IMPACT OF VEHICLE LOAD ON ASPHALTIC PAVEMEENT THICKNESS

*Kolo, S. S, **Jimoh Y.A, **Adeleke O. O. and ***Adama A. Y.

*Department of Civil Engineering, Federal University of Technology Minna,

**Department of Civil Engineering, University of Ilorin and
***Civil Engineering Section, Niger State Ministry of Works
E-Mail: bukysayo123@yahoo.com

ABSTRACT
Road networking is one of the strategic priorities for economic, social and political development of every country. In Nigeria, road are constructed without much regard to standards and technique and because of bad quality of some roads materials and in some cases due to increasing traffic density on demand use. The settlement characteristics of threes road were examined based on the traffic composition of vehicles on each of the roads, the roads are Minna-Suleja Road, Minna-Kotangora Road and Minna - Bida Road. It was discovered these roads have settlement of 16mm, 20mm and 13mm respectively, which are above the acceptable values recommended by various standard. This clearly shows that the studied roads are overloaded and hence the frequent failure experienced on the roads. Equation was also promulgated for pavement settlement after care observation Y= $2x^2 e^{-14} - xe^{-7} + 100.4$

KEYWORDS:

Pavement Thickness, Settlement, Axle load, Vehicular traffic and Leveling

1.0 INTRODUCTION

Asphalt is a mixture of mineral aggregates and binder usually bitumen. Bitumen is a heavy, dark brown to black mineral substance and one of several mixtures of hydrocarbons. Bitumen is a strong, versatile weather and chemical-resistant binding material which adapts itself to a variety of uses. Bitumen binds crushed stones and gravel (commonly known as aggregates) into firm, tough surfaces, termed asphalt, used for roads, streets, and airport run-ways (Roberts *et al.*, 1996)

The roads are constructed to carry traffic load which is not beyond the capacity of the road but unfortunately most of these designed road still failed with time. inconsistent of asphaltic properties together with ever increasing axle loads, high tire pressures and high temperatures are considered to be the most commonly observed causes behind pavement frequent failures, in most African countries and Nigeria in particular, the Federal Ministry of Works and recently FERMA have been having sleepless nights on the performance of the roads in the country.

Research work on settlement by Kennedy *et al.*, (1996) discovered that rutting/settlement in the Hot Mix Asphalt (HMA) layer will generally occur within the top 3 to 5 in (75-125mm). Also the major wheel rutting classification done by the Federal Highway Administration (FHA) in 1979, classified rutting into three levels of severity: i) Low, from 6 to 12.5 mm, ii) Medium, from 12.5 to 25 mm and iii) High, over 25 mm. It was also concluded by FHA that a settlement value of 12.5 mm is generally acceptable as the maximum allowable rut depth (Huang, 1993 & Kennedy *et al.*, 1996). Furthermore, three main classifications were also proclaimed by Mechanistic-Empirical Design Guide (MEPDG) for the permanent deformation behaviour of flexible pavement asphalt materials under a given set of material, load and environmental conditions; (i) primary stage which has high initial level of rutting with a decreasing rate of plastic deformations, predominantly associated with volumetric change, (ii) the secondary stage has small rate of rutting exhibiting a constant rate of change of rutting that is also associated with volumetric changes; however, shear deformations increase at increasing rate and (iii) third stage called the tertiary stage which has a high level of rutting predominantly associated with plastic (shear) settles under no volume change conditions as shown in Figure 1 **(**AASHTO, 2002**)**. Stumpf and Rooyen (2007) also stated that when an asphalt material is loaded with a stress (traffic loading) that is above the flow strength of the asphalt material, at 25^{o}C temperature the material will start to deform. It further added that the material will first deform rapidly, then, after some strain hardening has taken place, the material gets to a stage with a lower creep rate as shown in Figure 1. This stage is known as secondary creep, or steady state creep. In the third stage which is the tertiary stage the material becomes unstable and rapid collapse results.

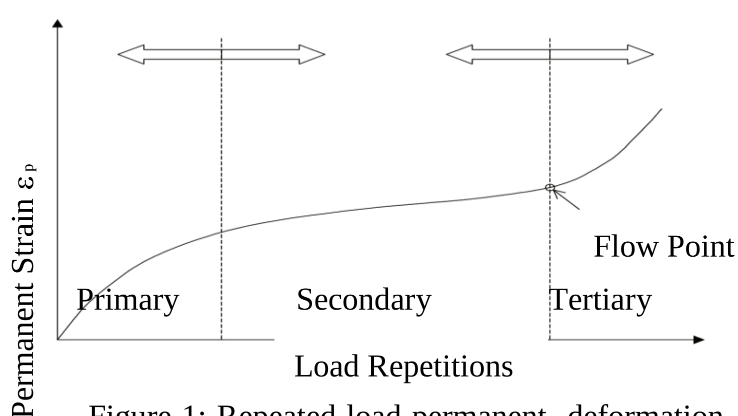

Figure 1: Repeated load permanent deformation behaviours of pavement materials (AASHO, 2002)

The extent of settlement taking place in the above (Figure 1) is important. The critical rut depth is generally set at 10 mm, it was also discovered that if the depth of 10mm is reached in the primary phase or in the first part of the secondary phase, the functional life of the Hot Mix Asphalt (HMA) layer is reduced drastically. In secondary phase, the rate of deformation slows down considerably. The dominant mode of deformation is caused by shear stress that overcomes flow strength of the material. The flow strength consists of two components, i.e. friction and cohesion. The deformation takes place in small iterations with each load application. Eventually the void condition and the level of permanent strain will cause the HMA to enter the tertiary phase and rapid unstable shear failure occurs (Carpenter, 1993).

It is worthy to note that most traffic-associated permanent deformation, rutting in particular, results from a rather complex combination of densification and plastic flow mechanisms. Plastic flow involves essentially no volume change and gives rise to shear displacements in which both depression and heave usually manifest.

Repetitions in wheel and axle loadings on a pavement can lead to damage, especially when the pavement is not designed to handle the nature and volume of traffic it is experiencing. The loadings are due to the motor vehicles that ply the highways, which include; the cycles, cars, buses and trucks that use that particular section of the roadway. In highway engineering, the major cause of surface damage results from the loadings imposed by heavier vehicles such as the trucks and the heavy buses. Vehicles, such as passenger cars and cycles have lesser damaging effect compared to the heavier ones.

It aimed that with this research work that the life's span of a newly constructed road pavement can be determined when volume of traffic is determined and the usage of road can be control

2.0 MATERIALS AND METHOD

The Hot Mix Asphalt (HMA) was used for this research work and hence the behaviour (settlement) of HMA, when subjected to repeated traffic loading and external weather conditions. Four months of intensive monitoring of repaired pothole was systematically conducted in the following stages;

1. Selection of material and equipment used
2. Site selection of failed pavement spot/location
3. Placement of hot mix asphalts on the selected failed spots of pavement.
4. Traffic count for estimation of traffic induced loads
5. Weekly monitoring of settlements
6. Result and data presentation and analysis.

2.1 Selection of material and equipment

The HMA material used for the work was produced in a laboratory after observing all necessary standards and procedures. This was then placed at the selected road spots of Minna-Suleja Road, Minna-Kotangora Road and Minna-Bida Road. The equipment used to carry out the field settlement monitoring include Levelling Instrument, Levelling Staff (4 metre) (1mm division), Scale Rule and Brush/Broom, Diggers, Shovels and a pattern compactor.

2.2 Site selection of failed pavement spot/location

In order to carry out this field work three experimental potholes were selected on each of the said roads based on alignment to each other. The site selected was well trafficked, also the potholes were on same side of the carriage way, longitudinally aligned and not far apart from each other for easy observation and in order to ensure that approximately equal traffic intensity traverses the repaired portions.

2.3 Placement of hot mix asphalts

The pothole surfaces were cut into square shape and excavated with the aid of diggers. After the excavation, the unwanted materials were removed with the aid of a shovel and the surfaces of the potholes were swept clean with the use of brush. Bitumen was then used to coat the pothole surfaces. This was done in order to ensure adequate bonding of the asphalts to the pothole surface of the roadway. The HMA was then introduced to the surface. The samples were carefully spread over the surface in order to ensure even distribution. Lastly, the samples were compacted with the use of an pattern compactor until an adequate compaction level was achieved.

A square shape measuring 35 cm × 35 cm was marked out on each of the patched potholes surfaces with white paint where the observation points were conspicuously identified. Five points were indicated in the square shape distributed as follows: four at the edges and one in the middle. The points on Minna – Suleja Road were labelled A1, A2, A3, A4, and A5; for Minna – Bida Road: B1, B2, B3, B4 and B5; and Minna – Kontangora Road: C1, C2, C3, C4 and C5.

Plates I shows the pothole patching and the settlement evaluation points.

volume on the road in accordance to traffic rules and also the axle loads of the various categories was also noted

2.5 Monitoring of Settlement

The settlement values were obtained by placing the leveling staff at each of the points marked on the surfaces of the asphalt samples as shown in Plate I the average of the readings were then taken as the new reduced level of the pot patched from which settlement determined for that week.

3.0 RESULTS AND DISCUSSION

3.1 Traffic and Axle Load Survey

Table 1 is the result of the traffic count conducted on the selected roads.

Table 1: Average daily traffic count and Axle load for all vehicles in one direction

Vehicle Type	Weight Per Axle (Ton)	Equivalent Factor (E.F) per Axle E.F = $[\frac{AXLE\ LOAD}{8}]^4$	MINNA - SULEJA ROAD ADT (No.)	Esa (millions Repetition per day)	Total esa Per day (millions Repetition per day)	MINNA - BIDA ROAD ADT (No.)	Esa (millions Repetition per day)	Total esa Per day (millions Repetition per day)	MINNA - KOTANGORA ROAD ADT (No.)	Esa (millions Repetition per day)	Total esa Per day (millions Repetition per day)
Car (2axle)	0.250, 0.60	0.000033	5346	0.176	12,323	4581	0.151173	20,955	2657	2657	7,608
Mini Bus (2axle)	1.290, 2.390	0.00864	318	2.75		247	2.13408		65	0.5616	
Medium Bus (3axle)	15.350, 14.260, 17.260	45.32	34	1,541		64	2,900		32	1,450	
Heavy Bus (4axle)	9.300, 16.170, 14.920, 14.640	66.06	33	2,180		160	10,570		31	2,048	
Truck (5axle)	4.730, 17.710, 17.910, 19.430, 18.340	111.68	77	8,599		67	7,483		13	1,452	

3.2 Settlement Result

Table 2 Show the results of the settlement pattern obtained on the field. The average readings of the marked points are presented in Table 2. Also shown in the table is the axle load per week as calculated in Table 1.

Table 2: Settlement of asphalt on the studied roads

Week	Minna-Suleja Road		Minna-Bida Road		Minna-Kontangora Road	
	Settlement	**Loading esa**	**Settlement**	**Loading esa**	**Settlement**	**Loading esa**
1	100.46	86,261	100.46	146,678	100.46	53,249
2	100.44	172,522	100.41	293,356	100.43	106,498
3	100.41	258,783	100.39	440,034	100.41	159,747
4	100.40	345,044	100.38	586,712	100.4	212,996
5	100.39	431,305	100.37	733,390	100.37	266,245
6	100.38	517,566	100.35	880,068	100.37	319,494
7	100.38	603,827	100.35	1,026,746	100.35	372,743
8	100.37	690,088	100.33	1,173,424	100.35	425,992
9	100.36	776,349	100.32	1,320,102	100.34	479,241
10	100.34	862,610	100.32	1,466,780	100.34	532,490
11	100.33	948,871	100.28	1,613,458	100.34	585,739
12	100.32	1,035,132	100.27	1,760,136	100.34	638,988
13	100.30	1,121,393	100.27	1,906,814	100.33	692,237
14	100.30	1,207,654	100.26	2,053,492	100.33	745,486

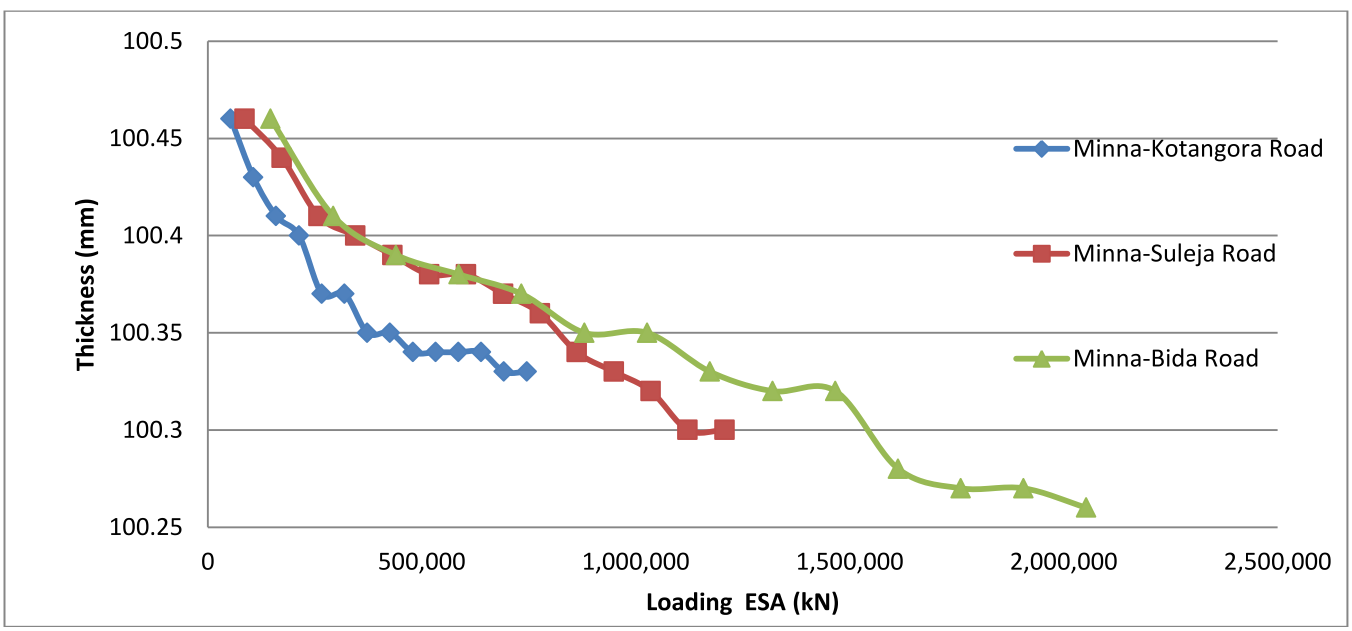

Figure 1: Road Settlement

3.3 Field Settlement Evaluation

The road settlement graphs in figure 1 shows that all the samples settled with increase in traffic which is in accordance with the standard specification. This is because in a standard specification, it is expected that asphalt samples whether cold or hot-mix should gradually settle with an increase in time under normal traffic loadings and atmospheric conditions.

The rate of settlement for each of the roads can also be deduced from the graph by comparing the settlement values on the vertical axis with the corresponding cumulative loading on the horizontal axis in order to have an insight on how well the asphalts were compacted by the traffic loads on weekly basis.

Mathematical model was derived for the three curves shown in Figure 1 and summarily the equation 1 was obtained as the general equation for the settlement. It can be said that this equation applied to all the road

$$Y = 2x^2 e^{-14} - xe^{-7} + 100.4 \quad (1)$$

Where Y= settlement

X = Axle load

And that the degree of closeness is $R^2 = 0.967$ where x is Axle load

It can therefore be said that for a particular settlement to occur axle load must be known and the limit of settlement and loading can be predicted when a road is newly constructed.

It can also be deduced that Minna – Suleja Road, is the most loaded of studied road closely followed by Minna – Bida Road.

In Figure 1 it is clear that all settlement took the same shape, showing gradual reduction as the road is been trafficked.

CONCLUSION

1. It can be concluded that vehicular load on pavement results to gradual decrease in pavement thickness either in whole or partial.
2. The model equation for pavement settlement was also obtained as follows

$$Y = 2x^2 e^{-14} - xe^{-7} + 100.4$$

$$R^2 = 0.967$$

Where

Y= Settlement

x = Axle load

3. It was deduced that the more the pavement is loaded the earlier the pavement will fail.

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