An Investigation into Road Pavement Failure Susceptibility Indices of Osogbo-Iwo Road

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Abstract
Osogbo-Iwo road in Osun state, Nigeria was investigated to determine failure susceptibility indices. The contribution of traffic[T], water table[D], geotechnical indices such as Maximum Dry Density and California Bearing Ratio[M] and [R], road cross-section elements such as cambering[A] and asphalt thickness[S] to road pavement failure were considered. The result showed a wide disparity between the specified Total TDRAMS Index(as shown by control Monitoringwell[MWC]) and the Total TDRAMS Indices of the failed segments of the road up to 151%. This shows how wide the non-conformity in the construction of Osogbo-Iwo road is from the engineering specifications, both in material and in workmanship and it is the major part of what is responsible for the road's incessant failure.
Keywords: TDRAMS, pavement failure, geotechnical indices, cambering

INTRODUCTION

Roads can be considered as causes as well as consequences of civilization. As civilization is advanced and prosperity increases, there is always an inevitable demand for better and speedier communication facilities especially roads. Indeed, it can truly be said that the prosperity of a nation or a state or even a local government is bound up with the state of its roads(O'Flaherty, 1973). According to Owolabi(1996), roads are essential equipment for the development of land, tapping resources of agriculture, minning and forestry, linking up different regions and thus promoting inter-regoinal trade; increasing industrial development; linking important cities and facilitating the movement of people; moving troops and supplies in times of emergency and carrying on of business of all descriptions. In developing countries of the world, the road network is probably the most widely used of the several means of transportation and it is an important index of development that touches the life of either rural or urban dwellers.

Roads of various categories in Nigeria have shown signs of failure in the form of cracking, rutting, deformation and potholes. In some cases, these signs of distress are pronounced within a short period of commissioning thus reducing its level of service. Dar-Hao(2009) reported repaired road that experienced recurring rutting and alligator cracking in few weeks of repair. The officials of various transportation departments want small potholes to deteriorate into craters and become death traps before they respond. As a road is constructed and opened to traffic, all sorts of activities develop around it and the hope of people in the locality are raised. These hopes and aspirations become dashed as the road deteriorates and its level of service diminishes(Owolabi and Abiola, 2011)

The developing countries have lost valuable infrastructures worth billions of dollars through the deterioration of roads and if much more is not done to preserve the roads, more billions of dollars would be lost (World Bank, 1989).The World Bank (1989) predicted the risk of massive deterioration in Nigerian new roads. According to the bank, many of the 21,000 km of paved roads in the Nigerian trunk road system were built with generous geometric features but weak pavements, which require structural enhancement. The bank suggested an extensive program to resurface and strengthen about 2,000 to 3,000 km of pavement annually at an estimated cost of $150 to $200 million. The bank concluded that the Nigerian trunk road system may deteriorate rapidly and require massive rehabilitation and construction in the next ten to fifteen years if the suggested resurfacing and strengthening were not carried out. This prediction has come to be.

Osogbo-Iwo road is part of Ibadan-Iwo-Osogbo road. Its problems started with its design in 1977 when the design consultant was changed. The problems continued with old Oyo State until 1992 when Osun State was created, and the state inherited the road and its problems. All efforts made to fix the incessant failure of the road, has been to no avail. It is therefore, in realization of this fact that an investigation was conducted into road pavement failure susceptibility indices of the road to solve the incidence of incessant pavement failure of the road.

The Study Area: Osogbo-Iwo Road

The Osogbo-Iwo road is located within latitudes 7° 37' 36.24"N and 7° 47' 22.08"N and longitudes 4° 09' 22.20"E and 4° 30' 23.58"E. The road connects Osogbo to Iwo and the adjoining towns and villages(see Fig. 1). The road is about 45 km long. The area around the road has an annual rainfall of about 1250mm and lies mainly in the deciduous forest area which spreads towards the grass land belt of Ikirun North of Osogbo. The area includes a regional topographic depression in form of a flood plain or wetland that exists between Origo/Osuntedo and Asamu/Telemu towns at a general contour elevation of about 274m (900ft) above the sea level, and it is drained by the Osun River and its tributaries.

MATERIALS AND METHODS

This investigation considered the contribution of traffic, water table, geotechnical indices such as MDD; CBR, road cross-section elements such as cambering and asphalt thickness to road pavement failure. To accomplish this, the road was traversed from Osogbo to Iwo in order to establish the failed segments. Physical observations were made on the fifteen (15) major failed sections. Monitoring wells were positioned at the fifteen (15) major failed sections to study ground water movement. Ground water levels at the installed monitoring wells were taken weekly for about 2 months in the first instance and monthly for 15 months up to March, 2011(Ola et al, 2009). The point count system model DRASTIC (Aller *et al,* 1987) a parametric method for groundwater vulnerability assessment was modified to assess the road pavement failure susceptibility at the different identified major failed segments. The DRASTIC model is used to assess the sensitivity of the groundwater system to human and natural impacts. The correct cross-section slopes for proper carriageway drainage were also investigated.

The traffic count along the road was taken for 7days spanning August 31 to September 6, 2009. The counting stations were situated at Osogbo and Iwo(Ola et al, 2009). Traffic load, hydrogeological characteristic (Depth to water table), geotechnical indices (Soaked CBR and Maximum Dry Density [MDD]) and road pavement engineering features (Pavement cross-section cambering and Asphalt thickness) were combined with the modified DRASTIC model, to produce road pavement failure susceptibility values for the various identified major failed segments along the case study road alignment. The traffic, geotechnical, highway and hydrogeologic settings (which make up the acronym TDRAMS) are: [T] Traffic load: [D] Depth to water table: [R] CBR of sub-grade (soaked): [A] Cambering: [M] Maximum Dry Density MDD:[S] Asphalt Thickness .

The field investigation undertaken consisted of fifteen (15) monitoring wells (3.0 m [10 feet] deep). Monitoring wells (Piezometers) were installed at each of the fifteen identified major failed segments(Ola et al, 2009). The borings were put down by rotary auger rig to advance the holes. 12.7cm (5 inches) diameter holes were drilled and samples were continuously taken. Jar samples were taken between intervals and at interval of 0.3m (1foot), 1.52m (5 feet) and 3.05m (10 feet). Standard penetration test (SPT) in conjunction with split spoon samples (and U2 samples where appropriate) were taken. The standard penetration test involves driving a 5.08cm (2.0 inches) O.D. split spoon sampler 60.9cm (24 inches) long through a depth of 45.7cm (18 inches) with a 63.6 kg (140 lb) hammer dropping 76.2cm (30 inches) for each blow. The standard penetration resistance N is the number of blows required to drive the sampler through the last 30.5cm (12 inches) of penetration. Similar procedures were followed for the U2 except that the tube was for undisturbed samples of 5.08cm (2 inches) diameter. The U2 is 5.5 cm (2.17 inches) I.D and 5.7 cm (2.24 inches) O.D. The record of casing blow counts was also kept.

All the samples retrieved were visually identified on site at the time of sampling, and taken to the Soil Mechanics Laboratory for more careful examination and detailed identification and classification. Relevant indices and engineering property tests such as CBR, moisture content, Atterberg limits, bulk density and grain size analysis tests were later performed on selected samples. The soil samples from the first 0.3m of this sampling are meant for sub-grade soil indices.

The general cross-section slope specification (camber) for roads in Nigeria is 2.5% for carriageway into the shoulders and 5% for shoulder into the drain(FHM, 1973). The cross-section study therefore, is to find out how far this specification was being adhered to during construction. This study was carried out with the use of measuring tape, twine and a spirit level. Two people held the twine across the road and from drain to drain. The twine which was held taut was allowed to touch the centre of the road. Two people carefully placed the spirit levels on the twine on each side of the road ensuring that the twine stayed horizontal. Measurements were therefore taken from the twine to the road surface at the edge of the road and at the edge of the verge. This activity was carried out at the fifteen (15) failed sections along the road. The asphalt thickness were also measured at the fifteen (15) failed sections along the road(Ola et al, 2009).

RESULTS AND DISCUSSION

Table 1 shows the results of monitoring the water table from the monitoring wells for 22 months. Monitoring wells 9 and 5 were vandalized in October and November, 2009 respectively. The table also shows the worst depth of water to ground surface for each of the monitoring wells. Table 2 shows the summary of the geotechnical tests for the sub-grade of the failed sections along the road. The engineering indices such as soaked CBR and MDD are summarized in this table. The table also shows the asphalt thickness at the fifteen (15) failed sections along the road. Table 3 shows the summary of the cross-section study. It could be seen from the table that none of the sections meet the required cross slope as specified in highway manual. Tables 4a and 4b show the computation of Total Equivalent Single Axle (TESA) from the traffic count carried out on the road with Osogbo and Iwo as counting stations respectively. The TESA for table 4a is assumed to be effective for the first seven (7) monitoring wells from Osogbo and the TESA for table 4b is effective for the last eight (8) monitoring wells from Osogbo or the first eight (8) monitoring wells from Iwo. Table 5 shows the TDRAMS rating system and weights. The table shows that some of these parameters have direct and inverse effects on road pavements. For example, for direct effect, as the traffic load increases the effect on the pavement also increases. But for the depth to water table, as the depth increases, the effect on the pavement decreases. All the parameter are ranged and given weights in accordance to the degree of severity their effects have on the road pavement. The traffic load has the greatest effect followed by nearness of water table to the pavement surface, then by the CBR, by the cambering to drain water off the road, by the MDD and finally by the asphalt thickness. This is why the weights assigned to them are 6, 5, 4, 3, 2 and 1 respectively.

Table 6 shows the TDRAMS Index Equation analysis for Osogbo-Iwo road. The TDRAMS Index, a measure of road pavement failure susceptibility is computed by summation of the products of ratings and weights for each factor as follows:

Total TDRAMS Index = $T_rT_w + D_rD_w + R_rR_w + A_rA_w + M_rM_w + S_rS_w$ ....(1)

Where

T_r = Rating for ranges of traffic load
T_w = Weights assigned to traffic loads
D_r = Ratings to the depth to water table
D_w = Weights assigned to the depth to water table
R_r = Ratings for ranges of CBR (soaked)
R_w = Weights for the CBR (soaked)
A_r = Ratings assigned to cambering
A_w = Weights assigned to cambering
M_r = Ratings for the Maximum Dry Density (MDD)
M_w = Weights for Maximum Dry Density (MDD)
S_r = Ratings for asphalt thickness
S_w = Weights for asphalt thickness

The higher the TDRAMS index**,** the greater the relative road pavement failure susceptibility**.** The TDRAMS index can be further divided into four categories: low, moderate, high, and very high. The TDRAMS indices for the fifteen (15) identified major failed segments along the road are as computed in table 6. The TDRAMS index for the ideal case scenario where the Depth to water table is farthest to the road pavement, soaked CBR is 50% and above, cambering is 3.75% on the average, maximum dry density MDD is 2100kg/m^3 and asphalt thickness is 0.05m, is as computed under the control monitoring well (MWC) in table 6. The control Total TDRAMS index is thus 63. This is the numerical score that indicates the least possible failure susceptibility degree. Location 7(16+400) has the least failure susceptibility (Total TDRAMS Index=118), while locations 3 and 11 (2+300 and 25+550) have the highest failure susceptibility (Total TDRAMS Index=158each). A 10% allowance over and above the ideal case gives the Total TDRAMS index of about 70. It is therefore worthy of note that the least Total TDRAMS index is 118 which is 55 (87%) over and above the value of the ideal case. The highest Total TDRAMS index is 158 which is 95 (151%) over and above the ideal case. It can be concluded that none of these locations has Total TDRAMS index within 50% of what they should be (the ideal case). This simply shows how far flung the construction of Osogbo-Iwo road is from the specification, both in material and in workmanship.

CONCLUSION

The modified point count system model, TDRAMS is a potent tool to assess the road pavement failure susceptibility at failed segment of any road as exemplified here. It can be used to rank the pavement failure susceptibility of a road so as to draw the attention of the relevant authority to the section of the road requiring urgent attention for rehabilitation. The wide disparity between the ideal Total TDRAMS index and the Total TDRAMS indices of the failed segments is what is responsible for the incessant failure of Osogbo-Iwo road.

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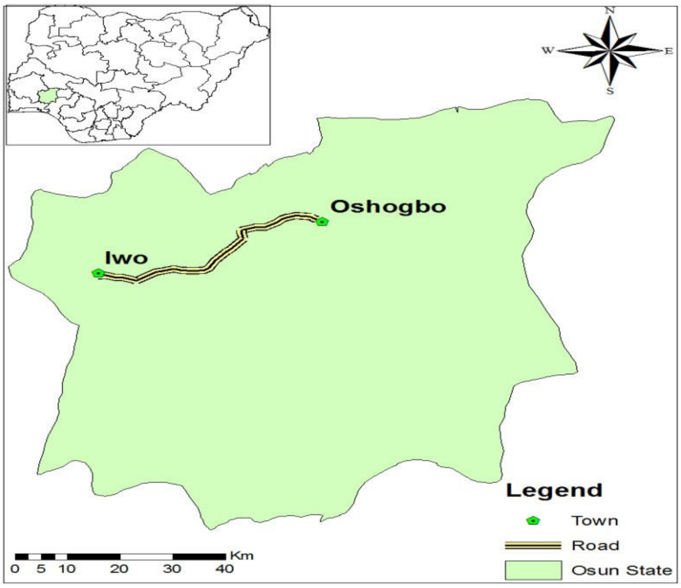

Fig. 1a: Map of Osun State showing Osogbo-Iwo road(with inset Map of Nigeria showing Osun State)

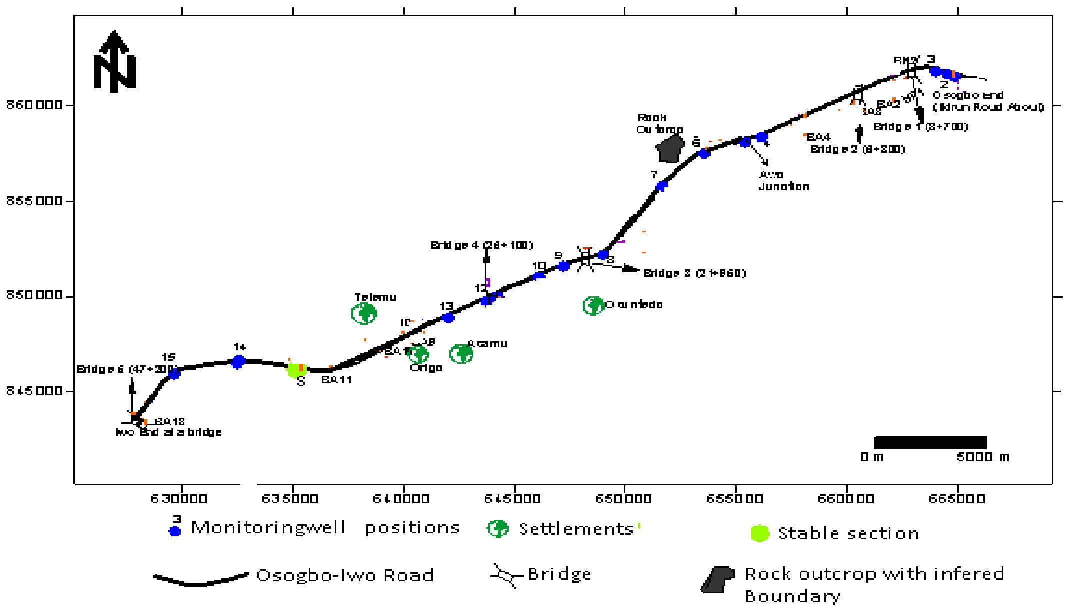

Fig.1b: Osogbo-Iwo Road showing positions of Monitoringwell and other features along the Road

Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.3, 2015

Table 1: Depth of Water to Ground Surface

Depth of Water to Ground Surface for Osogbo- Iwo Road

Location	Feature	Worst Depth of Water to ground surface	Aug. 2009		Sept.,2009		Sept., 2009		Oct.,2009		Oct., 2009		Nov., 2009	Dec., 2009	Jan., 2010	Feb., 2010	Mar., 2010	Apr., 2010	May, 2010	June, 2010
			15/8	22/8	3/9	10/9	17/9	24/9	2/10	9/10	16/10	23/10	19/11	22/12	16/1	16/2	20/3	21/4	20/5	18/6
Km1+500	MW1 (RHS)	1.43	3.05	2.23	2.20	2.20	1.80	2.51	2.00	2.10	2.24	2.30	2.42	-	-	-	-	-	-	-
Km1+540	MW2 (LHS)	1.34	-	2.85	2.85	-	-	2.38	-	-	-	-	-	-	-	-	-	-	-	-
Km2+300	MW3 (RHS)	-0.26	0.50	0.74	1.26	0.72	-0.23	-0.20	-0.16	-0.09	0.00	0.10	0.06	0.21	0.42	0.56	0.62	1.03	1.11	-0.04
Km11+070	MW4 (LHS)	0.31	0.31	-1.54	1.80	1.80	0.34	0.35	0.35	0.37	0.38	0.39	0.52	0.78	0.81	0.99	1.29	-	-	0.44
Km11+920	MW5 (LHS)	0.90	-	1.54	1.20	1.20	0.90	1.10	0.93	1.38	1.78	1.54	Vandalized							
Km13+820	MW6 (RHS)	-0.01	0.24	0.79	1.17	1.53	0.06	0.06	0.04	0.10	0.15	0.08	0.40	1.24	1.70	-	-	1.70	-	0.17

Table1: continued

Depth of Water to Ground Surface for Osogbo- Iwo Road

Location	Feature	Worst Depth of Water to ground surface	July, 2010	Aug., 2010	Sept., 2010	Oct., 2010	Nov., 2010	Dec., 2010	Jan., 2011	Feb., 2011	Mar., 2011
			19/7	20/8	20/9	21/10	19/11	20/12	18/1	20/2	19/3
Km1+500	MW1 (RHS)	1.43	-	2.35	1.43	1.50	-	-	-	-	-
Km1+540	MW2 (LHS)	1.34	-	-	1.45	1.34	-	-	-	-	-
Km2+300	MW3 (RHS)	-0.26	0.34	-0.10	-0.18	-0.26	0.06	0.29	0.40	0.49	0.59
Km11+070	MW4 (LHS)	0.31	0.72	0.31	0.13	0.14	0.70	0.87	1.01	1.17	1.70
km11+920	MW5 (LHS)	0.90	Vandalized								
Km13+820	MW6 (RHS)	-0.01	0.30	0.05	-0.01	0.01	0.34	1.74	-	-	1.60

Table1: continued

Location	Feature	Worst Depth of Water to ground surface	Depth of Water to Ground Surface for Osogbo- Iwo Road																			
			Aug. 2009		Sept.,2009		Sept., 2009		Oct.,2009		Oct., 2009		Nov., 2009	Dec., 2009	Jan., 2010	Feb., 2010	Mar., 2010	Apr., 2010	May, 2010	June, 2010
			15/8	22/8	3/9	10/9	17/9	24/9	2/10	9/10	16/10	23/10	19/11	22/12	16/1	16/2	20/3	21/4	20/5	18/6
Km16+400	MW7 (LHS)	-0.16	1.52	0.00	0.23	0.20	-0.16	-0.13	-0.08	0.00	0.04	0.07	0.22	0.52	0.88	1.29	1.58	2.00	2.28	2.16
Km21+0270	MW8 (RHS)	-0.29	1.98	0.88	1.04	1.03	1.93	0.60	1.34	2.07	2.21	2.31	2.31	-	-	-	-	-	1.70	1.95
Km23+200	MW9 (LHS)	1.35	-	1.35	1.80	2.37	1.90	-	Vandalized											
Km24+000	MW10 (LHS)	1.02	-	1.02	1.58	1.50	1.24	1.26	1.24	1.24	1.26	1.28	1.29	1.53	1.82	1.99	2.07	2.07	1.92	1.46
Km25+550	MW11 (RHS)	0.05	0.24	0.10	0.54	0.48	0.25	0.42	0.23	0.30	0.36	0.95	1.65	1.90	2.25	2.53	-	-	0.40	1.20
Km27+100	MW12 (LHS)	-0.05	0.24	0.43	0.80	0.72	0.28	0.40	0.02	0.00	0.13	0.49	1.34	1.91	-	-	-	-	0.05	0.38

Table1: continued

Location	Feature	Worst Depth of Water to ground surface	Depth of Water to Ground Surface for Osogbo- Iwo Road								
			July, 2010	Aug., 2010	Sept., 2010	Oct., 2010	Nov., 2010	Dec., 2010	Jan., 2011	Feb., 2011	Mar., 2011
			19/7	20/8	20/9	21/10	19/11	20/12	18/1	20/2	19/3
Km16+400	MW7 (LHS)	-0.16	1.98	0.18	-0.03	-0.05	0.16	0.78	1.33	1.57	1.92
Km21+070	MW8 (RHS)	-0.29	2.14	-0.29	0.36	0.39	1.64	-	-	-	-
Km23+200	MW9 (LHS)	1.35	Vandalized								
Km24+000	MW10 (LHS)	1.02	1.70	1.22	1.18	1.19	1.25	2.03	1.94	2.04	2.06
Km25+550	MW11 (RHS)	0.05	2.04	0.11	0.05	0.07	1.81	2.28	2.45	-	2.46
Km27+100	MW12 (LHS)	-0.05	0.68	-0.05	-0.25	-0.22	0.40	1.96	-	-	-

Table1: continued

Location	Feature	Worst Depth of Water to ground surface	Depth of Water to Ground Surface for Osogbo- Iwo Road								
			July, 2010	Aug., 2010	Sept., 2010	Oct., 2010	Nov., 2010	Dec., 2010	Jan., 2011	Feb., 2011	Mar., 2011
			19/7	20/8	20/9	21/10	19/11	20/12	18/1	20/2	19/3
Km28+770	MW13 (RHS)	0.00	1.19	0.57	0.00	0.27	0.94	1.45	-	-	-
Km38+500	MW14 (RHS)	0.02	0.59	0.32	0.27	0.26	0.33	0.52	0.74	0.85	0.93
Km41+150	MW15 (RHS)	0.71	1.18	0.71	0.83	0.98	1.17	1.47	1.42	1.43	1.48

Location	Feature	Worst Depth of Water to ground surface	Depth of Water to Ground Surface for Osogbo- Iwo Road																	
			Aug. 2009		Sept.,2009		Sept., 2009		Oct.,2009		Oct., 2009		Nov., 2009	Dec., 2009	Jan., 2010	Feb., 2010	Mar., 2010	Apr., 2010	May, 2010	June, 2010
			15/8	22/8	3/9	10/9	17/9	24/9	2/10	9/10	16/10	23/10	19/11	22/12	16/1	16/2	20/3	21/4	20/5	18/6
Km28+770	MW13 (RHS)	0.00	-	1.77	1.40	1.86	0.80	1.00	0.38	0.71	1.04	1.12	1.16	1.37	1.57	-	-	-	-	0.60
Km38+500	MW14 (RHS)	0.02	0.46	1.68	0.47	0.40	0.02	0.12	0.15	0.13	0.13	0.14	0.25	0.48	0.60	0.72	0.93	1.03	0.67	0.52
Km41+150	MW15 (RHS)	0.71	1.83	1.54	1.70	1.87	0.93	1.04	1.11	1.16	1.09	1.26	1.39	1.47	1.51	1.51	1.51	1.47	1.04	1.10

Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.3, 2015

Table 2: Summary of Sub-Grade (Failed Sections) Laboratory Testing Results for Osogbo-Iwo Rd.

CHAINAGE / Thickness of Asphalt(m)	LOCATION	NATURAL MOISTURE CONTENT%	SPECIFIC GRAVITY	ATTERBERG LIMITS (%)				COMPACTION TEST		C.B.R		POCKET PENETROMETER kN/m²		SIEVE ANALYSIS % PASSING					AASHTO CLASSIFICATION CLASS	GROUP INDEX	DESCRIPTION
				LL	PL	PI	LS	W_{Opt} (%)	γ_{Dry} (g/cc)	UNSOAKED	SOAKED	UNSOAKED	SOAKED	1/2" 12.0mm	#3 6.7mm	#8 2.36mm	#36 0.425mm	#200 0.075mm			
1+500/0.05	1	5.0	2.65	35.0	31.0	4.0	5.0	8.5	2.00	67	20	488	245	93	76	52	36	34	A-2-4	0	Clayey gravelly SAND
1+540/0.05	1	4.7	2.65	36.6	30.9	5.7	5.0	8.0	2.01	68	19	488	245	95	75	54	35	32	A-2-4	0	Clayey gravelly SAND
2+300/0.04	1	5.1	2.65	29.6	16.2	20.6	5.7	11.0	2.00	52	11	485	246	100	100	97	54	45	A-6	5	Gravelly sandy CLAY
11+070/0.04	2	20.5	2.50	37.0	20.0	17.0	5.0	11.0	1.85	70	22	463	245	100	100	95	62	53	A-6	7	Gravelly sandy CLAY
11+920/0.05	2	22.5	2.52	37.0	21.1	15.9	5.7	12.0	1.75	69	23	463	245	100	100	98	64	52	A-6	7	Gravelly sandy CLAY
13+820/0.05	2	14.1	2.58	25.9	15.0	10.9	7.1	13.5	1.94	47	18	425	220	97	90	80	48	43	A-6	5	Gravelly sandy CLAY
16+400/0.03	3	19.2	2.65	37.3	22.9	14.4	2.1	8.4	2.08	74	45	492	393	92	75	65	30	27	A-2-6	1	Clayey sandy GRAVEL
21+070/0.05	3	12.6	2.66	33.5	29.1	4.4	7.1	11.0	2.12	65	54	538	420	100	99	97	58	43	A-4	4	Clayey SILT with trace gravel
23+200/0.05	4	11.2	2.67	44.0	18.3	25.7	10.7	11.0	2.02	85	16	507	326	99	81	52	25	23	A-2-7	1	Clayey gravelly SAND
24+000/0.05	4	11.3	2.66	29.0	21.3	7.7	5.0	11.5	1.96	74	49	402	334	100	95	78	45	44	A-4	3	Clayey SILT with trace gravel
25+550/0.05	5	10.2	2.66	34.5	13.3	21.2	6.4	12.0	2.00	47	9	381	189	100	93	71	42	38	A-6	8	Gravelly sandy CLAY
27+100/0.06	5	11.1	2.66	31.0	19.0	12.0	0.7	10.1	1.91	71	34	494	224	100	93	68	20	17	A-2-4	0	Clayey gravelly SAND
28+770/0.03	6	19.7	2.56	32.0	18.2	13.8	1.4	13.0	1.80	77	69	472	380	68	56	42	20	17	A-2-4	0	Clayey gravelly SAND
38+500/0.05	7	5.9	2.65	33.0	29.1	3.9	7.1	7.0	1.71	68	39	447	220	99	92	86	58	49	A-4	3	Clayey SILT with trace gravel
41+150/0.04	8*	5.4	2.76	34.6	17.5	17.1	5.0	7.0	1.97	52	14	494	221	93	79	63	23	21	A-2-6	2	Clayey sandy GRAVEL
Average										66	29										

Table 3: Road Cross-section Study for Osogbo-Iwo Road

Chainage	Shoulder Width(m)	Carriageway width (m)	Existing Cross-Section Slope (%)				Average	Remarks
			LS	LC	RC	RS		
1+500	1.5	7.3	3.9	2.1	2.2	1.5	2.4	Inadequate
1+540	1.6	7.3	2.7	2.1	1.9	1.6	2.1	Inadequate
2+300	1.6	7.3	0.0	0.0	0.0	1.6	0.4	Inadequate
11+070	1.6	7.3	4.9	0.9	1.0	1.6	2.1	Inadequate
11+920	1.5	7.3	0.0	0.0	0.0	0.0	0.0	Adequate
13+820	1.8	7.3	4.9	1.2	1.5	4.0	2.9	Inadequate
16+400	1.9	7.3	7.8	1.9	1.4	7.9	4.8	Adequate
21+070	1.1	7.3	4.5	1.2	1.1	5.0	3.1	Inadequate
23+200	1.4	7.3	7.0	2.8	1.9	4.5	4.1	Adequate
24+000	1.6	7.3	4.7	2.5	2.8	4.0	3.0	Inadequate
25+550	1.6	7.3	6.0	0.8	0.7	5.8	3.3	Inadequate
27+100	1.4	7.3	2.9	1.7	2.5	3.3	2.6	Inadequate
28+770	1.2	7.3	4.1	2.3	1.8	3.8	3.0	Inadequate
38+500	1.6	7.3	5.1	0.9	0.0	5.3	2.8	Inadequate
41+150	1.6	7.3	3.9	2.0	1.6	4.2	2.9	Inadequate
Highway Manual Specifications	1.5	7.3	5	2.5	2.5	5	3.8	

Source: Geotechnical Investigative Study of Osogbo-Iwo Road
NOTE:, LC = Left Carriageway LS = Left Shoulder
RC = Right carriageway, RS = Right Shoulder

Table 4a: Axle load Distribution and Total Equivalent (80KN) Single Axle Computations for 2009 Traffic Count along Osogbo-Iwo Road for Osogbo counting station.

Axle Load (KN)	Single Axle per 100 Trucks			Tandem Axle per 100 Trucks			
	Number (No)	Factor (F)	No x F	Number (No)	Factor (F)	No X F	Classification of traffic at Osogbo counting station
Under 9	-	0.0002	-				Car=67%
9-18	-	0.002	-				Truck=18%
18-27	132	0.01	1.32				2-Axle=8%
27-36	-	0.03	-				Trailers=7%
36-45	-	0.08	-				ADT=2,829vehs
45-54	-	0.18	-				
54-63	-	0.35	-				
63-72	-	0.61					
72-81	35	1.00	35.00				
171-180				15	1.72	25.80	
180-189				9	2.13	19.17	
189-198				6	2.62	15.72	
Total			**36.32**			**60.69**	

Total Equivalent 80KN Single Axle (TESA) per 100 trucks on Osogbo-Iwo Road = 36.32+60.69 = 97.01

Source: Geotechnical Investigative Study of Osogbo-Iwo Road(2009)

$$(ESAL)_0 = \frac{TESA(\%Truck)}{100}\frac{(ADT)}{2}$$

Where

$(ESAL)_0$ =initial ESAL on the day the road is opened to traffic.

TESA = Total Equivalent Single Axle Load

ADT = Average Daily Traffic.(Yoder and Witczak, 1976).

Table 4b: Axle load Distribution and Total Equivalent (80KN) Single Axle Computations for 2009 Traffic Count along Osogbo-Iwo Road for Iwo counting station

Axle Load (KN)	Single Axle per 100 Trucks			Tandem Axle per 100 Trucks			
	Number (No)	Factor (F)	No x F	Number (No)	Factor (F)	No X F	Classification of traffic at Iwo counting station
Under 9	-	0.0002	-				Car=66%
9-18	-	0.002	-				Truck=18%
18-27	145	0.01	1.45				2-Axle=8%
27-36	-	0.03	-				Trailers=8%
36-45	-	0.08	-				ADT=3,144vehs
45-54	-	0.18	-				
54-63	-	0.35	-				
63-72	-	0.61					
72-81	39	1.00	39.00				
171-180				18	1.72	30.96	
180-189				10	2.13	21.30	
189-198				7	2.62	18.34	
Total			**40.45**			**70.60**	

Source: Geotechnical Investigative Study of Osogbo-Iwo Road(2009)

Total Equivalent 80KN Single Axle (TESA) per 100 trucks on Osogbo-Iwo Road = 40.45+70.60 = 111.05

Table 5: TDRAMS Rating System and Weights

Parameter	Range	Rating	Weight
Traffic Load (KN)	0-25 25-50 50-75 75-100 100-125 125-150 150-175 175-200 200+	1 2 5 8 10 12 14 16 18	6
[D] Depth (m)	0 - 0.4 0.4 - 0.8 0.8 - 1.2 1.2 - 1.8 1.8 - 2.2 2.2- 2.6 2.6 – 3.00+	10 8 6 4 3 2 1	5
[R] Sub-grade CBR Soaked(%)	0-10 10-20 20-30 30-40 40-50 50+	9 7 5 4 2 1	4
[A] Cambering (%)	0-0.75 0.75-1.50 1.50-2.25 2.25-3.00 3.00-3.75 3.75+	8 7 5 3 2 1	3
[M] MDD (kg/m^3)	0-400 400-800 800-1200 1200-1600 1600-2100 2100+	10 8 5 4 2 1	2
[S] Asphalt Thickness (m)	0-0.01 0.01-0.02 0.02-0.03 0.03-0.04 0.04-0.05 0.05+	7 6 5 4 2 1	1

Table 6: TDRAMS Index Equation Analysis for Osogbo-Iwo Road(Sub-grade)

Factors	Data on Monitoringwells						Rating						Weight	Index Value for Monitoringwells					
	MW1	MW2	MW3	MW4	MW5	MW6								MW1	MW2	MW3	MW4	MW5	MW6
T(Traffic load at Failed Section(KN))	97	97	97	97	97	97	8	8	8	8	8	8	6	48	48	48	48	48	48
D(Depth to water Table at Failed Section(m))	1.43	1.34	-0.26	0.13	0.90	-0.01	6	6	10	10	7	10	5	30	30	50	50	35	50
R(Soaked CBR at Failed Section(%))	20	19	11	22	23	18	7	7	7	5	5	7	4	28	28	28	20	20	28
A(Cambering of Failed Section(%))	2.4	2.1	0.0	0.0	0.0	2.9	3	5	8	8	8	3	3	9	15	24	24	24	9
M(MDD of Sub-grade at Failed Section(kg/cu.m))	2,000	2,010	2,000	1,850	1,750	1,940	2	2	2	2	2	2	2	4	4	4	4	4	4
S(Asphalt Thickness at Failed Section(m))	0.05	0.05	0.04	0.04	0.05	0.05	2	2	4	4	2	2	1	2	2	4	4	2	2
							Total TDRAMS Index							121	127	158	150	133	141
							Degree of susceptibility to Failure							3rd	3rd	15th	13th	7th	14th

Table 6: TDRAMS Index Equation Analysis for Osogbo-Iwo Road(Sub-grade) [cont'd]

Factors	Data on Monitoringwells						Rating						Weight	Index Value for Monitoringwells					
	MW7	MW8	MW9	MW10	MW11	MW12								MW7	MW8	MW9	MW10	MW11	MW12
T(Traffic load at Failed Section(KN))	97	111	111	111	111	111	8	10	10	10	10	10	6	48	60	60	60	60	60
D(Depth to water Table at Failed Section(m))	-0.16	-0.29	1.35	1.02	0.05	-0.05	10	10	6	7	10	10	5	50	50	30	35	50	50
R(Soaked CBR at Failed Section(%))	45	54	16	49	9	34	2	2	7	2	9	4	4	8	8	28	8	36	16
A(Cambering of Failed Section(%))	4.8	3.0	3.0	3.5	3.3	2.6	1	3	3	2	2	3	3	3	9	9	6	6	9
M(MDD of Sub-grade at Failed Section(kg/cu.m))	2,080	2,120	2,020	1,960	2,000	1,910	2	1	2	2	2	2	2	4	2	4	4	4	4
S(Asphalt Thickness at Failed Section(m))	0.03	0.05	0.05	0.05	0.05	0.06	5	2	2	2	2	1	1	5	2	2	2	2	1
							Total TDRAMS Index							118	131	133	115	158	140
							Degree of susceptibility to Failure							2nd	5th	7th	7th	15th	10th

Table 6: TDRAMS Index Equation Analysis for Osogbo-Iwo Road(Sub-grade)[cont'd]

Factors	Data on Monitoringwells						Rating						Weight	Index Value for Monitoringwells					
	MW13	MW14	MW15	MWC										MW13	MW14	MW15	MWC		
T(Traffic load at Failed Section(KN))	111	111	111	81			10	10	10	8			6	60	60	60	48		
D(Depth to water Table at Failed Section(m))	0.00	0.02	0.71	3.0			10	10	8	1			5	50	50	40	5		
R(Soaked CBR at Failed Section(%))	69	39	14	50			1	4	7	1			4	4	16	28	4		
A(Cambering of Failed Section(%))	3.0	2.8	2.9	3.8			3	3	3	1			3	9	9	9	3		
M(MDD of Sub-grade at Failed Section(kg/cu.m))	1,800	1,710	1,970	2,100			2	2	2	1			2	4	4	4	2		
S(Asphalt Thickness at Failed Section(m))	0.03	0.05	0.04	0.05			5	2	4	1			1	5	2	4	1		
							Total TDRAMS Index							132	141	145	63		
							Degree of susceptibility to Failure							6th	11th	12th	1st		