



**EVALUATION OF THE STRUCTURAL PERFORMANCE OF ASPHALTIC
CONCRETE HIGHWAY PAVEMENT
(ZUBA-GWAGWALADA-SHEDA AS A CASE STUDY)**

BY

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**A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
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JANUARY, 2016.

DECLARATION

I hereby declare that this thesis has been composed by me and that it is a record of my own research. It has not been accepted in any previous application for a higher degree. All quotations and other sources of information are specifically acknowledged by means of references.

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CERTIFICATION

This thesis titled “**EVALUATION OF THE STRUCTURAL PERFORMANCE OF ASPHALTIC CONCRETE HIGHWAY PAVEMENT (ZUBA-GWAGWALADA-SHEDA AS A CASE STUDY)**” by M~~B~~A~~E~~Z~~U~~E N~~K~~W~~U~~T~~E~~ D~~O~~N~~A~~T~~U~~S has been duly supervised, corrected and hereby approved. It meets the regulations governing the award of Doctor of Philosophy (Ph.D) in Civil Engineering of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated first to Divine Spirit for Its guidance, enlightenment and support throughout its duration and then to my dear wife Uche Judith and my beloved children Chioma, Ugo, Chu and Ife for their patience, encouragement, support and continuous words of advice: Chioma from Port-Harcourt, Ugo from Glasgow, Chu from Atlanta, and Ife from Halifax.

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ABSTRACT

This research is a study of the structural performance of the asphaltic concrete pavement of the Zuba-Gwagwalada-Sheda section of the Lokoja-Abuja highway from chainage 1km+500m to chainage 29km+800m. A Pavement Serviceability Rating (PSR) was conducted, followed by a Pavement Condition Index (PCI) study. A Truck traffic study was then conducted and used to determine Equivalent Standard Axle Loads (ESALs). Further, the Benkelman Beam (BB) and the Dynamic Cone Penetrometer (DCP) tests were carried out. Laboratory tests including bitumen penetration and bitumen content, Marshall Stability and Flow, Particle size distribution, and California Bearing Ratio (CBR) among others were then conducted on the pavement layer materials to obtain engineering properties relevant to pavement performance. Whereas the visual pavement distress survey recorded alligator cracking and rutting or permanent deformation as the most prominent distresses, PSR and PCI studies individually rated the pavement as “poor”. The predicted ESALs were obtained as 13.76 million standard axles. Whereas the BB study indicated that the pavement has failed, the DCP test results indicated that strength properties of the lower pavement layers exceeded minimum requirements. Results of laboratory tests compared fairly well with requirements of national and international specifications which constitute the benchmark for good performance. Results of the 13.76 million ESALs and CBR of subgrade of 16.2% from these tests and the American Association of State Highway and Transportation Officials’ (AASHTO’s) flexible pavement performance equation were used to obtain the Structural Number (SN) of 4.9, required of the pavement to support the predicted loads. The actual Structural Number of 4.33 of the existing pavement based on pavement layer thicknesses and layer structural coefficients was less than the required SN. This difference between the required and the actual (or applied) Structural Number is a major determinant of pavement life span. Future truck loads were also predicted to cumulate to 26.63 million ESALs in the next 20 years: an indication therefore that the pavement under study may require to be reconstructed to the standard of a perpetual (long lasting) pavement if premature failure is to be avoided.

2.4.1: Performance Indices	-	-	-	-	-	-	-	-	31
2.4.1.1: Pavement Serviceability Rating, PSR	-	-	-	-	-	-	-	-	31
2.4.1.2: Present Serviceability Index, PSI	-	-	-	-	-	-	-	-	32
2.5 Distresses in asphalt concrete pavements	-	-	-	-	-	-	-	-	39
2.5.1: Alligator cracking or fatigue cracking	-	-	-	-	-	-	-	-	40
2.5.2: Rutting or permanent deformation	-	-	-	-	-	-	-	-	41
2.5.2.1: Air voids:	-	-	-	-	-	-	-	-	42
2.5.2.3: Types of rutting in asphaltic concrete:	-	-	-	-	-	-	-	-	43
2.5.2.3.1: Rutting by densification:	-	-	-	-	-	-	-	-	43
2.5.2.3.2: Rutting by shear failure	-	-	-	-	-	-	-	-	45
2.5.3: Severity of pavement distress	-	-	-	-	-	-	-	-	47
2.6: Paved road deterioration/performance models:	-	-	-	-	-	-	-	-	47
2.6.1: Performance prediction models	-	-	-	-	-	-	-	-	47
2.7 Standard specifications	-	-	-	-	-	-	-	-	50
2.7.1: Summary of the Relevant Federal Ministry of Works (FMW) Specification	-	-	-	-	-	-	-	-	50
2.7.2 Grading requirements for soil aggregate materials	-	-	-	-	-	-	-	-	52
2.7.3 Other specifications	-	-	-	-	-	-	-	-	53
2.7.4 ASTM Test Method D1557 (2012) and AASHTO Test Method T180 (2011)	-	-	-	-	-	-	-	-	53
2.8 The Benkelman Beam Test	-	-	-	-	-	-	-	-	63
2.9 The dynamic cone penetrometer test:	-	-	-	-	-	-	-	-	65
2.9.1 Uses of the DCP test	-	-	-	-	-	-	-	-	65
2.9.2 Pavement performance evaluation standard using dynamic cone penetration index, DCPI	-	-	-	-	-	-	-	-	65
2.9.3 Monitoring compaction for new roads	-	-	-	-	-	-	-	-	66
2.9.4: Weak points of the DCP apparatus	-	-	-	-	-	-	-	-	66
2.9.5: Correlations between DCP penetration resistance (mm/blow) and California bearing ratio of pavement layer materials.	-	-	-	-	-	-	-	-	66
2.9.6: Correlation between unconfined compression strength, UCS and DCPI	-	-	-	-	-	-	-	-	68
2.10: Truck traffic	-	-	-	-	-	-	-	-	69
2.10.1: Pavement distress and damage	-	-	-	-	-	-	-	-	69
2.10.2: Failure criteria due to traffic loading	-	-	-	-	-	-	-	-	69

2.10.2.1: Fatigue failure criteria	-	-	-	-	-	-	-	-	70
2.10.2.2: Rutting or permanent deformation criteria:	-	-	-	-	-	-	-	-	71
2.10.3: The standard axle load	-	-	-	-	-	-	-	-	72
2.10.4: Equivalency factors and equivalent axle loads on road pavements	-	-	-	-	-	-	-	-	72
2.10.5: Load equivalency factor, LEF	-	-	-	-	-	-	-	-	73
2.10.6: The exponential power law	-	-	-	-	-	-	-	-	73
2.10.7: Theoretical method	-	-	-	-	-	-	-	-	75
2.10.8: Mechanistic method	-	-	-	-	-	-	-	-	75

CHAPTER THREE: MATERIALS AND METHODS

3.0: Preamble	-	-	-	-	-	-	-	-	78
3.1: Pavement Serviceability Rating(PSR) questionnaire study	-	-	-	-	-	-	-	-	78
3.2: Pavement Condition Index (PCI) study	-	-	-	-	-	-	-	-	81
3.2.1 Deduct Value (DV) and Corrected Deduct Value (CDV)	-	-	-	-	-	-	-	-	84
3.3: Truck Traffic Study	-	-	-	-	-	-	-	-	86
3.4: Benkelman Beam Deflection Study	-	-	-	-	-	-	-	-	88
3.5: Dynamic Cone Penetrometer (DCP) measurement of the Zuba-Gwagwalada Sheda highway.	-	-	-	-	-	-	-	-	91
3.6: Sub-Soil Tests-	-	-	-	-	-	-	-	-	95

CHAPTER FOUR: ANALYSIS AND DISCUSSION OF RESULTS

4.1 Preamble	-	-	-	-	-	-	-	-	119
4.2 Pavement Serviceability Rating (PSR)	-	-	-	-	-	-	-	-	119
4.3 Pavement Condition Index	-	-	-	-	-	-	-	-	199
4.4: truck traffic:	-	-	-	-	-	-	-	-	120
4.4.1: The average annual daily truck traffic	-	-	-	-	-	-	-	-	120
4.4.2: Cumulative ESALS for reconstruction:	-	-	-	-	-	-	-	-	121
4.4.3: Perpetual pavement:	-	-	-	-	-	-	-	-	122
4.5: Benkelman beam deflection:	-	-	-	-	-	-	-	-	122
4.6 Dynamic cone penetrometer (DCP) measurement:	-	-	-	-	-	-	-	-	123
4.7 Discussion of sub-soil test results.	-	-	-	-	-	-	-	-	131
4.7.1 Discussion of test result of engineering properties of materials sampled from the wearing and binder courses of the asphaltic concrete pavement.	-	-	-	-	-	-	-	-	131

4.7.2	Materials sampled from the stone base	-	-	-	-	-	-	-	-	140
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CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1	Conclusion	-	-	-	-	-	-	-	-	166
5.2	Recommendations	-	-	-	-	-	-	-	-	167
	References	-	-	-	-	-	-	-	-	170
	Appendices	-	-	-	-	-	-	-	-	175

LIST OF TABLES

Table 2.1: Elemental Analysis of Bitumens from Various Sources. - - -	12
Table 2.2: Effects of Practical Stress Conditions on the Relative Stiffness of 100 pen Bitumen (Jackson and Dhir, 1996) - - - - -	22
Table 2.3: Decision Matrix for Asphaltic Concrete. - - - - -	35
Table 2.4: Relative remaining life and maintenance requirements against PCI (Michael Smith/City of Dunwoody GA., 2010). - - - - -	37
Table 2.5: Distresses in asphalt concrete pavements - - - - -	39
Table 2.6: Federal ministry of works specifications subgrade and pavement layer Materials - - - - -	50
Table 2.6(a): Marshal stability requirements for bitumen-surfaced roads in tropical and sub-tropical countries (Overseas Road Note 31, 1998) - - - - -	51
Table 2.6(b): Aggregate grading requirements for asphalt concrete surfacings (Overseas Road Note 31, 1998) - - - - -	52
Table 2.7: AASHTO grading requirements for soil aggregate materials (AASHTO Designation m147, Reported by Oguara, 2006) - - - - -	53
Table 2.8: Asphalt institute requirements for untreated aggregates and sub-base Materials - - - - -	54
Table 2.9: AASHTO classification of soils and soil aggregates (Garber and Hoel 2002)	55
Table 2.10: Unified soil classification system uses (Garber and Hoel, 2002). -	57
Table 2.11: Comparable soil groups in the AASHTO and uses systems. - -	58
Table 2.12: CBR based on AASHTO soil classification (pavement design process-mass highway, 2006. Massachusetts DOT). -	59
Table 2.13: Minimum pavement thickness for new and reconstructed flexible pavements (Pavement Design Process-Mass Highway, Massachusetts DOT, 2006). -	60
Table 2.14: Materials strength coefficients (Pavement Design Criteria Manual, Section ii, City of Colorado Springs, 2010).	61
Table 2.15: Structural number strength coefficients from different studies (Asian Development Bank, et al. HDM4, 1995). - - - - -	62
Table 2.16: Nominal pavement condition from deflection (Division of Roads and Transport Technology, CSIR, 2001) - - -	64
Table 2.17: Pavement structural conditions identification standard. (Division of Roads and Transport Technology, CSIR, 2001) - - -	64
Table 2.18: Correlation between CBR and DCPI (Amini, 2003). - - -	67
Table 2.19: Suggested classification for granular soils using DCP test (Huntley, 1990).	68

Table 2.20: Percent layer distribution of rutting in the AASHO road test.	-	-	72
Table 2.21: Load equivalency factors for different axle loads (Overseas Centre, Transport Research Laboratory, 1993).	-	-	74
Table 3.1: Rating scales of the questionnaire form	-	-	79
Table 3.2: Percentages of questionnaires returned.	-	-	79
Table 3.3: Serviceability rating of road.	-	-	80
Table 3.4: Weighted scores and pavement serviceability rating (PSR)	-	-	81
Table 3.5: Distresses at varying locations	-	-	82
Table 3.6: Percentages of distress and deduction values	-	-	83
Table 3.7: Total deduct values (TDV),q = number of distress entries with deduct value of over 5 points, corrected deduct values (CDV)and pavement condition index (PCI)	-	-	85
Table 3.8: Truck traffic count for measurement of annual daily truck traffic (ADTT)			87
Table 3.9: Present and back - calculated annual daily truck traffic	-	-	88
Table 3.10: Benkelman beam deflection test results	-	-	90
Table 3.11: Chainages and points of identification.	-	-	92
Table 3.12: Dynamic Cone Penetrometer (DCP) test results at point H	-	-	92
Table 3.13: Dynamic Cone Penetrometer (DCP) test results at point I	-	-	93
Table 3.14: Dynamic Cone Penetrometer (DCP) test results at point J	-	-	94
Table 3.15: Dynamic Cone Penetrometer (DCP) test results at point K	-	-	95
Table 3.16: Chainages and points of identification.	-	-	96
Table 3.17: Thickness of various layers – at location L.	-	-	97
Table 3.18: Results of tests on wearing course - core L.	-	-	97
Table 3.19: Results of tests on binder course - core L.	-	-	98
Table 3.20: Particle size distribution of wearing course aggregates- core L	-	-	99
Table 3.21: Particle size distribution of binder course aggregates- core L.	-	-	100
Table 3.22: Particle size distribution of stone-base material- core L	-	-	101
Table 3.23: Results of tests on sub-base course material- core L.	-	-	102
Table 3.24: Particle size distribution of sub-base material – core L.	-	-	102
Table 3.25: Results of tests of parameters for sub-grade material- core L.	-	-	103
Table 3.26: Particle size distribution of sub-grade material-core L.	-	-	103
Table 3.27: Thickness of various layers –at location M.	-	-	104

Table 3.28: Results of tests on wearing course - core M	-	-	-	-	104
Table 3.29: Results of tests on binder course - core M	-	-	-	-	105
Table 3.30: Particle size distribution of wearing course aggregates- core M-	-	-	-	-	106
Table 3.31: Particle size distribution of binder course aggregates-core M	-	-	-	-	107
Table 3.32: Particle size distribution of stone base materials - core M	-	-	-	-	108
Table 3.33: Results of tests of parameters of sub-base course material - core M.	-	-	-	-	108
Table 3.34: Particle size distribution of sub-base material – core M -	-	-	-	-	109
Table 3.35: Results of tests of parameters of sub-grade material –core M	-	-	-	-	110
Table 3.36: Particle size distribution of sub-grade material – core M	-	-	-	-	111
Table 3.37: Thickness of various layers – at location N	-	-	-	-	111
Table 3.38: Results of tests on wearing course - core N	-	-	-	-	112
Table 3.39: Results of tests on the binder course – core N	-	-	-	-	113
Table 3.40: Particle size distribution of wearing course aggregates- core N -	-	-	-	-	113
Table 3.41: Particle size distribution for binder course aggregates-core N	-	-	-	-	114
Table 3.42: Particle size distribution of stone- base material- core N	-	-	-	-	114
Table 3.43: Summary of test results on sub-base course material-core N	-	-	-	-	115
Table 3.44: Particle size distribution of sub-base material – core N -	-	-	-	-	115
Table 3.45: Results of tests of parameters of sub-grade materials-core N	-	-	-	-	116
Table 3.46: Particle size distribution of sub-grade material –core N	-	-	-	-	116
Table 4.1: Average Pavement Layer Thicknesses	-	-	-	-	124
Table 4.2: Schematic of Amount Penetration and the Number of Blows taken by each Pavement Layer. (See also Table 3.12 of Chapter three).	-	-	-	-	125
Table 4.3: Dynamic Cone Penetration Index Values at Location H	-	-	-	-	126
Table 4.4: Dynamic Cone Penetration Index Values at Location I	-	-	-	-	126
Table 4.5 Dynamic Cone Penetration Index Values at Location J	-	-	-	-	126
Table 4.6 Dynamic Cone Penetration Index Values at Location K	-	-	-	-	127
Table 4.7: Average Layer DCPI Values of the Zuba-Gwagwalada-Sheda Highway Pavement.	-	-	-	-	127
Table 4.8: Predicted Values (from DCPI) of CBR, UCS and Sub-grade Modulus, M_r	-	-	-	-	129
Table 4.9: Suggested Levels of Reliability for Various Functional Classifications	-	-	-	-	163
Table 4.10: Standard Deviation S_o	-	-	-	-	164
Table 4.11: Standard Normal Deviation (Z_R) Values Corresponding to selected levels of Reliability	-	-	-	-	164

LIST OF FIGURES

Fig. 2.1: Typical Flexible Pavement - - - - -	6
Fig. 2.2: Load Distribution Methods in Flexible Pavements and Rigid Pavements -	6
Fig. 2.3: Stabilized Base Pavements (National Center for Asphalt Technology, 2008).	7
Fig. 2.4: Other Flexible Pavement Types. - - - - -	7
Fig: 2.5: Global Bitumen Use and Application Areas - - - - -	12
Fig. 2.6: Temperature Effects on the Viscosity on Different Grades of Bitumen. (Nick, 2010, pp137) - - - - -	13
Fig. 2.7: The Penetration and Softening Point Tests (Nick, 2010, pp138). -	14
Fig. 2.8: Strain/Time Curve for a Linear Visco-Elastic Material under Constant Stress (Croney, 1977, pp411).- - - - -	15
Fig. 2.9: The Visco-Elastic Behaviour of Bitumen (Nick, 2010, pp138). -	15
Fig. 2.10: Dynamic Modulus (National Center for Asphalt Technology, NCAT Auburn University, 2008). - - - - -	16
Fig. 2.11: Stress/Strain Behaviour of a Bitumen at Various Frequencies of Loading and Temperatures. - - - - -	18
Fig. 2.12a: Relationship between Complex Modulus, Air Voids and Temperature for Asphaltic Concrete with 50 pen and 100 pen Binders (loading frequency, 4 cycles per second)(after Shook and Kallas). - - - - -	19
Fig. 2.12b: Relationship between Complex Modulus, Asphalt Content and Temperature for Asphaltic Concrete with 100 pen Bitumen Compacted to 4% Air Voids (loading frequency, 4 cycles per second). - - - - -	19
Fig 2.13: Loading Time as a Function of Vehicle Speed and Layer Thickness. -	23
Fig. 2.14: van Der PoelNomograph for Predicting the Stiffness of Bitumen (Jackson and Dhir, 1996). - - - - -	23
Fig. 2.15: Nomograph for Penetration Index of Bitumen (van Der Poel, 1954). -	24
Fig. 2.16:Nomograph for Evaluation of Penetration Index from Softening Point and Penetration (Pfeiffer and Doormal, 1936). - - - - -	25
Fig. 2.17:Relationship between Chemical Composition and Penetration Index (Lubbers, 1985). - - - - -	26
Fig. 2.18: The Effect of Temperature and Loading Time on Stiffness of a Low Penetration Index Bitumen (The Shell Bitumen Industrial Handbook, 1995). - -	26
Fig. 2.19: The Effect of Temperature and Loading Time on Stiffness of a High Penetration Index Bitumen (The Shell Bitumen Industrial Handbook, 1995).	27

Fig. 2.20: Comparison of Permanent Strain for Asphalt and Hot Rolled Asphalt Mixtures. --	-	-	-	-	-	-	-	27
Fig. 2.21: Standard Hot Mix Asphalt Aggregate Sieves (Wisconsin Dept. of Transportation, WisDOT. 2010)	-	-	-	-	-	-	-	28
Fig. 2.22: Nomograph for the Determination of Fatigue Strength (Derived From Cooper and Pell).	-	-	-	-	-	-	-	28
Fig. 2.23: Distribution of Wheel Load Pressure through Flexible Pavement Structure (Asphalt Institute, 1991).	-	-	-	-	-	-	-	29
Fig. 2.24: Flexible Pavement Load Distribution (National Center for Asphalt Technology, 2008).	-	-	-	-	-	-	-	29
Fig. 2.25: Tensile and Compressive Strains in Flexible Pavements (Huang, 1993).	-	-	-	-	-	-	-	30
Fig. 2.26: Stress Distribution at Flexible Pavement Surface Layer (National Center for Asphalt Technology, 2008).	-	-	-	-	-	-	-	30
Fig. 2.27: PSR Form.	-	-	-	-	-	-	-	32
Fig. 2.28: Pavement Condition Index, PCI Scale.	-	-	-	-	-	-	-	33
Fig. 2.29: Generalised Pavement Life Cycle Curve (Nichols Consulting Engineers, 2009).	-	-	-	-	-	-	-	34
Fig. 2.30: Decision Trees, Asphaltic Pavement.	-	-	-	-	-	-	-	34
Fig. 2.31: Categories of pavement maintenance.	-	-	-	-	-	-	-	35
Fig. 2.32: Understanding the pavement condition index, PCI score (Michael Smith/City of Dunwoody Ga., 2010).	-	-	-	-	-	-	-	36
Fig. 2.33: Illustration of multiple treatment strategies.	-	-	-	-	-	-	-	37
Fig. 2.34: Pavement condition deterioration effects on maintenance costs (Shahin and Walther, 1990).	-	-	-	-	-	-	-	38
Figs. 2.35a: Fatigue cracking process in asphaltic concrete pavement	-	-	-	-	-	-	-	40
Figs. 2.35b: Fatigue cracking process in asphaltic concrete pavement.	-	-	-	-	-	-	-	41
Fig. 2.36: Alligator or fatigue cracking in asphaltic concrete pavements.	-	-	-	-	-	-	-	41
Fig. 2.37a: Typical densification rutting (Asian Dev. Bank/N.D Lea International Ltd., 1995).	-	-	-	-	-	-	-	44
Fig. 2.37b: Rutting by densification of the asphaltic concrete surface layer.	-	-	-	-	-	-	-	44
Fig. 2.38a: Rutting by shear failure (Asian Dev. Bank/N.D Lea International Ltd., 1995)	-	-	-	-	-	-	-	45
Fig. 2.38b: Rutting in asphalt layer by shear failure.	-	-	-	-	-	-	-	46
Fig. 2.38c: General rutting profile in asphaltic concrete.	-	-	-	-	-	-	-	46

Fig. 2.39a:Examples of flexible pavements performance prediction curves(Federal Highway Administration, FHWA,1990)-	-	-	-	-	-	-	49
Fig. 2.39b: Pavement condition versus age (FHWA,1990).	-	-	-	-	-	-	49
Fig. 2.40: The Benkelman Beam.	-	-	-	-	-	-	63
Fig. 2.41: In-situ foundation characterisation using the Dynamic Cone Penetrometer, (DCP).	-	-	-	-	-	-	65
Fig. 2.42:Sample DCP test result(Overseas Centre,Transport Research Laboratory,1993).	-	-	-	-	-	-	67
Fig. 2.43: Variation of vertical and radial stress with depth on centre line of load.	-	-	-	-	-	-	75
Fig. 2.44: Pavement behavior under moving wheel load (a) stresses acting on element	-	-	-	-	-	-	76
Fig. 3.4: Typical section of core pit.	-	-	-	-	-	-	117
Fig4.1: Wearing course specification grading envelop for core L	-	-	-	-	-	-	136
Fig4.2: Wearing course specification grading envelop for core M	-	-	-	-	-	-	137
Fig4.3: Wearing course specification grading envelop for core N	-	-	-	-	-	-	137
Fig4.4: Binder course specification grading envelop for core L	-	-	-	-	-	-	138
Fig4.5: Binder course specification grading envelop for core M	-	-	-	-	-	-	138
Fig4.6: Binder course specification grading envelop for core N	-	-	-	-	-	-	139
Fig4.7: Stone base grading curve for core L	-	-	-	-	-	-	140
Fig 4.8: Stone base grading curve for core M-	-	-	-	-	-	-	141
Fig 4.9: Stone base grading curve for core N -	-	-	-	-	-	-	141
Fig 4.10: Sub-base grading curve for core L -	-	-	-	-	-	-	144
Fig 4.11: Sub-base grading curve for core M -	-	-	-	-	-	-	144
Fig4.12: Sub-base grading curve for core N -	-	-	-	-	-	-	145
Fig 4.13: Liquid Limit curve for sub base core L	-	-	-	-	-	-	146
Fig 4.14: Liquid Limit curve for sub base core M	-	-	-	-	-	-	146
Fig4.15: Liquid Limit curve for sub base core N	-	-	-	-	-	-	147
Fig 4.16: California Bearing ratio curve for sub base core L -	-	-	-	-	-	-	148
Fig 4.17: California Bearing Ratio Curve for Sub Base Core M	-	-	-	-	-	-	149
Fig 4.18: California Bearing Ratio curve for sub base core N	-	-	-	-	-	-	150
Fig 4.19: Compaction curve for subbase core L	-	-	-	-	-	-	151
Fig 4.20: Compaction curve for subbase core M	-	-	-	-	-	-	151
Fig 4.21: Compaction curve for subbase core N	-	-	-	-	-	-	152
Fig 4.22: Sub-grade grading curve for core L-	-	-	-	-	-	-	153

Fig4.23: Sub-grade grading curve for core M	-	-	-	-	-	154
Fig 4.24: Sub-grade grading curve for core N	-	-	-	-	-	154
Fig 4.25: Liquid Limit curve for sub grade core L	-	-	-	-	-	156
Fig 4.26: Liquid Limit curve for sub grade core M	-	-	-	-	-	156
Fig 4.27: Liquid Limit curve for sub grade core N	-	-	-	-	-	157
Fig 4.28: Compaction curve for sub-grade core L	-	-	-	-	-	158
Fig4.29: Compaction curve for sub-grade core M	-	-	-	-	-	158
Fig 4.30: Compaction curve for sub-grade core N	-	-	-	-	-	159
Fig 4.31: California Bearing Ratio curve for sub grade core L.	-	-	-	-	-	160
Fig 4.32: California Bearing Ratio curve for sub grade core M	-	-	-	-	-	161
Fig 4.33: California Bearing Ratio curve for sub grade core N	-	-	-	-	-	161

LIST OF PLATES

Plate I: The structure of Bitumen	-	-	.	-	-	--	-	11
Plate II: Typical photograph of the truck traffic study.	-	-				--	-	86
Plate III: Typical photograph of the truck traffic study.	-	-				-	-	87
Plate IV: Typical photograph of the Benkelman beam deflection study.	-					-	-	89
Plate V: Typical photograph of the Benkelman beam deflection study.	-					-	-	89
Plate VI: Typical photograph of the cores showing wearing and binder courses	-							118
Plate VII: Typical photograph of the cores showing subgrade, wearing and binder courses								118

LIST OF APPENDICES

Appendix A-1: AASHTO Pavement Serviceability Rating (PSR) Form	176
Appendix A-2: Summary of Calculation Method for Pavement Condition Index (PCI) (US Corps of Army Engineers)	177
Appendix A-3: Deduct Value Computation for Alligator Cracks in Sample 1, location A. (Deduct Value = 56)	178
Appendix A-4: Deduct Value Computation for Rutting in Sample 2, Location B (Value 61)	179
Appendix A-5: Corrected Deduct Value Computation for Sample 2, Location B. (CDV=63)	180
Appendix A-6: Corrected Deduct Value Computation for Sample 3, Location C. (CDV=63)	181
Appendix A-7: Conversion Factors for Obtaining the Equivalent Number of Standard Axles (Dept. Of Transport, 1978)	182
Appendix A-8: Demanded Structural Number Solution using the AASHTO Flexible Pavement Nomograph	183
Appendix A-9: Perpetual Pavements	184
Appendix A-10: Benkelman Beam Deflection Data Analysis	185
Appendix A-11: Relationship between Standard Deflection and Life: Granular Road Bases (Division of Roads and Transport Technology, CSIR, 2001).	186
Appendix A-12: DCP Test Results at Location H	187
Appendix A-13: DCP Test Results at Location I	188
Appendix A-14: DCP Test Results at Location J	189
Appendix A-15: DCP Test Results at Location K	190
Appendix A-16: Details of Tests on Bitumen from Wearing Course-Core 1	191
Appendix A-17: Details of Determination of Bulk Specific Gravity of Asphaltic Concrete Wearing Course-Core 1	192
Appendix A-18: Marshall Stability Test Results: AC Type: Wearing Course-Core L	193
Appendix A-19: Marshall Stability Test Results: AC Type: Binder Course-Core L	194
Appendix A-20: Asphalt Concrete Aggregates Grading: Ac Type: Wearing Course-Core L	195

Appendix A-21: Asphalt Concrete Aggregates Grading: AC Type:	
Binder Course-Core L-	196
Appendix A-22: Stone-Base Aggregates Grading: Core L	197
Appendix A-23: Stone-Base Aggregates Grading: Core L	198
Appendix A-24: Determination of Moisture Density Relation of Sub-Base 1-Core L	199
Appendix A-25: Determination of Moisture Density Relation of Sub-Base 2-Core L	200
Appendix A-26: Determination of CBR of Sub-Base1-Core L	201
Appendix A-27: Determination of CBR of Sub-Base2-Core L	202
Appendix A-28: determination of Atterberg (Consistency) Limits of Sub-Base 1- Core L	203
Appendix A-29: Determination of Atterberg (Consistency) Limits of Sub-Base 2- Core L	204
Appendix A-30: Sub-Base 1 Sieve Analysis – Core L	205
Appendix A-31: Sub-Base 2 Sieve Analysis – Core L	206
Appendix A-32: Determination of Moisture Density Relation of Sub-Grade Material – Core L-	207
Appendix A-33: Determination of CBR of Sub-Grade Course Materials – Core L	208
Appendix A-34: Determination of Atterberg (Consistency) Limits of Sub-Grade Course – Core L	209
Appendix A- 35: Sieve Analysis of Sub-Grade Material – Core L	210
Appendix A-36: Details of Tests on Bitumen from Wearing Course - Core M	211
Appendix A-37: Details of Determination of Bulk Specific Gravity of Asphaltic Concrete Wearing Course-Core M	212
Appendix A-38: Marshall Stability Test Results: AC Type: Wearing Course-Core M	213
Appendix A-39: Marshall Stability Test Results: AC Type: Binder Course-Core M	214
Appendix A-40: Asphalt Concrete Wearing Course Aggregates Grading Analysis – Core M	215
Appendix A-41: Stone-Base Aggregates Grading Analysis - Core M	216
Appendix A-42: Determination of Moisture Density Relation of Sub-Base Course – Core M	217
Appendix A-43: Determination of CBR of Sub-Base Course – Core M	218
Appendix A-44: Determination of Atterberg (Consistency) Limits of Sub-Base Course – Core M	219

Appendix A-45: Sub-Base Course Materials Sieve Analysis – Core M	-	-	220
Appendix A-46: Determination of Moisture Density Relation Of Sub-Grade Layer – Core M	-	-	221
Appendix A-47: Determination of CBR of Sub-Grade Course – Core M	-	-	222
Appendix A-48: Determination of Atterberg (Consistency) Limits of Sub-Grade Layer – Core M	-	-	223
Appendix A-49: Sub-Grade Layer Materials Sieve Analysis – Core M	-	-	224
Appendix A-50: Details of Tests on Bitumen from Wearing Course - Core N	-	-	225
Appendix A-51: Details of Determination of Bulk Specific Gravity of Asphaltic Concrete Wearing Course-Core N	-	-	226
Appendix A-52: Details of Marshall Stability Test Results: AC Type: Wearing Course-Core N-	-	-	227
Appendix A-53: Details of Marshall Stability Test Results: AC Type: Binder Course-Core N-	-	-	228
Appendix A-54: Asphalt Concrete Wearing Course Aggregates Grading – Core N	-	-	229
Appendix A-55: Asphalt Concrete Binder Course Aggregates Grading – Core N	-	-	230
Appendix A-56: Stone-Base Aggregates Grading Analysis - Core N	-	-	231
Appendix A-57: Determination of Moisture Density Relation of Sub-Base Layer-Core N-	-	-	232
Appendix A-58: Determination of CBR of Sub-Base – Core N	-	-	233
Appendix A-59: Determination of Atterberg (Consistency) Limits of Sub-Base Course1 – Core N	-	-	234
Appendix A-60: Sub-Base Course Materials Sieve Analysis – Core N	-	-	235
Appendix A-61: Determination of Moisture Density Relation of Sub-Grade Layer – Core N	-	-	236
Appendix A-62: Determination of CBR of Sub –Grade – Core N	-	-	237
Appendix A-63: Determination of Atterberg (Consistency) Limits of Sub-Grade Layer – Core N-	-	-	238
Appendix A-64: Sub-Grade Layer Materials Sieve Analysis – Core N	-	-	239
Appendix A- 65: The Marshall Stability Test Method	-	-	240

Appendix A-66: The Superpave Tester (U.S. Department of Transportation, Federal Highway Administration. National Highway Institute, NHI)	-	-	241
Appendix A-67: Superpave Shear Tester (National Centre for Asphalt Technology, NCAT)	-	-	242
Appendix A-68a: Penetration Index Of Binder:	-	-	243
Appendix A-68b: Penetration	-	-	244

LIST OF ABBREVIATIONS/SYMBOLS

σ	-	Stress, σ_c	-	Compressive stress
σ_t	-	Tensile stress		
ε	-	Strain		
ε_c	-	Compressive strain		
ε_t	-	Tensile strain		
AASHTO	-	American Association of State Highway and Transportation Officials		
AC	-	Asphaltic Concrete		
ADTT _n	-	Annual Daily Truck Traffic, n years after opening the road to traffic		
ADTT _p	-	Present Annual Daily Truck Traffic		
AI	-	Asphalt Institute		
a_i	-	Structural layer coefficient of the i th pavement layer		
ASTM	-	American Society for Testing and Materials		
BB	-	Benkelman Beam		
BC	-	Binder Course		
BS	-	British Standard		
CBR	-	California Bearing Ratio		
CDV	-	Corrected Deduct Value		
CSIR	-	Division of Roads and Transport Technology of South Africa		
C_v	-	Ratio of volume of compacted aggregate to volume of aggregate plus binder		
DCP	-	Dynamic Cone Penetrometer		
DCPI	-	Dynamic Cone Penetrometer Index		
D_i	-	Thickness of the i th pavement layer		
DSN	-	Deviator Structural Number		
DV	-	Deduct Value		
E	-	Young's Modules of Elasticity		
E^*	-	Dynamic Complex Modules of Elasticity		
ESALs	-	Equivalent Standard Axle Loads		

ESAL _o -	-	Equivalent Standard Axle Loads, at the time the road was opened to traffic
ESAL _n -	-	Equivalent Standard Axle Loads, n years after the road was opened to traffic
FMW	-	Federal Ministry of Works
GP	-	Poorly Graded Granular Material
GW	-	Well Graded Granular Material
HDM	-	Highway Design and Maintenance Model
J1	-	Component of Strain in Phase with Stress in a visco-elastic material eg., Bitumen
J2	-	Component of Strain 90 ⁰ out of phase with stress in a visco-elastic material.
kN	-	Kilonewton
LEF	-	Load Equivalency Factor
LL	-	Liquid Limit
MDD	-	Maximum Dry Density
MN	-	Meganewton
MOW	-	Ministry of Works
M _r	-	Subgrade Resilient Modulus
NCAT	-	National Centre for Asphalt Technology
N _f	-	Number of load repetitions to failure
N _p	-	Non Plastic
OMC	-	Optimum Moisture Content
PCC	-	Portland Cement Concrete
PCI	-	Pavement Condition Index
PCR	-	Pavement Condition Rating
PEU	-	Pavement Evaluation Unit (of the Federal Ministry of Works)
PI	-	Plasticity Index
PL	-	Plastic Limit
PSI	-	Pavement Serviceability Index
PSR	-	Pavement Serviceability Rating

RD	-	Average Depth of Wheel-path rut
RRD	-	Representative Rebound Deflection
S_{bit}	-	Stiffness modulus of bitumen
S_E	-	Stiffness modulus
SGC	-	Superpave Gyrotory Compactor
SHRP	-	Strategic Highway Research Program
S_{mix}	-	Stiffness modulus of a bituminous mix
SST	-	Superpave Shear Tester
Superpave	-	Superior Performing Asphalt Pavements
SV	-	Slope Variance
T	-	Temperature in 0C
t	-	Time of loading in seconds
TDV	-	Total Deduct Value
TGF	-	Traffic Growth Factor
TLF	-	Truck Load Factor
UCS	-	Unconfined Compression Strength
VIM	-	Voids in Mix (of Asphaltic Concrete)
V_v	-	Void content
WASHO	-	Western Association of State Highway Organizations
WC	-	Wearing Course