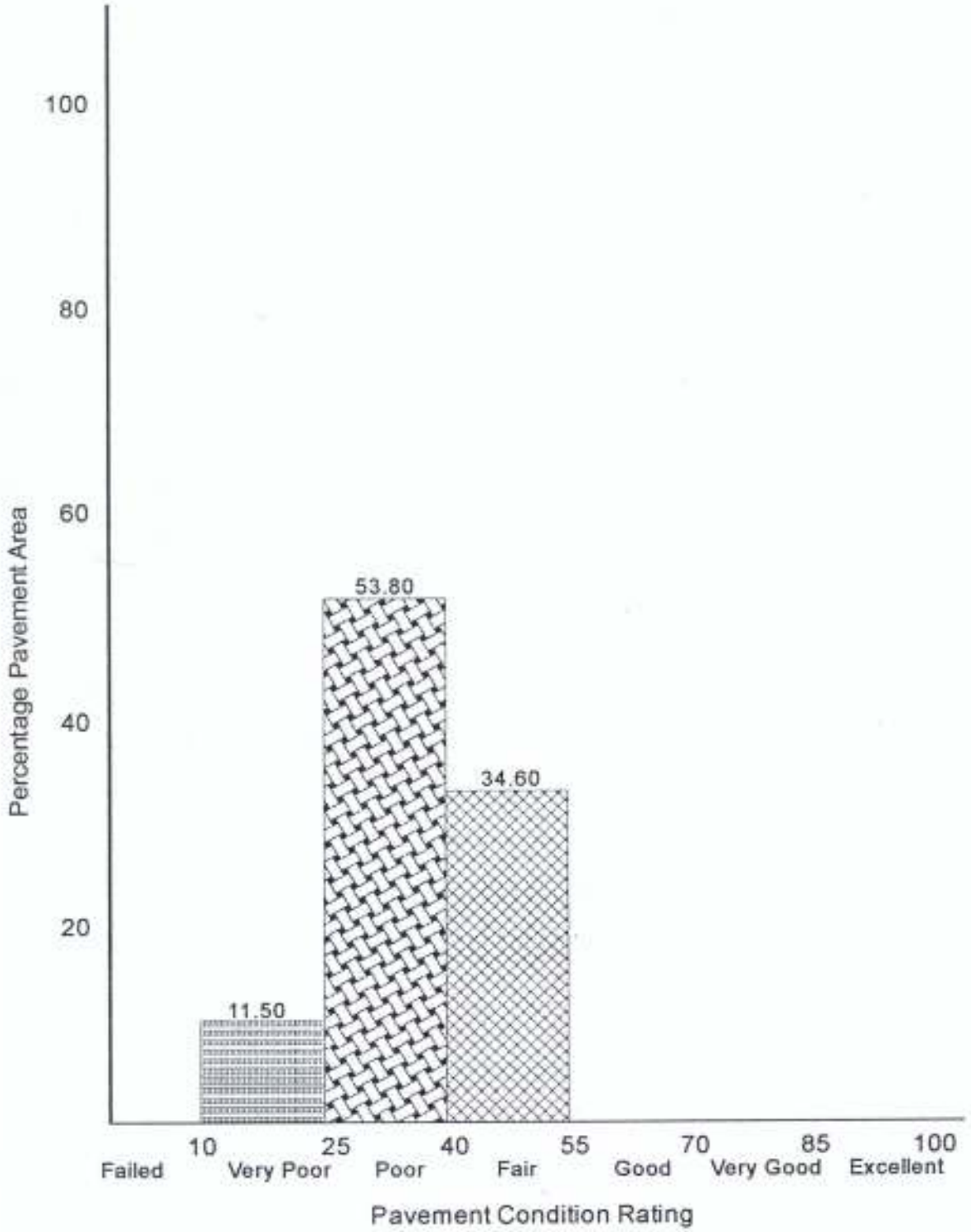


Fig.4.1 Pavement Condition Rating For Port Harcourt Runway(03/21)

.Estimation of average pavement index values showed that the rating conditions for the Airport pavements using the guidelines in [Fig3.2] [Perfect PCI] is shown as follows:-

Lagos Runway	PCI 23	Very poor
Abuja Runway	PCI 57	Good
Kano Runway	PCI 94	Excellent
Port-Harcourt Runway	PCI 36	Poor

Using the individual PCI values in tables 11 through 14 in the Appendix 2, the ratings were computed, the percentages of the pavement areas falling within each rating, group or category were computed as shown in the summary sheet in Table 15 above. The above results indicated that 30 percent of Runway 36L/18R of Lagos Runway is poor while 70 percent is very poor. For Abuja Runway 04/22, 53.6 percent is good while 46.40 percent is fair, for the newly rehabilitated Kano Runway 06/24, 92.3 percent is excellent while the remaining 7.7 percent is good. Port-Harcourt Runway 03/21 has 34.6 percent fair and 53.8 percent poor while 11.5 percent is very poor in rating.

Based on the above findings, the Airport pavements in Lagos and Port-Harcourt should be rehabilitated urgently to avoid a total closure.

4.3 TEST RESULTS FROM DYNAMIC CONE PENETRATION.

4.3.1 subsoil and Ground Water Conditions

4.3.2 Subsoil condition

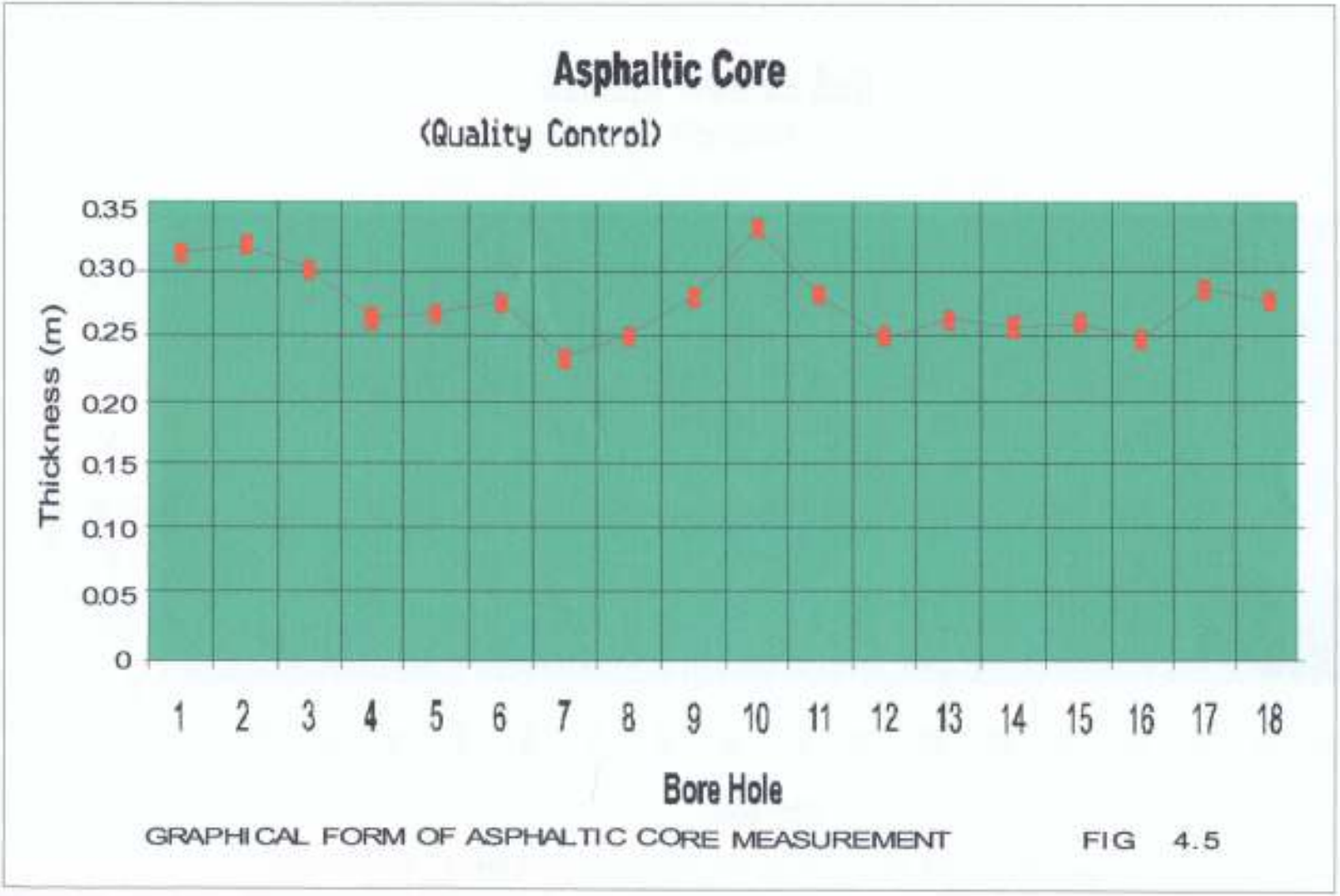
The summary of the subsoil profile at the cored locations are as presented in the table titled measurement of thickness [m] in fig.4.2 which is also represented in a graphical forms.

PROJECT : Sub soil Testing / Pavement Investigation .Summary
LOCATION : PORT HARCOURT AIRPORT

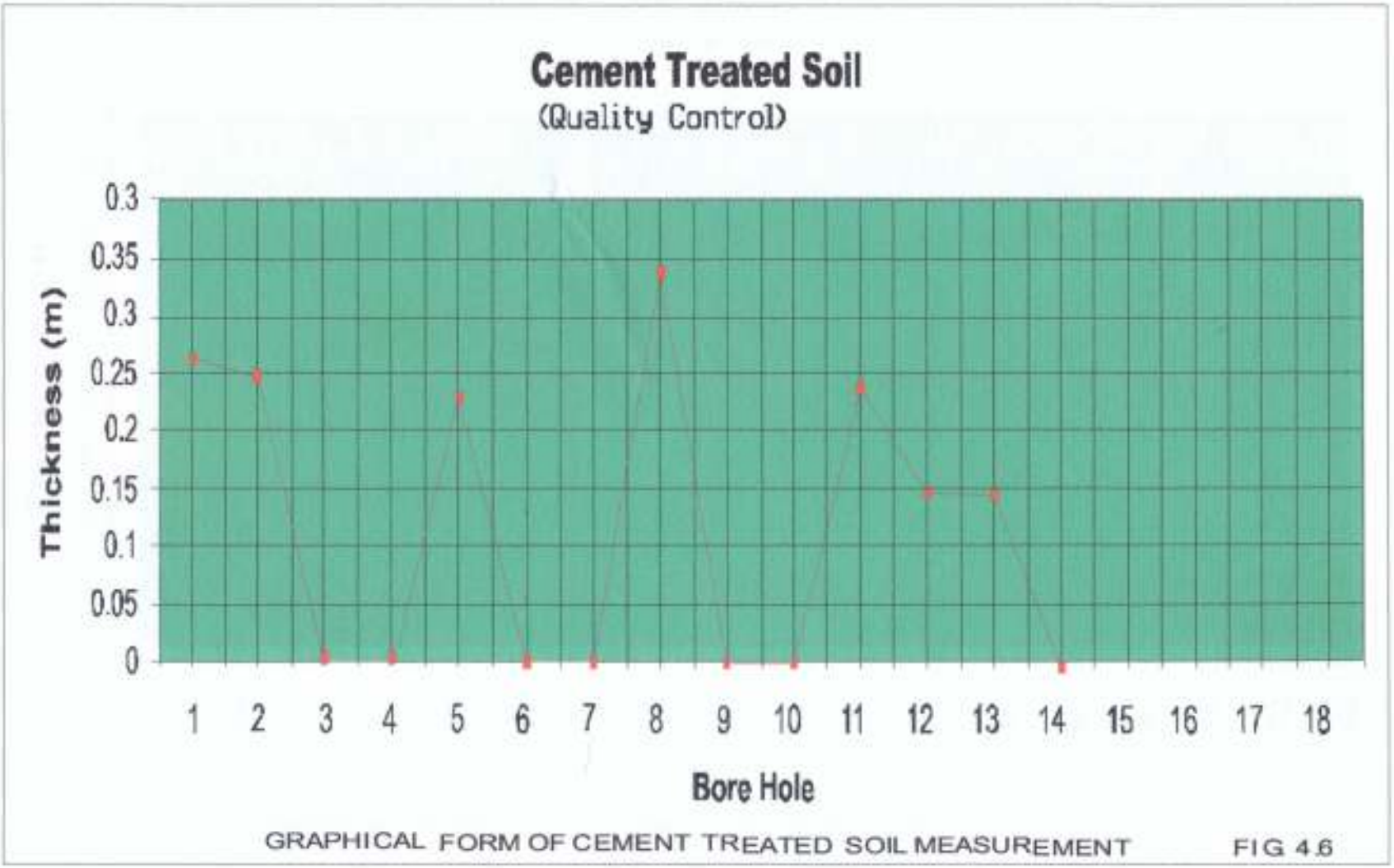
MEASUREMENT OF THICKNESS (m)

Bore Hole NO.	Asphaltic Cores	Cement Treated Soil	Sub- Grade
1	0.310	0.260	0.430
2	0.318	0.244	0.438
3	0.300	0.000	0.700
4	0.260	0.000	0.740
5	0.263	0.232	0.505
6	0.273	0.000	0.727
7	0.230	0.000	0.770
8	0.248	0.340	0.412
9	0.280	0.000	0.720
10	0.330	0.000	0.670
11	0.280	0.240	0.480
12	0.245	0.150	0.605
13	0.260	0.150	0.590
14	0.256	0.000	0.744
15	0.258	0.000	0.742
16	0.245	0.000	0.755
17	0.285	0,000	0.715
18	0.277	0.000	0.723

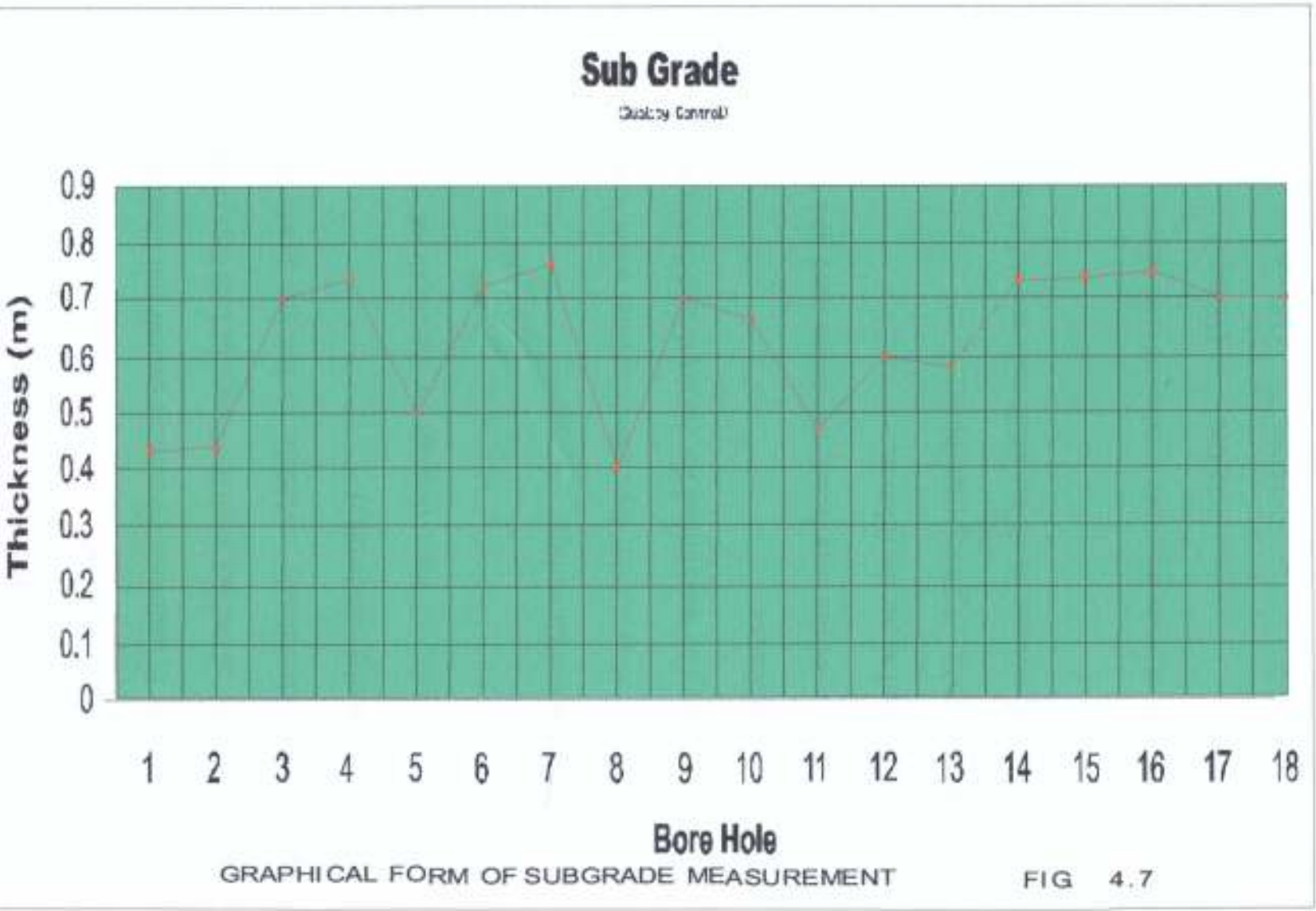
Fig.4.2



GRAPHICAL FORM OF ASPHALTIC CORE MEASUREMENT FIG 4.5



GRAPHICAL FORM OF CEMENT TREATED SOIL MEASUREMENT FIG 4.6



GRAPHICAL FORM OF SUBGRADE MEASUREMENT FIG 4.7

From the logs, all the points tested consist of asphalt of varying thickness [but not less than 10cm at any given point]

The above layer is underlain by cement treated soil usually orange brown silty sandy clay in some places and not at all the locations [see logs in appendix.1]

This layer is immediately underlain by the sub grade [brown silty, sandy, clay / blackish brown silty, sandy clay].

For the DCP tests, all went through to the depth of -2.00m below the pavement structure.

4.3.3 Ground Water Condition

At all points cored to -1.00m depth, underground water was not encountered, thus, the water level cannot be ascertained for the depth and duration of the investigations.

4.3.4 Sub grade Support

In the DCP tests of the core holes, the cones used had an angle of 60 degrees. The CBR is computed as per the relation,

Log (CBR) = 2.632 – 1.28 log (mm/blow)

The CBR computations of all the DCP tests are valid up to 3m below the pavement surface..

The insitu CBR at insitu moisture conditions is as below:

Average value	=	76.0%	(18tests)
Standard deviation	=	26.7%	(18tests)

85% value = 49.3% at insitu moisture content

= 25.0% soaked condition (50% of insitu)

If soaked conditions are assumed, the soaked CBR value will be approximately 25%, this is half the insitu CBR value. This indicates excellent sub grade support, which is also due to the presence of lateritic sub grade below the base course

4.3.5 Existing Pavement

18 bore hole logs were analyzed and the asphalt layers are brittle and aged (more than 23 years) for pavement analysis and new overlay computations, the existing asphalt layer is considered as conventional aggregate base. Hence, the existing structural layers can be represented as below:

Existing asphalt concrete layers as aggregate base

= 112mm

Existing aggregate base

= 204mm

Total base = 316mm.

Hence, the existing pavement can be re-written as

Existing aggregate base = 316mm
Sub base (minimum) = 250mm
Subgrade insitu CBR >15 - 20

4.4 PAVEMENT STRUCTURAL UPGRADING/ DESIGN/REHABILITATION

The tests carried out showed that both the subgrade, subbase and base were in excellent condition except part of the base and the asphalt wearing course which was as a result of age and as a result of this some parts of the asphalt wearing course was used as base hence the design for the upgrading.

For pavement design, departing aircraft are critical and is assumed to be at Maximum Take Off Weight [MTOW]. This assumption compensates for the landing aircraft which has a considerably lower weight, and in line with FAA-USA recommendations [reference 2]

In order to designate one design aircraft for pavement upgrading for Port- Harcourt runway pavement, aircraft types operating at Port-Harcourt Airport were examined for their contribution to pavement damage. This pavement damage was computed based on the Aircraft classification Number [ACN] and corresponding number of movements as seen in Fig.4.6

Therefore a Boeing 747-400 at 396 tons MTOW was designated as the Design Aircraft for the pavement Rehabilitation Design for Port-Harcourt International Airport runway. This aircraft has an ACN = 57 for sub grade category "A" i.e. CBR > 15and the number of equivalent B747-400 departures for the year 2006 was 255 and the total aircraft departures for the 2006 was 1166.

For the pavement upgrading of Port-Harcourt runway with code 03/21, a design Traffic of 2000 equivalent B747-400 departures per year was recommended for pavement design of 20 years.

The design traffic for 20 years for runway 03/21 is 20x2000 = 40,000 equivalent B747- 400 departures per year at 396 tons MTOW.

In order to accommodate this future traffic at runway 03/21, a structural overlay was required as shown below. See cross section 3 in the appendix 3/1

AC Surface course – 130mm – new overlay
Existing pavement (equivalent Base) – 316mm
Existing Sub base – 250 – 500mm

Project: PHC runway overlay Location: Runway 03/21 Date: 25/02/06		

Details of design aircraft:

Number in list below: 1
Design aircraft: B-747-400
Weight: 396000kg
ACN: 57FLEXIBLE
SUB GRADE: A High strength sub grade
Period of traffic: 1 year 2005

	AIRCRAFT TYPE	WEIGHT KG	ACN FLEX	SUBG (at)	ANNUAL MOVEMENTS	DEP/ARR	TOTAL MOVEMENT	EQUIVALENT DEPARTURES
1	B747-400	396000	57	A	255	D	255	255
2	B-767	179000	48	A	112	D	99	76
3	B-757	110000	29	A	99	D	99	27
4	B-727-200	95500	53	A	327	D	327	252
5	B-727-300	65000	35	A	154	D	154	52
6	A-300	165000	49	A	175	D	175	120
7	A-310-200	14200	40	A	102	D	102	48
8	BAC-1-11	47400	29	A	437	D	437	76
9	MD-11	275000	64	A	190	D	197	260
		TOTAL	1851			1858		1166

Fig.4.6

4.5 Introduction of Asphalt Crack Relief Layer (CRL)

The climatic condition of Port-Harcourt was considered during the design which necessitated the introduction of the crack relief layer due to its specific functions to the runway pavement.

Crack Relief Layer (CRL) is a gap graded stone reach mix with at least 20% air voids at a binder content of 3-3.5%.It is made up of 100 percent crushed material, placed as an interlayer between base course and asphalt concrete surface course. The aggregate size to be used is 25mm- maximum size. The mix is extremely stable against shear, virtually incompressible and relatively cheap. The large amount of air voids help in preventing the occurrence of reflective cracks. Based on the above analysis, the new structural upgrading will consist of two layers of asphalt overlay as shown below which consists of a Crack Relief Layer and an Asphalt Surface Course. At the keel section, the thickness is 70mm CRL and 60mm ACSC which tapers to the pavement edge as shown on the section in appendix.3. The CRL layer must be properly drained and the pavement edges have to be day lighted to allow for free flow of any infiltrated water out of the pavement. Based on the introduction of CRL in this rehabilitation, the new overlay thus becomes as shown below.

AC Surface course – 130mm – new overlay
Existing pavement (equivalent Base) – 316mm
Existing Sub base – 250 – 500mm

The new layer with CRL thickness

AC Surface course – 60mm

Asphalt Crack Relief Layer (CRL) – 70mm

Existing Pavement

Although there are some disadvantages in the application of Crack Relief Layer (CRL) and these are-;

(a) Bonding is usually low as a result of low bitumen and low fine which can easily lead to segregation.

(b) It is not meant to be laid and exposed for a long period of time.

(c) Laying and compaction need experienced professionals to avoid water seepage into the base course

4.6 PROPOSED COST EFFECTIVE METHOD OF RUNWAY PAVEMENT MAINTENANCE SYSTEM

For a proper record keeping on the runway pavement which in turn leads to cost effectiveness in terms of maintenance, the following must be observed-

4.6.1(a) Design Pavement Data

A form such as Fig 4.7 includes the history of all Airport pavements, from original construction to the most recent changes and additions, such as that of Port-Harcourt Airport runway rehabilitation. Also the history of the surface of the pavement which includes, thickness, strength, base, subbase and subgrade will be determined.

_____AIRPORT

DESIGN PAVEMENT STRUCTURAL DATA **REVISED: _____**

FACILITY: _____LOCATION, OR SECTION DESIGNATION FROM LAYOUT: _____

CONSTRUCTION DATE	DESIGNED BY	PAVEMENTS SURFACE TYPE/THICKNESS / STRENGTH	BASE TYPE/THICKNESS/ STRENGTH	SUBBASE TYPE/THICKNESS/ STRENGTH	SUBGRADE TYPE/STRENGTH

Figure 4.7. Design pavement structural data

4.6.2(b) Pavement Structural Evaluation Summary

If possible or if it is available, a summary of the last structural evaluation data would be provided see Fig 4.8. The important aspect of this section is that the maximum allowable load the pavement can sustain and the weight of the operating aircraft would be determined.

_____AIRPORT

PAVEMENT STRUCTURAL EVALUATION SUMMARY

FACILITY	LOCATION	DATE OF EVALUATION	TYPE OF EVALUATION	EVALUATED BY	ALLOWANCE LOAD (AIRCRAFT, LOAD, DEPARTMENT	THICKNESS AND TYPE OF OVERLAY RECOMMENDED

Figure 4.8. Pavement structural evaluation summary

4.6.3(c) Pavement Maintenance Records

When, where and what type of maintenance has been performed (see Fig. 4.9). The important thing about this is the location where the maintenance would be performed is captured, date performed as well as by who, it goes on to determine the type of maintenance performed and the reason.

_____AIRPORT

CHRONOLOGICAL PAVEMENT MAINTENANCE RECORD

FACILITY	LOCATION	DATE PERFORMED	PERFORMED BY	TYPE MAINTENANCE	REASON FOR MAINTENANCE

Fig.4.9 Pavement maintenance record

4.6.4(d) Aircraft Traffic Data Survey

The type of aircraft, typical gross loads, and airport facilities most likely used by the aircraft and the frequency of operation see Fig. 4.10 with these information available, adequate maintenance plans would be drawn.

TRAFFIC DATA SURVEY _____ **AIRPORT**

TYPE OF OPERATION	AIRCRAFT OPERATOR	TYPE OF AIRCRAFT	FACILITY MOST FREQUENTLY USED			TYPICAL GROSS WEIGHT	DEPARTURES PER DAY
			RUNWAY	TAXIWAY	APRON		
AIR CARRIER							
COMMUTER							
CARGO							
MILITARY							

FIGURE 4.10 Traffic data survey

The advantages of this is;-

(1) It schedules maintenance in terms of location, period and need instead of at random maintenance.

(2) It determines the actual load of each aircraft that operates in the airport that is if the Aircraft classification number (ACN) is equivalent to the pavement condition number (PCN) of that particular runway pavement.

(3) It enables one to know the type of material(s) to be used during each maintenance/ rehabilitation thereby reducing cost of maintenance/rehabilitation.

CHAPTER FIVE

5.0 CONCLUSION

The purpose of this study is to assess the operational surface condition of the selected airports runway pavement in Nigeria and determine the serviceability rating (s), the methodology adopted helped in the identification of various distresses associated as well as the revelation of the ratings of each of the airport runway pavement. As a result of further analysis carried out using the method of the pavement condition index (PCI) the rating (s) of each airport runway assessed was revealed with Lagos and Port-Harcourt airports having the PCI of 23 and 36 respectively which represents poor and very poor in rating measuring from the prefect PCI of 100, this calls for an urgent rehabilitation of the two airports.

Further tests were also carried out in Port-Harcourt Airport runway pavement which is the case study and the geo technical information determined, this was used for the design of the rehabilitation work. With the combination of these results, the cost effectiveness of future runway pavement maintenance/ rehabilitation was proposed.

Based on these facts, this study has been able to the best of my knowledge achieved its primary purpose that is the determination of serviceability rating (s) of the International Airport runway pavements in Nigeria.

6.0 RECOMMENDATONS

Based on the above findings the following recommendations were made. Prior to overlay, the following preparatory works are necessary-;

Crack Repair

All cracks wider than 6mm should be filled with a fine asphalt mix repair material. This is normally made of one part of RC-3/MC-3 plus three parts of fine sand, plus 1% of Portland cement by weight of sand. The mix should have a pouring consistency; the addition of cement allows the mix to harden within a reasonable time.

Removal of Areas of Existing Wearing Course

At locations of alligator cracks as described in chapter three, the existing Wearing Course has to be milled to a depth of approximately 40mm and replaced with a similar thickness of Asphalt Surface Course/Wearing Course. The same treatment applied to areas of shear failure such as at Runway End 21 and the apron taxiway. (See in appendix 4/2)

While patching such areas, it is very important to apply a Tack Coat of straight bitumen PEN60/70 instead of Cutback such as RC-3 or MC-3, because it creates a better adhesion.

Removal of Rubber Deposit and Paint Markings

In order to ensure a good bond between the existing asphalt surface and the new overlay, rubber deposit areas and large paint marking areas such as Touch Down Zone (TDZ) should be milled to a depth of 5-10mm.see Appendix 4/3for the construction work on site.

The Federal Airports Authority of Nigeria must adopt the system of maintenance/rehabilitation of these runway pavements as proposed in the fourth chapter of this study because this will not only save cost in terms of materials and equipment rather it will reduce the system of total closure of the entire runway whenever rehabilitation work is being carried out.

The maintenance/rehabilitation of Airport runway is a capital intensive venture therefore the Federal Government of Nigeria should endeavour to set aside special funds for a regular maintenance than the adoption of a total shutdown which causes a huge revenue loss to the operators and other stakeholders in the Airport.

Finally the Federal Airports Authority of Nigeria must train its maintenance Engineers/Technicians in order to keep them abreast with, the current materials, equipment, and trends that facilitate repairs/rehabilitation of Airport runway pavements.

The rehabilitation of Port-Harcourt airport which was used as a case study has since been successfully completed and put into operation.

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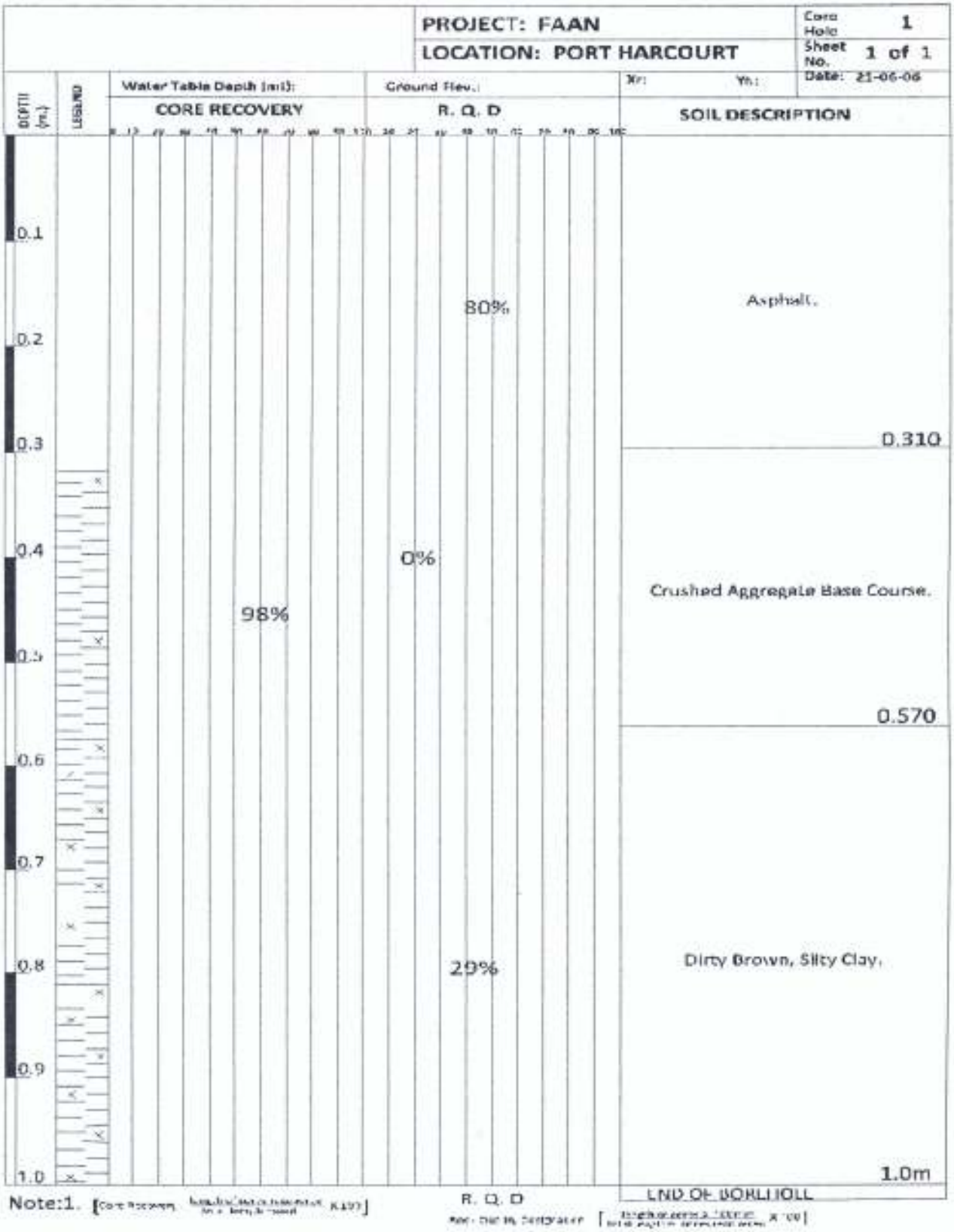
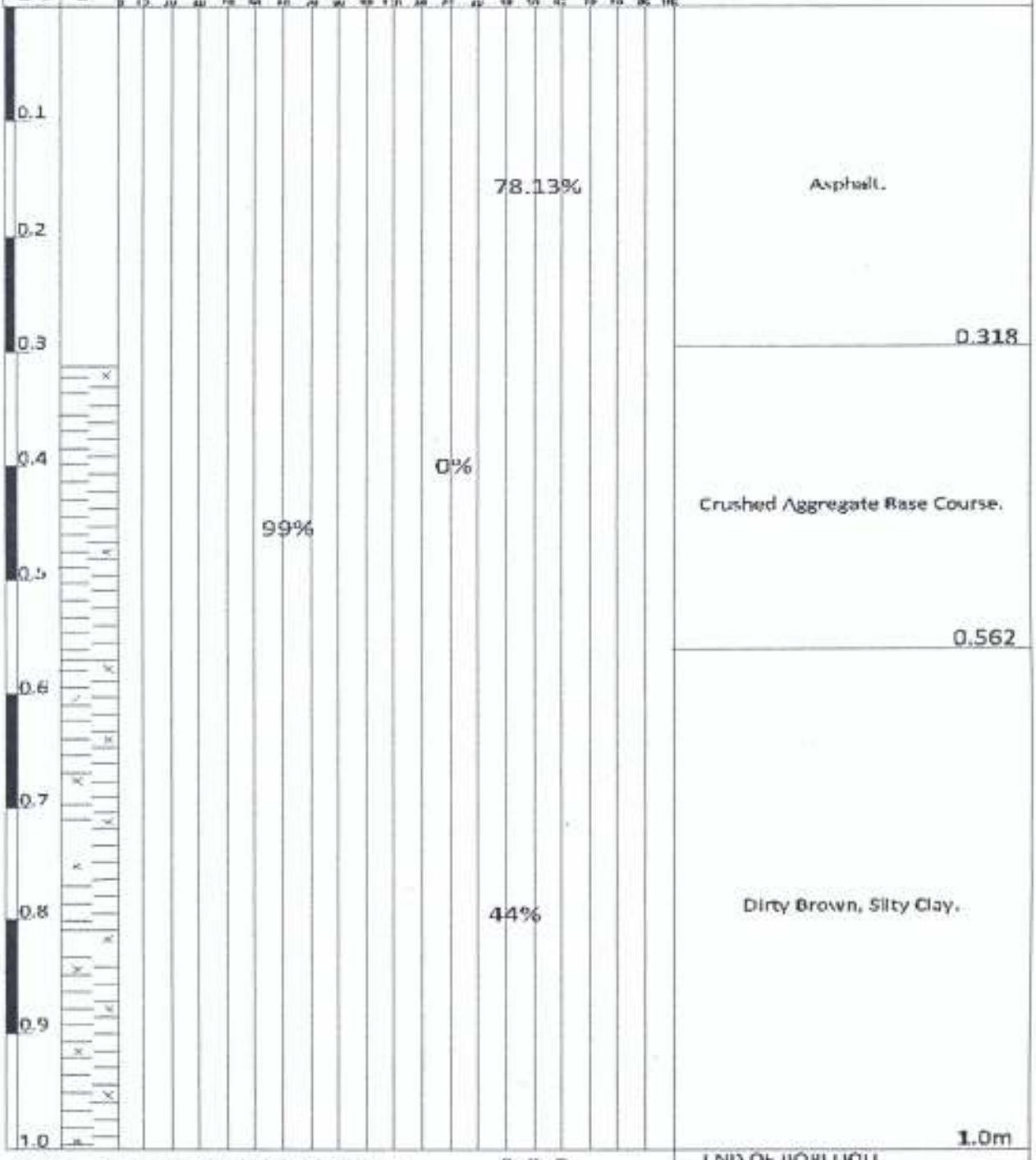
APPENDICES.

APPENDEX. 1

RESULTS OF THE DYNAMIC CONE PENETRATION TESTS (DCPT)

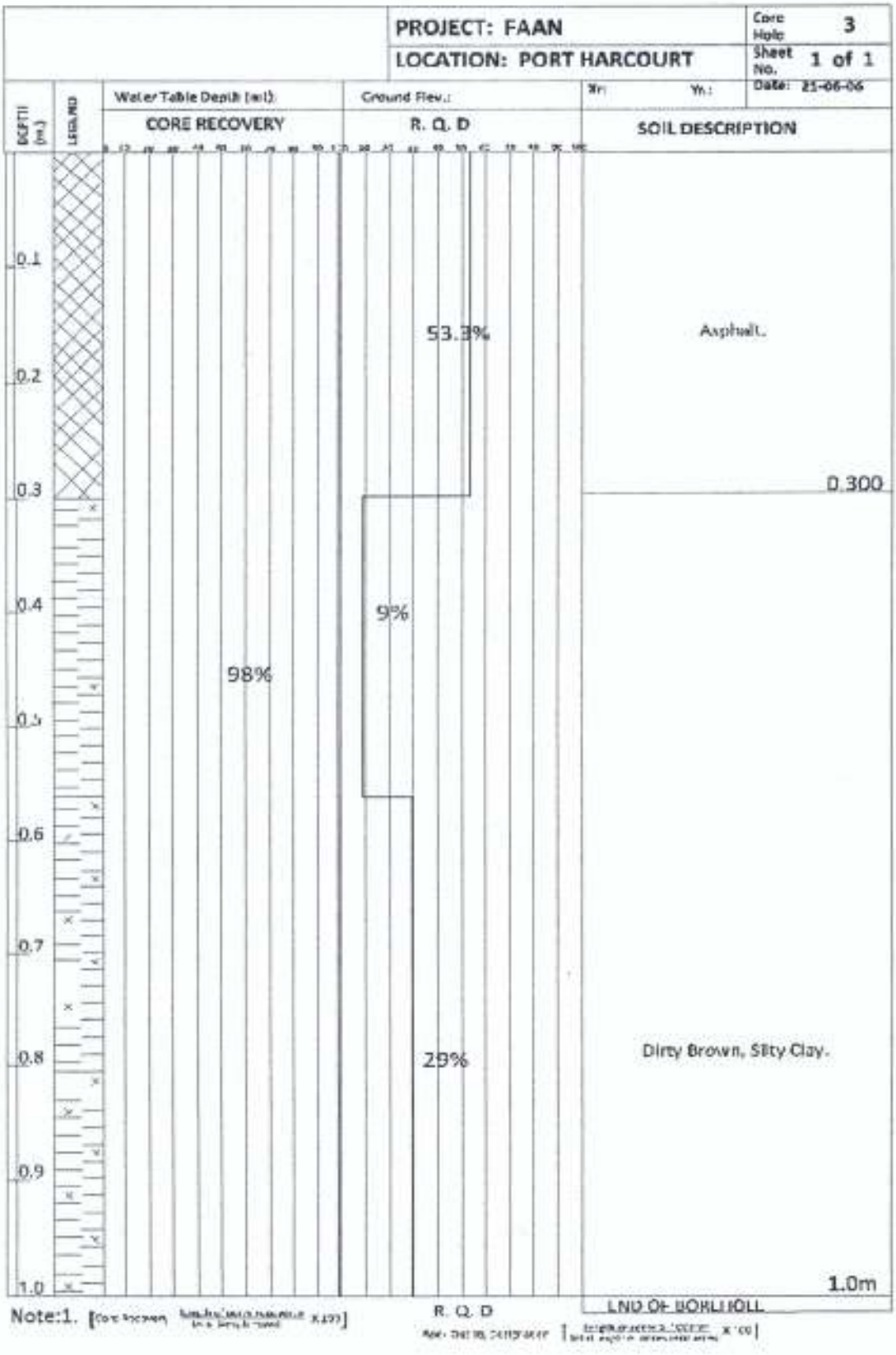

PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 1
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Flev.:
Xr:
Yr:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
80%
0%
98%
29%
Asphalt.
0.310
Crushed Aggregate Base Course.
0.570
Dirty Brown, Silty Clay.
1.0m
END OF BORELOLL
Note:1.
R. Q. D

	PROJECT: FAAN	Core Hole 2
	LOCATION: PORT HARCOURT	Sheet No. 1 of 1
Water Table Depth (m):	Ground Elev.:	Xr: Yh.: Date: 21-06-06



Note:1. [Core Recovery = Length of Core Recovered / Length of Core Run x 100]

R. Q. D = Sum of Lengths of Core Pieces ≥ 100mm / Length of Core Run x 100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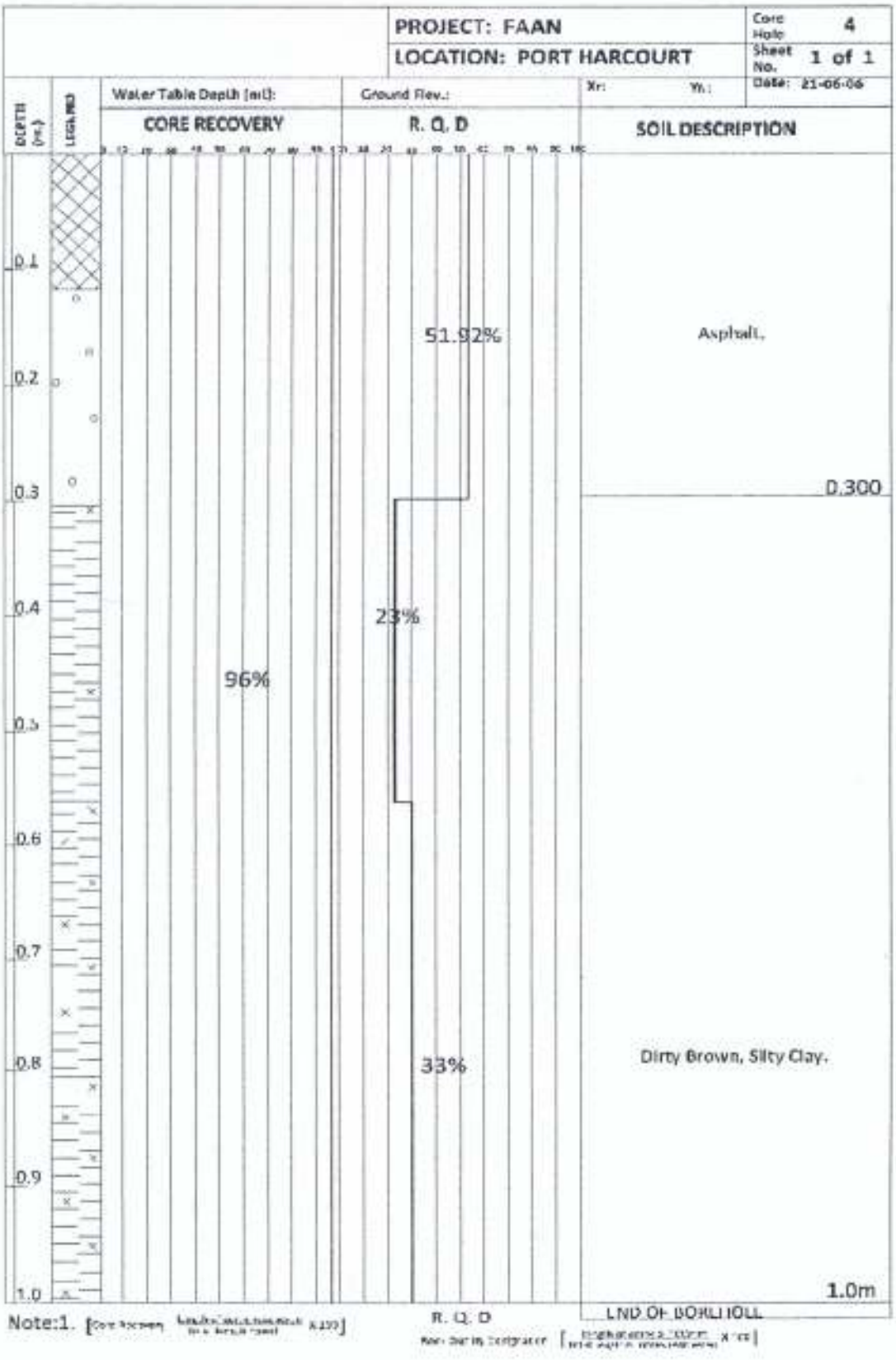
LOCATION: PORT HARCOURT
Core Hole 3
Sheet No. 1 of 1
Date: 25-06-06
Water Table Depth (m):
Ground Flev.:
Xn: Yn:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
53.3%
9%
98%
29%
Asphalt.
0.300
Dirty Brown, Silty Clay.
1.0m
END OF BOREHOLL
Note:1.
R. Q. D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LOCATION: PORT HARCOURT
Core Hole 4
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Elev.:
Xr: Yr:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
51.92%
23%
96%
33%
Asphalt.
0.300
Dirty Brown, Silty Clay.
1.0m
END OF BORE HOLE
Note:1.
R. Q. D

PROJECT: FAAN

LOCATION: PORT HARCOURT

Core Hole: 5

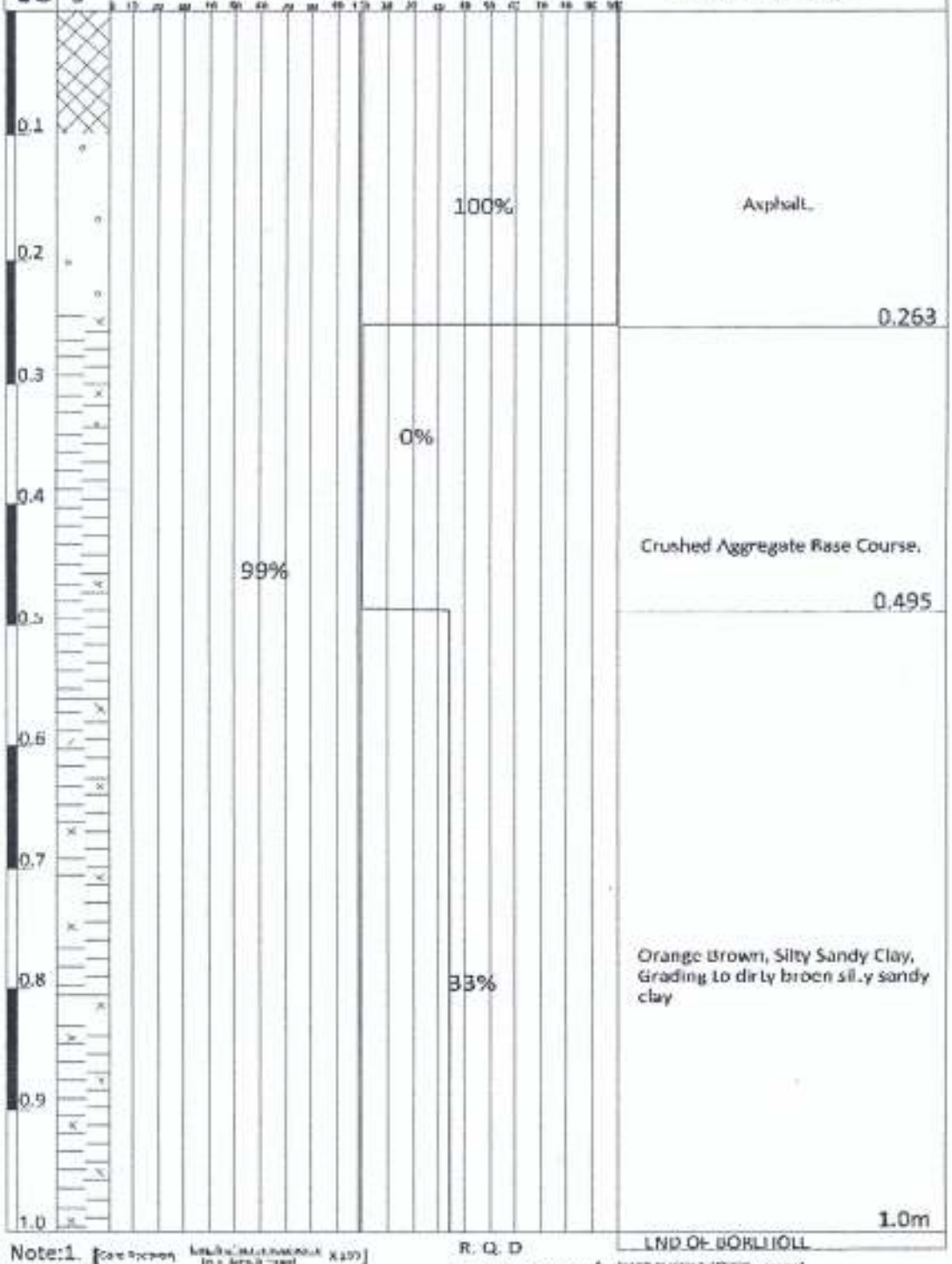
Sheet No.: 1 of 1

Date: 25-06-08

Water Table Depth (m):

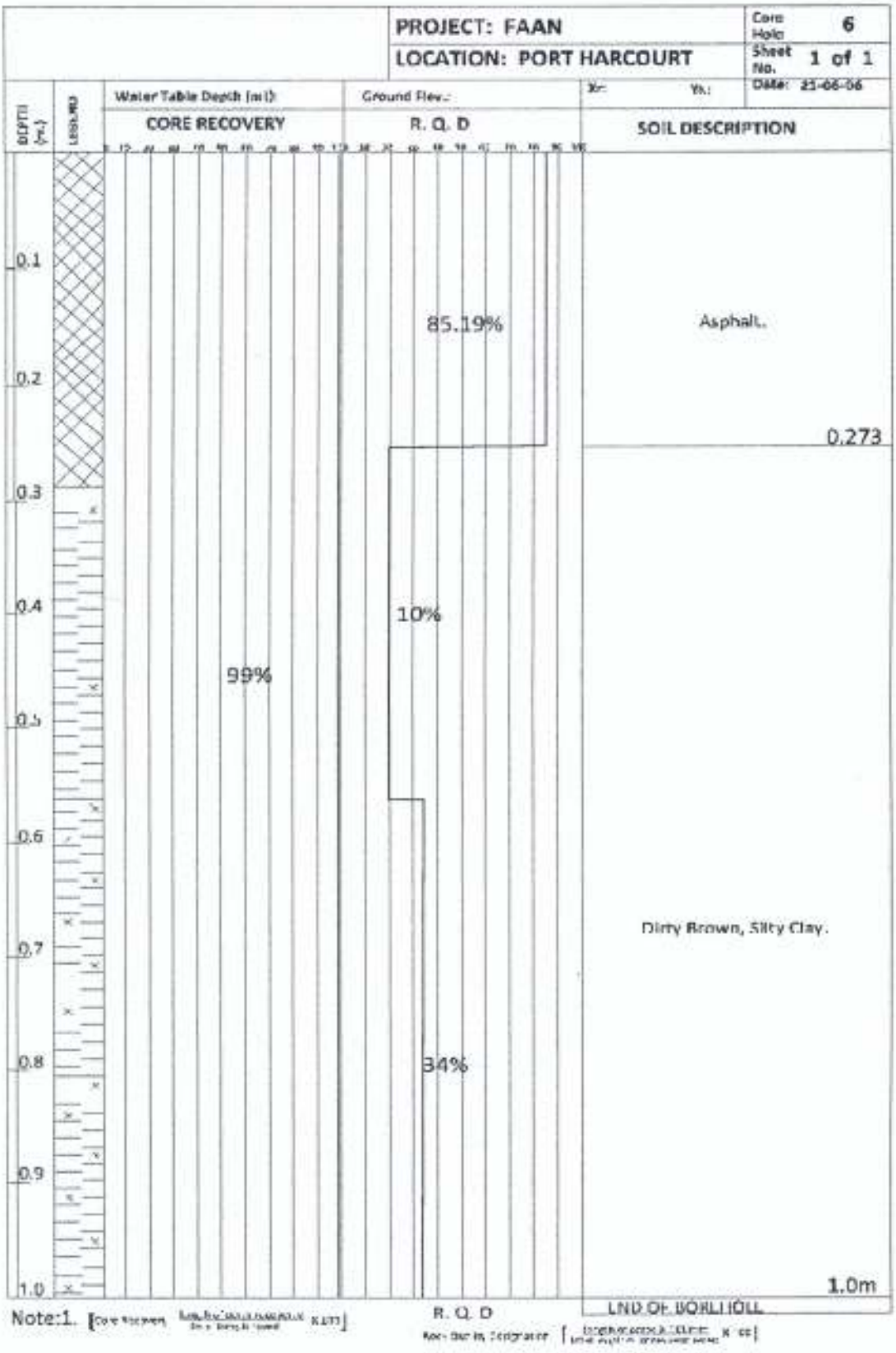
Ground Rev.:

Xr: Yr:



Note:1. [Core Recovery ... x 100]

R. Q. D [... x 100]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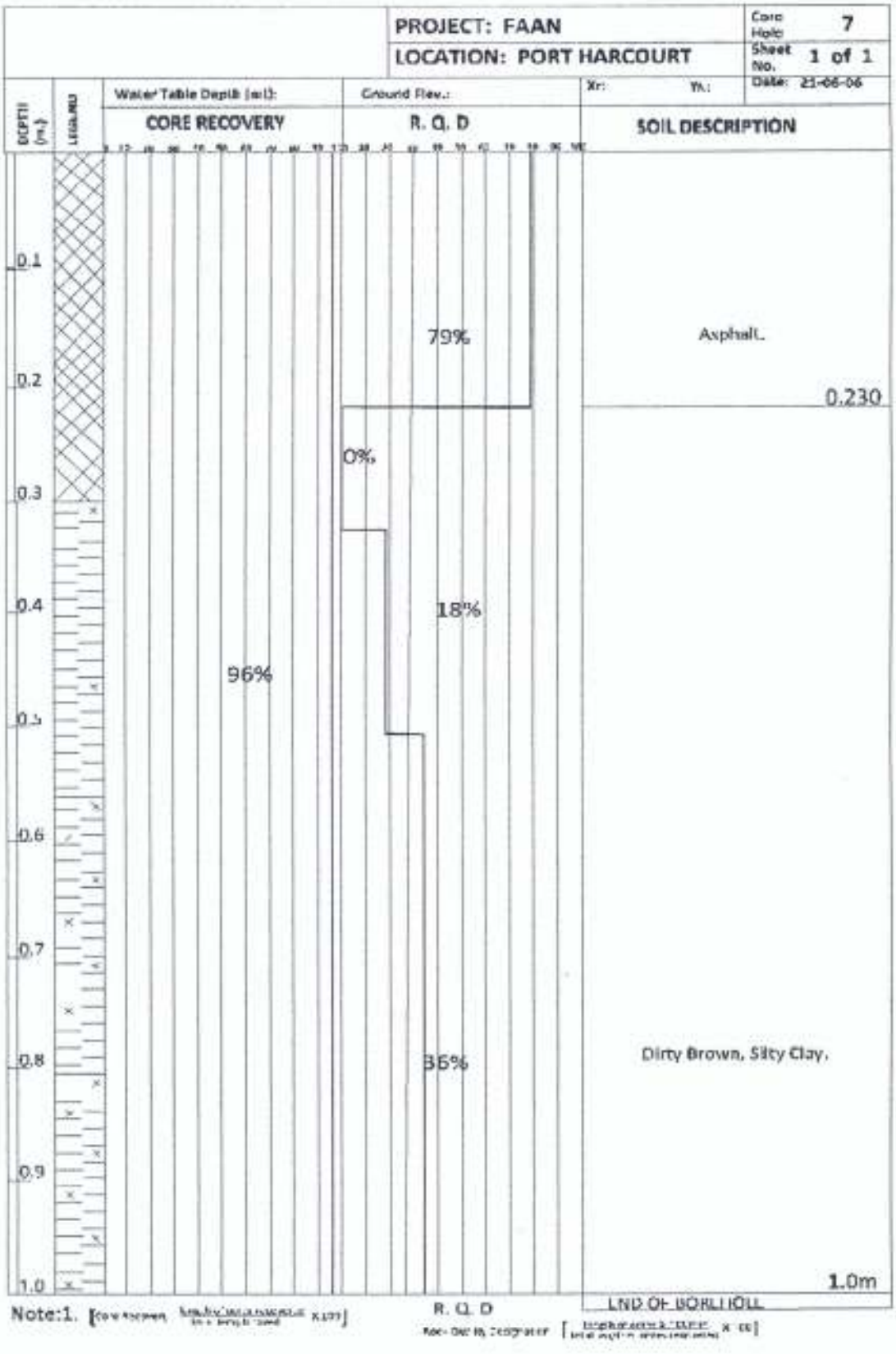
LOCATION: PORT HARCOURT
Core Hole 6
Sheet No. 1 of 1
Date: 23-06-06
Water Table Depth (m):
Ground Elev.:
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
DEPTH (m)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
85.19%
99%
10%
34%
Asphalt.
0.273
Dirty Brown, Silty Clay.
1.0m
END OF BORE HOLE
Note:1.
R. Q. D

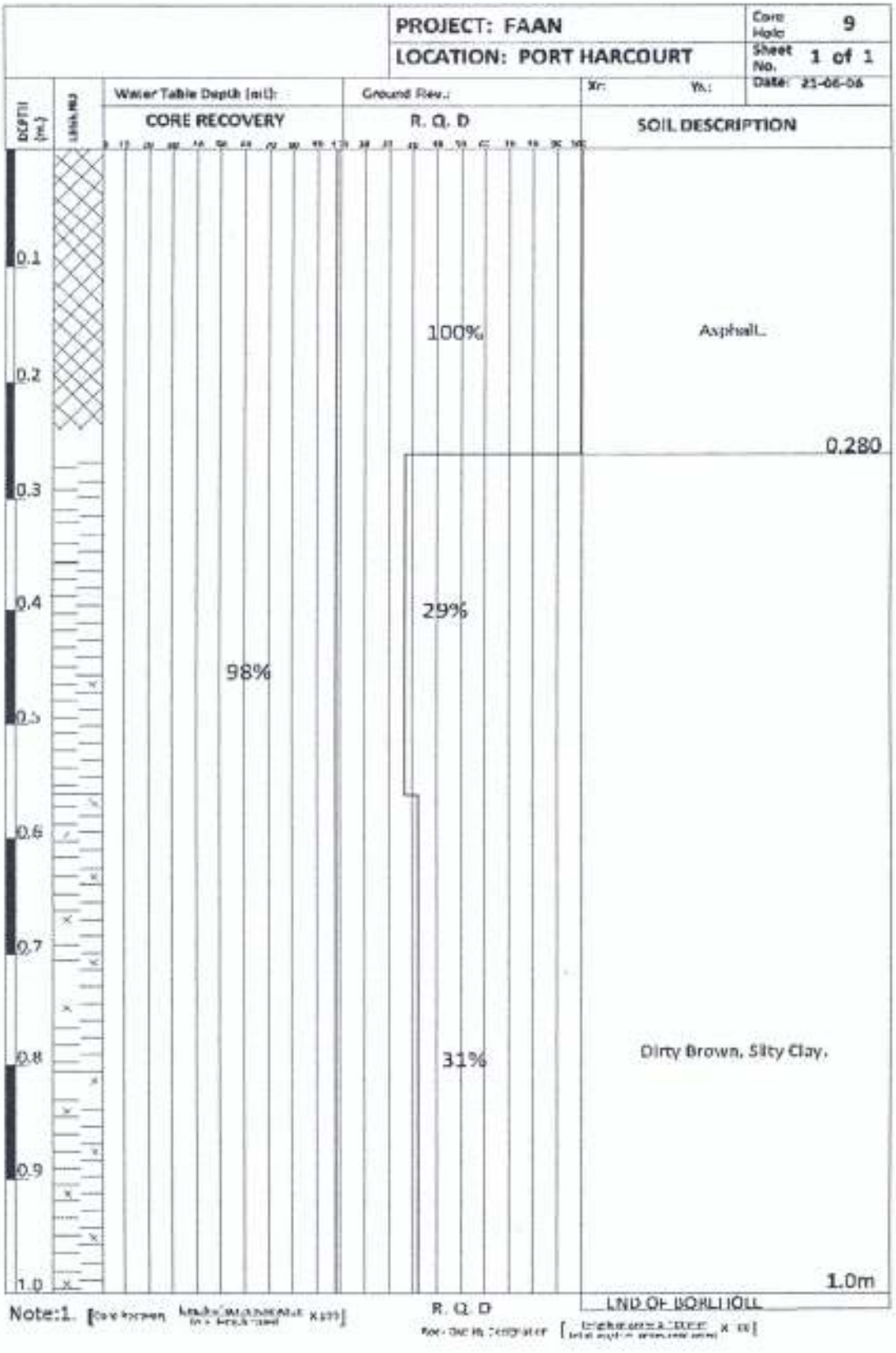

PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole: 7
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Elev.:
Xr:
Yr:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
79%
0%
18%
96%
36%
Asphalt.
0.230
Dirty Brown, Silty Clay.
1.0m
END OF BORE HOLE
Note:1.
R. Q. D

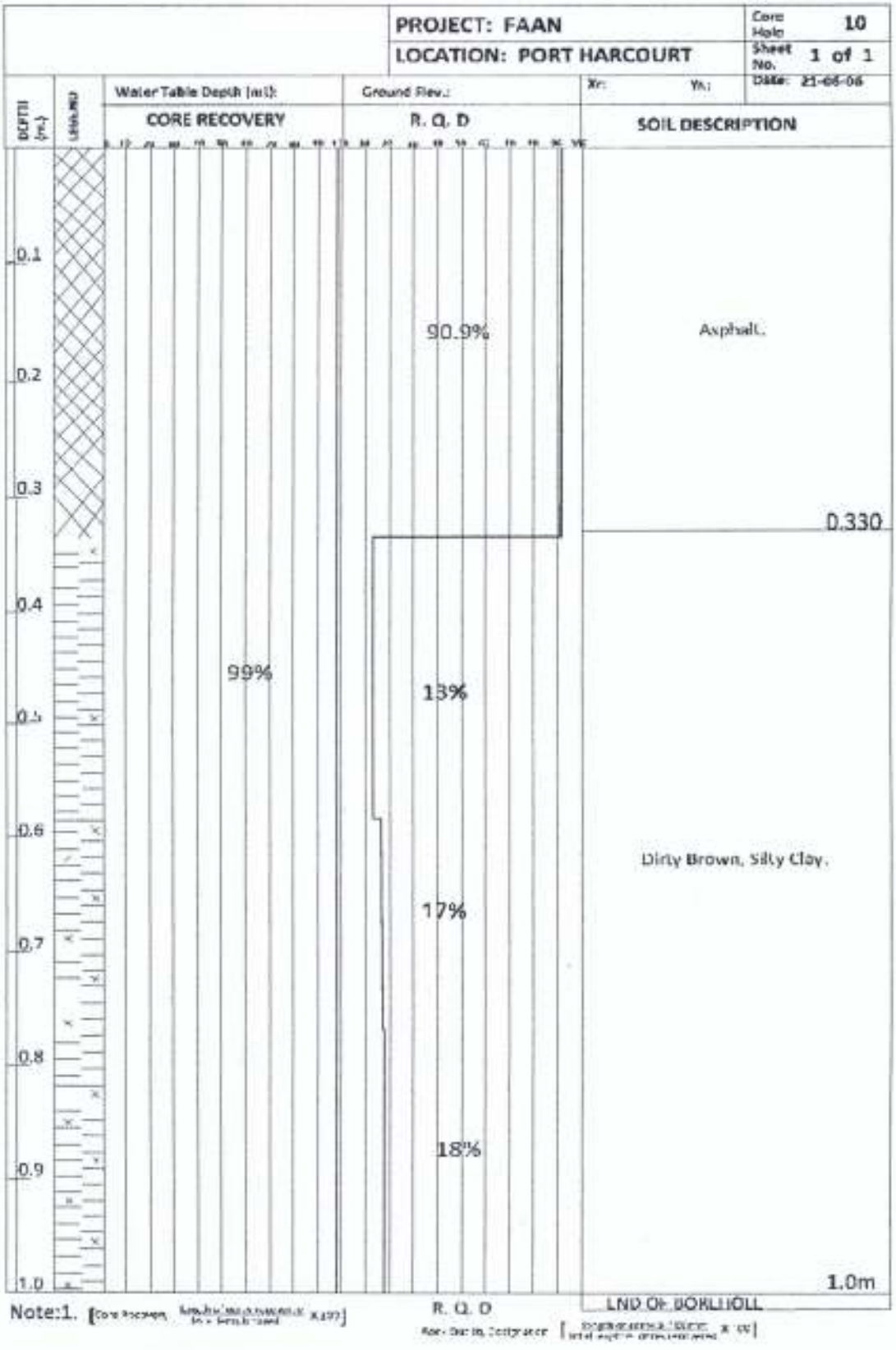
	PROJECT: FAAN	Core Hole: 8
	LOCATION: PORT HARCOURT	Sheet No. 1 of 1
	Water Table Depth (m):	Ground Elev.: Xr: Yr: Date: 21-06-06

DEPTH (m)	LEGEND	CORE RECOVERY	R. Q. D	SOIL DESCRIPTION
0.1			79%	Asphalt.
0.2				0.248
0.3				
0.4			0%	Crush Aggregate Base Course.
0.5		98%		
				0.588
0.6				
0.7				
0.8			20%	Dirty Brown, Silty Clay.
0.9				
1.0				1.0m
				END OF BORE HOLE

Note:1. [illegible]

R. Q. D [illegible]


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 9
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Rev.:
Xr:
Yr:
DEPTH (m.)
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
100%
29%
98%
31%
Asphalt.
0.280
Dirty Brown, Silty Clay.
1.0m
END OF BORE HOLE
R. Q. D
Note:1.


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 10
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Elev.:
Xr:
Yr:
DEPTH (m)
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
90.9%
99%
13%
17%
18%
Asphalt.
0.330
Dirty Brown, Silty Clay.
1.0m
END OF BORELOLL
Note:1.
R. Q. D

	PROJECT: FAAN	Core Hole 11
	LOCATION: PORT HARCOURT	Sheet No. 1 of 1
	Water Table Depth (m):	Ground Elev.: Xn: Yn: Date: 21-06-06

DEPTH (m.)	LEGEND	CORE RECOVERY	R. Q. D	SOIL DESCRIPTION
0.1			85.71%	Asphalt.
0.2				
0.280				
0.3				
0.4		98%	10%	Crush Aggregate Base Course.
0.5				
0.520				
0.6				Dirty Brown, Silty Clay.
0.7				
0.8			29%	
0.9			10%	
1.0				1.0m
				END OF BOREHOLE

Note:1. [illegible] R. Q. D [illegible]

PROJECT: FAAN

LOCATION: PORT HARCOURT

Core Hole 12

Sheet No. 1 of 1

Date: 23-06-06

Water Table Depth (m):

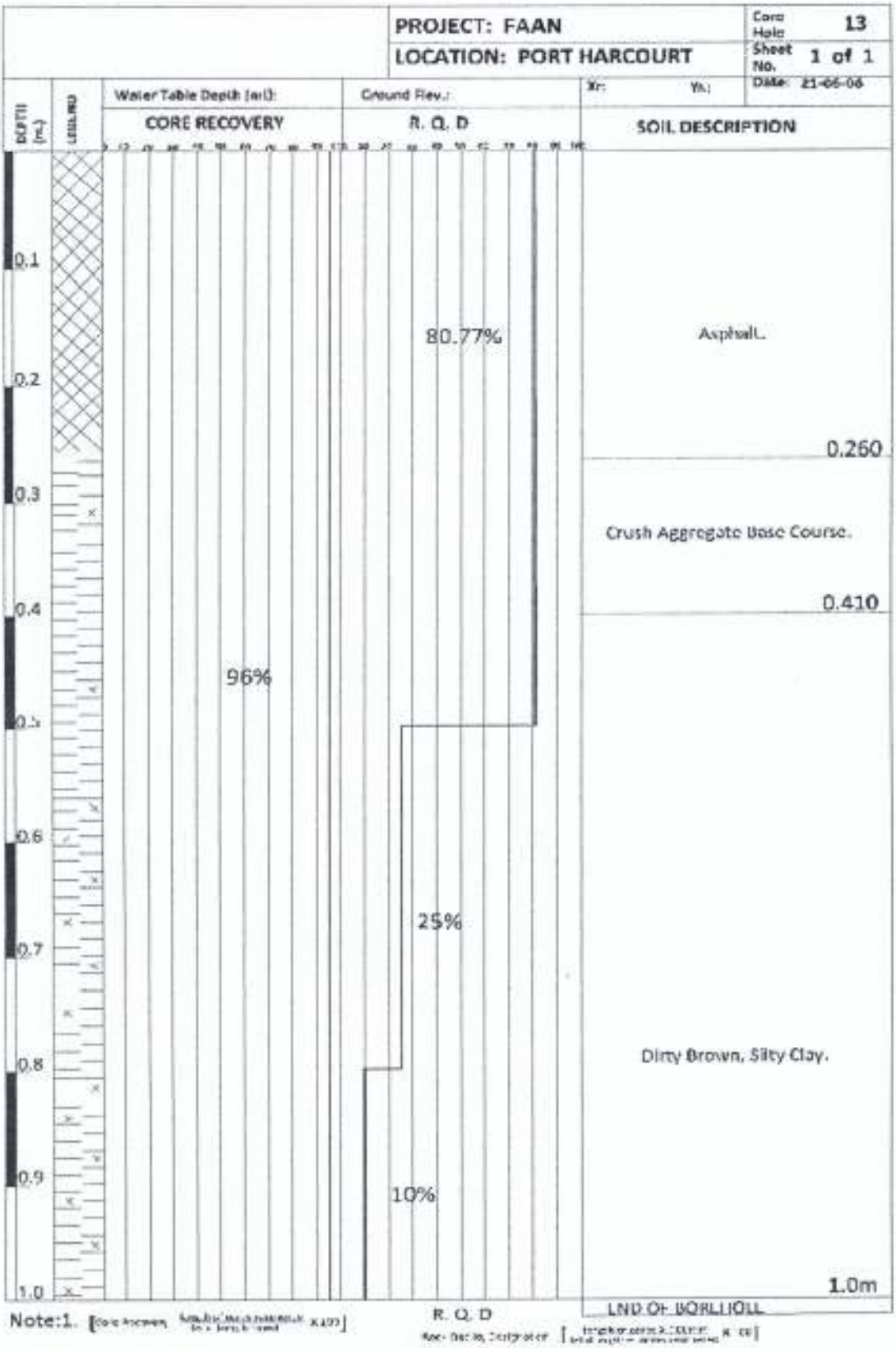
Ground Elev.:

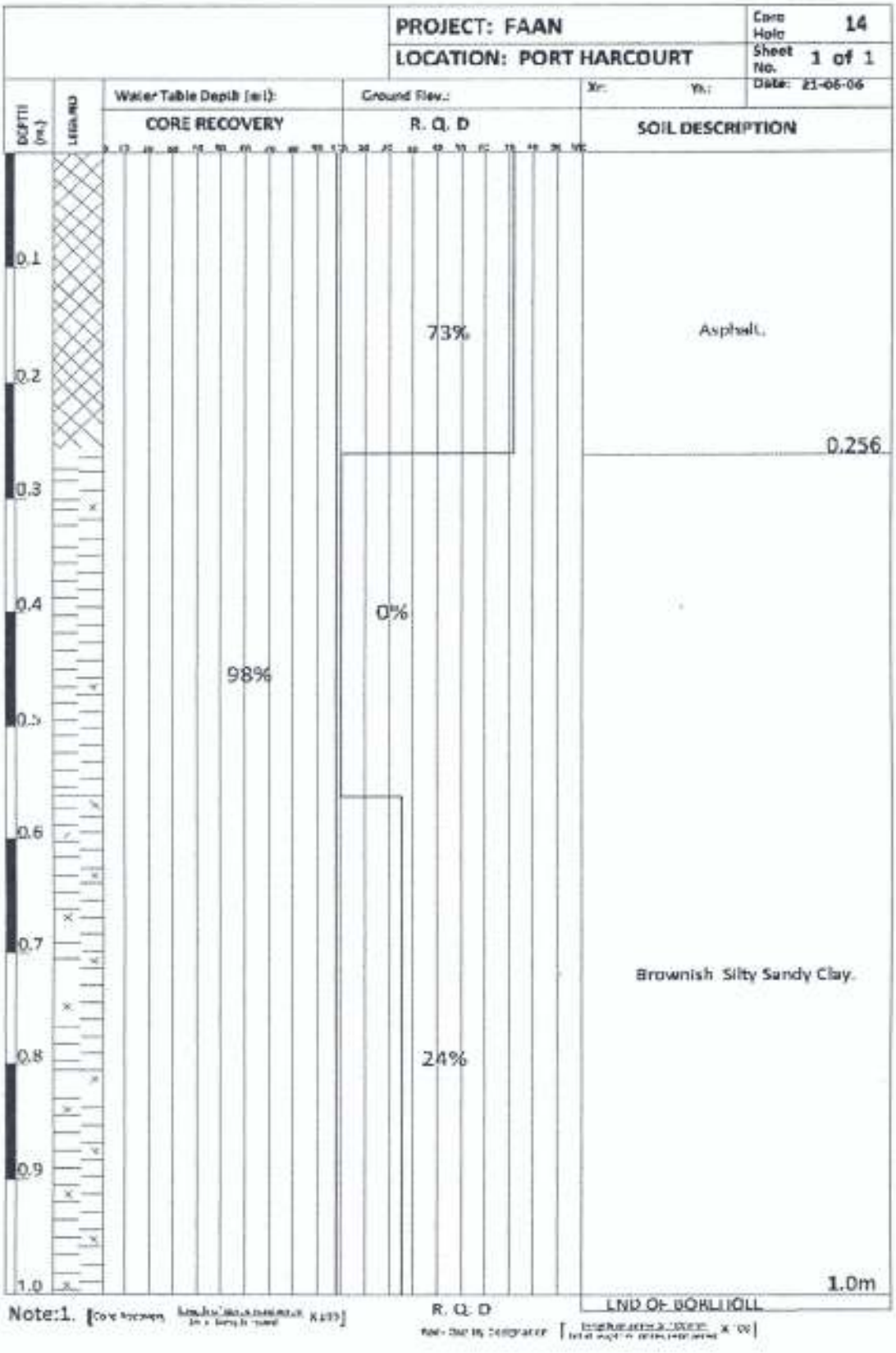
Xn: Yn:

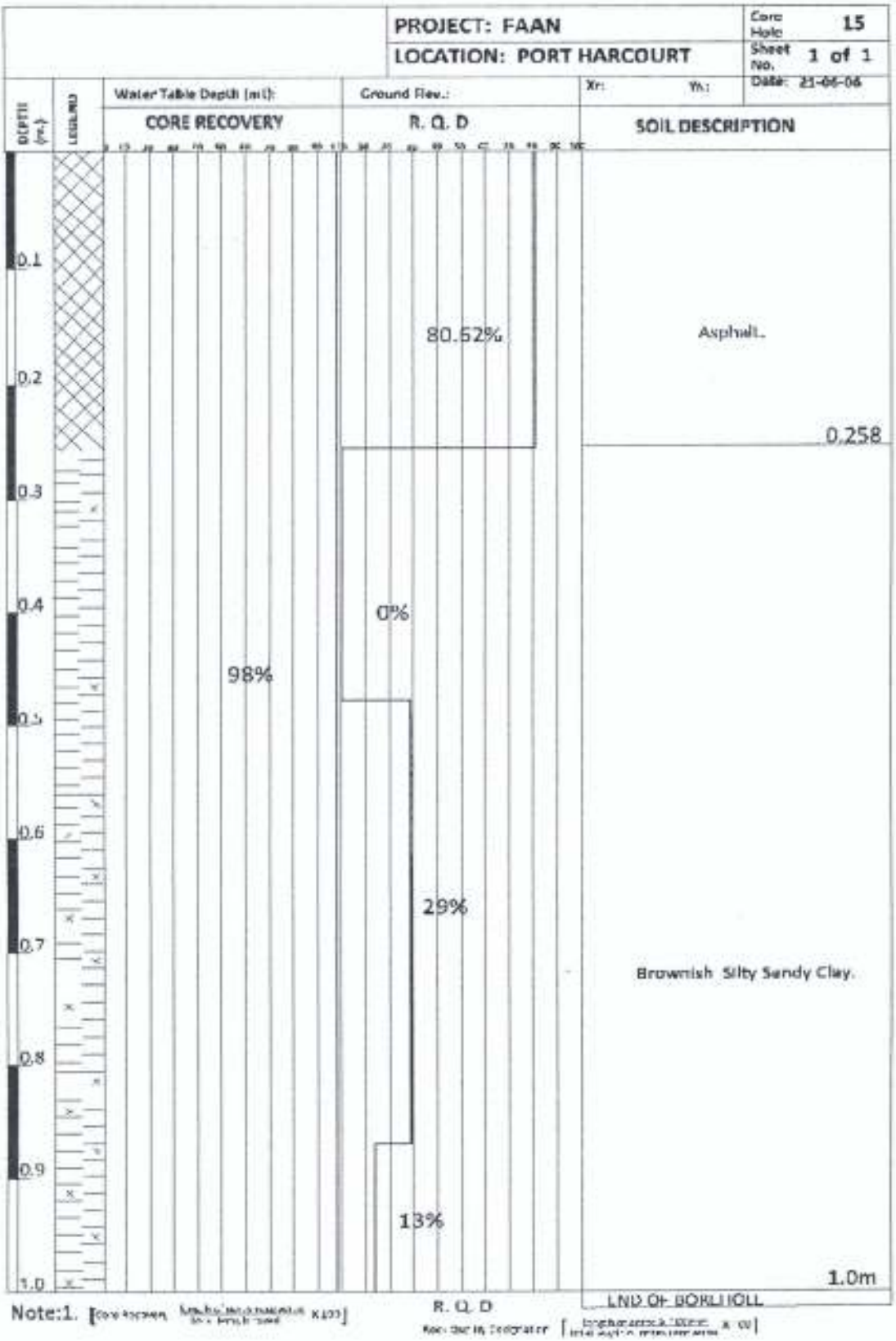
DEPTH (m)	LEGEND	CORE RECOVERY	R. Q. D	SOIL DESCRIPTION
0.1			80%	Asphalt.
0.2				
0.245				
0.3				
0.4		96%	10%	
0.395				
0.5				
0.570				
0.6				
0.7				
0.8			41%	Dirty Brown, Silty Clay.
0.9				
1.0				1.0m
				END OF BORE HOLE

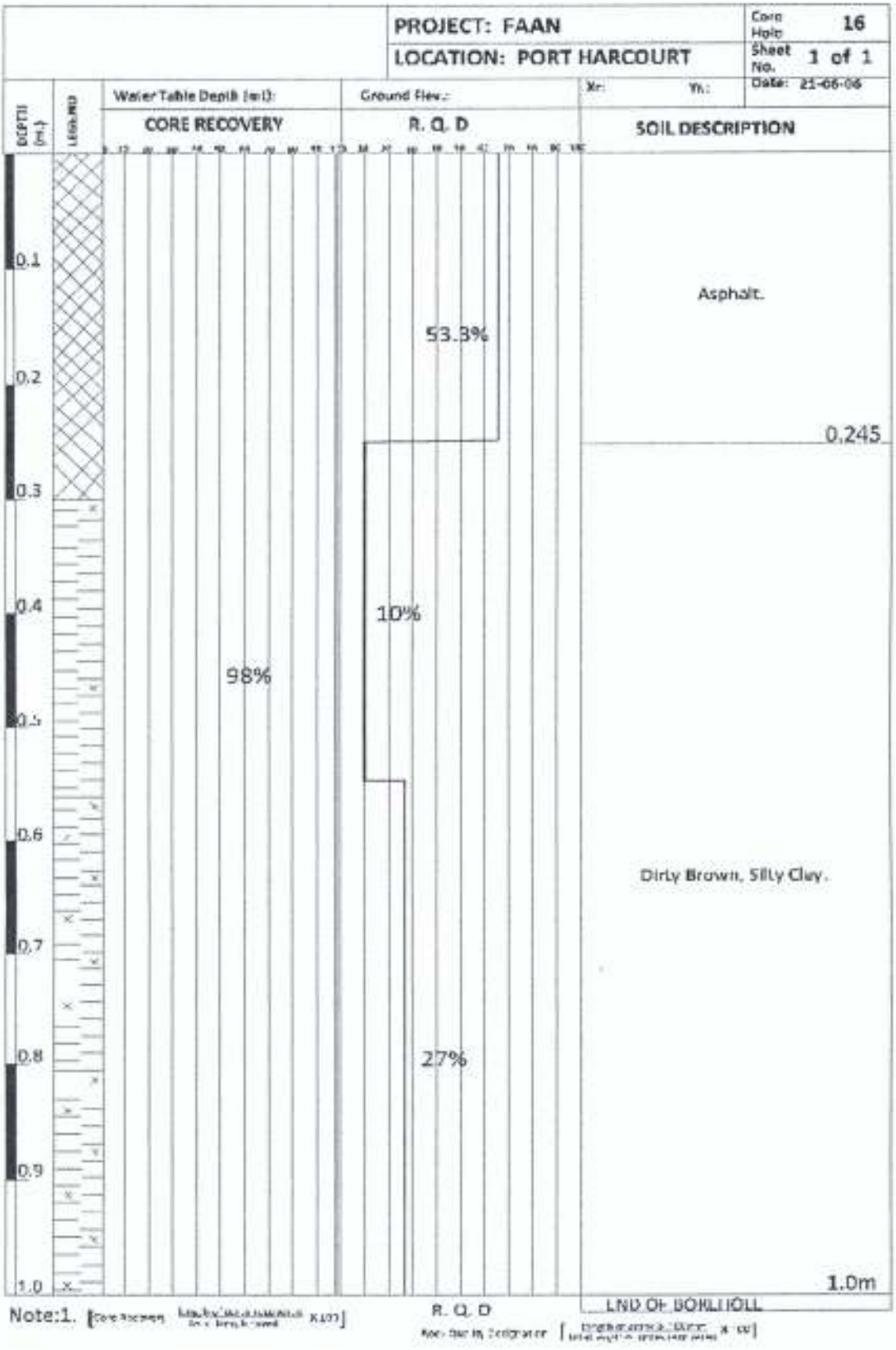
Note:1. [illegible]

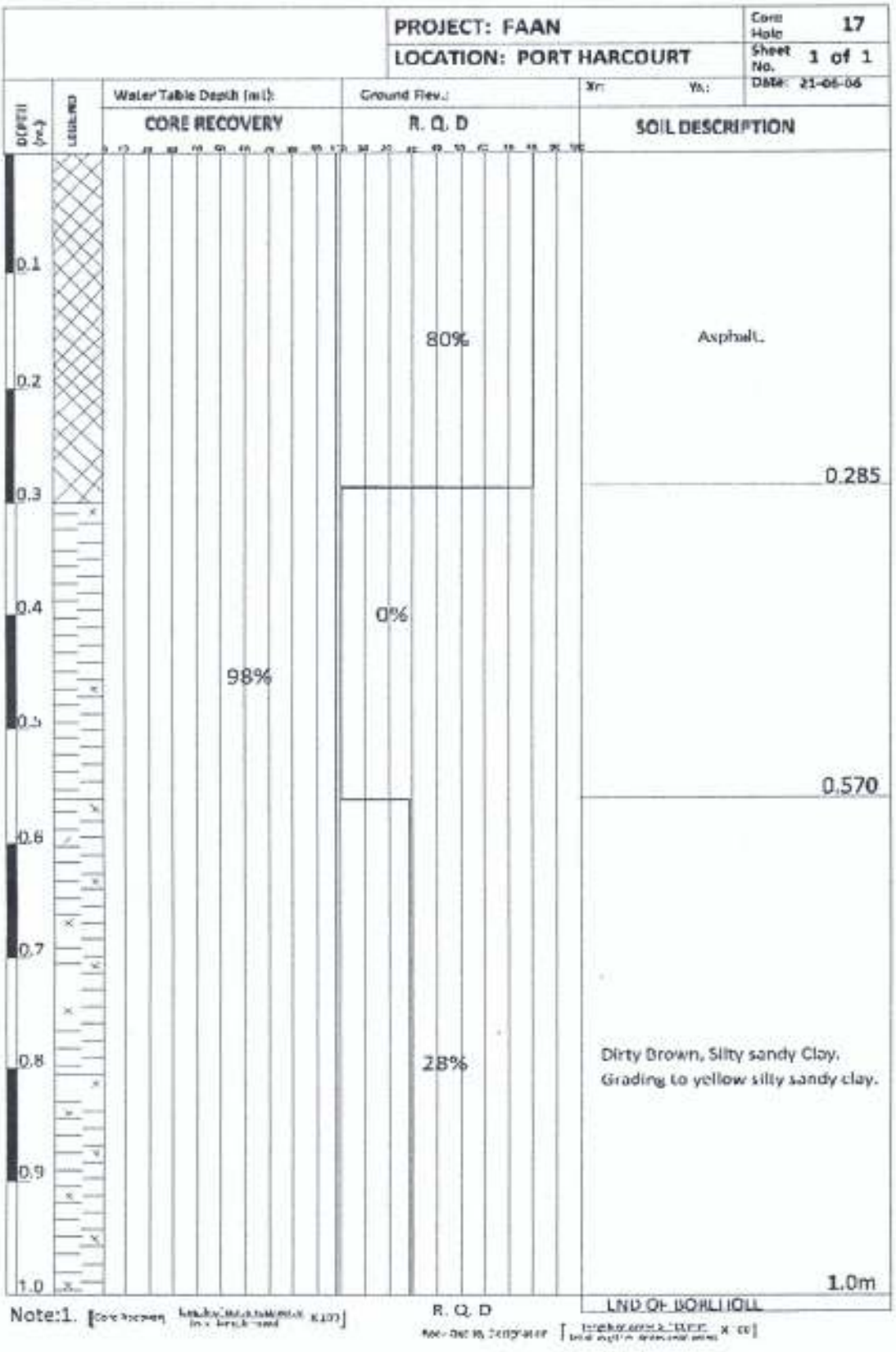
R. Q. D [illegible]


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 13
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Rev.:
Xr:
Yr:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
80.77%
96%
25%
10%
Asphalt.
0.260
Crush Aggregate Base Course.
0.410
Dirty Brown, Silty Clay.
1.0m
END OF BORELOG
Note:1.
R. Q. D


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 14
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Elev.:
Xr:
Yr:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
73%
0%
24%
98%
Asphalt.
0.256
Brownish Silty Sandy Clay.
1.0m
END OF BORE HOLL
Note:1.
R. Q. D


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 15
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Elev.:
Xr:
Yh:
DEPTH (m.)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
80.52%
98%
0%
29%
13%
Asphalt.
0.25m
Brownish Silty Sandy Clay.
1.0m
END OF BORE HOLE
Note:1.
R. Q. D


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 16
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Flev.:
Xr:
Yr:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
53.3%
Asphalt.
0.245
10%
98%
Dirty Brown, Silty Clay.
27%
1.0m
END OF BOREHOLE
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Note:1.
R. Q. D


PROJECT: FAAN
LOCATION: PORT HARCOURT
Core Hole 17
Sheet No. 1 of 1
Date: 21-06-06
Water Table Depth (m):
Ground Elev.:
Xm:
Ym:
DEPTH (m)
LEGEND
CORE RECOVERY
R. Q. D
SOIL DESCRIPTION
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
80%
0%
98%
28%
Asphalt.
0.285
0.570
Dirty Brown, Silty sandy Clay.
Grading to yellow silty sandy clay.
1.0m
END OF BOREHOLE
Note:1.
R. Q. D

PROJECT: FAAN

LOCATION: PORT HARCOURT

Core Hole 18

Sheet No. 1 of 1

Date: 21-06-06

Water Table Depth (m):

Ground Elev.:

Xm: Ym:

DEPTH (m) | LEGEND | CORE RECOVERY | R. Q. D | SOIL DESCRIPTION

0.1

0.2

0.3

0.4

0.5

0.6

0.7

0.8

0.9

1.0

82.14%

16%

17%

99%

Asphalt.

0.277

Yellowish . Silty Sandy Clay.

1.0m

END OF BOREHOLE

Note:1.

R. Q. D

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 1
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 - 1.20	22		
-1.20 - 1.40	32		
-1.40 -1.60	48		
-1.60 -1.80	32		
-1.80 -2.00	37		
-2.00 -2.20	32		
-2.20 -2.40	25		
-2.40 -2.60	25		
-2.60 -2.80	24		
-2.80 -3.00	29		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 2
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	22		
-1.20- 1.40	32		
-1.40 -1.60	48		
-1.60 -1.80	32		
-1.80 -2.00	37		
-2.00 -2.20	32		
-2.20 -2.40	25		
-2.40 -2.60	25		
-2.60 -2.80	24		
-2.80 -3.00	29		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 3
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	15		
-1.20 -1.40	25		
-1.40 -1.60	33		
-1.60 -1.80	22		
-1.80 -2.00	23		
-2.00 -2.20	24		
-2.20 -2.40	24		
-2.40 -2.60	23		
-2.60 -2.80	22		
-2.80 -3.00	21		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 4
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	18		
-1.20 -1.40	23		
-1.40 -1.60	25		
-1.60 -1.80	26		
-1.80 -2.00	25		
-2.00 -2.20	25		
-2.20 -2.40	25		
-2.40 -2.60	25		
-2.60 -2.80	26		
-2.80 -3.00	28		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 5
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
1.00 -1.20	7		
1.20- 1.40	21		
1.40 -1.60	23		
1.60 -1.80	20		
1.80 -2.00	26		
2.00 -2.20	24		
2.20 -2.40	26		
2.40 -2.60	25		
2.60 -2.80	27		
2.80 -3.00	24		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 6
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	13		
-1.20 -1.40	21		
-1.40 -1.60	23		
-1.60 -1.80	41		
-1.80 -2.00	22		
-2.00 -2.20	21		
-2.20 -2.40	22		
-2.40 -2.60	23		
-2.60 -2.80	23		
-2.80 -3.00	23		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 7
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	17		
-1.20 -1.40	21		
-1.40 -1.60	20		
-1.60 -1.80	22		
-1.80 -2.00	22		
-2.00 -2.20	23		
-2.20 -2.40	23		
-2.40 -2.60	22		
-2.60 -2.80	22		
-2.80 -3.00	21		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 8
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 - 1.20	6		
-1.20 -1.40	19		
-1.40 -1.60	24		
-1.60 -1.80	24		
-1.80 -2.00	26		
-2.00 -2.20	25		
-2.20 -2.40	26		
-2.40 -2.60	27		
-2.60 -2.80	27		
-2.80 -3.00	26		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 9
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	9		
-1.20 -1.40	17		
-1.40 -1.60	22		
-1.60 -1.80	23		
-1.80 -2.00	23		
-2.00 -2.20	23		
-2.20 -2.40	25		
-2.40 -2.60	24		
-2.60 -2.80	23		
-2.80 -3.00	24		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 10
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	11		
-1.20 -1.40	23		
-1.40 -1.60	22		
-1.60 -1.80	21		
-1.80 -2.00	21		
-2.00 -2.20	23		
-2.20 -2.40	22		
-2.40 -2.60	21		
-2.60 -2.80	20		
-2.80 -3.00	19		

YNAMIC PENETROMETER TEST	PROJECT	TEST NO. 11
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

EPTH (m)	BLOW COUNT		REMARK
.00 -1.20	9		
.20 -1.40	24		
.40 -1.60	23		
.60 -1.80	21		
.80 -2.00	20		
.00 -2.20	23		
.20 -2.40	22		
.40 -2.60	24		
.60 -2.80	24		
.80 -3.00	20		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 12
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	6		
-1.20 -1.40	23		
-1.40 -1.60	25		
-1.60 -1.80	26		
-1.80 -2.00	27		
-2.00 -2.20	24		
-2.20 -2.40	24		
-2.40 -2.60	25		
-2.60 -2.80	27		
-2.80 -3.00	29		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 13
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00- 1.20	17		
-1.20 -1.40	21		
-1.40 -1.60	20		
-1.60 -1.80	22		
-1.80 -2.00	22		
-2.00 -2.20	23		
-2.20 -2.40	22		
-2.40 -2.60	22		
-2.60 -2.80	20		
-2.80 -3.00	21		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 14
			SHEET NO. 1 of 1
			DATE : 21-06-06
			MACHINE: (TF 2985) Dynamic Penetrometer
			GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 - 1.20	13		
-1.20 -1.40	21		
-1.40 -1.60	23		
-1.60 -1.80	22		
-1.80 -2.00	21		
-2.00 -2.20	23		
-2.20 -2.40	24		
-2.40 -2.60	23		
-2.60 -2.80	24		
-2.80 -3.00	24		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 15
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 - 1.20	26		
-1.20 - 1.40	48		
-1.40 -1.60	55		
-1.60 -1.80	25		
-1.80 -2.00	20		
-2.00 -2.20	20		
-2.20 -2.40	21		
-2.40 -2.60	20		
-2.60 -2.80	20		
-2.80 -3.00	22		

DYNAMIC PENETROMETER TEST		PROJECT	TEST NO. 16 SHEET NO. 1 of 1 DATE : 21-06-06 MACHINE: (TF 2985) Dynamic Penetrometer GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 - 1.20	15		
-1.20 - 1.40	24		
-1.40 -1.60	25		
-1.60 -1.80	23		
-1.80 -2.00	24		
-2.00 -2.20	24		
-2.20 -2.40	23		
-2.40 -2.60	20		
-2.60 -2.80	20		
-2.80 -3.00	19		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 17
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 -1.20	15		
-1.20- 1.40	25		
-1.40 -1.60	33		
-1.60 -1.80	22		
-1.80 -2.00	23		
-2.00 -2.20	24		
-2.20 -2.40	24		
-2.40 -2.60	23		
-2.60 -2.80	22		
-2.80 -3.00	21		

DYNAMIC PENETROMETER TEST	PROJECT	TEST NO. 18
		SHEET NO. 1 of 1
		DATE : 21-06-06
		MACHINE: (TF 2985) Dynamic Penetrometer
		GROUND WATER

DEPTH (m)	BLOW COUNT		REMARK
-1.00 - 1.20	13		
-1.20 - 1.40	24		
-1.40 -1.60	23		
-1.60 -1.80	24		
-1.80 -2.00	24		
-2.00 -2.20	24		
-2.20 -2.40	23		
-2.40 -2.60	22		
-2.60 -2.80	20		
-2.80 -3.00	21		

APPENDIX 2

RESULTS OF THE PAVEMENT CONDITION INDEX (PCI)

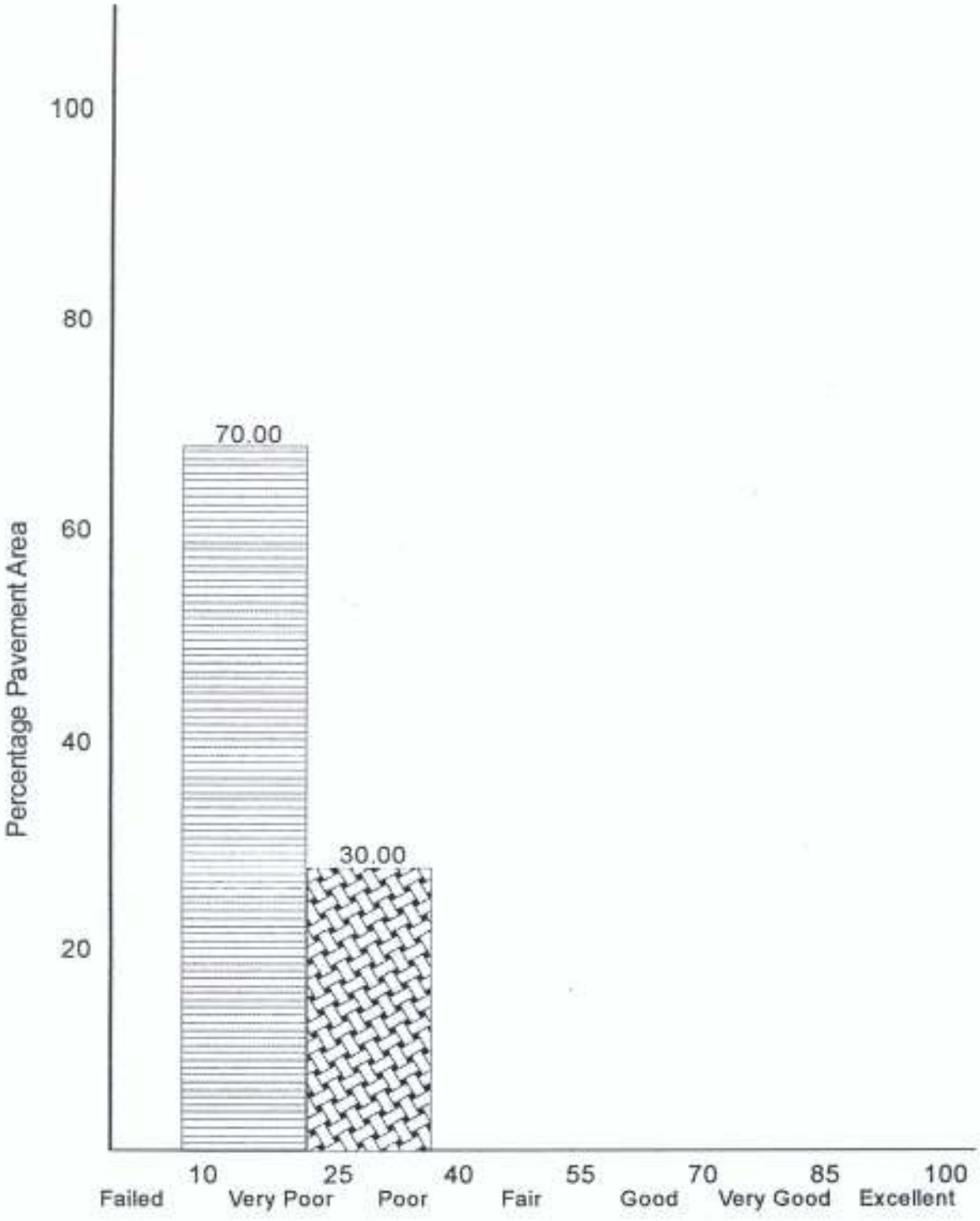


Fig. 8 Pavement Condition Rating For Lagos Runway (18L/36R)

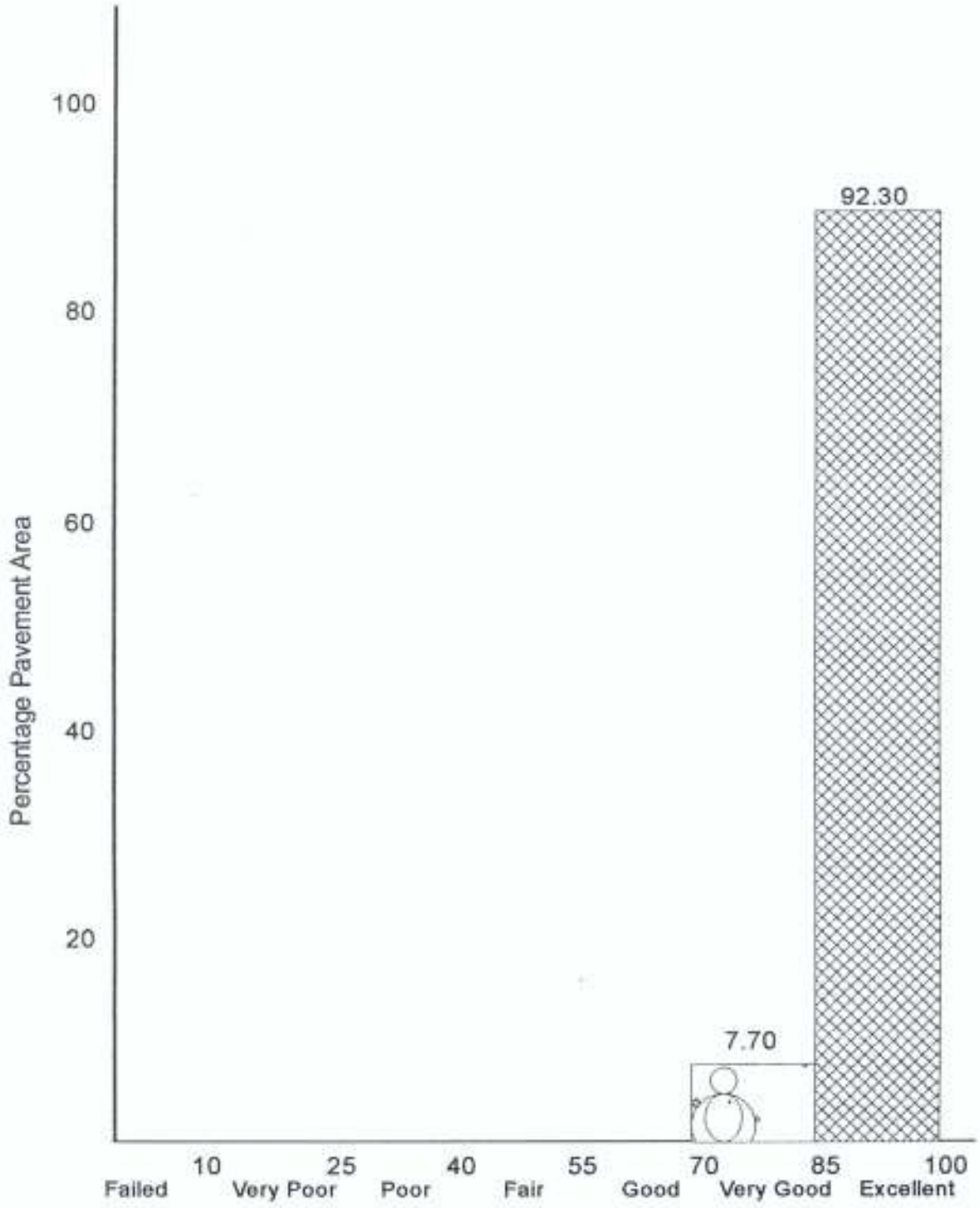


Fig. 9 Pavement Condition Rating For Kano Runway (06/24)

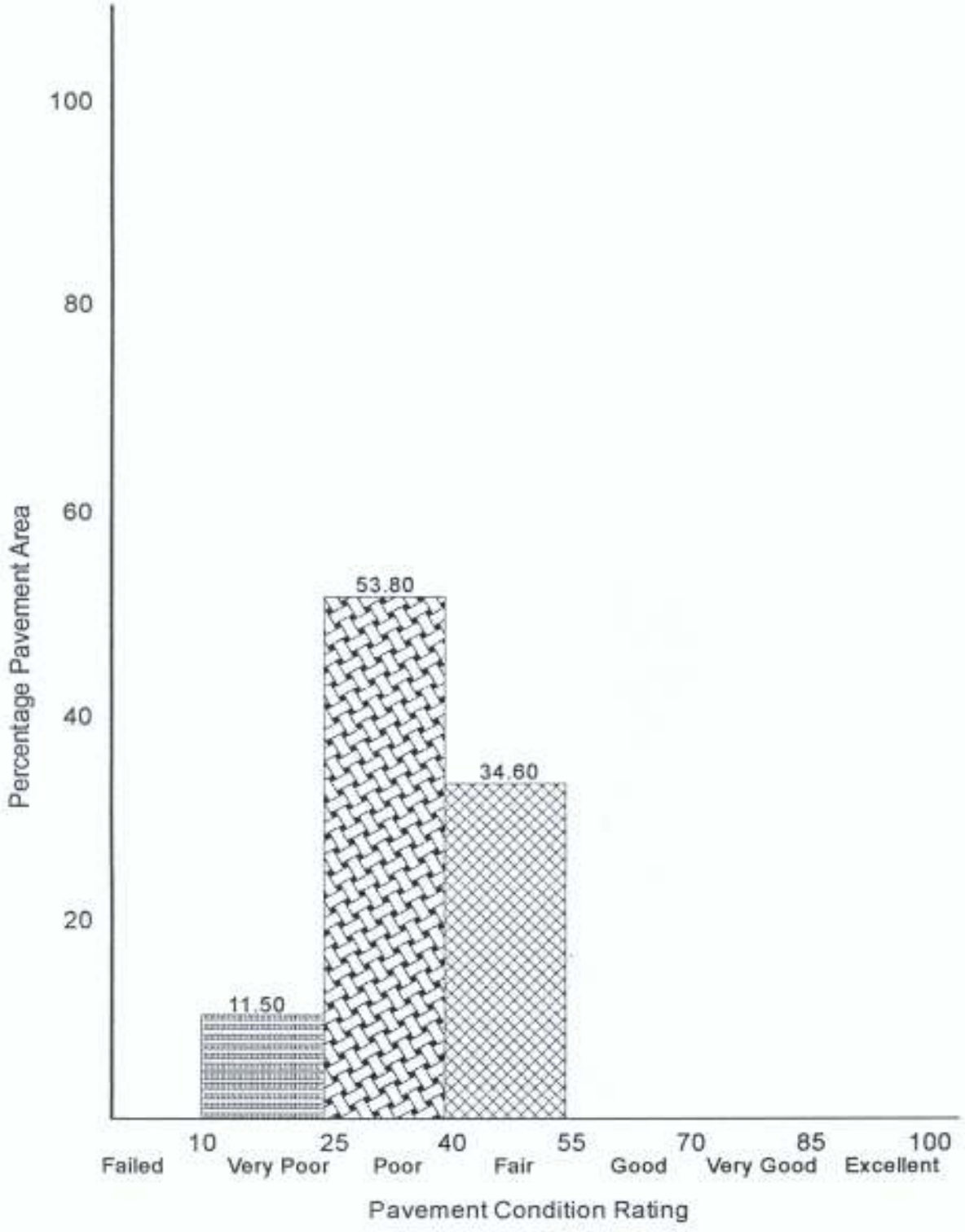


Fig. 10 . Pavement Condition Rating For Port Harcourt Runway(03/21)

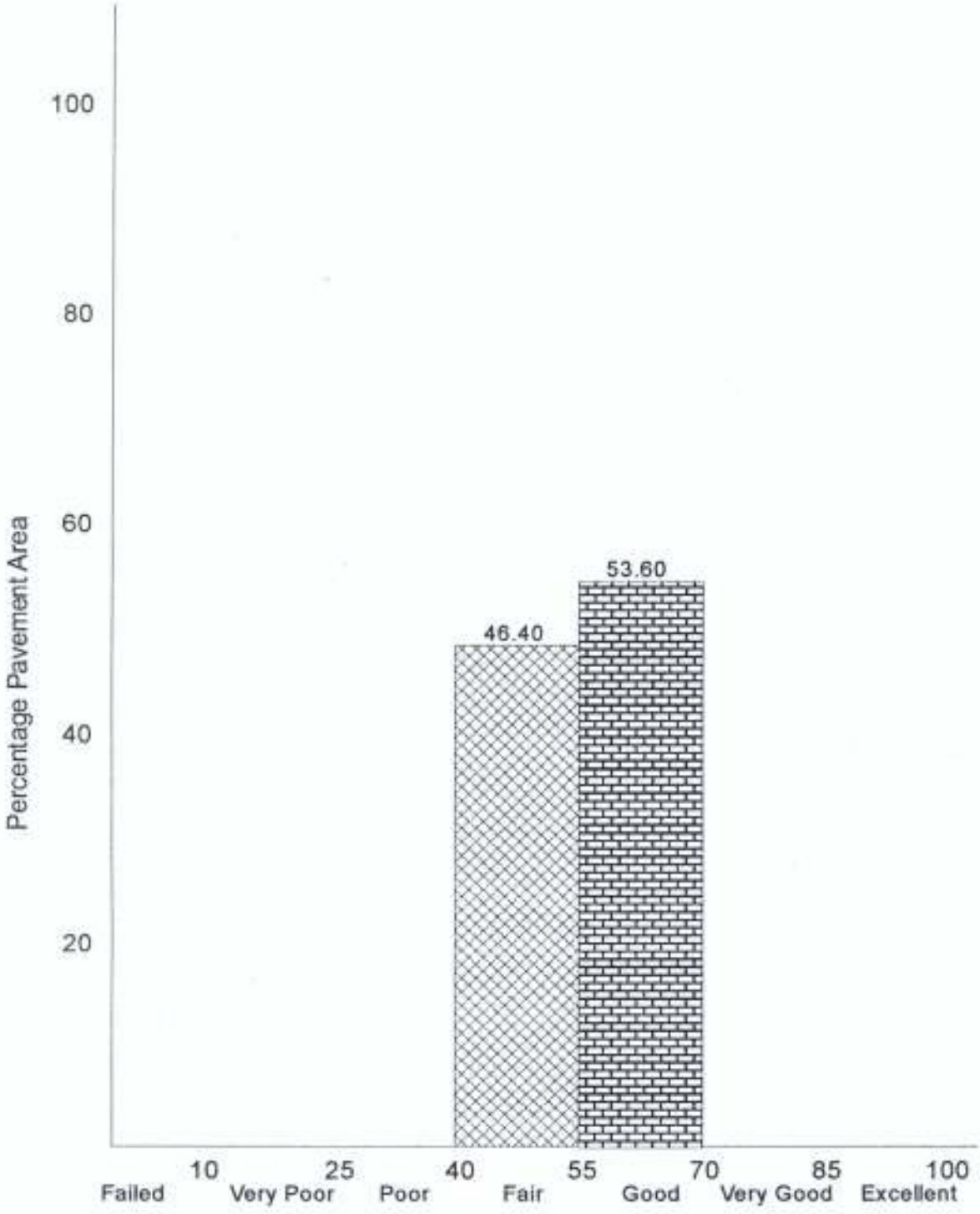


Fig. 11 Pavement Condition Rating For Abuja Runway(04/22)

TABLE II: FEATURE SUMMARY FOR RUNWAY 01L/19R LAGOS

Airport: Murtala Mohammed Airport, Lagos

Airport Facility: Runway 01L/19R

Total No. of sample units: 30

Sample Unit No.	Sample Unit Area, m2	PCI	Sample Unit No.	Sample Unit Area, m2	PCI
1	450	20	16	450	29
2	450	31	17	450	22
3	450	22	18	450	18
4	450	24	19	450	21
5	450	19	20	450	31
6	450	22	21	450	29
7	450	26	22	450	27
8	450	17	23	450	22
9	450	26	24	450	24
10	450	18	25	450	30
11	450	20	26	450	16
12	450	26	27	450	23
13	450	23	28	450	20
14	450	25	29	450	22
15	450	22	30	450	17
		341			351

Average PCI for feature: 23

Rating Condition: very poor

TABLE 12: FEATURE SUMMARY FOR RUNWAY 04/22, ABUJA

Airport: Nnamdi Azikiwe Airport, Abuja

Airport Facility: Runway 04/22

Total No. of sample units: 28

Sample Unit No.	Sample Unit Area, m2	PCI	Sample Unit No.	Sample Unit Area, m2	PCI
1	450	63	15	450	57
2	450	54	16	450	52
3	450	52	17	450	64
4	450	50	18	450	66
5	450	61	19	450	60
6	450	62	20	450	62
7	450	65	21	450	59
8	450	53	22	450	68
9	450	54	23	450	53
10	450	66	24	450	47
11	450	58	25	450	48
12	450	50	26	450	56
13	450	49	27	450	55
14	450	55	28	450	69
		792			816

Average PCI for feature: 57

Rating Condition: good

TABLE 13: FEATURE SUMMARY FOR RUNWAY 06/24, KANO

Airport: Mallam Aminu Kano Airport, Kano

Airport Facility: Runway 06/24

Total No. of sample units: 26

Sample Unit No.	Sample Unit Area, m2	PCI	Sample Unit No.	Sample Unit Area, m2	PCI
1	450	94	14	450	100
2	450	98	15	450	93
3	450	83	16	450	100
4	450	100	17	450	88
5	450	100	18	450	95
6	450	100	19	450	94
7	450	92	20	450	86
8	450	96	21	450	92
9	450	88	22	450	100
10	450	98	23	450	100
11	450	94	24	450	100
12	450	91	25	450	90
13	450	85	26	450	92
		1219			1230

Average PCI for feature: 94

Rating Condition: excellent

TABLE 14: FEATURE SUMMARY FOR RUNWAY 03/21, PORTHARCOURT

Airport: Port Harcourt

Airport Facility: Runway 03/21

Total No. of sample units: 26

Sample Unit No.	Sample Unit Area, m2	PCI	Sample Unit No.	Sample Unit Area, m2	PCI
1	450	45	14	440	27
2	450	43	15	450	32
3	450	22	16	450	29
4	450	48	17	450	42
5	450	35	18	450	35
6	450	43	19	450	36
7	450	36	20	450	27
8	450	39	21	450	36
9	450	47	22	450	33
10	450	26	23	450	39
11	450	41	24	450	23
12	450	33	25	450	44
13	450	28	26	450	43
		486			446

Average PCI for feature: 36

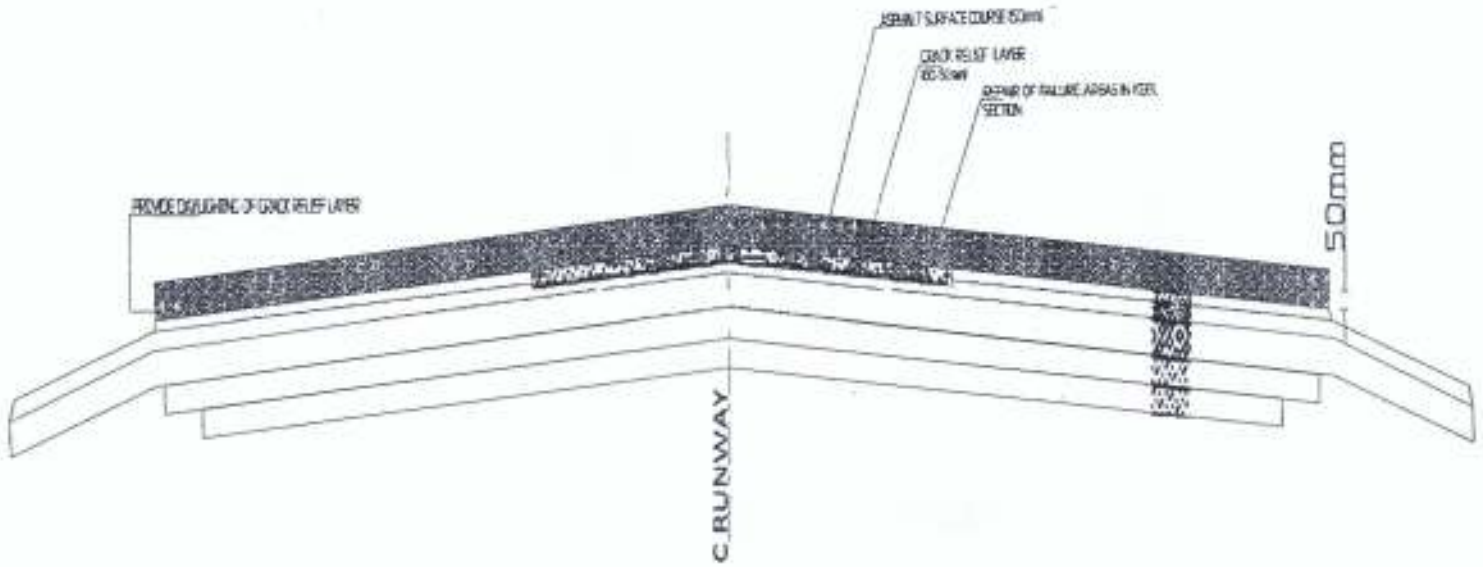
Rating Condition: poor

APPENDIX 3

CROSS SECTION OF THE PORT-HARCOURT RUNWAY PAVEMENT

SHOWING THE THICKNESS OF CRL AS WELL AS THE MILLING PORTIONS

PORT-HARCOURT INTERNATIONAL AIRPORT, PORT- HARCOURT, NIGERIA.



STRUCTURAL UPGRADING RUNWAY 03/21

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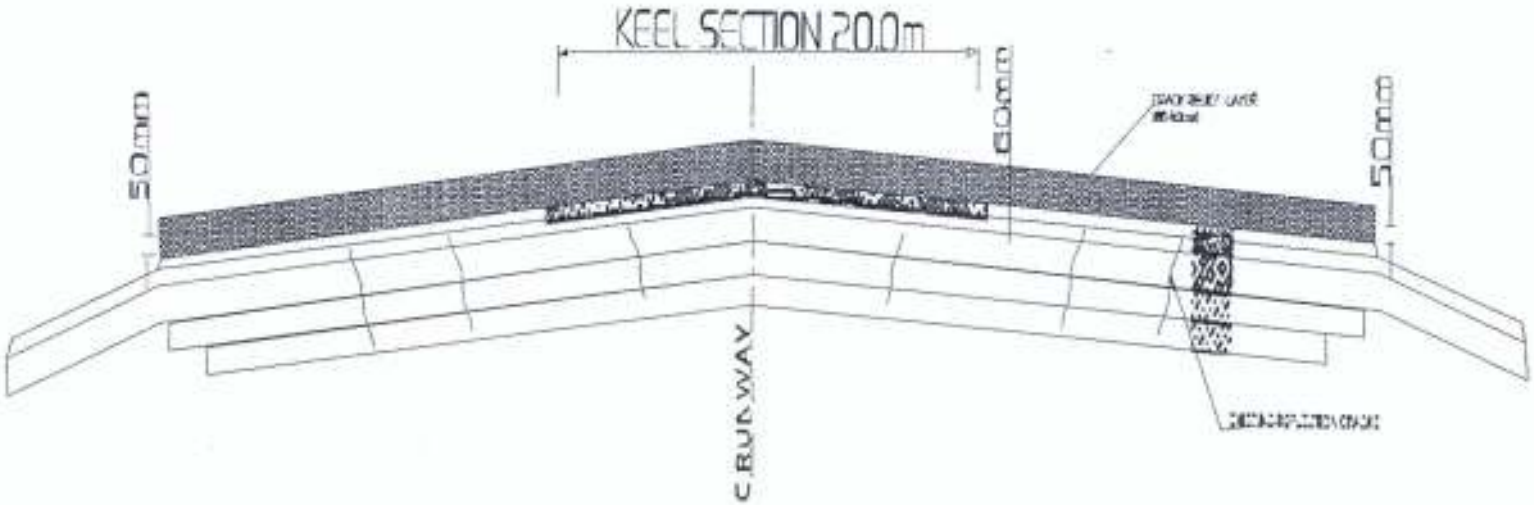
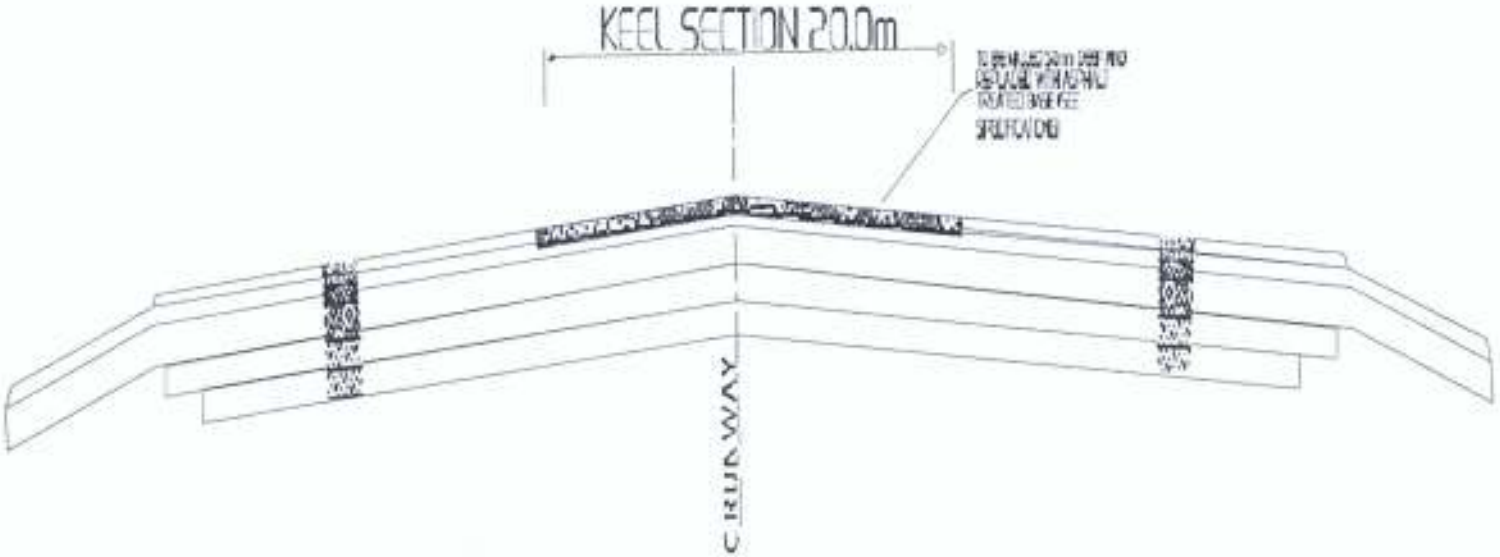
PORT-HARCOURT INTERNATIONAL AIRPORT, PORT- HARCOURT, NIGERIA.



PROTECTION AGAINST REFLRCTION CRACKS RUNWAY 03/21

PORT-HARCOURT INTERNATIONAL AIRPORT, PORT-HARCOURT, NIGERIA.



REMOVAL AND REPLACEMENT OF FAILED AREAS RUNWAY 01L - 19R

APPENDIX 4

PICTURES SHOWING DIFFERENT STAGES OF CONSTRUCTION WORK IN PORT-HARCOURT INTERNATIONAL AIRPORT.

CORING TEST IN PROGRESS

TEST FLIGHT ON RUNWAY

AIRCRAFT DEPARTING FROM THE COMPLETED RUNWAY