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Assessment of the Effects of Surface And Subsurface Moisture On ADO-AFAO Road Pavement Failure In Ekiti-State, Nigeria.

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Abstract :
Effects of surface and subsurface moisture on highway pavement failure in Ado-Afao Ekiti road were evaluated to determine the major causes of the deterioration of the pavement. Samples of soil were collected at five different locations along along Ado-Afao Ekiti road and the following geotechnical tests were conducted on the samples; sieve analysis, permeability, compaction, CBR, Triaxial and Atterberg limits. The results showed that the soils have liquid limit ranging from 15.8% - 17.6%, are non-plastic, linear shrinkage ranging from 0% to 3%, maximum dry density ranging from 3180g/cc to 3448 g/cc, optimum moisture content ranging from 8.2 to 9.2%, cohesion ranging from 9g/cc to 50g/cc, angle of friction ranging from 8^0 to 13^0, CBR value from 10.6 to 30.2, coarse material ranging from 65.1% to 69.9% while the fine material ranging from 30.1% to 34.9% and the permeability ranging from $3.69x10^{-2}$ x 5.8710^{-2}m/s. All the soils are classified as organic silt of medium compressibility containing less plasticity according to Casangrade and A-2-6 (silty soil) of fair to poor rating in terms of possible use as subgrade material according to AASHTO classification. The CBR values of all samples of the soil are low compared to the standard value of 80. The permeability of the soil is high, therefore, the soil is unsuitable for road construction. The strength of the soil will further be reduced when there is rise in the level of water table and this can cause failure of the pavement upon the application of pressure.

Keywords: Assessment, effects, surface and subsurface moisture, highway failure, Ado-Afao-Ekiti Road

INTRODUCTION

Pavement is a structural material placed above a sub-grade layer. In asphaltic pavement, it is typically a multi-layered system, comprising the sub-grade (support), sub-base, base course and surfacing (Ogundipe, M.O., 2008). Its principle function is to receive load from the traffic and transmits it through its layers to the sub-grade. It should be designed, such that its surface is impervious to prevent water from getting into the lower layers and sub-grade because of the damages that can be caused by water. (Rowell, 1994).

Water accumulating excessively in pavement layers contributes to problems which may cause premature failure of the structure, and unsafe operating conditions for motorized traffic (Arika et al, 2009). The pavement must be constructed in such a way that if peradventure water is able to enter the road pavement, there would be a way out for the water, this is usually through a sub-base layer that is drained to an installed drainage system or road side ditch (Summers, 2010).

Accumulation of moisture into the pavement subgrade can adversely affect pavement performance, leading to accelerated pavement deterioration. Infiltration of water into the various layers of the pavement if not properly controlled can lead to some of the following: softening of the pavement layers and sub-grade by becoming saturated and remaining so for prolonged periods, loss of bonding between pavement layers due to saturation with moisture, degradation of the quality of pavement and sub-grade material due to interaction with moisture, piping or erosion and swelling (Wikipedia, 2010).

Water entering the pavement and adjacent highway components has many sources. The largest and often overlooked, sources of “free” water (water not bound by any form of energy or potential) entering the structural section is atmospheric precipitation, which supplies surface water in form of rain, snow, hail, condensing mist, dew etc (Arora, 2008).

Water reaches the structural section by infiltrating through cracks in the pavement surface, the shoulders and side ditches (Dake, 1983). Capillary action causes moisture to rise from the water table, transporting this to the pavement structure. The height of water rise due to capillary action varies, depending on the grain size of the soil.

According to C.J Summers, most aggregates have a greater affinity for water than they do bitumen and with the presence of water and movement of the aggregate it is quite possible for the binder film on the aggregate particle to be broken and water to come into contact with the aggregate surface, hence its infiltration to the underlying components of the pavement.

The road in the area of case study (Ado-Afao) is greatly characterized with failure like potholes, heaving (swelling and shrinkage) etc that can be due to inadequate surface and subsurface moisture control. The main purpose of this work is to identify the effect of inadequate moisture control on highway pavement failure.

Materials and Methods

Disturbed and undisturbed samples were collected from five (5) different locations in the area of case study.

Part of the collected soil samples were filled inside polythene bags to retain their insitu moisture, the remaining portion of the soils were spread inside trays for drying and lumps were broken. The soil samples designated as A,B,C,D and E were subsequently tested to determine their atterberg limits, sieve analysis, permeability, compaction characteristics and strength characteristics. The tests were conducted in accordance with BS 1377 and AASHTO specification.

Results and Discussion

The various results obtained from the tests were analysed and presented as tables 1-7.

Table 1 shows the results of sieve analysis of all the samples. The results revealed that the coarse material for the samples are 65.9, 66.7, 65.5, 65.1 and 69.9 for soil samples A,B,C,D and E respectively. While the fine material for the samples are 34.1, 33.3, 34.5, 34.9 and 30.1 for soil samples A,B,C,D and E respectively. The soils can be classified as organic silt of medium compressibility containing less plasticity according to Casangrade and A-2-6 (silty soil) of fair to poor rating in terms of possible use as subgrade materials according to AASHTO classification.

Table 2 shows the result of Atterberg limits. The plasticity index of the samples A,B,C,D and E have values of 17.2%, 16.0%, 18.1%, 15.8% and 17.6% respectively.

The results of compaction characteristics (table 3) gave the OMC of 9.2%, 8.2%, 9.2%, 8.3% and 8.6% for samples A,B,C,D and E respectively, while the MDD are 2997g/cc, 3050g/cc, 3114g/cc, 3047g/cc and 2909g/cc for the samples A,B,C,D and E respectively.

Table 4 shows the results of permeability test carried out on the samples. The result shows that samples A,B,C,D and E have values 4.11, 3.69, 4.65, 4.32 and 5.87×10^{-2}m/s respectively. The CBR values are 12.8, 15.1, 23.4, 30.2% and 10.6 for A,B,C,D and E respectively as shown in table 5. The results show that the soils fall into the category of fair-poor soils which indicate that there is need for improvement of the soils for suitability as subgrade material.

The cohesion (c) and angles of internal friction (∅) of the samples are shown in table 6. Values of cohesion ranges from 9g/cc to 50g/cc while angles of internal friction ranges from 8^0 to 13^0.

Table 7 shows the result of linear shrinkage of samples A,B,C,D and E with values of 0,0,2,0 and 3 respectively.

Table 1: Results of Sieve Analysis

	A	B	C	D	E
Gravel %	4.6	1.1	1.4	0.3	0.7
Sand %	61.3	65.6	64.1	64.8	69.2
Clay %	34.1	33.3	34.5	34.9	30.1

Table 2: Results of Atterberg Limits

	A	B	C	D	E
L.L. %	17.2	16.0	18.1	15.8	17.6
P.L. %	NP	NP	NP	NP	NP
P.I %	17.2	16.0	18.1	15.8	17.6

Table 3: Results of Compaction Characteristics

	A	B	C	D	E
MDD g/cc	2997	3050	3114	3047	2909
OMC %	9.2	8.2	9.2	8.3	8.6

Table 4: Results of Permeability

	A	B	C	D	E
K(m/s) $\times 10^{-2}$	4.11	3.69	4.65	4.32	5.87

Table 5: Results of CBR Tests

	A	B	C	D	E
CBR	12.8	15.1	23.4	30.2	10.6

Table 6: Results of Triaxial Tests

	A	B	C	D	E
Cohesion (C)	18	9	23	50	19
g/cc	10	11	13	8	9
Angle of internal					

friction ($\varnothing$)^0

Table 7: Results of Linear Shrinkage

	A	B	C	D	E
L.S %	0	0	2	0	3

Conclusion

From the analysis, the sieve analysis result showed that the soil samples can be classified as organic silt of medium compressibility and containing less plasticity which makes them unsuitable for road construction.

The result of CBR test showed that, samples A,B,C,D and E have low CBR values. The low CBR values can be caused by the presence of moisture and this can also cause pavement failure.

The plastic limit and plasticity index showed that the soils are unsuitable for road construction.

The strength of the materials used will be reduced when there is a rise in the level of water table and this will result to the failure of the pavement as pressure is applied. Hence, there is need to improve or stabilize the soil.

Problems noticed include non provision of drainage facilities, to solve this problem, good drainage and adequate camber must be provided.

The strength of the soil is not adequate; the soil must be removed and replaced.

Recommendation

Surface and sub-surface moisture is majorly responsible for the deplorable state of the pavement on Ado Afao Ekiti road in order to reduce the effect, the following are recommended:

It must be ensured during the construction of the road pavement that the materials to be used are suitable for construction purpose, such materials must not allow easy infiltration of water and must have good strength properties. The materials must not be susceptible to heaving (swelling and shrinkage) to avoid failure of the pavement structure during rise in water table.

Appropriate corrective measures such as stabilization, full compaction etc can also be taken in order to improve the strength properties of the soil. Good drainage system and adequate camber must be provided during the construction and pavements should be constructed such that ingression of water is prevented.

Finally, proper maintenance programme must be put in place.

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