Soil Moisture and Density Measurements at Australian Aerodromes

Mesures de teneur en eau et de densité effectuées sur des pistes d'atterrissage en Australie

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Summary

To obtain data for the development of a procedure for assessing the strength of airfield pavement subgrades under Australian climatic conditions periodical measurements have been made of soil moisture contents and densities at a number of airfields.

This paper presents typical observations at three aerodromes and includes a summary of observations at forty other aerodromes.

The measurements indicate the advantage of using the ratio of moisture content to plastic limit in preference to moisture content in describing the moisture condition. At any site, for a particular subgrade soil and drainage condition, it is found that this ratio is nearly constant showing only small seasonal variations. Rules are given for estimating the value of this ratio for clayey soils under good and poor drainage conditions.

Sommaire

Afin d'obtenir des données pour développer un procédé permettant d'évaluer la résistance des sols de fondation de pistes d'atterrissage dans les conditions climatiques de l'Australie, des mesures de teneurs en eau et de densités ont été faites dans un certain nombre d'aérodromes.

Ce rapport présente des observations typiques recueillies sur trois aérodromes et un résumé d'observations faites sur quarante autres aérodromes.

Ces mesures montrent que pour caractériser le matériau mis en place il y a avantage à employer le rapport de la teneur en eau à la limite de plasticité. Pour un emplacement, un sol et des conditions de drainage donnés, ce rapport est presque constant et ne montre que de faibles variations saisonnières. Des règles sont énoncées permettant l'estimation de ce rapport pour des sols argileux, aussi bien dans de bonnes que dans de mauvaises conditions de drainage.

Introduction

Loxton, Beavis and *McNicholl* (1948) described a procedure for evaluating the influence of the moisture content of the subgrade on the thickness required for a flexible airfield pavement. Considerable investigation has been undertaken since 1948 and

Table 1*a* Properties of Materials referred to in Tables 2 to 6
Propriétés des matériaux Tables 2 à 6

Material	*Classification*		*Mechanical Analysis*													*Atterberg Limits*				*Linear Shrinkage*	*Specific Gravity*	*Modified A.A.S.H.O. Compaction*	
			% Passing B.S. Sieve Size									*% Smaller than*											
	H.R.B.	*U.S. Eng.*	$\frac{3}{4}''$	$\frac{3}{8}''$	$\frac{3}{16}''$	*7*	*14*	*25*	*52*	*100*	*200*	*.05 MM*	*.02 MM*	*.005 MM*	*.002 MM*	*LL %*	*PL %*	*PI %*	*SL %*			*Dry Density*	*Opt. Moist.*
Essendon:																							
Crushed Rock	A1	GW	100	80	60	46	33	27	22	17	15	12	9	5	3	23	19	4	≈ 18	≈ 4	2.93	138	9.0
Silt Stone	A4	ML	100	98	96	87	78	74	70	63	52	49	36	23	18	22	18	4	19	5	2.70	125	10.4
Clay	A7	CH				100	99	97	94	91	89	89	81	70	62	81	27	54	12.5	21.5	2.65	101	20.0
Daly Waters:																							
Red Brown Clay	A4–6	CL				100	98	93	78	62	55	54	49	43	39	35	17	18	15.2	9.8	2.66	—	—
Yellow Brown Clay	A4–6	CL				100	97	92	78	60	53	50	46	41	37	33	15	18	14.3	9.5	2.68	—	—
Eagle Farm:																							
Silty Clay	A7	CH				100	99.5	99	99	96	87	87	—	—	—	50	23	27	—	12.5	—	111	15.7

Table 1*b* Meteorological Data for Localities Referred to in Tables 2 to 6
Données météorologiques pour les localités énumérées aux Tableaux 2 à 6

Locality	*Essendon-Latitude 37° 44′ S.*					*Daly Waters-Latitude 16° 16′ S.*					*Eagle Farm-Latitude 27° 30′ S.*				
Period	*Mean Monthly Value*				*Mean Annual Value*	*Mean Monthly Value*				*Mean Annual Value*	*Mean Monthly Value*				*Mean Annual Value*
	July–Sept.		*Jan.–March*			*Jan.–March*		*July–Sept.*			*Jan.–March*		*July–Sept.*		
	Max.	*Min.*	*Max.*	*Min.*		*Max.*	*Min.*	*Max.*	*Min.*		*Max.*	*Min.*	*Max.*	*Min.*	
Rainfall, Points	274	254	232	162	2762	638	473	22	5	2647	651	571	223	200	4527
Max.daily temp.°F	72	63	80	75	68	98	95	96	84	94	85	82	76	68	78
Min. daily temp. °F	53	46	58	54	49	75	72	64	53	67	69	66	55	49	60
Humidity, Percent	68	60	66	57	69	67	63	43	39	51	72	66	73	64	68

Note: Under monthly values first period is three consecutive months with highest rainfall and second period is three consecutive months with lowest rainfall

Table 2 Comparison of Density Determinations Made in 1947 and 1950
Comparaison des densités déterminées en 1947 et 1950

Site		*Essendon Airport 79° Runway Chainage 5300′ Pavement 200′ Wide*																			
Location		*75′ Left of C.L.*				*25′ Left of C.L.*				*25′ Right of C.L.*				*75′ Right of C.L.*				*Mean*			
Date of Measurement		*Nov. 1947*		*Nov. 1950*		*Nov. 1947*		*Nov. 1950*		*Nov. 1947*		*Nov. 1950*		*Nov. 1947*		*Nov. 1950*		*Nov. 1947*		*Nov. 1950*	
Material	*Depth Below R-W Surface*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*	*D.D.*	*MC*
Crushed Rock	0″– 7″	—	—	144	4.5	—	—	—	—	—	—	137	3.4	—	—	130	14.6	—	—	—	—
	6″–11″	—	—	—	—	—	—	—	—	—	—	—	—	—	—	125	12.6	—	—	—	—
Siltstone	11″–17″	112	11.3	110	11.9	113	12.7	117	13.3	120	10.0	96	10.2	111	16.7	117	12.5	114	12.7	110	11.9
	18″–25″	110	9.4	106	12.1	105	12.3	106	12.8	109	9.4	114	8.4	107	12.2	—	—	108	10.8	108	11.1
Clay	25″–34″	86	30.0	84	27.8	85	23.2	87	25.1	—	—	84	16.0	76	31.2	90	25.1	82	28.1	86	23.5
	34″–44″	84	25.8	85	27.5	89	23.2	85	25.0	—	—	91	25.6	89	26.6	89	25.9	87	25.2	87	26.0
	44″–48″	—	—	94	23.5	—	—	86	25.8	—	—	96	22.7	—	—	82	24.3	—	—	89	24.1

Note: D.D. is dry density in lb./cu.ft. of material in situ MC is moisture content of material as a percentage of dryweight of soil

Table 3 Individual Moisture Measurements Made in 1950
Mesures individuelles de teneurs en eau faites en 1950

Site		*Essendon Airport 79° Runway Chainage 5300′ Pavement 200′ Wide*														
Material	*Depth Below Top of Subgrade*	*Bore P 75′ Left of C.L.*			*Bore Q 25′ Left of C.L.*			*Bore S 25′ Right of C.L.*			*Bore R 75′ Right of C.L.*			*Mean*		
		MC	*PL*	*MC/PL*	*MC*	*PL*	*MC/PL*	*MC*	*PL*	*MC/PL*	*MC*	*PL*	*MC/PL*	*MC*	*PL*	*MC/PL*
Clay	0″–6″	27.8	27.2	1.02	25.1	22.8	1.10	16.0	27.0	.59	25.1	24.0	1.05	23.5	25.3	.94
	6″–12″	27.5	28.5	.97	25.8	24.0	1.07	25.6	22.8	1.12	25.9	24.2	1.07	26.2	24.9	1.06
	12″–18″	23.5	24.9	.94	25.9	23.1	1.12	22.7	23.1	.98	24.3	23.2	1.05	24.1	23.6	1.02
	24″	21.0	24.0	.87	20.9	20.0	1.05	18.5	21.1	.88	23.6	23.1	1.02	21.0	22.1	.95
	36″	19.8	22.0	.90	18.5	17.5	1.06	20.3	23.9	.85	22.7	22.3	1.02	20.3	21.4	.96
	48″	20.4	22.4	.91	16.6	17.2	.97	22.2	24.9	.89	22.9	22.5	1.02	20.5	21.7	.95
	60″	21.4	23.4	.91	20.6	19.4	1.06				19.8	18.6	1.06	20.6	20.5	1.01
	72″	17.7	21.3	.83							—	—	—	17.7	21.3	* .83
	84″										16.9	15.3	1.10	16.9	15.3	*1.10
	96″										20.0	16.2	1.23	20.0	16.2	*1.23
	108″										27.5	23.7	1.16	27.5	23.7	*1.16

Note: MC is moisture content as a percentage of dry weight of soil PL is plastic limit of soil Each value is the mean of at least three observations except where marked *

the current procedure has been detailed in a paper presented to an Australian conference (*Loxton, McNicholl, Bickerstaff*, 1952). In connection with the development of this procedure measurements of the moisture content and density of subgrade soils have been made at a large number of airfields in Australia and it is a summary of this data which is presented herewith (Tables 1*a*, 1*b*).

Measurements of Density

Density measurements have been undertaken at many aerodromes but to keep this paper to a reasonable length only one set of observations is presented. Table 2 records measurements at Essendon Airport where the average aircraft movements are 1,100 per week, 40% of which are aircraft with weights

Table 4 Comparison of Moisture Measurements. Various Locations—November 1950
Comparaisons de mesures de teneurs en eau, effectuées sur différents emplacements, novembre 1950

Site		*Essendon Airport, Victoria 79° Runway Pavement 200′ Wide*											
Location		*4*			*6*			*2*			*5*		
Chainage		*5300′*			*1000′*			*5300′*			*4900′*		
Distance from C.L.		*25′ to 75′ R. and L.*			*Centre Line*			*120′ Left of C.L.*			*250′ Right of C.L.*		
Surface		*Pavement 27″ Thick*			*Pavement 27″ Thick*			*Unpaved*			*Unpaved*		
Material	*Depth Below Top of Subgrade*	*MC*	*PL*	*MC/PL*	*MC**	*PL**	*MC*/PL*	*MC*	*PL*	*MC/PL*	*MC*	*PL*	*MC/PL*
Clay	6″	23.5	25.3	.93	32.2	28.3	1.14	17.3	21.5	.80	—	—	—
	12″	26.2	24.9	1.05	22.5	19.0	1.18	24.9	27.9	.89	22.8	22.6	1.01
	18″	24.1	23.6	1.02	—	—	—	25.9	28.8	.90	20.3	19.8	1.03
	24″	21.0	22.1	.95	23.0	17.9	1.29	26.9	27.1	.99	23.4	23.1	1.01
	36″	20.3	21.4	.95	35.3	27.7	1.27	22.0	23.1	.95	23.0	22.8	1.01
	48″	20.5	21.7	.95	36.1	31.2	1.16	19.9	20.3	.98	23.9	22.4	1.07
	60″	20.6	20.5	1.01	38.9	33.6	1.16	17.4	18.8	.93	23.0	21.4	1.08
	72″	17.7*	21.3*	.83	—	—	—	13.6*	15.0*	.91	22.6*	21.0*	1.08
	84″	16.9*	15.3*	1.10	35.9	28.7	1.25	16.8	17.7	.95	24.6	22.3	1.10
	96″	20.0*	16.2*	1.23	34.1	29.8	1.14	19.7*	21.3*	.93	26.6	23.2	1.15
	108″	27.5*	23.7*	1.16	—	—	—	—	—	—	27.0	24.6	1.10

Note: Each value is the mean of at least three observations except where marked *
MC is moisture content as a percentage of the dry weight of soil PL is the plastic limit

exceeding 40,000 lbs. The heavy subgrade clay has shown no significant increase in density due to this traffic.

At other localities measured densities have changed from their original values, depending on soil type, compaction during construction, subsequent traffic and the moisture content, but the final values are lower than the densities achieved when a sample at the particular moisture content is compacted using the modified A.A.S.H.O. compaction procedure.

Observations of Moisture Content at One Location

From preliminary investigations it was realized that the results of a single measurement of moisture content could not be relied upon and it is now the practice for each set of observations to measure the moisture content at not less than four separate points, spaced approximately five feet apart and to mean the results for each depth.

Table 5 Comparison of Moisture Measurements 1947 to 1950
Comparaisons de mesures de teneurs en eau, 1947 à 1950

Site		*Essendon Airport, Victoria 79° Runway Chainage 5300′ Pavement 200′ Wide*																	
Location		*4*								*2*									
Distance from C.L.		*Bores Located 25′ and 75′ Right and Left of Centre Line*								*120′ Left of Centre Line*									
Surface		*Pavement 27″ Thickness*								*Unpaved*									
Date of measurement		*Oct. 1947*		*Nov. 1948*		*Nov. 1949*		*Nov. 1950*		*Oct. 1947*		*April 1948*		*Nov. 1948*		*Nov. 1949*		*Nov. 1950*	
Material	*Depth Below Surface of Clay*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*
Clay	6″	29.4	1.21	28.2	1.16	26.8	1.08	23.5	0.93	17.6	—	17.6	0.92	15.1	0.78	16.6	0.89	17.3	0.80
	12″	23.2	1.01	23.5	1.04	23.3	1.08	26.2	1.05	23.2	0.94	26.3	1.02	24.6	0.92	23.2	0.97	24.9	0.89
	18″	21.8	1.01	20.3	1.06	20.1	1.05	24.1	1.02	—	—	26.6	1.02	27.5	0.98	26.4	1.00	25.9	0.90
	24″	21.5	1.06	18.6	1.02	19.6	0.97	21.0	0.95	23.1	1.08	24.5	1.05	23.9	0.96	26.6	1.03	26.9	0.99
	36″	21.2	1.12	18.3	1.00	17.8	0.96	20.3	0.95	20.0	—	21.3	0.97	22.0	0.98	19.9	0.99	22.0	0.95
	48″	—	—	17.0	1.02	18.1	0.99	20.5	0.95	18.3	1.01	19.8	0.98	20.3	0.98	20.0	1.00	19.9	0.98
	60″	19.9	1.12	16.6	1.05	18.5	1.05	20.6	1.01	17.7	—	19.4	0.95	18.5	0.96	18.3	1.00	17.4	0.93
	72″	—	—	—	—	—	—	17.7	0.83	—	—	18.2	0.95	—	—	—	—	*13.6	0.91
	84″	21.4	1.20	18.1	1.04	*19.4	*1.05	16.9	1.10	18.7	—	20.5	1.07	17.2	0.99	17.1	1.04	16.8	0.95
	96″	—	—	*23.6	*1.04	—	—	20.0	1.23	19.9	1.07	22.2	1.07	*18.1	0.95	*18.3	*1.01	*19.7	0.93
	108″	—	—	—	—	*26.1	*1.06	27.5	1.16	—	—	—	—	—	—	*21.3	*1.08	—	—

Note: Each value is the mean of at least three observations except where marked *

Table 3 gives the individual measurements for one locality though in this case the individual points are spaced further apart than is our present procedure. This table illustrates the value of using the ratio of moisture content to plastic limit in lieu of the actual value of moisture content. If this ratio is to be determined the sample from the bore must be mixed by kneading and then split into two portions, one for moisture determination and one for plastic limit. The plastic limit sample must not be dried out prior to testing.

	Moisture Content	*Ratio* $\frac{\textit{Moisture Content}}{\textit{Plastic Limit}}$
Mean	26.5%	1.06
Standard Deviation	5.9	0.11
Coefficient of Variation	22.0%	10.5%

The advantage of using this ratio is emphasised by the values of mean and standard deviation for 61 measurements made on the subgrade clay at Essendon Airport in November 1950 given above. The observations were at a number of locations and at various depths.

Moisture Measurement at a Number of Locations at One Airport

Table 4 gives a comparison of the results from a number of locations at the Essendon Airport. For each location the values are a mean of at least three measurements. It is interesting to note that below pavements the variations with depth are smaller than in unpaved areas. Also for depths below the limit for seasonal variations the values obtained beneath pavements are approximately the same as the values obtained in unpaved areas.

Periodical Observations of Moisture Content

Observations similar to those given in Tables 3 and 4 have been undertaken at Essendon at approximately six monthly intervals since the 79° runway was constructed in 1947. These observations are summarized in Table 5. Within the accuracy of the measurements they indicate no significant variation between the wet and dry periods of the year nor from year to year.

Table 6 is a tabulation of results similar to Table 5 for measurements below pavements at Eagle Farm Airport and at Daly Waters aerodrome and the adjoining Stuart Highway.

Table 6 Moisture Content Measurements at Daly Waters and Eagle Farm 1948 to 1951
Mesures de teneurs en eau à Daly Waters et Eagle Farm, 1948 à 1951

Site		*Stuart Highway Daly Waters Northern Territory*									
Location / *Surface*		*No. 1, 2.5 Miles North of Aerodrome Turnoff–C.L. of Road* / *Pavement 5"–7" Gravel, Sealed*									
Date of Measurement		*Oct. 1948*		*Mar. 1949*		*Nov. 1949*		*April 1951*		*Nov. 1951*	
Material	*Depth Below R-W Surface*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*
Gravel	6"										
Topsoil	8"	5.9	.44	6.6	.52			6.9	.56	6.2	.52
6"–15"	16"					10.5	.68	10.9	.80	9.6	.60
Red-	24"					12.9	.69	11.8	.75	10.4	.63
Brown	32"	11.6	.63	12.2	.63	11.9	.71	12.6	.71	11.7	.64
Clay	40"					14.4	.74	13.5	.73	11.9	.64
	48"	12.2	.62	13.0	.64			12.7	.67	10.9	.62

Site		*Stuart Highway Daly Waters Northern Territory*									
Location / *Surface*		*No. 3, 3.3 Miles South of Aerodrome Turnoff–C.L. of Road* / *Pavement 5"–7" Gravel, Sealed*									
Date of Measurement		*Oct. 1948*		*Mar. 1949*		*Nov. 1949*		*April 1949*		*Nov. 1951*	
Material	*Depth Below R-W Surface*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*
Gravel	6"										
Topsoil	8"							7.4	.67	7.2	.58
6"–20"	16"	10.5	.77	10.1	.99	—	—	10.6	.93	10.1	.86
Yellow-	24"							12.0	.89	12.1	.83
Brown-	32"	11.5	.72	12.9	.87	—	—	12.5	.85	13.0	.82
Clay	40"							12.2	.88	12.2	.78
	48"	11.9	.72	12.7	.90	—	—	10.3	.76	12.4	.78

Site		*Daly Waters Aerodrome, Northern Territory*									
Location / *Surface*		*S.E. End 40° R.W. Chainage 2600', on C.L.* / *Pavement 5"–7" Gravel, Sealed*									
Date of Measurement		*Mar. 1949*		*Nov. 1949*		*April 1950*		*April 1951*		*Nov. 1951*	
Material	*Depth Below R-W Surface*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*
Yellow	8"	9.4	.72	5.0	—			7.2	.52	6.2	.39
Silty	16"			7.9	—			10.6	.81	7.8	.57
Loan	24"			11.9	.75	11.0	.71	12.7	.78	10.7	.63
	32"	13.8	.78	13.0	.76	12.4	.72	13.6	.79	11.5	.66
	40"			13.9	.71	13.5	.71	14.2	.81	10.3	.62
	48"	14.2	.70	14.4	.71	13.8	.69	14.4	.77	12.5	.66

Site		*Eagle Farm Aerodrome, Queensland*							
Location / *Surface*		*40° R-W, Chainage 1950', on C.L.* / *Pavement 9"–13" Gravel, Sealed*							
Date of Measurement		*Sept. 1949*		*Dec. 1949*		*March 1950*		*July 1950*	
Material	*Depth Below R-W Surface*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*	*MC*	*MC/PL*
Silty	24"	27.1	1.18	16.3	0.68	28.0	1.07	21.7	1.20
Clay	36"	26.0	1.33	21.6	0.98	28.8	1.36	27.1	1.27
	48"	24.3	1.09	29.3	1.30	26.5	1.11	26.0	1.06
	60"	26.1	1.13	26.7	1.19	28.6	1.15	28.2	1.13
	72"	28.6	1.13	26.8	1.18	30.8	1.20	31.6	1.17

Table 7 Meteorological Data, Typical Soil Properties, Estimated and Measured Moisture Contents at Various Aerodromes
Données météorologiques, propriétés typiques du sol, teneur en eau, estimée et mesurée sur plusieurs pistes d'atturissage

Location	Latitude °S	Annual Rainfall In.	Mean-daily Max. Temp. °F	Soil Classification: Textural	Soil Classification: H.R.B.	Soil Classification: U.S. C. of E.	L.L. %	P.L. %	Passing B.S. 36 Sieve %	Ratio Field Moisture Content / Plastic Limit: Estimated, Drainage Good	Estimated, Drainage Poor	Measured	Conditions at Site where Moisture Measured: Drainage	Pavement	Climate
Queensland															
Amberley	27° 39′	33.7	81.2	Si. Loam	A4	CL	32	15	66	0.7	1.0	0.8–1.0	Poor	Runway	Coastal
Amberley				Si. Clay	A7	CH	77	32	99	1.0	1.3	1.0–1.2	Poor	Runway	Coastal
Camooweal	19° 55′	15.3	90.6	Clay	A6	CH	55	37	97	0.7	1.1	0.7*	Good	Apron	Inland
Cloncurry	20° 41′	18.6	90.1	Clay	A6-7	CL	43	18	96	0.7	1.0	1.1*	Poor	Apron	Inland
Cooktown	15° 28′	70.2	84.4	Cl. Loam	A4	CL	34	20	88	0.8	1.0	1.0*	Poor	Runway	Coastal
Cunnamulla	28° 04′	14.6	82.6	Clay	A4-7	CL	40	17	96	0.7	1.0	0.5–0.7*	Good	Unpaved	Inland
Eagle Farm	27° 30′	45.3	78.1	Sa. Silt	A4	SF	21	15	94	0.7	0.9	0.3–0.7*	Average	Apron	Coastal
Eagle Farm				Clay	A8	CH	85	32	95	1.1	1.4	1.2–1.4	Poor	Runway	Coastal
Kingaroy	26° 25′	31.0	78.0	Sa. Loam	A4-7	CL	57	29	72	0.9	1.1	1.0*	—	Unpaved	Inland
Longreach	23° 26′	16.5	88.1	Clay	A7	CH	48	20	75	0.7	1.0	0.8*	Average	Apron	Inland
Mackay	21° 10′	67.3	79.8	Loam	A4	ML	24	16	83	0.8	0.9	0.6–1.1*	Poor	Apron	Coastal
Mackay				Clay	A7	CH	60	30	97	1.0	1.2	1.0*	Poor	Apron	Coastal
Maryborough	25° 31′	46.2	80.0	Clay	A7	CH	49	20	94	0.9	1.1	1.2*	Poor	Runway	Coastal
Mount Isa	20° 45′	13.0	90.0	Clay	A7	CL	44	21	93	0.6	1.0	0.6*	Good	Unpaved	Inland
Rockhampton	23° 23′	39.7	83.5	Clay	A7	CH	68	24	98	1.0	1.2	1.0*	Average	Runway	Coastal
Roma	28° 35′	23.4	82.2	Clay	A7	CH	61	23	97	0.8	1.2	0.8–1.1*	Poor	Unpaved	Inland
Townsville	19° 16′	46.9	82.2	Si. Loam	A4	SF	26	19	93	0.7	0.9	0.8–1.2*	Av. to Poor	Runway	Coastal
Townsville				Clay	A6	CH	49	17	98	0.9	1.1	1.1–1.3*	Av. to Poor	Runway	Coastal
New South Wales															
Bankstown	33° 57′	35.6	74.1	Si. Loam	A4	ML	28	20	94	0.7	1.0	0.8*	Average	Apron	Coastal
Bankstown				Si. Clay	A6	CH	63	21	98	1.0	1.2	1.0–1.1*	Average	Apron	Coastal
Broken Hill	32° 00′	9.6	76.2	Clay	A4-7	CL	38	18	81	0.7	1.1	0.5*	Good	Runway	Inland
Broken Hill												0.8*	Poor	Runway	Inland
Canberra	35° 20′	22.5	67.5	Clay	A6	CL	43	16	97	0.8	1.1	0.6*	Good	Runway	Inland
Canberra				Clay	A7-6	CH	51	19	97	0.9	1.2	0.9–1.2*	Poor	Runway	Inland
Corowa	36° 00′	20.3	72.4	Loam	A4	ML	21	17	85	0.6	1.0	0.6*	Average	Runway	Inland
Dubbo	32° 10′	22.0	77.6	Clay	A4	CL	32	12	85	0.7	1.0	1.0*	Poor	Runway	Inland
Griffiths	34° 16′	15.8	74.2	Cl. Loam	A4	CL	32	15	86	0.7	1.0	0.8*	Average	Runway	Inland
Kempsey	31° 05′	45.4	78.1	Clay	A6	CH	54	19	99	0.9	1.2	1.2–1.4*	Poor	Unpaved	Coastal
Narranderra	34° 42′	17.0	72.0	Cl. Loam	A6	CL	36	16	95	0.7	1.1	1.1*	Poor	Runway	Inland
Nowra	34° 57′	38.3	72.7	Clay	A7	CH	63	32	96	1.0	1.2	1.2	Poor	Runway	Coastal
Richmond	33° 36′	29.3	75.2	Clay	A7	CL	39	18	100	0.8	1.1	1.0	Poor	Apron	Coastal
Schofield	33° 00′	30.0	70.0	Si. Loam	A4	CL	33	23	87	0.7	1.1	0.4–0.8	Average	Apron	Coastal
Schofield					A6	CH	53	19	99	0.9	1.2	1.0–1.1	—	Apron	Coastal
Wagga	35° 09′	21.3	74.1	Clay	A7	CH	50	19	93	0.8	1.1	1.0*	Poor	Apron	Inland

Abbreviations: Cl. = Clay   Si. = Silty   Sa. = Sandy   Av. = Average

These examples are quoted on account of the climatic and drainage differences of these sites (see Tables 6 and 7). It will be noted that the comments made in the previous paragraph apply also to these observations.

Moisture Contents Measured at Many Aerodromes

Moisture measurements have been made at more than forty aerodromes in Australia situated between latitude 12° S and 43° S with wide extremes of climate.

Table 7 lists the typical properties of the soils at these sites and the results of the moisture measurements. The majority of the results are from a single set of measurements but at a few sites periodical observations have been undertaken. These results indicate that the largest factor affecting the ratio of the moisture content to the plastic limit is drainage but it is also affected by properties of the soil and the climate.

At a new aerodrome site where no pavements exist it is difficult to obtain reliable information as to the equilibrium moisture condition which will develop in the pavement subgrades. Thus it is desirable for design purposes to be able to estimate the ratio of moisture content to plastic limit either from simple soil tests and the available meteorological data or from measurements of the ratio of moisture content to plastic limit at depths below the limit of seasonal variation.

The following approximate relations which have been derived from observations at the sites tabulated in Table 7 give a guide to the probable subgrade equilibrium moisture condition (for

Table 7 Continued
Suite

Location	Latitude °S	Annual Rainfall In.	Mean-daily Max. Temp. °F	Soil Classification: Textural	Soil Classification: H.R.B.	Soil Classification: U.S. C. of E.	L.L. %	P.L. %	Passing B.S. 36 Sieve %	Ratio Field Moisture Content / Plastic Limit: Estimated, Drainage Good	Ratio: Estimated, Drainage Poor	Ratio: Measured	Conditions at Site where Moisture Measured: Drainage	Pavement	Climate
Victoria															
Essendon	37°44′	25.5	67.7	Clay	A7	CH	81	27	98	1.1	1.4	1.1	Good	Runway	Coastal
Lara	38°00′	20.2	67.1	Clay	A7	CH	93	32	98	1.1	1.5	1.1*	Average	Road	Coastal
Mangalore	36°50′	23.2	70.0	Clay	A7	CL	45	20	93	0.8	1.1	0.8–1.0*	Average	Runway	Inland
Mildura	34°14′	10.6	76.4	Sa. Clay	A4	ML	27	18	88	0.6	1.0	0.5–0.7*	Average	Runway	Inland
Mildura												1.3*	Poor	Runway	Inland
Moorabbin	37°55′	25.6	67.4	Clay	A7	CH	61	21	86	0.9	1.3	1.2–1.4	Poor	Unpaved	Coastal
Pt. Cook	37°56′	22.3	67.7	Clay	A7	CH	87	30	99	1.1	1.4	1.1*	Average	Apron	Coastal
Swan Hill	35°22′	13.2	74.0	Sa. Cl. Loam	A2-6	SF / CL	45	17	82	0.7	1.1	0.8*	Average	Runway	Inland
Warrnambool	38°57′	27.2	63.9	Clay	A7	CH	101	41	95	1.2	1.4	0.9–1.0*	Average	Unpaved	Coastal
Sale	38°10′	23.9	68.6	Si. Clay	A7	CL	42	22	95	0.8	1.1	1.0	Average	Runway	Coastal
Tasmania															
Cambridge	42°50′	37.1	58.0	Loam	A4	ML	28	18	88	0.8	1.1	0.9*	Average	Runway	Coastal
Cambridge				Sa. Cl. Loam	A4	ML–CL	31	12	87	0.8	1.1	1.1*	Average	Runway	Coastal
Llanherne	43°00′	37.1	58.0	Clay	A7	CH	106	39	99	1.3	1.6	1.2*	Average	Unpaved	Coastal
South Australia															
Gawler	34°40′	17.3	73.6	Cl. Loam	A4	CL	24	12	98	0.6	1.0	0.8*	Good	Runway	Inland
Gawler												1.1*	Poor	Runway	Inland
Oodnadatta	27°34′	5.3	81.6	Clay			31	18	67	0.6	1.0	0.6–1.1*	Av. to Poor	Runway	Inland
Port Pirie	33°11′	13.2	76.8	Sa. Cl. Loam	A7	CL	44	23	99	0.7	1.1	1.1*	Poor	Runway	Inland
Salisbury	34°48′	17.3	73.6	Clay	A6	CH	57	20	93	0.8	1.2	1.0*	Average	Roads	Inland
Pimba	31°00′	7.0	80.4	Clay	A7	CL	43	24	82	0.8	1.1	0.7	Good	Runway	Inland
Western Australia															
Guildford	31°57′	34.1	76.1	Clay	A7	CH	53	23	73	0.9	1.2	1.0*	Poor	Runway	Coastal
Pearce	31°40′	34.0	76.0	Clay	A6	CL	47	20	77	0.8	1.1	1.0	Poor	Runway	Coastal
Northern Territory															
Daly Waters	16°16′	26.5	94.0	Clay	A4	CL	33	16	85	0.6	0.9	0.6	Average	Runway	Inland
Darwin	12°26′	60.5	90.9	Sa. Clay	A2P	SF	35	16	82	0.7	1.0	0.8	Average	Runway	Coastal

Notes: 1. Measured moisture contents marked * are the result of a number of observations at one date—Unmarked figures are the mean of periodical measurements.
2. Drainage is classified as
(*a*) *Good*—Surface is well graded and has a slope of 1% or steeper, no water table, true or perched, exists in the vicinity of the soil;
(*b*) *Average*—Water occasionally lies on the surface or in its vicinity for limited periods, no water table in the vicinity of the soil;
(*c*) *Poor*—Water lies on the surface or in the vicinity for lengthy periods, a perched water table exists in or above the soil or the true water table is at a very shallow depth.

the minus No. 36 B.S. sieve material) for Australian climates for relatively impermeable soils (plasticity index greater than 9).

$$\frac{\text{Moisture Content}}{\text{Plastic Limit}} = 0.78 + \frac{LL}{150} - \frac{T}{200} + \frac{R}{250},$$ where the drainage is good

$$\frac{\text{Moisture Content}}{\text{Plastic Limit}} = 1.20 + \frac{LL}{150} - \frac{T}{200},$$ where the drainage is poor

where LL = liquid limit
T = mean maximum daily temperature °F
R = annual rainfall in inches.

Values, estimated using these relations are given in columns 11 and 12 of Table 7.

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