CHAPTER 6

DYNAMIC CONE PENETROMETER (DCP)- AIDED EVALUATION OF THE BEHAVIOUR OF PAVEMENTS WITH CEMENTITIOUS LAYERS

CONTENTS PAGE

6.1 INTRODUCTION AND BACKGROUND

Permanent deformation measurements (Chapter 4) as well as the in situ resilient properties (Chapter 7) of pavement systems are normally used to describe the behaviour of the pavement. As was indicated in Chapter 3, the Dynamic Cone Penetrometer (DCP) is also used to measure in situ strength conditions of pavements, and hence may be used to aid the understanding of specific behavioural patterns observed during traffic loading of pavements. Marais et al (1982) confirmed the use of the DCP in the evaluation of pavement strength and pavement composition, in association with the HVS. They concluded that the internal strength of the various pavement layers could be evaluated before HVS tests started and changes occurring as a result of traffic loading could be monitored with the DCP. This assisted in quantifying the concepts of traffic moulding, pavement strength - balance and load sensitivity, which confirmed that a pavement behaves as a system.

In this chapter, a description of the behaviour of pavements with lightly cementitious layers according to the DCP is given. A new concept, viz **"Pavement Strength - Balance Paths"** is introduced which assists in describing the behaviour of pavements on a more quantitative basis than in the past.

6.2 CONCEPT OF PAVEMENT STRENGTH - BALANCE PATHS

In Chapter 3, the DCP- classification system for pavements is described in detail. This classification system is based on the two unique DCP - parameters, viz A and B. Parameter B describes the **Standard Pavement Strength Balance Curve** (SPBCs), while parameter **A** describes the **Degree of Balance** in terms of the total deviation (area) of the DCP data from the best fit SPBC.

According to this classification system, each DCP measurement (and therefore the pavement) is classified according to its in situ strength - balance at the time of measurement, which is sufficiently defined by the parameters A and B. If the pavement is monitored during HVS testing, ie at various stages of trafficking, changes in A and/or B, may reflects changes in the pavement owing to traffic loading.

According to the findings of Marais et al (1982), lightly unbound gravel base pavement systems showed a tendency to be "moulded" as a result of traffic into states of strength which differ from the original values before HVS testing.

They further stated that:

> "The discrete strength values in successive layers become modified so that there is a more gradual reduction in strength with depth. The relatively abrupt interlayer strength variations are smoothed out, and the extent to which this phenomenon manifests itself is determined by the load sensitivity of the pavement, ie the strength and composition of the various pavement layers relative to the traffic load. Thus it may be observed that a particular pavement exhibits no traffic - associated deformation for many years, whilst another may show early signs of traffic moulding, manifested as deformation."

Traffic moulding of overstressed pavement layers occurs as a result of trafficking. This concept is illustrated in Figure 6.1. As shown, this moulding usually results in the densification of one or more of these unbound layers, thereby increasing their strength (mainly shear) sufficiently to withstand the traffic loading. Alternatively, depending on the quality of material, a layer may not attain sufficient strength and may fail in shear. Also, the moulding deformation in a layer may be such that the layer above it cannot accommodate the strain and becomes overstressed and fails.

This phenomenon may cause either an increase or a decrease in the bearing capacity of the pavement, but always results in a loss of riding quality. A decrease in riding quality does not therefore necessarily constitute a reduction in pavement bearing capacity, but a continuing or accelerating decrease in riding quality is likely to do so.

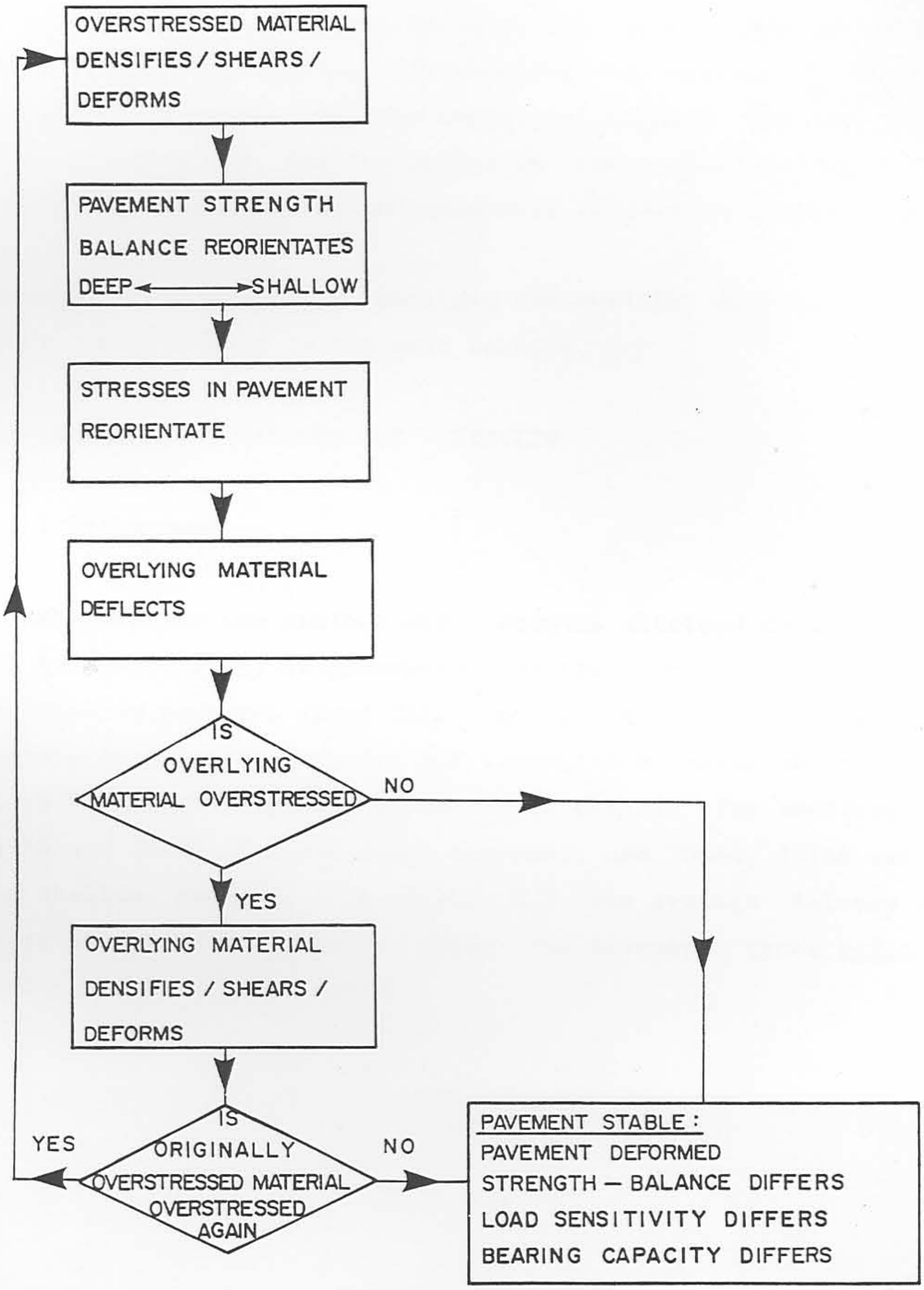


FIGURE 6.1

TRAFFIC MOULDING OF OVERSTRESSED PAVEMENT LAYERS

(Marais et al, 1982)

In addition, pavement mouldability and load sensitivity show seasonal variations since the strength of materials can strongly be affected by environmental conditions, especially the moisture content.

Marais et al (1982) concluded that for lightly unbound pavements it appears that the ultimate effect of the moulding phenomenon is the achievement of a better strength-balanced pavement system, because of a smoother relationship of strength versus depth. It is, however, my opinion that this is not always true for pavements with lightly cementitious layers, as fatigue failure and crushing in the top of the cemented base under traffic may result in an even more unbalanced pavement. This concept, however, is useful and contributes to the understanding of pavement behaviour.

The concept of Pavement Strength - Balance Paths, however, may assist in a better quantitative description of traffic moulding of a pavement.

The **Pavement Strength - Balance Path** is defined as the **change in** the **pavement strength - balance relationship as a direct result of traffic loading under prevailing environmental conditions. The strength - balance is described by the degree of balance (A) and the pavement balance number (B), and any change in one or both of these values as a result of traffic and/or environmental conditions defines the path.**

Strength - balance paths obtained for the HVS sections tested in this study are discussed in the next section.

6.3 ANALYSIS OF VARIOUS DCP - RESULTS

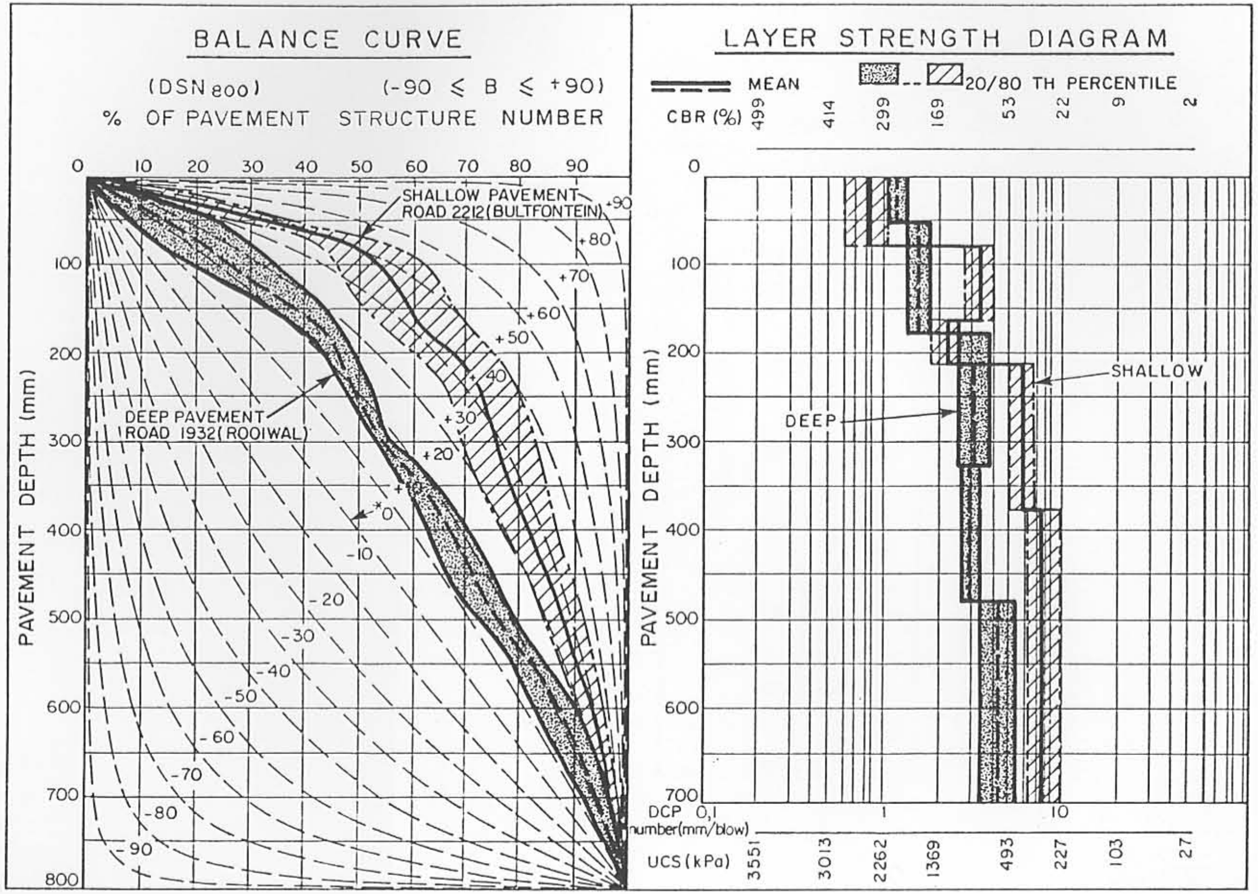
6.3.1 Background

In this section the various DCP - results obtained during HVS testing on the two basic types of pavements, ie the deep (Road 1932, Rooiwal) and the shallow pavement (Road 2212, Bultfontein) are considered. For the purpose of this chapter, the DCP - results of three of the HVS sections of each pavement type are discussed in detail. The sections are 275A4, 289A4 and 294A4, for the deep pavement, and 306A4, 307A4 and 308A4 for the shallow pavement. In Figure 6.2 the **average Balance Curves** and **Layer Strength Diagrams** of these two pavement types <u>before</u> any HVS trafficking are illustrated.

The figure indicates that the average balance curves of the pavements are different, with that of the deep pavement at a lower balance number (B = 19) and that of the shallow pavement at a higher balance number (B = 41). The shaded areas on Figures 6.2 and 6.3 refer to the 20th and 80th percentile of all the results used to calculate the average values. (In Appendix E, a detailed summary of the various DCP results on these two pavements are given according to the computerised graphical layout, described in Appendix C. The average results in Figures 6.2 and 6.3, were calculated from the results in Figures E.11, E.19, and E.27, for the deep pavement, and from the results in Figures E.38, E.48 and E.56, for the shallow pavement).

Figure 6.2 also indicates the two sets of Layer Strength Diagrams for these pavements with important differences in DCP penetration rates of the various layers notable. For the balance curves and the layer strength diagrams, both the 20th and 80th percentile values are also indicated. (The DCP results discussed here are limited to only six measurements per type of pavement (two per test section), because of the relative destructive nature of the DCP test on cemented pavement layers on an HVS test section. Therefore the average and percentile values of these results are given only as estimates of the pavement definition, and are mainly used to compare the two pavement types, rather than to be representative of very accurate "statistical" descriptions of these pavements. In the latter event, at least 30 different DCP measurements per pavement type is necessary to define the pavement structure properly, using the normal distribution theory).

In Figure 6.3 the Normalised Curves and the Layer Strength Diagrams of the re - defined layers (in terms of layer thickness) of the two pavements are illustrated. The normalised curves show the deviation (A_i) from the Standard Pavement Balance Curve (SPBC) with depth (see Chapter 3). For the shallow pavement, a maximum positive deviation occurs at approximately 75 mm, which is indicative of the average in situ (effective) thickness of the cemented base layer of this pavement. For the deep pavement, the maximum deviation occurs at approximately 160 mm, indicating a thicker cemented base. The layer strength diagrams also indicate large differences in the penetration rates for both the upper and lower layers of both pavements. Detailed DCP analysis of the two pavements are given in Appendix E, see Figures E1 to E10.



* Numerical (B-value) refers every time to the curve below.

FIGURE 6.2

DCP - BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF THE TWO TYPES OF PAVEMENTS STUDIED

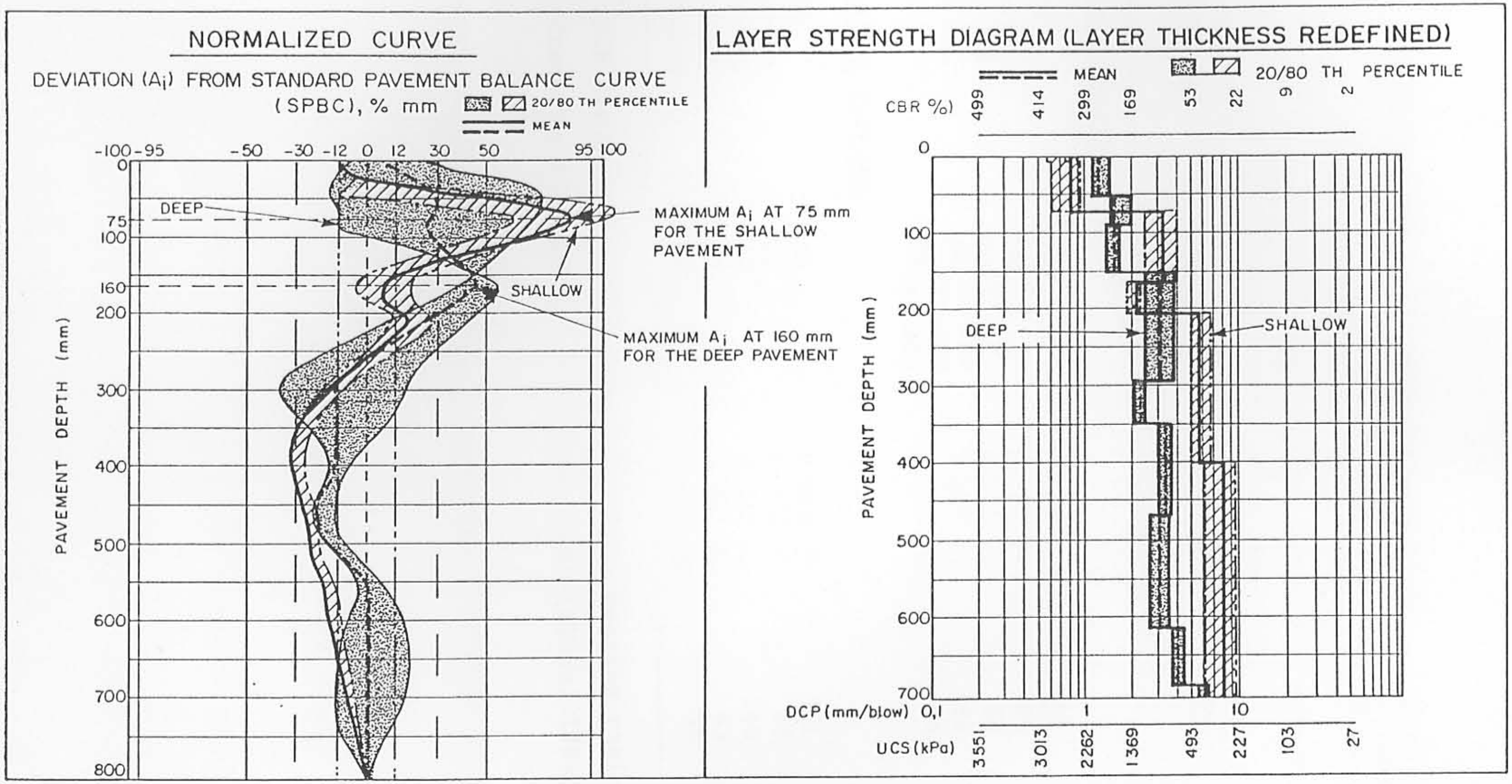


FIGURE 6.3

NORMALIZED CURVES AND LAYER STRENGTH DIAGRAMS OF THE REDEFINED LAYERS (IN SITU THICKNESS) OF THE DEEP AND SHALLOW PAVEMENTS STUDIED

A summary of the average measured basic DCP-parameters for these two pavement types before HVS trafficking (N = 0) are given in Tables 6.1 and 6.2. Table 6.1 indicates that the balance number B of the shallow pavement is almost twice that of the deep pavement, and, together with BN_{100}, is the strongest indicator of the basic difference between these two types of pavements. Table 6.2 indicates the DCP numbers (average penetration rates) at various depths in these pavements, together with the DCP - derived California Bearing Ratio (CBR) and Unconfined Compression Strength (UCS). Note the relatively smooth decrease in these values with increasing depth of the deep pavement, while irregularities at a depth of approximately 81 to 160 mm are evident in the shallower pavement, causing a higher imbalance of the pavement (see Table 6.1).

TABLE 6.1 AVERAGE BASIC DCP-PARAMETERS FOR THE TWO PAVEMENTS (HVS SECTIONS 275A4, 289A4 AND 294A4)

DCP-PARAMETER	DEEP (ROAD 1932)	SHALLOW (ROAD 2212)
DSN_{800}	397	352
B	19	41
A	1398	2089
BN_{100}	27	56
DCP-CLASSIFICATION	AVERAGELY BALANCED DEEP (ABD)	AVERAGELY BALANCED SHALLOW (ABS)

TABLE 6.2 AVERAGE DCP - PENETRATION RATES, CBR AND UCS (HVS SECTIONS 306A4, 307A4 AND 308A4)

DEPTH (mm)	PARAMETER	DCP NUMBER (mm/blow)	CBR*	UCS*
DEEP PAVEMENT:				
0-50	DN_{50}	1,3(0,2)	251	1940
51-180	DN_{51-180}	1,7(0,3)	198	1574
181-330	$DN_{181-330}$	3,2(0,7)	93	809
331-480	$DN_{331-480}$	3,1(0,4)	96	832
481-800	$DN_{481-800}$	4,2(1,2)	66	598
SHALLOW PAVEMENT:				
0-80	DN_{80}	0,8(0,3)	331	2474
81-160	DN_{81-160}	3,5(0,7)	85	746
161-210	$DN_{161-210}$	2,3(0,4)	145	1197
211-375	$DN_{211-375}$	5,9(1,0)	43	410
376-800	$DN_{376-800}$	7,7(2,0)	30	299

* DCP derived parameters for California bearing ratio (CBR) and Unconfined Compressive Strength (UCS) (Kleyn, 1984).

6.3.2 Deep pavement (Road 1932 at Rooiwal): Results and discussion

In the following paragraphs the emphasis is on the changes in the pavement system as a result of traffic loading rather than the actual differences between the two pavements as discussed in Paragraph 6.3.1. The HVS trafficking was done with the normal dual wheel load configuration.

In Table 6.3 the average DCP-numbers (DN in mm per blow) at different depths and at different number of load repetitions on the three sections of the deep pavement are given.

TABLE 6.3 AVERAGE DCP-NUMBERS OF THE THREE TEST SECTIONS ON THE DEEP PAVEMENT AT ROOIWAL

HVS-SECTION (HVS Test Load)	REPETITIONS	DCP NUMBER (mm/blow)		IN SITU MOISTURE
		DN_{50} *	DN_{50-180} **	
275A4 (40 kN)	0	1,2 (0,3)	1,8 (0,4)	DRY
	10^6	1,3 (0,3)	1,8 (0,5)	DRY
	$2,1 \times 10^6$	2,2 (0,5)	1,8 (0,4)	DRY
	$2,1 \times 10^6$	3,2 (0,3)	2,9 (0,4)	WET
289A4 (70 kN)	0	1,9 (0,4)	1,1 (0,3)	DRY
	10^6	2,7 (0,5)	1,7 (0,4)	DRY
	$1,9 \times 10^6$	2,6 (0,3)	2,2 (0,5)	DRY
	$1,9 \times 10^6$	2,2 (0,3)	2,0 (0,6)	WET
294A4 (100 kN)	0	0,7 (0,3)	2,1 (0,6)	DRY
	10^6	1,2 (0,2)	2,6 (1,0)	DRY
	$1,8 \times 10^6$	1,8 (0,6)	2,5 (0,5)	DRY
	$1,8 \times 10^6$	2,2 (0,8)	3,3 (1,4)	WET

* DN_{50} = the average rate of penetration in the top 50 mm of the cemented base layer.

** DN_{50-180} = the average rate of penetration from a depth of 50 mm to a depth of 180 mm in the cemented base layer.

() Standard deviation in the rate of penetration.

The table indicates that the DN_{50} increases at a higher rate than DN_{50-180}, especially for Sections 275A4 and 294A4. Furthermore, the DN_{50} at the end of the various tests is two to three times higher for all sections than the initial DN_{50}, indicating a weakening in the upper 50 mm of the base layer. In Chapters 4 and 5, this weakening was described as a compression failure (crushing) at the top of the cemented base layer.

In Section 289A4, evidence of a decrease in DN_{50} after approximately 1,9 x 10^6 repetitions in the wet state indicates compaction (densification) in the top of the layer, which was directly responsible for a relatively high rate of deformation in this section (see also Paragraph A.2, in Appendix A). The table indicates that traffic moulding of the deep pavement is caused by crushing failure as well as compaction (Section 289A4) in the top of the pavement, depending on the initial state of the base layer. Detailed DCP analyses of the various HVS test sections are also summarised in Appendix E. The information summarised in Appendix E (Figures E11 to E34) in respect of the deep pavement, indicates that more drastic changes in the rate of penetration occurred in the upper layers (0-180 mm) than in the lower layers, and illustrates the type of "shallow" failure expected for deep pavements.

In Figures 6.4, 6.5 and 6.6 balance curves and layer strength diagrams of these three sections of the deep pavement at various stages of HVS trafficking are illustrated. The figures indicate that there is a reduction in the B-value as a result of trafficking, which is also reflected in changes in the layer strength diagrams owing to fatigue and crushing failure of the base. In Table 6.4 the average calculated A and B parameters at various stages of trafficking and moisture conditions are given.

TABLE 6.4 AVERAGE A AND B PARAMETERS FOR THE THREE SECTIONS ON THE DEEP PAVEMENT.

HVS-SECTION	TEST LOAD* (kN)	REPETITIONS (ACTUAL)	A	B
275A4	40	0	956	20
		10^6	1109	9
		2,1 X 10^6 (DRY)	1413	11
		2,1 X 10^6 (WET)	956	5
289A4	70	0	2285	18
		10^6	1772	8
		1,9 X 10^6 (DRY)	1226	-3
		1,9 X 10^6 (WET)	1224	1
294A4	100	0	3134	18
		10^6	2790	9
		1,9 X 10^6 (DRY)	2077	-3
		1,9 X 10^6 (WET)	1637	1

* Dual wheel load

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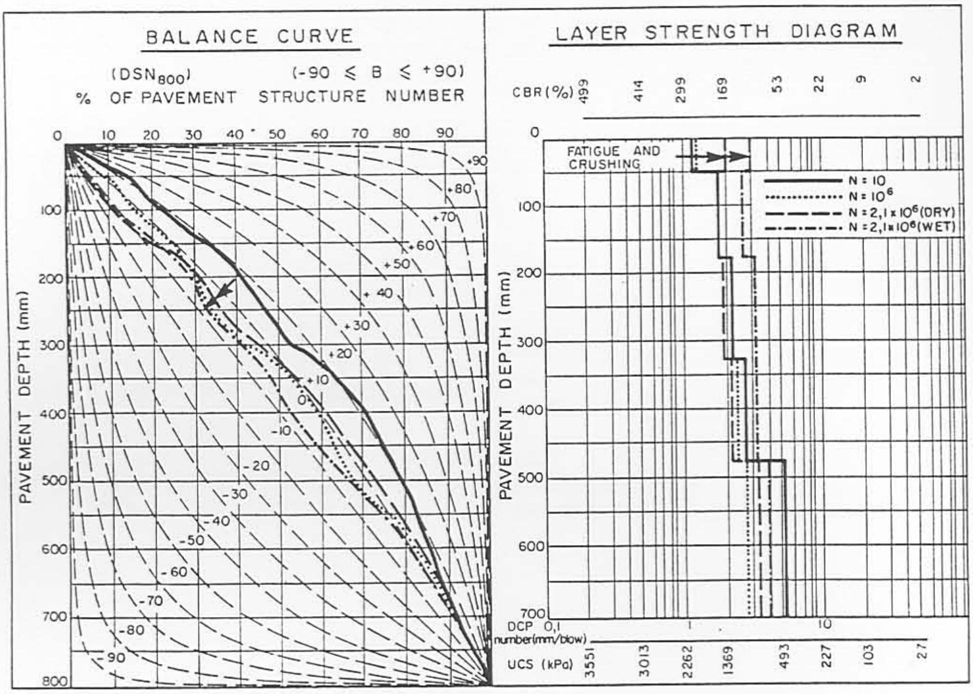

FIGURE 6.4

DCP BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF HVS TEST SECTION 275A4

940-4-5910/ BS *(INITIAL DCP-CATEGORY IV : WELL BALANCED DEEP STRUCTURE (WBD))*

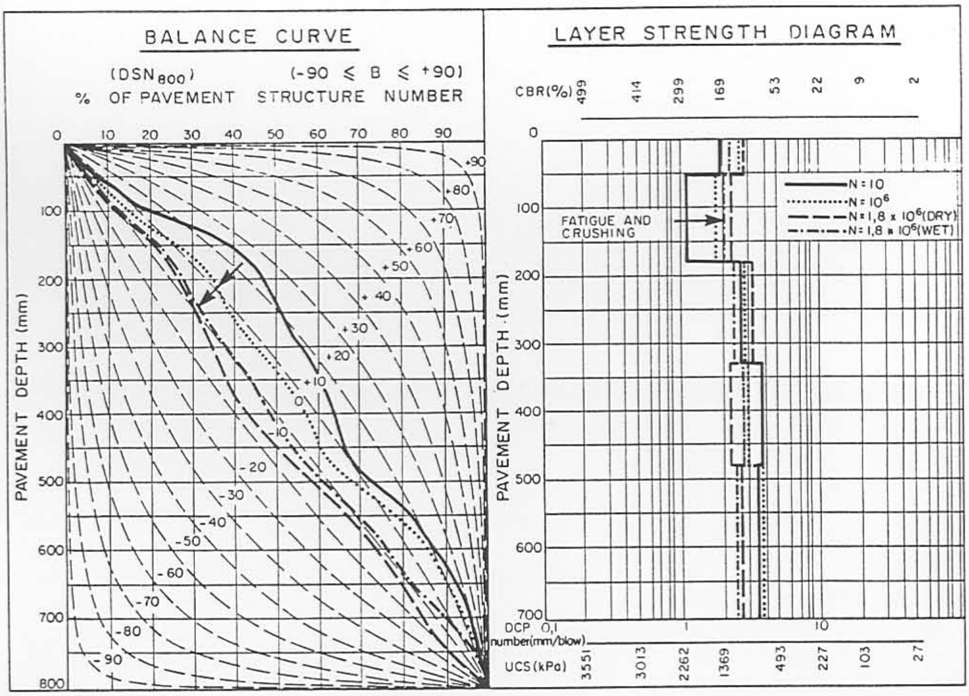

FIGURE 6.5

DCP BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF HVS TEST SECTION 289A4 (INITIAL DCP-CATEGORY V: AVERAGELY BALANCED DEEP STRUCTURE (ABD))

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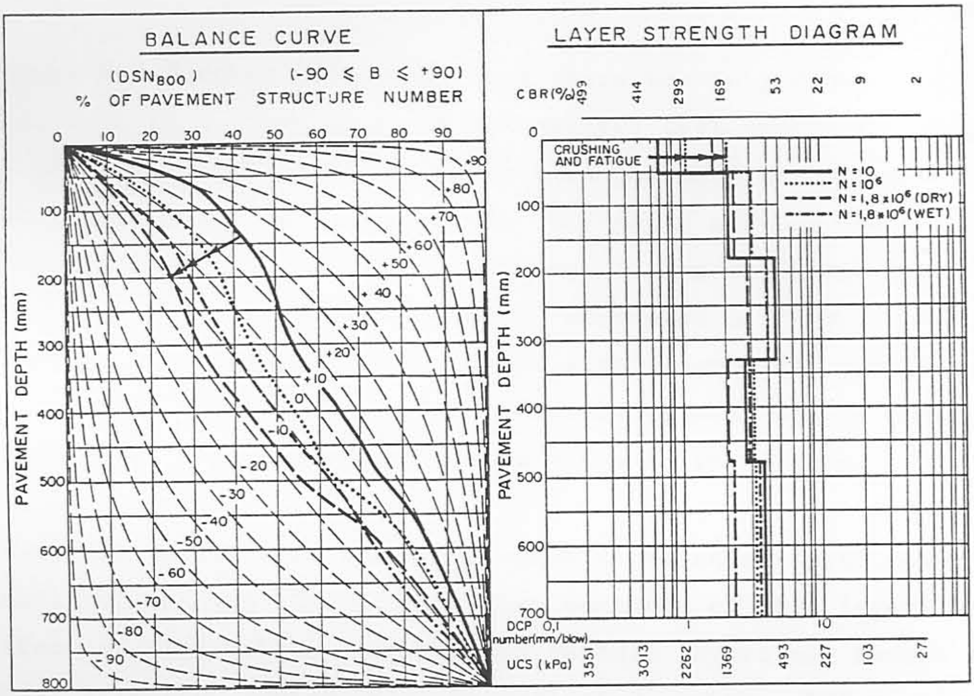

FIGURE 6.6

DCP BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF HVS TEST SECTION 294A4 (INITIAL DCP-CATEGORY VI : POORLY BALANCED DEEP STRUCTURE (ABD))

The table indicates that the Balance Number (B) changes more rapidly than the deviation from standard balance (A). Figure 6.7 shows the change in A at various stages of trafficking on the three sections of the deep pavement, and appears to improve (A_i decrease to zero) as the traffic moulding process progresses, especially in the upper layers of the pavement.

To aid the illustration of the changes caused by to traffic loading in the pavement, the **concept of balance - paths** has been introduced. In Figure 6.8 typical balance - paths (changes in A and B) for the deep pavement as a result of trafficking are illustrated. The figure indicates that the deep pavement becomes deeper (decrease in B-parameter) as a result of traffic loading, and slightly better balanced (decrease in A-parameter). With further increase in trafficking B becomes negative, indicating an **inverted pavement**, according to the classification system described in Chapter 3. This is a further quantification of the crushing failure effect in the top of the cemented base layer of deep pavements. A higher penetration rate (DCP number) in the top of the pavement as a result of crushing failure, in this case, implies a lower balance number, B.

Figure 6.8 further indicates that there was a greater initial (N = 0) variation in A, than in B, of the various test sections. Parameter A is sensitive to variations in the in situ pavement structure, because A is the area (deviation) between the DCP data and the best fit standard pavement balance curve, B. Variation in the different layer strengths in a pavement system is therefore reflected more by the A parameter, than the B parameter. The figure also shows the combined effect of trafficking and an increase in moisture content of the pavement layers on A and B, depicted by the broken lines in the figure.

It is also postulated that a pavement's balance - path may change as a result of <u>changes</u> in the moisture content of the layers <u>without</u> the effect of trafficking. Wetting of certain layers may reduce the in situ shear strength, which will be reflected by the DCP penetration rate (DCP-Number), and hence the A and B-parameters. Close inspection of these balance - paths may, however, assist in discovering the underlying reasons for these changes by identifying moisture sensitive layers,

DEVIATION FROM STANDARD PAVEMENT BALANCE CURVES (SPBCs),(DEVIATION, A_i)

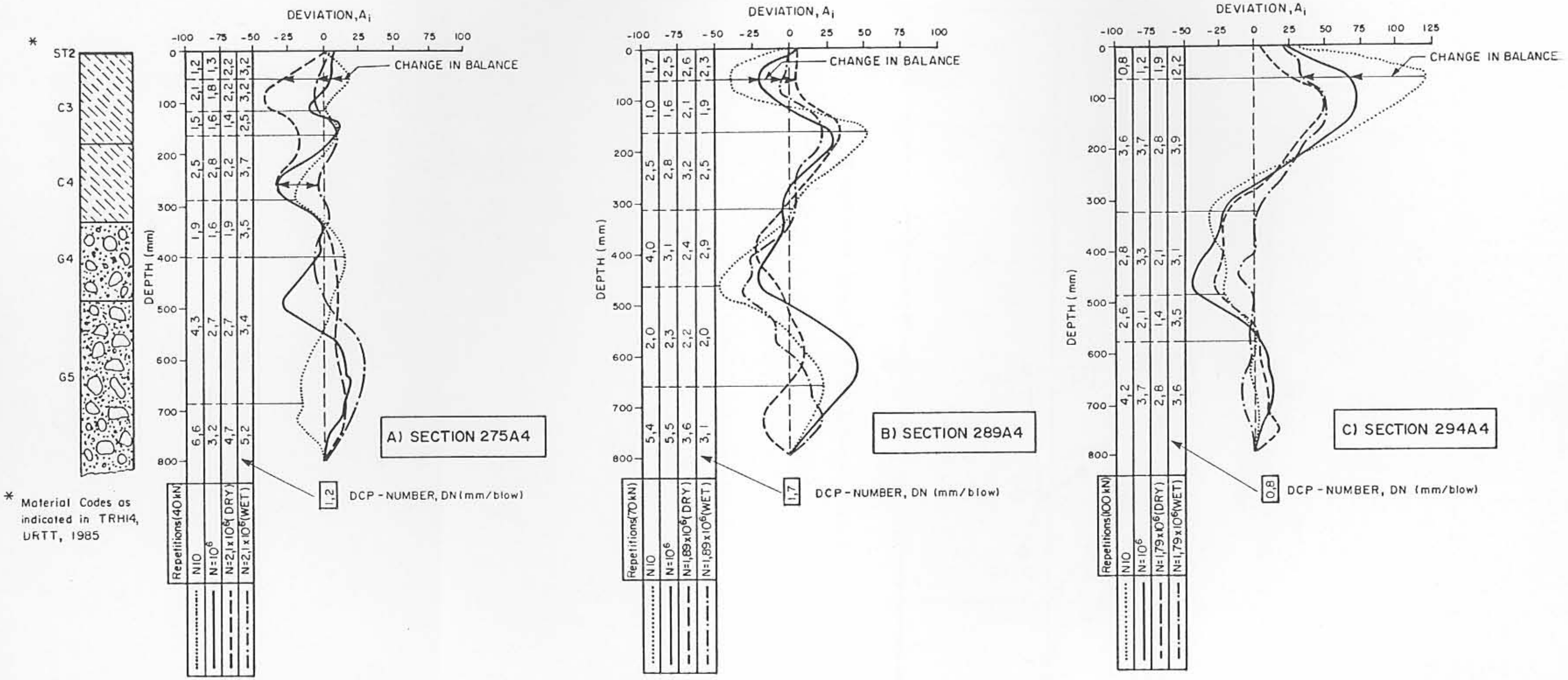

FIGURE 6.7

CHANGE IN DEVIATION FROM STANDARD BALANCE (A_i) AT VARIOUS STAGES OF TRAFFICKING ON THREE OF THE HVS TEST SECTIONS ON THE DEEP PAVEMENT (ROAD 1932, ROOIWAL)

DCP – CLASSIFICATION SHEET
PAVEMENT BALANCE PATHS

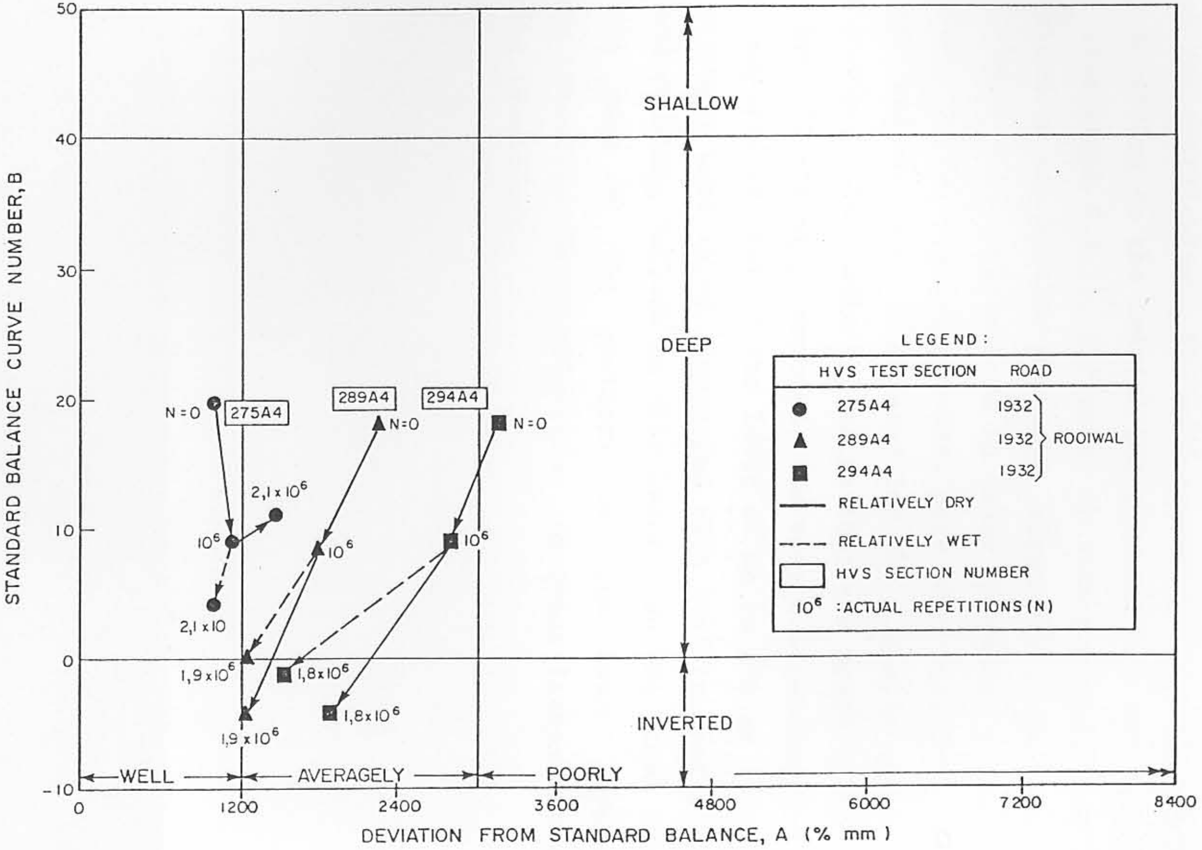

FIGURE 6.8

ILLUSTRATION OF THE BALANCE PATHS FOUND DURING ACCELERATED (HVS) TESTING FOR THE VARIOUS SECTIONS TESTED ON THE DEEP PAVEMENT (ROOIWAL) which in itself may assist in the description of the general pavement behaviour.

In summary, the balance - paths of the deep pavements evaluated here, show that both the balance number (B) and the degree of balance or deviation from standard balance (A), **decrease** as a result of traffic loading, and/or the effect of an increase in moisture content of the layers.

6.3.3 Shallow pavement (Road 2212 at Bultfontein): Results and discussion.

In this paragraph the shallow pavement structure is analysed. These sections were also trafficked with the normal dual wheel load configuration. The test sections are described by the various DCP parameters and are discussed as for deep pavements. In Table 6.5 the average DCP-numbers of the four test sections on the shallow pavement are given.

The table shows the DCP numbers (DN_i) at different depths and at various stages of HVS trafficking. The main reason for the variations in depth is that, according to the initial DCP measurements and degree of balance analysis (Paragraph 6.3.1), different in situ pavement layer thicknesses were obtained in the shallow pavement structure from those in the deep pavement (Table 6.3). Variations in layer thickness between the various test sections on the shallow pavement were also measured, and therefore average DCP numbers were calculated for the in situ layer thicknesses for each section. The table indicates that the upper 64 mm to 90 mm on this pavement is strongly cemented, as very low penetration rates were obtained compared to that of the lower 64 mm to 184 mm. The DCP numbers for the stronger base layer <u>increased</u> with traffic loading, indicating fatigue and crushing failure in this layer. On the other hand, the DCP numbers in most of the sections for the lower layers <u>decreased</u> indicating compaction or densification in these layers as a result of trafficking (moulding).

TABLE 6.5 AVERAGE DCP-NUMBERS OF THE THREE SECTIONS ON THE SHALLOW PAVEMENT AT BULTFONTEIN

HVS-SECTION (HVS Wheel Load)	REPETITIONS	DCP NUMBER (mm/blow)		IN SITU MOISTURE
		DN_{90} *	DN_{90-170} **	
306A4 (40 kN)	0	0,7 (0,4)	2,5 (0,4)	DRY
	10^6	0,7 (0,3)	1,4 (0,3)	DRY
	1,4 X 10^6	1,2 (0,3)	1,8 (0,7)	DRY
	2,45 X 10^6	2,0 (0,7)	2,8 (0,8)	DRY
	2,45 X 10^6	2,0 (0,5)	1,9 (0,4)	WET
		DN_{64} *	DN_{64-152} **	
307A4 (70 kN)	0	0,9 (0,3)	4,3 (1,6)	DRY
	10^6	1,7 (0,5)	2,6 (1,0)	DRY
	2,45 X 10^6	1,2 (0,4)	0,7 (0,2)	DRY
	2,45 X 10^6	1,7 (0,3)	1,0 (0,2)	WET
		DN_{80} *	DN_{80-184} **	
308A4 (100 kN)	0	0,8 (0,4)	3,4 (1,0)	DRY
	10^6	1,7 (0,4)	3,1 (1,4)	DRY
	2,46 X 10^6	1,3 (0,4)	3,2 (0,6)	DRY
	2,46 X 10^6	0,7 (0,2)	2,0 (0,9)	WET

* DN_i = the average rate of penetration in the top i mm of the cemented base layer.

** DN_{i-r} = the average rate of penetration from a depth of i mm to a depth of r mm in the cemented base layer.

() = Standard deviation in the rate of penetration.

The table also shows that the DN of the top 64 mm to 90 mm (DN_{64}, DN_{80}, and DN_{90}) increased during dry conditions, while that of the weaker subbase layer (DN_{90-170}, DN_{64-152} and DN_{80-184}) decreased. This is a direct result of the densification in the subbase, as also shown by the MDDs (see Paragraph 4.3.4.3, Chapter 4). According to the MDD results, approximately 34 to 53 percent of the permanent deformation measured on the surface of the pavement occurred within the subbase.

In Figures E38 to E63 in Appendix E, detailed DCP analyses of the sections on the shallow pavement are summarised and illustrated. A summary of the most important DCP analysis on these test sections is given in Figures 6.9, 6.10 and 6.11. These figures indicate the balance curves and layer strength diagrams at various stages of

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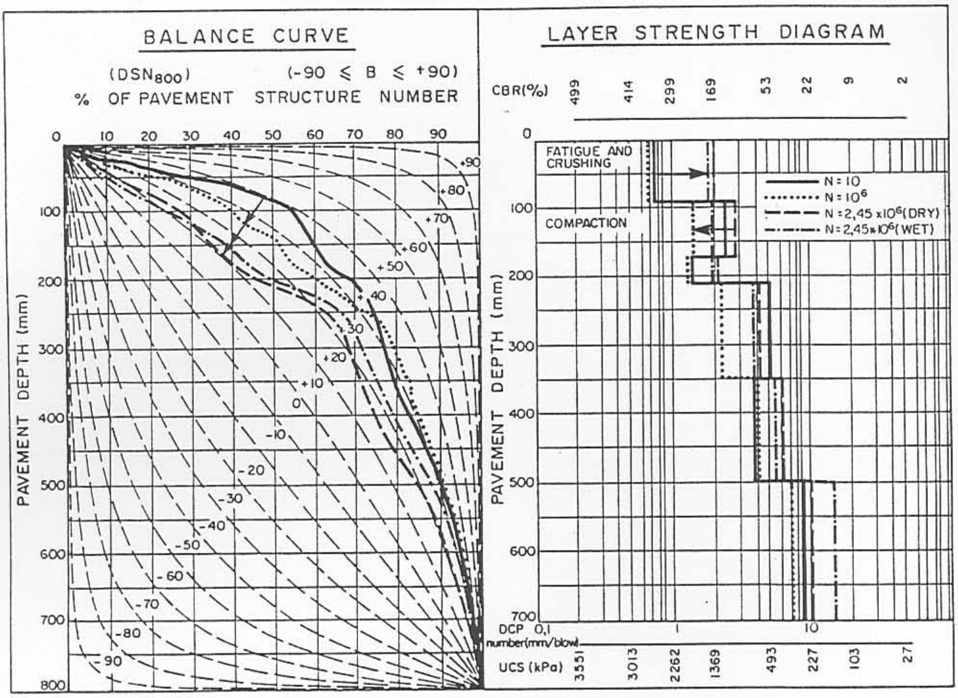

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FIGURE 6.9

DCP BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF HVS TEST SECTION 306A4 (INITIAL DCP-CATEGORY II : AVERAGELY BALANCED SHALLOW STRUCTURE (ABS))

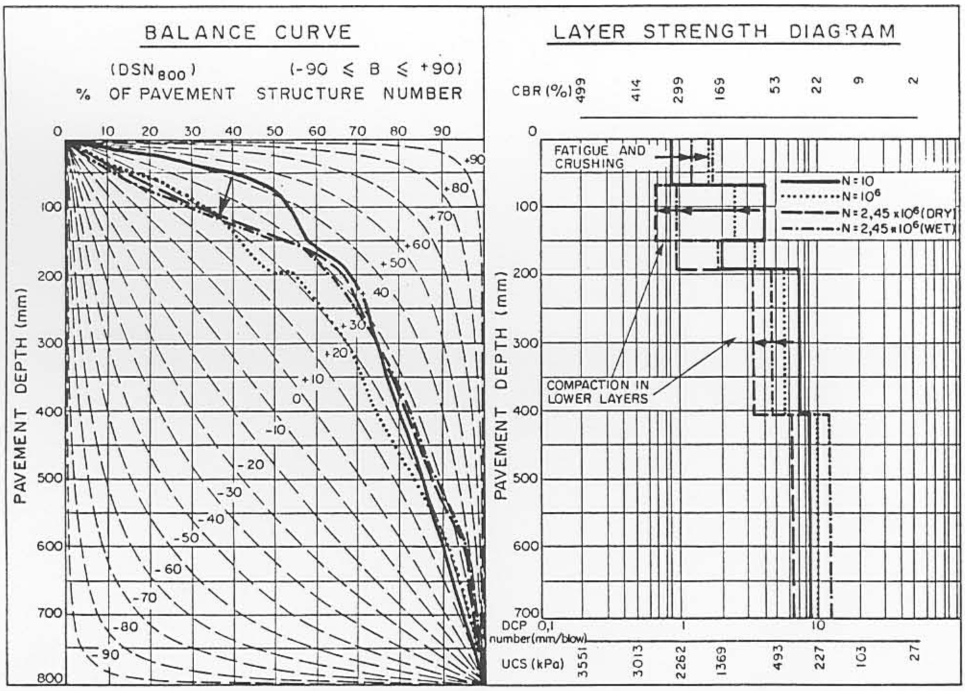

FIGURE 6.10

DCP BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF HVS TEST SECTION 307A4 (INITIAL DCP-CATEGORY II : AVERAGELY BALANCED SHALLOW STRUCTURE (ABS))

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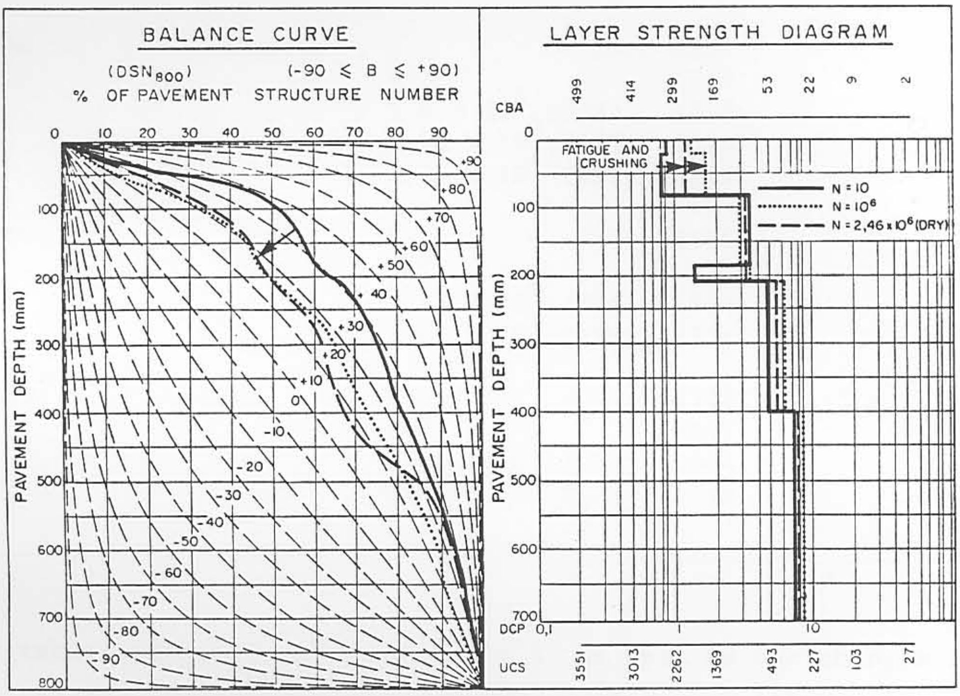

FIGURE 6.11

DCP BALANCE CURVES AND LAYER STRENGTH DIAGRAMS OF HVS TEST SECTION 308A4 (INITIAL DCP-CATEGORY V : AVERAGELY BALANCED DEEP STRUCTURE (ABD)) trafficking of three of the sections tested on this pavement, viz 306A4, 307A4 and 308A4. Decreases in the balance curves (B) are also evident here, with accompanying changes in the layer strength diagrams, as a result of trafficking. Note the densification in the lower layers of Sections 306A4 and 307A4 (Figures 6.9 and 6.10).

In Figure 6.12, changes in the deviation from standard balance (A) with HVS - trafficking are illustrated. The figure indicates that most of the changes occurred in the upper 200 mm of the pavement. Unlike that of the deep pavement (Figure 6.7), the A parameter decreased towards zero and increased numerically again towards relatively high negative values. This is indicative of the pavement becoming better balanced initially (lower A) and then becoming poorly balanced again (higher negative A), but with improved strength in the initial weaker subbase. During this process the strength of the initial well-cemented base decreased owing to fatigue failure and crushing.

In Table 6.6 the average calculated A and B parameters associated with the DCP measurements at various stages of trafficking and environmental conditions on the shallow pavement are given.

TABLE 6.6 AVERAGE A AND B PARAMETERS FOR THE THREE SECTIONS ON THE SHALLOW PAVEMENT.

HVS-SECTION	TEST LOAD (kN)	REPETITIONS (ACTUAL)	A	B
306A4	40	0	1711	42
		10^6	1057	39
		1,4 X 10^6 (DRY)	1235	33
		2,45 X 10^6 (DRY)	1629	28
		2,45 X 10^6 (WET)	2717	33
307A4	70	0	2986	42
		10^6	836	29
		2,45 X 10^6 (DRY)	1984	37
		2,45 X 10^6 (WET)	1724	38
308A4	100	0	1709	39
		10^6	1311	27
		2,46 X 10^6 (DRY)	2304	27
		2,46 X 10^6 (WET)	1218	36

The table indicates the decrease in B, as well as the changes in A. The balance paths for these pavement sections are illustrated in Figure 6.13.

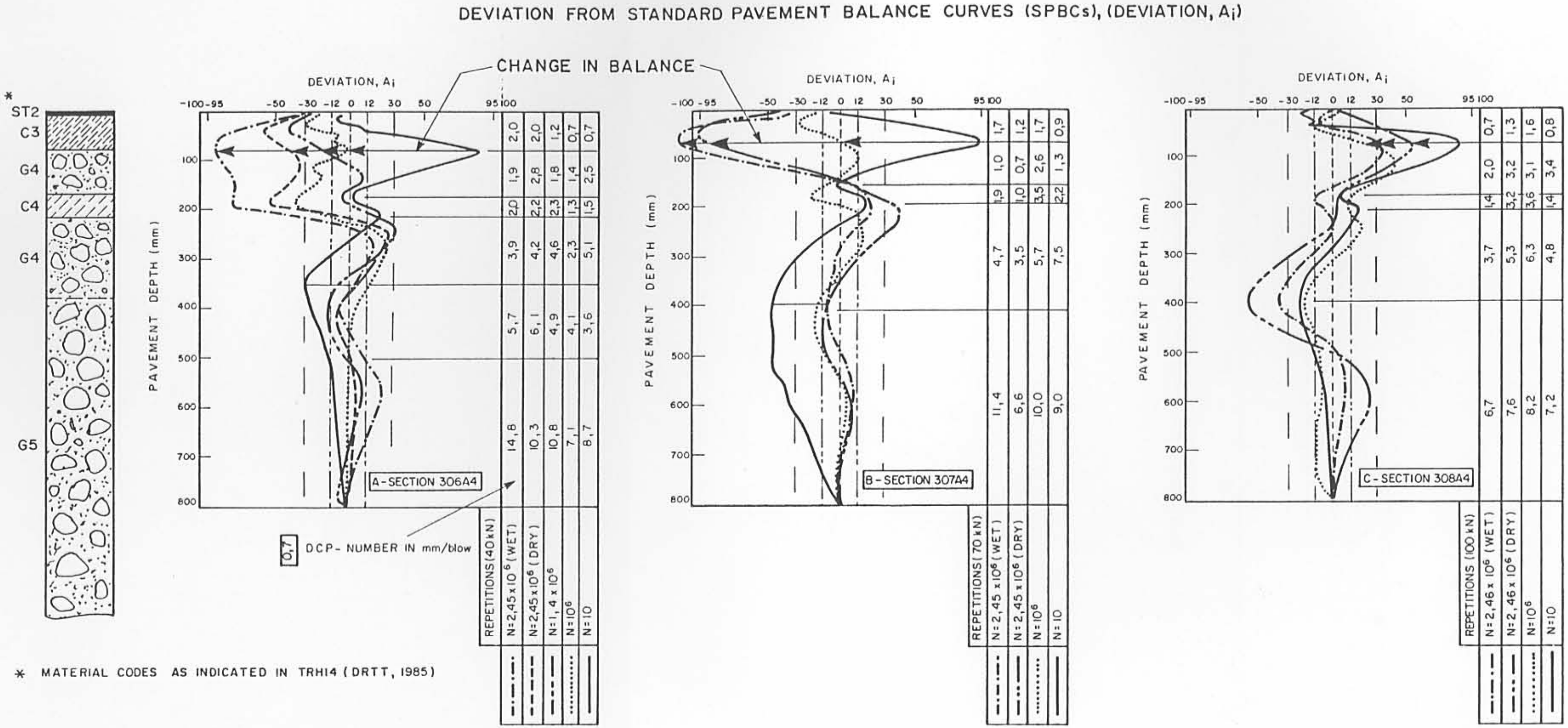

FIGURE 6.12

CHANGE IN DEVIATION FROM STANDARD BALANCE (Ai) AT VARIOUS STAGES OF HVS-TRAFFICKING ON THREE OF THE SECTIONS ON THE SHALLOW PAVEMENT (ROAD 2212, BULTFONTEIN)

940-4-5910/ BS

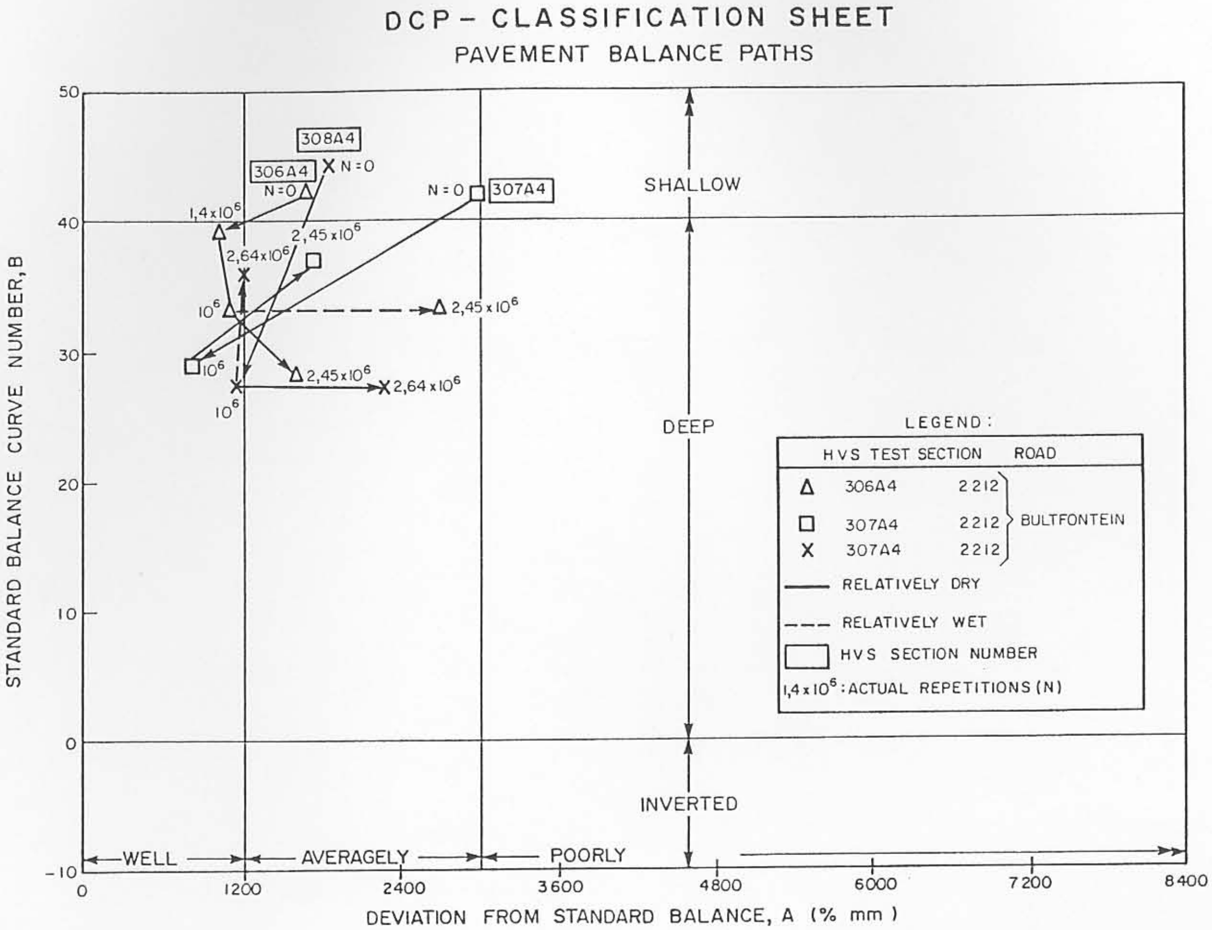

FIGURE 6.13

ILLUSTRATION OF THE BALANCE PATHS FOUND DURING ACCELERATED (HVS) TESTING FOR THE VARIOUS SECTIONS TESTED ON THE SHALLOW PAVEMENT (BULTFONTEIN)

The figure shows that, as for deep pavements, B decreases with increased traffic, but that the degree of balance A does not improve significantly (decrease in A).

It must, however, be remembered that the balance paths shown here are based on relatively few DCP results, and that variations in A and B are also possible owing to both vertical and horizontal variations in <u>natural</u> pavement layer strengths. To incorporate these variations for better definition of the the balance paths, additional DCP measurements are necessary.

The concept of balance paths, nevertheless, appears to be a useful method for quantifying pavement moulding as a result of trafficking, and although this may be improved in the future, it already quantifies traffic moulding better than methods used previously.

6.3.4 Balance paths for excessively high single wheel load tests

In addition to the previously discussed test sections, two relatively high <u>single wheel load</u> tests (150 kN single wheel load, aircraft wheel, see Paragraph 4.4 in Chapter 4) were performed; one on each type of pavement (deep and shallow, HVS test Sections 337A4 and 309A4, respectively). In Table 6.7 the average DCP penetration rates at different stages of trafficking on both sections are given, and indicates that the penetration rate for the upper 64 mm to 112 mm of both pavements increased as a result of trafficking. This increase is directly related to the fatigue and crushing failure of the upper section of the base layer. Note the relatively few load (stress) repetitions needed to initiate these failures compared to that of the normal dual wheel load tests (40 kN to 100 kN) discussed in Paragraphs 6.3.2 and 6.3.3. This is a clear indication of the damaging effect of higher contact stresses on the cementitious base layer.

The DCP penetration rate of the lower layers, however, decreased which is indicative of densification (compaction) as a result of trafficking. Therefore the lower layers became relatively stronger, whereas the upper layers became weaker, converting the shallow pavement to a deep pavement.