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Durability Assessment of Laterite Rock Asphalt Concrete Blended with Portland Cement and Waste Polythene Under Extreme Moisture Condition

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ABSTRACT

The consequential cost of obtaining granites used as coarse aggregate for construction is quite high and in the distant future might run into depletion. The need to source for alternative materials for highway pavement construction becomes necessary. One of such materials is laterite rock, however laterite on its own is unsuitable because of its porosity. The present study focused on complete replacement of granite using laterite rock. The studied further entailed characterizing laterite rock blended with 8% Portland cement and Waste polythene so as to make it suitable for use in highway pavement under low traffic condition. The study was simulated in the laboratory by submerging samples and studied the effect of Portland cement and Waste polythene on laterite rock asphalt concrete. Results obtained revealed that the addition of 8% Portland cement and Waste polythene up to 25% enhanced durability and stability of laterite rock asphalt concrete even under the condition of submerged in water

Keywords: Laterite rock asphalt concrete, Portland cement, waste polythene, RSI, FDI, SDI, submerge

1.0 INTRODUCTION

Asphalt concrete is a composite material commonly used for road surfacing parking lots, airports, as well as the core of embankment dams. The mix is composed primarily of aggregates and asphalt cements. Some types of asphalt mixes are also used in pavement base course. The design of asphalt paving mix, as with the design of other engineering materials is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure. These materials basically include bitumen, aggregates (fine and coarse), and mineral filler.

Reducing the cost of construction of asphalt concrete pavement while maintaining the necessary properties is one of the concerns of the highway engineer. Aggregates occupy 95% of the volume of asphalt concrete and affect its properties, mix proportion, and economy to a large extent. Thus, any effort of reducing the cost of aggregate will have a direct impact on reducing the cost of construction [1]-[25]. This has given rise to the need to investigate various non-conventional aggregates which can be sourced locally and are cheaper to make satisfactory data available to serve as alternatives. There is abundance of Lateritic materials all over the world, especially in tropical regions with high characteristic rainfall and persistently high temperatures. The typical regions of occurrence of laterite include India, Burma, Indonesia, Malaysia, Australia, Africa, and interior parts of South America [42]. An extensive area of Nigeria is covered with laterite materials in various weathered states, ranging from clay laterite, sandy laterite to rock laterite [17].

Lateritic soils contribute to the general economy of the tropical and subtropical regions where they are in abundance because, they are widely utilized in civil engineering works as construction materials for roads, houses, landfill for foundations, embankment dams, etc. As a road construction material, they form the sub-grade of most tropical road, and can also be used as sub-base and base courses for roads that carry light traffic [2].

Laterite rock as an aggregate is unsuitable for use as coarse aggregate in hot mix asphalt concrete due to its high porosity and moisture absorption.

Therefore, to solve these maladies, Portland cement at 8% content by weight of the aggregates was used as void filler material. Lastly, waste polythene bag was used to blend the mixture in other to solve the problem of moisture intrusion at varying percentages between 5-25% by weight of asphalt cement at optimum binder content.

This article is aimed at durability assessment of laterite rock asphalt concrete blended with Portland cement and waste polythene under submerged condition using RSI, FDI, SDI

2.0 MATERIALS AND METHOD

This research work was achieved using the following procedure as described below.

Sample Preparation

Asphalt Concrete Mix design is basically the selection and proportioning of an economic blend of aggregates and asphalt to produce a mix having:

- sufficient asphalt to ensure a durable pavement
- sufficient mix stability to satisfy the demands of traffic without distortion or displacement
- sufficient voids in the total compacted mix to allow for additional amount of compaction under traffic loading without flushing, bleeding or loss in stability; yet low enough to prevent harmful air and moisture.
- sufficient workability to permit efficient placement of the mix without segregation.

Based on these requirements, samples were prepared using the Marshall Design procedures for asphalt concrete mixes as per ASTM D-1559. The procedure involved the preparation of a series of test specimens for a range of asphalt contents such that test data curves showed well defined optimum values. Each specimen required approximately 1200g of the total weight of the mixture. Tests were scheduled on the basis of 0.5 percent increments of asphalt content with at least two asphalt contents above and below the expected optimum binder content. In order to provide adequate data, two test specimens were prepared for each of the binder content used; each specimen having 64mm thick by 100mm diameter size. Two classes of hot mix asphalt (HMA) concrete were prepared; unmodified laterite rock HMA concrete and modified laterite rock HMA concrete. All samples were prepared for low traffic volumes.

Retained Strength Index (RSI): is evaluated using Eqn. 1 below

$$RSI = \frac{S_i}{S_o} \times 100 \qquad (1)$$

Where; RSI = retained strength index, S_i = stability after immersion at time t_i or stability of conditioned specimen and S_o = stability before immersion or unconditioned specimen.

First Durability Index (FDI): is defined as the sum of the slopes of the conservative sections of the durability curve, (Craus J. et.al. 1981) mathematically it is expressed;

$$\mathbf{FDI} = \sum_{i=0}^{n-1} \frac{S_i - S_i +_1}{ti + 1 - ti} \qquad (2)$$

Where;

$\mathbf{S_{i+1}}$= percent retained strength at time t_{i+1}

$\mathbf{S_i}$= percent retained strength at time t_i

$\mathbf{t_{i+1}}$and $\mathbf{t_i}$= immersion times.

Second Durability Index (SDI)

$$\mathbf{SDI} = \frac{1}{t_n} \sum_{i=0}^{n-1} Ai = \frac{i}{2t_n} \sum_{i=0}^{n-1} (S_i - S_{i+1}) \times [2t_n - (t_{i+1} - t)] \qquad (3)$$

Where;

$\mathbf{S_{i+1}}$= percent retained strength at time t_{i+1}

$\mathbf{S_i}$= percent retained strength at time t_i

$\mathbf{t_i, t_{i+1}}$= immersion times (which is being calculated from the beginning of the test).

Thus it is considered crucial to note that when considering pavement durability using the Durability Index (DI); the higher the index value, the more the loss of strength or stability of the pavement therefore, the less durable the pavement becomes. Similarly, if the pavement durability is assessed using the Retained Strength Index (RSI); the lower the index value the less durable the pavement becomes (Ali, 2013).

3.0 RESULTS (Tables & Figures)

Table 1 : Schedule of Mix proportion for Aggregates (Laterite & sand)

Sieve (mm)	Specification Limit	% passing Aggregate A (Gravel)	% passing Aggregate B (Sand)	Proportion. (0.62A)	Mix Proportn. (0.38B)	Mix Proportion (0.62A+0.38B)	Remark
19.1	100	100.0	100.0	62	38	100.0	Satisftry
12.7	76-98	90.4	100.0	55.9	38	93.90	Satisf'try
9.52	64-84	41.6	100.0	25.79	38	63.8	Satisf'try
4.75	40-60	17.1	98.9	10.60	37.58	48.18	Satisf'try
1.18	23-41	8.6	83.0	5.33	31.54	36.87	Satisf'try
0.425	7-20	6.3	13.0	3.91	4.94	8.85	Satisf'try
0.300	3-13	4.8	3.0	2.98	1.14	4.12	Satisf'try
0.075	2-7	3.8	0.2	2.36	0.08	2.44	Satisf'try
0		0	0	0	0	0	

Table 2: Retained Stability (N) of modified Laterite Rock Asphalt Concretes at 8% PC content and varying percentages of WP at different immersion times (days)

WP (%)	Immersion Time (Days)					
	0	1	2	3	4	5
0	13390.0	13195.3	12646.6	12009.4	11563.9	10613.9
5	13761.7	13561.1	12995.9	12339.8	11850.6	10812.1
10	14370.0	14160.0	13567.6	12880.2	12153.9	11070.3
15	16096.4	16080.5	15186.6	140 20.5	12702.8	12422.8
20	18728.8	17971.8	17761.8	17358.8	15606.5	14749.1
25	19981.9	19260.7	18881.7	18210.5	16550.4	15973.2

Note: PC – Portland Cement
WP – Waste Polythene

Table 3: Retained Stability Index (%) of modified Laterite Rock Asphalt Concretes at 8% PC content and varying percentages of WP at different immersion times (days)

WP (%)	Immersion Time (Days)					
	0	1	2	3	4	5
0	100	98.5459	96.2904	95.1417	93.1015	91.2848
5	100	98.5623	96.4322	95.3915	93.3356	91.8367
10	100	98.5886	95.8164	95.4335	93.6611	92.0843
15	100	98.9012	97.4411	96.3215	94.5016	92.4736
20	100	99.2315	97.7311	96.7581	94.7061	93.1054
25	100	99.5645	98.0323	97.5123	95.4452	93.8838

Note: PC – Portland Cement
WP – Waste Polythene

Table 4: First Durability Index (FDI) of modified Laterite Rock Asphalt Concretes at 8% PC content and varying percentages of WP at different immersion times (days)

WP (%)	Immersion Time (Days)					
	1	2	3	4	5	FDI after 5days of immersion
0	1.4541	2.2555	0.5743	2.0402	0.9083	7.23250
5	1.4377	2.1301	0.5203	2.0559	0.7494	6.89351
10	1.4114	2.7722	0.1914	1.7724	0.7884	6.93585
15	0.7685	1.4601	0.5598	1.8199	1.0143	5.62231
20	0.7685	1.5004	0.4865	2.0522	0.8003	5.60775
25	0.4355	1.5322	0.2601	2.0671	0.7807	5.07552

Table 5: Second Durability Index (SDI) of modified Laterite Rock Asphalt Concretes at 8% PC content and varying percentages of WP at different immersion times (days)

WP (%)	Immersion Time (Days)					
	1	2	3	4	5	SDI after 5days of immersion
0	9.4516	12.4052	4.5948	5.1005	4.5417	36.0939
5	9.3450	11.7155	4.1628	5.8397	3.7472	34.8104
10	9.1741	15.2471	1.5316	4.4311	3.9421	34.3258
15	7.1422	8.0305	4.4784	4.5497	5.0702	29.2709
20	4.9952	8.2522	3.8921	5.1301	4.0017	26.2712
25	2.8307	8.4271	2.0802	5.1677	3.9035	22.4091

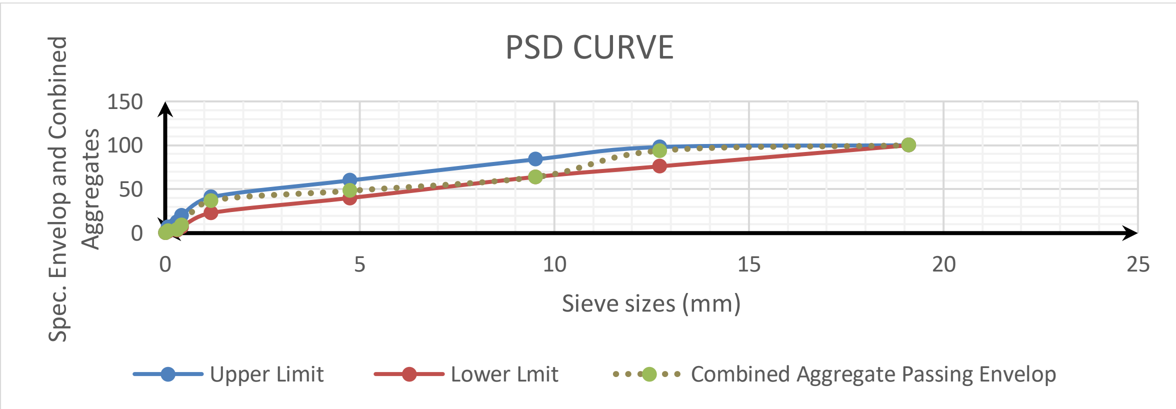

Figure 1: Particle Size Distribution Envelope for Blended Aggregates

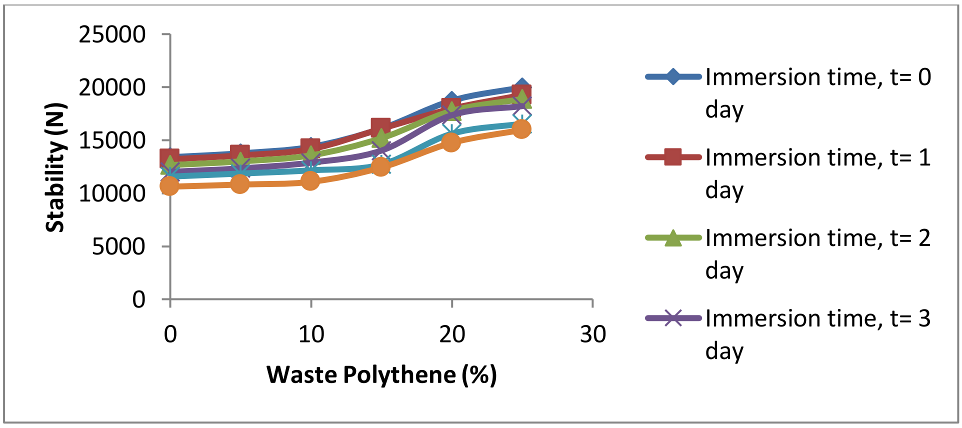

Figure 2: Stability Values Against Waste Polythene

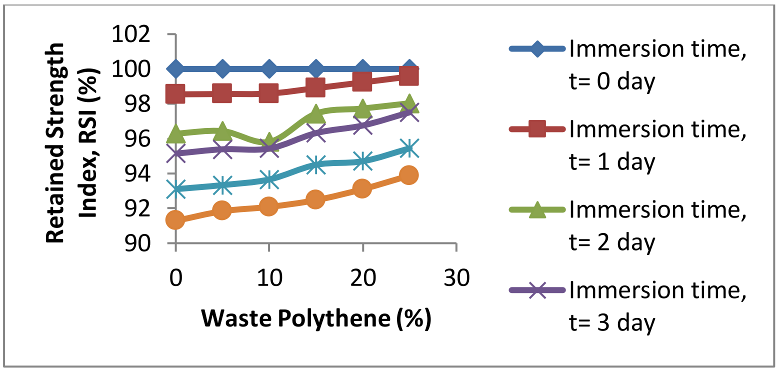

Figure 3: Plot of RSI Against Waste Polythene

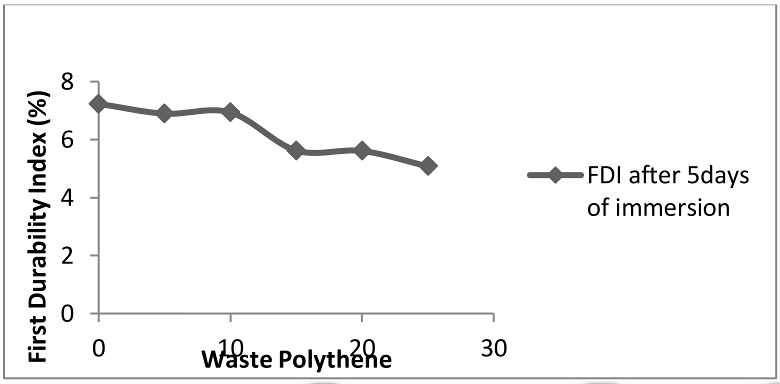

Figure 4: Durability Values Against Waste Polythene

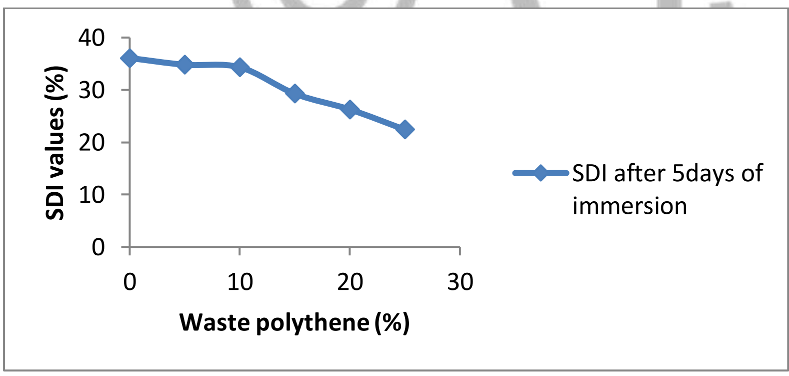

Figure 5: Plot of SDI Values Against Waste Polythene

4.0 DISCUSSION

Durability Evaluation Using Stability

It is noticed that stability values where increasing as WP dosage increases and maximum stability was obtained for 25% WP as 19981.9N at day 0; 19260.7N at day 1; 18881.7N at day 2; 18210.5N at day 3; 16550.4N at day 4 and 15973.2N at day 5 immersion separately. The results revealed that durability is achieved upon addition of waste polythene to improve asphalt concrete as shown in Table 2 and Figure 2 above.

Durability Evaluation Using RSI

Table 3 and Figure 3 shows that the retained stability index (%) of the modified laterite rock asphalt concrete were increasing upon the addition of waste polythene and best RSI values was established for 25% dosage of WP and the maximum RSI were determined as 99.5645% at day 1; 98.0323% at day 2; 97.5123% at day 3; 95.4420% at day 4 and 93.8838% at day 5 immersion times. Results indicate that waste polythene is functional material that can be used to improve durability of asphalt pavement.

Durability Assessment Using FDI

It is established that durability index by concept of first order computation decreased linearly with increasing dosage of waste polythene content up to 25% as shown in Table 4. Relevant literatures have established that durability index clearly explain the loss in strength or stability of asphalt concrete. It is observed that a high value of DI revealed a pavement with high loss of strength and stability leading to low durability of pavement and a low value of DI revealed a pavement with low loss of strength and stability leading to a better durability. Results obtained as shown in figure 4 revealed a loss of strength/stability of the asphalt concrete pavement wearing course, however, increasing in durability as a result of addition of WP with the least value determined 5.076%. Therefore, waste polythene addition into asphalt concrete wearing course production improved durability/ stability within submerged water environment.

Durability Assessment Using SDI

Table 5 illustrate the results obtained for durability index by concept of second order decreased linearly with increasing waste polythene content as an improvement material for asphalt concrete and minimum of SDI were obtained for 25% WP. Relevant literatures have established that durability index clearly explain the loss in strength or stability of asphalt concrete. Results revealed in figure 5 shows that asphalt concrete wearing course decreasing its loss in stability/strength whereas increasing in durability as a result waste polythene addition as 25% WP has least DI of 22.4091%. It can say that addition of waste polythene (WP) improves stability or duration of asphalt concrete wearing course in submerged environment.

5.0 CONCLUSION

The following deductions was drawn from this research;

i. Properties such as stability, density, flow, and voids, obtained from the modified laterite rock concrete was better than that of the conventional (unmodified) laterite rock concrete due to the addition of 8% Portland cement and Waste polythene.

ii. Retained Stability RSI increased with increase in the percentage of Waste Polythene in the mix.

iii. That the addition of Waste Polythene and cement to asphalt pavement wearing course submerged in moisture or water can improve the durability of the pavement.

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