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ISSN: 2350-0743

International Journal of Recent Advances in Multidisciplinary Research

Vol. 05, Issue 12, pp.4311-4319, December, 2018

RESEARCH ARTICLE

COMPARATIVE COST ANALYSIS OF FLEXIBLE AND RIGID PAVEMENT THE NIGERIAN FACTOR

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ARTICLE INFO

Article History:

Received 25th September, 2018

Received in revised form 20th October, 2018

Accepted 18th November, 2018

Published online 26th December, 2018

Keywords:

Cost analysis

Nigerian factor.

ABSTRACT

The economic and social development of nations all over the world relay to a large extent on the quality of its road transportation system. Vast amounts of money have been invested and are still being invested in the construction of roads. Similarly, large amount of money is required to ensure that these roads having been constructed can continuously fulfill their function. Nigerian roads presently are largely dominated by flexible pavements, even with the glaring evidence that these roads have been consistently performing poorly, this however has call for a lot of both periodic and routine maintenance funds, establishment of Road maintenance agencies at states and Federal levels making the overall pavement costs substantially high and thus posing the possible challenge of not giving returns on investment by the end of the design period. Therefore, the study is focused on reviewing the existing pavements and their performance on the roads under the different soil CBR and eventually forming an opinion on the best suited pavement. Both flexible and rigid/concrete are the two commonly used pavements globally. The unit cost for each of the pavement were computed for a comparative cost analysis. The results for the thicknesses of the flexible pavement at CBR value of 12% against the following Equivalent single axial loads (ESAL) of 0.3, 0.5, 1.10, 2.25, 4.5 and 8.0 are 425,460,400,403,530 and 470 respectively. The results of the flexible pavement design thicknesses presented above shows a general increase of thickness from left to right and decreases from top to bottom an indication that the thickness of flexible pavement is greatly influence by the traffic load and soil strength. While that of rigid pavement thicknesses are 297, 315, 341, 348, 366 and 391 at Equivalent single axial loads (ESAL) of 0.3, 0.5, 1.10, 2.25, 4.5and 8.0. The cost implication for the flexible pavement at 12% CBR are 66.384, 80.996, 116.998, 129.819, and 141.989 (MN) and that for the rigid pavement are 79.458, 85.724, 94.775, 97.211, 103.477, 112.179 (MN) all at the same pavement thicknesses.

INTRODUCTION

There is a global economic crisis, ranging from global warming, falling of crude oil price etc. more and more countries are experiencing economic recession due to this crisis and Nigeria is not left out as it economic main stay depend on crude oil. The country has suffered so much set beck in capital project development such as road in recent times due to this phenomenon, therefore there is an urgent need for Institutions, Establishments, Government, Parastatals and Individuals to start having a rethink on how resources especially money is spent and managed. A complete or almost complete change from the old way things were being done is advocated. Thus, infrastructural development especially roads is one area to start from given its economic importance to any society. In the face of scarce funds and limited budgets, transportation officials must constantly choose the most cost effective project alternatives. As transportation agencies consistently rank amongst the top sector in public spending, choosing the most cost effective type of pavement while still providing a high quality service to the traveling public is one of the most important management decisions to be made in highway and transportation planning. Nigerians roads presently are largely dominated by flexible pavements, even with the glaring evidence that these roads have performed poorly, this therefore call for a lot of both periodic and routine maintenance with it attendance requirement for funds that are not readily available, making the overall pavement costs substantially high and posing the possible challenge of not giving returns on investment by the end of the design period. Uhlmeyer *et al.,* (2000) states that flexible pavements generally require reconstruction or rehabilitation every 10 to 15years while rigid pavements, on the other hand, has a design life of between 20 and 45 years with little maintenance or rehabilitation. Thus, it should come as no surprise that rigid pavements are often used in urban, high traffic areas. But, naturally, there are trade-offs, example, when a flexible pavement requires major rehabilitation, the options are generally less expensive and quicker to perform than for rigid pavements. The two most important factors that govern pavement design are soil sub-grade strength and traffic loading.

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Depending on the strength of sub-grade soil, the layer thicknesses of flexible as well as rigid pavements are determined. All hard surfaced pavement types can be categorized into two major groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous or asphalt materials. These can be either in the form of pavement surface treatments such as a bituminous surface treatment (BST) generally found on lower volume roads or, hot mix asphalt (HMA) surface courses generally used on higher volume roads such as the interstate highway network. These types of pavements are called flexible since the total pavement structure bends or deflect due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate the flexing. On the other hand, rigid pavements are composed of a concrete surface course. Such pavements are substantially stiffer than flexible pavements due to the high modulus of elasticity of the concrete material. Further, these pavements can have reinforcing steel, which is generally used to reduce or eliminate joints. Each of these pavement types distributes load over the sub grade in a different fashion. Rigid pavement, because of concrete's high elastic modulus, tends to distribute the load over a relatively wide area of subgrade. The concrete slab itself supplies most of a rigid pavement's structural capacity. Flexible pavement uses more flexible surface course and distributes loads over a smaller area. It relies on a combination of layers for transmitting load to the sub-grade (Uhlmeyer *et al.,* 2000).

Figure 1.0. Shows the variation in load transfer for the two pavements

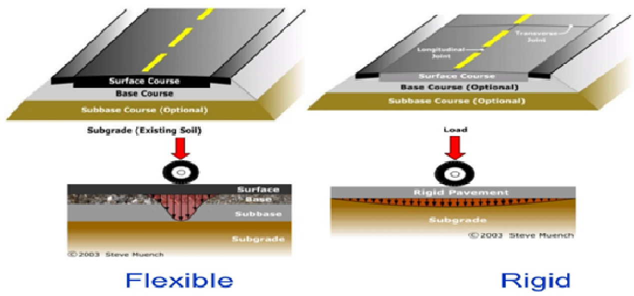


Fig. 1.1 schematic diagram of both flexible and rigid pavements

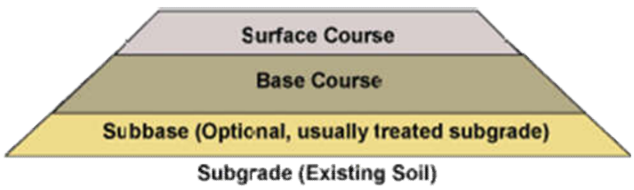


Figure 1.2. Cross Section of flexible pavement

According to Kadyali et al (2013), a pavement is a relatively stable crust constructed over the natural soil for the purpose of supporting and distributing wheel loads and for providing an adequate wearing course. A highway pavement is designed to support the wheel loads imposed on it from traffic movements.

Table 1.0 Subgrade Classification

	Subgrade Class Designation					
	S1	S2	S3	S4	S5	S
Subgrade CBR ranges (%)	2	3 -	5 -	8 -	15 -	3

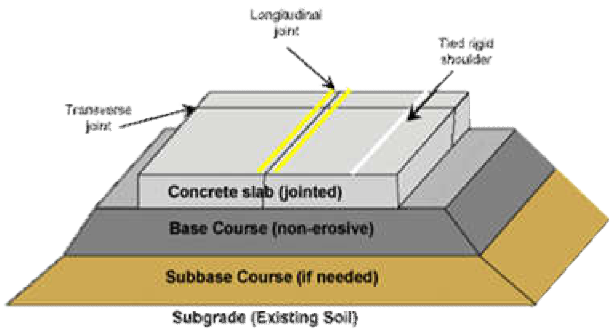


Figure 1.3. Cross Section of Rigid pavement

He further states that additional stresses are also imposed by changes in the environment, it should be strong enough to resist the stresses imposed on it and should be thick enough to distribute the external loads on the earthen sub-grade so that the sub-grade itself can safely bear it. Oguara, (2006), said the term pavement refers to the hard materials constituting the structure of a road that are constructed on top of the natural soil and are usually made up of layers with different quality of materials with the highest quality material at or near the surface. Pavements are designed to provide a safe and comfortable driving surface to the public for a long period of time at the lowest possible costs. This usually requires good design thickness and materials used should be able to withstand major defects to avoid early appearance of defects.

It should provide easy repairs for such major defects as:

- Cracking,
- Deformations,
- Disintegration and wear.

The main factors to be considered in the design of pavement are;

- Traffic load.
- Soil characteristics.
- Environment.
- Funds availability
- Materials.
- Construction technique.
- Operational and maintenance cost.

Oguara (2006), again opined that the selection of a pavement type is not an exact science but one which the Highway Engineer or road administrator must make a good judgment predicated upon the above factors while recognizing political and government preferences. Although Pavements are damaged at a shorter period due to changes in the soil properties and repeated application of wheel loads which may result in excessive settlement. Further moisture variation, Increase (or) decrease of water content in the soil causes further deterioration of the pavement which necessitates routine maintenance at a higher cost.

Types of pavements: Basically, pavements are divided into two categories, they are:

Flexible Pavement: More than 95% of the total paved roads in Nigeria are constructed with flexible pavement though there is a high debate amongst industries players, especially Highway Engineers, Government Agencies and Ministries responsible for road administration on the choice of flexible as compare to rigid pavement. Some players opine that rigid pavement is durable and cheaper at the long run. Kadyali et al (2006), defined flexible pavement as essentially a layered system which has a low flexural strength. Thus the external load is largely transmitted to the sub-grade by the lateral distribution with increasing depth. Because of the low flexural strength the pavement deflects momentarily. Also Rogers (2003) said a highway pavement is composed of a system of overlaid strata of chosen processed materials that is positioned on the in-situ soil, termed the subgrade. Its basic requirement is the provision of a uniform skid-resistant running surface with adequate life span and requiring minimum maintenance. Most asphalt surfaces are built on bases and subbases of various materials; although some 'full depth' asphalt surfaces are built directly on the native subgrade. In areas with very soft or expansive subgrades such as clay or peat, thick gravel bases or stabilization of the subgrade with Portland cement or lime may be required.

Anon, (1991), Flexible pavements usually consist of a bituminous surface under laid with a layer of granular material and a layer of a suitable mixture of coarse and fine materials. Traffic loads are transferred by the wearing surface to the underlying supporting materials through the interlocking of aggregates, the frictional effect of granular materials, and cohesion of fine materials. (Garber et al 2009). Fig 1.2 shows a conventional cross section of a flexible pavement which usually consist of surface or wearing course, granular base course, sub base course (usually made up of a weaker material than the base course) and subgrade. The structural capacity of flexible pavements is attained by combined action of the different layers of the pavement. The load is directly applied on the wearing course and it gets dispersed with depth in the base, sub-base and then ultimately to the ground or sub-grade layers. Flexible pavements are designed in such a way that the load transmitted to the subgrade does not exceed its bearing capacity. The layers are designed to take advantage of the decreasing magnitude of stresses with depth which account for the decrease in the strength of material with depth from top to bottom. The thickness design of flexible pavements is a complex engineering problem involving a large number of variables. The main design variables that controls the design is the estimated traffic which is expressed in terms of equivalent single axle load (ESAL) and sub-grade strength measured in terms of California bearing ratio (CBR). In Oguara (2006) a minimum of 10 years' service life is generally aimed at for the bituminous surface pavements. For bituminous concrete pavements, it is desirable to achieve a service life of 20years this however with a periodic maintenance of the surface.

Wearing course or surface course: According to Garber et al (2009). The surface course is the upper course of the road pavement and is constructed immediately above the base course. The surface course in flexible pavements usually consists of a mixture of mineral aggregates and asphalt. It should be capable of with-standing high tired pressures, resisting abrasive forces due to traffic, providing a skid-resistant driving surface, and preventing the penetration of surface water into the underlying layers. Gichaga and Parker (1988), in their work also state that the most commonly used surfacing material in construction of a flexible pavement are bituminous materials which are normally applied in thin layers ranging from 25mm to 100mm. Such materials include asphaltic concrete, gap-graded asphalt, sand asphalt, emulsion slurry seal and surface dressing. It further gives the key tests that should be done on surfacing materials which include Los Angeles Abrasion tests, Aggregate Crushing Value, Flakiness Index, Sulphate Content, grading amongst other tests. Gransberg, (2005) states that depending on the temperature at which it is applied, asphalt is categorized as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt. Hot mix asphalt is applied at temperatures over 300 degrees F with a free floating screed. Warm mix asphalt is applied at temperatures of 200 to 250 degrees F, resulting in reduced energy usage and emissions of volatile organic compounds. Cold mix asphalt is often used on lower volume rural roads, where hot mix asphalt would cool too much on the long trip from the asphalt plant to the construction site.

Base course: The base course is constructed immediately above the subbase. It is placed immediately above the subgrade if a subbase course is not required. This course usually consists of granular materials such as crushed stone. According Garber et al. (2009). The specifications for base course materials usually include stricter requirements than those for subbase materials, particularly with respect to their plasticity, gradation, and strength. Materials that do not have the required properties cannot be used as base materials if they are properly stabilized with Portland cement, asphalt, or lime. In some cases, high-quality base course materials also may be treated with asphalt or Portland cement to improve the stiffness characteristics of for heavy-duty pavements. (Rogers 2003). State that road base is the main structural layer whose main function is to withstand the applied wheel stresses and strains incident on it and distribute them in such a manner that the materials beneath it does not become overloaded. Therefore, the thickness and type of material required for the construction of this layer depends upon the traffic load estimated, type of material to be used and the strength of the sub grade. Thus, road base materials must remain stable in water and be unaffected by frost and have a satisfactory CBR.

Sub-Base course: This course is located immediately above the subgrade; the subbase course component consists of material of a superior quality to that which is generally used for subgrade construction or in most cases consist of the same quality of material that has been mechanically stabilized to enhance its strength. Again Garber (2009). The requirements for subbase materials usually are given in terms of the gradation, plastic characteristics, and strength. When the quality of the sub-grade material meets the requirements of the subbase material, the subbase component may be omitted. Rogers (2003). The function of the subbase is to provide a platform on which to place the road base material as well as to insulate the subgrade below it against the effects of inclement weather. These layers may form the temporary road surface used during the construction phase of the highway. The available material can be treated with other materials to achieve the necessary properties. This process of treating soils to improve their engineering properties is known as stabilization.

Sub-grade: This is the natural occurring soil underlying the road corridor. it is to a large extent one of the most important factors to be consider in the formation of road pavement.

Table 1.2. Summary of Comparison between Rigid and Flexible pavements

Flexible Pavements	Rigid Pavements
1. Deformation in the sub grade is transferred to the upper layers	1. Deformation in the subgrade is not transferred to subsequent layers
2. Design is based on load distributing characteristics of the component layers	2. Design is based on flexural strength or slab action
3. Have low flexural strength	3. Have high flexural strength
4. Load is transferred by grain to grain contact	4. No such phenomenon of grain to grain load transfer exists
5. Have low completion cost but repairing cost is high	5. Have low repairing cost but completion cost is high
6. Have low life span (High Maintenance Cost)	6. Life span is more as compare to flexible (Low Maintenance Cost)
7. Surfacing cannot be laid directly on the sub grade but a sub base is needed	7. Surfacing can be directly laid on the sub grade
8. No thermal stresses are induced as the pavement have the ability to contract and expand freely	8. Thermal stresses are more vulnerable to be induced as the ability to contract and expand is very less in concrete
9. That is why expansion joints are not needed	9. That is why expansion joints are needed
10. Strength of the road is highly dependent on the strength of the sub grade	10. Strength of the road is less dependent on the strength of the sub grade
11. Rolling of the surfacing is needed	11. Rolling of the surfacing in not needed
12. Road can be used for traffic within 24 hours	12. Road cannot be used until 14 days of curing
13. Force of friction is less Deformation in the sub grade is not transferred to the upper layers.	13. Force of friction is high
14. Damaged by Oils and Certain Chemicals	14. No Damage by Oils and Greases

Sourced: Tiwari (2005).

Table 3.1 Design Traffic Class Designation

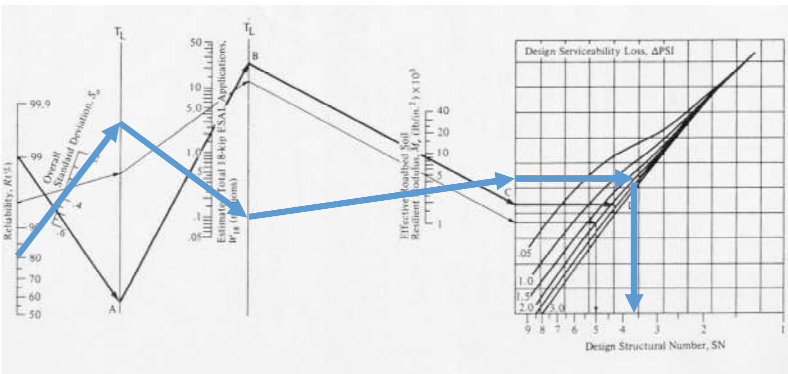
	Design Traffic Class Designation								
	T1	T2	T3	T4	T5	T6	T7	T8	T9
Traffic ranges (million ESAs)	< 0,3	0,3 –0,7	0,7 –1,5	1,5 - 3	3 - 6	6 - 10	10 - 17	17 - 30	30 –100

Source: Federal Ministry of Works Highway Manual part 1 Volume III (2013).

Table 3.2 Average Design Traffic Class Designation

	Design Traffic Class Designation (Average)								
	T1	T2	T3	T4	T5	T6	T7	T8	T9
Average Traffic Load in (million ESAs)	0.3	0.5	1.1	2.25	4.5	8.0	13.4	24.0	65.0

Source: Federal Ministry of Works Highway Manual part 1 Volume III (2013).



$W = 0.3 \times 10^6$
$R = 80\%$
$S_o = 0.4$
$CBR = 2\% \therefore M_r = 1500 \times 2 = 3000$ psi
$\Delta psi = 4.5 - 2.0 = 2.5$
$SN = 3.6$
Try 1
$a_1 = 0.33$, $a_2 = 0.14$, $a_3 = 0.11$, $m_2 = 1.0$, $m_3 = 0.8$
$3.6(25.4) = a_1D_1 + a_1D_2m_2 + a_3D_3m_3$
$91.44 = 0.33 \times 25 + 0.14 \times 100 \times 1.0 + 0.11 \times D_3 \times 0.8$
$91.44 = 8.25 + 12 + 0.088D_3$
$91.44 = 8.25 + 14 + 0.088D_3$
$91.44 = 22.25 + 0.088D_3$
$\frac{91.44}{22.334} = \frac{22.338D_3}{22.334}$
$D_3 = 4.09$mm
$91.44 - 22.25 = 0.088D_3$
$\frac{69.19}{0.0\ 88} = 786.25 \cong 786$mm say 800mm
$D_1 = 25$mm----- Wearing course
$D_2 = 100$mm----- Base course
$D_3 = 800$mm----- Subbase course

Figure 3.0 Design chart for flexible pavement.

Also, the subgrade is usually the natural material located along the horizontal alignment of the pavement and serves as the foundation of the pavement structure. It also may consist of a layer of selected borrow materials, Highway manual part 1 volume iii (2013). States that the subgrade is largely determine by the location the road, that is, by the geology of the area traversed by the road. The subgrade material of any road is usually classify according to the California bearing ratio (CBR) of the area i.e. either soaked or unsoaked but for purpose of design the soaked CBR values are usually used. According to Kbukwo (2013). The aim of the design process is to protect the bearing capacity of the in situ subgrade material in order that the road pavement will be able to fulfill its service objective over the design period. The bearing capacity and quality of the subgrade (or roadbed or fill) is of prime importance in the selection of pavement type and is improved by overlaying it with layers of material to achieve an integrated and structurally balanced system. As much as the possible the highway engineer make sure that the sub-grade is not be exposed to weather during construction and must be covered with sub-base as soon as possible. The sub-grade must be protected from surface water by providing an impermeable layer. Strength of the sub-grade depends on adequate drainage therefore drainage must be provided to keep the water table at least 1m below the formation level.

Classification of subgrade: The classification of the subgrade is one of the first steps toward effective pavement design. However, Highway manual part 1 volume iii (2013). The first step in the classification of the subgrade for the purposes of pavement design, involves the determination of uniform sections in terms of subgrade condition, based on geological and soil property assessments and other physical assessments such as the Dynamic Cone Penetrometer (DCP) test or in situ bearing tests. The classification of these sections in terms of the California Bearing Ratio (CBR), to represent realistic conditions for design. In practice, this means determining the CBR strength for the wettest moisture condition likely to occur during the design life, at the density expected to be achieved in the field. The classification of subgrade condition in this guide is similar to RN31 as shown in table 1.1.

Rigid pavement: This are highway pavements normally constructed of Portland cement concrete and may or may not have a base course between the subgrade and the concrete surface. They have been divided into three basic types:

- Jointed plain (JPCP),
- Jointed reinforced (JRCP) and
- Continuously reinforced (CRCP).

The difference between each type is the jointing system used to control crack development. In the case of flexible pavement only about 5% of Nigeria roads are paved with rigid pavement though this pavement appears to be more durable. Rigid pavements have some flexural strength that permits them to sustain a beamlike action across minor irregularities in the underlying material. Thus, the minor irregularities may not be reflected in the concrete pavement. Properly designed and constructed rigid pavements have long service lives and usually are less expensive to maintain than flexible pavements. The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. Oguara (2006) states that rigid pavements possess considerable flexural strength that permits them to bridge over localized subgrade failure and the area of inadequate support. Unlike flexible pavement, depression occurring beneath well designed rigid pavement has little or no influence on the structural capacity of the pavement. Thus, the major factor considered in the design of rigid pavement is the structural strength of the concrete. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil. (Hamza 2015). Assert that rigid pavements are generally used in constructing airport and major highways, such as those in the interstate highway system. In addition, they commonly served as heavy-duty industrial floor slabs, port and harbor yard pavements, and heavy-vehicle Park or terminal pavements. Like flexible pavements, highway pavements are designed as all-weather, long lasting structures to serve modern day high-speed traffic. Offering high quality riding surfaces for safe vehicular travel, they function as structural layers to distribute vehicular wheel loads in such a manner that the induced stresses transmitted to the subgrade soil are of acceptable magnitudes. Because of the high exothermic reaction that takes place during the setting and hardening of concrete, rigid pavement is usually constructed with joints in order to allow for expansion and contraction movement of the pavement without warping of the pavement.

Houben (2005) states that the concrete slab is the main load carrying element. Because concrete slab has high elastic modulus, small depressions in the subgrade are easily bridged over, but if the depressions in the subgrade are large, the slab may crack. The loading due to traffic is considered in terms of magnitude and more significantly in terms of repetitions. Thus, in design, we consider loading in terms of repeated equivalent standard axles during the design life of the pavement. Guyer (2009) highlights that the design procedure for reinforced concrete pavements uses the principle of allowing a reduction in the required thickness of plain concrete pavement due to the presence of the steel reinforcement. The design procedure has been developed empirically from a limited number of prototype test pavements subjected to accelerated traffic testing. Although some cracking will occur in the pavement under the design traffic loadings, the steel reinforcing will hold the cracks tightly closed. The reinforcing will prevent spalling or faulting at the cracks and provide a serviceable pavement during the anticipated design life. Essentially, the design method consists of determining the percentage of steel required, the thickness of the reinforced concrete pavement, and the minimum allowable length of the slabs.

Tiwari (2005) summarizes comparison between concrete and flexible pavement as shown below:

Ogura (2006). State that design and construction of pavements have been primarily based on empiricism or experience with theory only playing a subordinate role. The empirical pavement design methods include but not limited to

- California Bearing Ratio method (CBR).
- American Association of State Highway and Transportation Officials method (AASHTO).
- Portland Cement Association method (PCA).
- Asphalt Institute Design Method (AID).
- Road note 31 design Method.
- Road note 29 design Guide.
- Shell pavement design method.
- Hveem stabilometer design method.
- Group index method.
- Mechanistic method.

Table 3.2. Recommended load transfer coefficients for various pavement Types and design condition

Shoulder load transfer devices	Asphalt		Tied PCC	
	YES	NO	YES	NO
Pavement type	3.2	3.8-4.4	3.5-3.1	3.6-4.1
1.Plain join and jointed reinforce				
2.Contentiously reinforced concrete Pavement (CRCP)	2.9-3.2	N/A	2.3-2.9	N/A

Table 3.3. Recommended values of drainage coefficient (Cd) for rigid Pavement

Quality of drainage	Percent time pavement structure is expose to moisture Levels approaching saturation			
	Less than 1%	1-5%	5-25%	Greater than 25%
Excellent	1.25-1.20	1.20-1.15	1.15-1.10	1.10
Good	1.20-1.15	1.15-1.10	1.10-1.00	1.00
Fair	1.15-1.10	1.10-1.00	1.00-0.90	0.90
Poor	1.10-1.00	1.00-0.90	0.90-0.80	0.80
Very poor	1.00-0.90	0.90-0.80	0.80-0.70	0.70

Table 3.4. Suggested levels of reliability for various functional Classifications

Functional classification	Recommended urban	Level of Reliability rural
Interstate, freeways or expressways	85-99.99	80-99.9
Principal arterials	80-99	75-95
Collectors	80-95	75-95
Local	50-80	50-80

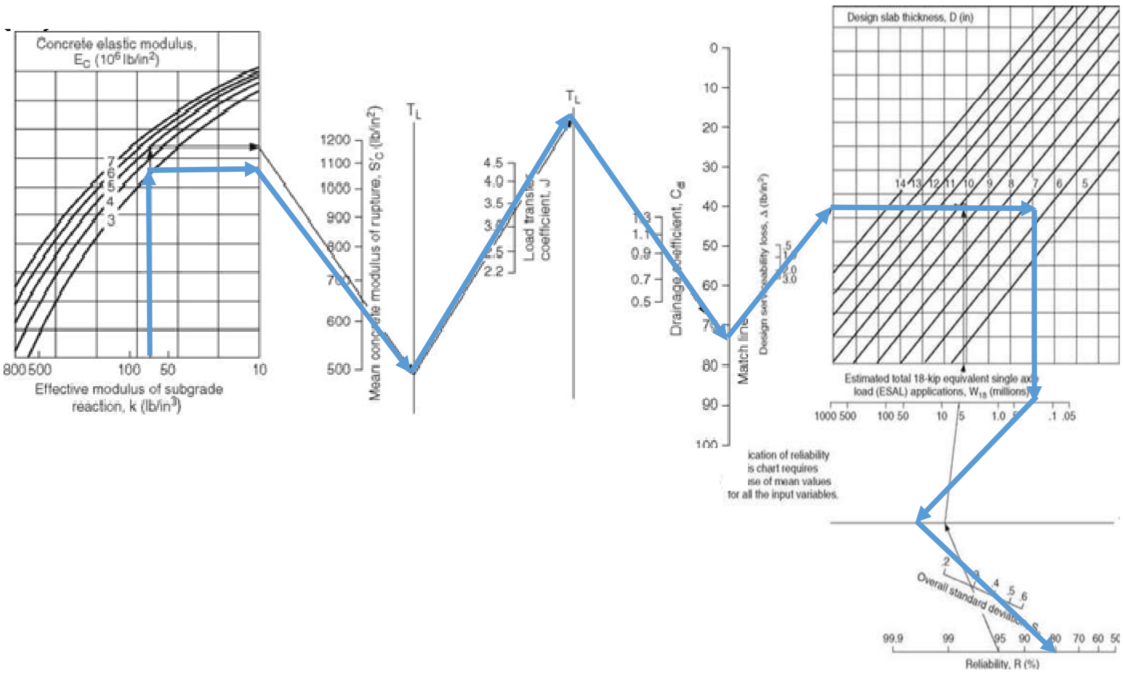


Figure 3.1. Design chart for Rigid pavement

- Modulus of Subgrade Reaction, K_{eff} = 70 psi
- Traffic, W_{18} = 0.3×10^6
- Design Reliability, R = 80%
- Overall Standard Deviation, S_0 = 0.40
- ΔPSI = 2.5
- Elastic Modulus, E_c = 3,000,000 psi
- Modulus of Rupture, S_c = 650 psi
- Load Transfer Coefficient, J = 3.3
- Drainage Coefficient, C_d = 1.0
- Pavement thickness D. = 6.8 inch or 173mm

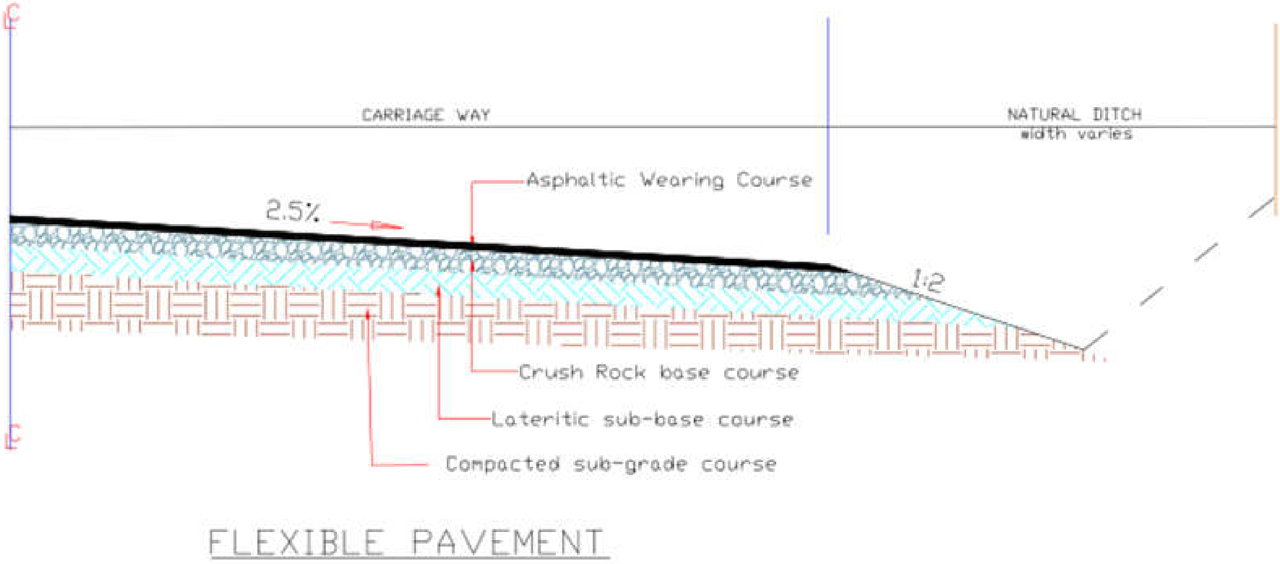


Figure 3.2. Flexible Pavement Section

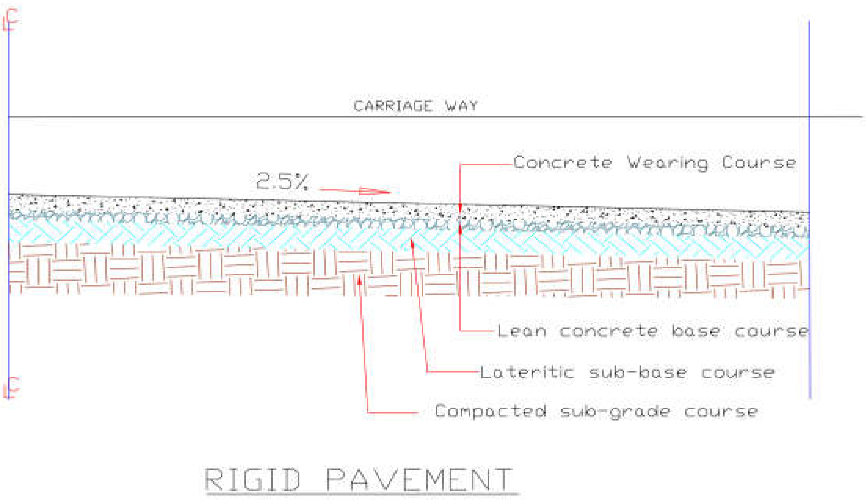


Fig 3.3. Rigid Pavement Section

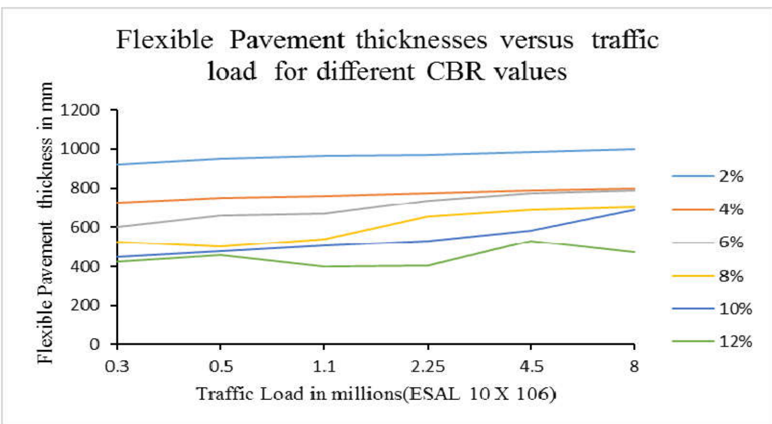


Figure 4.0. Flexible pavement thickness versus traffic load for different CBR.

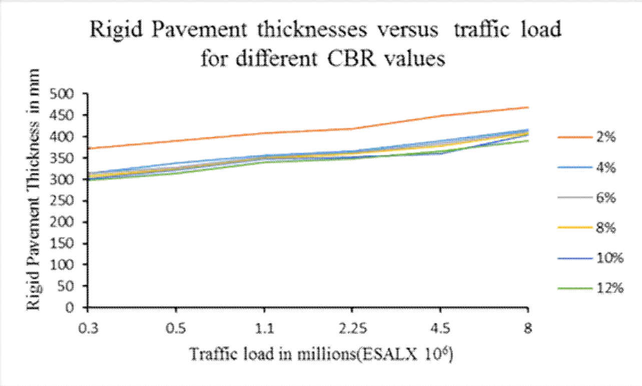


Fig 4.1 Rigid pavement thickness versus traffic load for different CBR

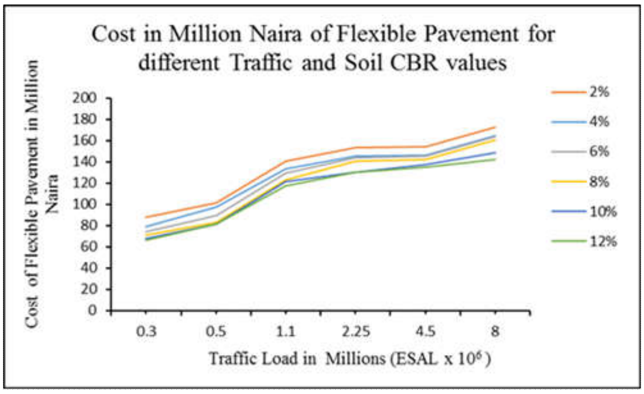


Figure 4.2 Cost of Flexible pavement versus traffic load for different CBRs.

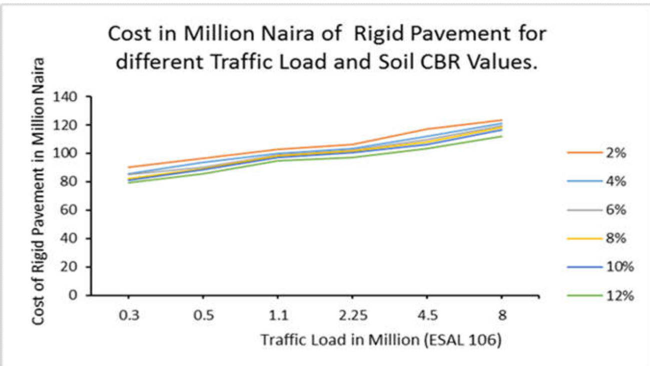


Figure 4.3 Cost of Rigid pavement versus traffic load for different CBRs.

All the methods stated above have been used at one point by highway engineers in the design of either rigid or flexible pavement. However, in this work AASHTO Design guide was used to design both the flexible and rigid pavement

MATERIALS AND METHODS

Two key data that were used to determine the thickness of the various pavements for this research work, which are common to both Flexible and Rigid pavements are:

- Traffic data.
- Soil Strength (Bearing Capacity of Sub-grade).

Other factors used for the flexible pavement design in accordance with AASHTO design guideline includes:

- Design Reliability Factor R (%).
- Pavement performance (serviceability performance PSI).
- Layer coefficient for surface (a_1), base (a_2), subbase(a_3).
- Drainage coefficient for untreated and subbase data
- Standard Deviation (S_0) for each pavement types according AASHTO.

Factors such as Reliability(R), Standard Deviation(S_0), Estimated future traffic (W_{80}) and design Serviceability loss (ΔPSI) are common to both flexible and rigid pavement design. However, factors unique to rigid pavement includes:

- Subgrade Strength in terms of Modulus of Subgrade Reaction K (Ib/in^3)
- Concrete properties such as

Concrete elastic modulus, $E_{c.}$ (10^6 Ib/in^2).
Mean Concrete modulus of rapture, $S_{C.}$ (Ib/in^2).

- Load Transfer coefficient, J.
- Drainage Coefficient, Cd.

Source of Data

Date used for this work was from the following sources:

- Federal Ministry of works
- Cross River State Ministry of works.
- Consultants.

However, for the purpose this research works the average of each of the traffic class was found and used for design as shown in Table 3.2 From the Federal Ministry of Works Highway Manual Part 1: Design Volume III. in Nigeria, the standard axle load is 80kN. (Legally permissible axle load is 8.2 tonnes). The cumulative damaging effect of all individual axle loads is expressed as the number of equivalent 80kN single axle loads (ESAs or E80s). The ESAs thus represent the number of standard loads that would cause the same damage to the pavement, as the actual traffic spectrum of all the axle loads. A total of seventy-two (72) pavements thirty-six (36) of each, flexible and rigid pavement were design their thickness computer for cost analysis

Flexible pavement design: A total of thirty-six (36) flexible pavement were design for this work using soil bearing capacity CBR % as stated in table 4. Above and traffic loads as tabulated in table 3.1. A typical design for case 1 where the traffic load $W_{80} = 0.3 \times 10^6$ soil bearing capacity. CBR = 2%, M_R = 3000 psi, and other design parameters mention are use in the flexible pavement to determine the structural number of the pavement as shown in Figure 3.1

A similar analysis was carried for other percentages of soil bearing capacity and traffic load totaling 36 number.

Rigid pavement design: Apart from the two key parameter i.e. Soil CBR and Traffic load used other pavement structure characteristics use in the design were picked from the tables as indicate below. Table 3.2 Recommended load transfer coefficients for various pavement.

A typical rigid pavement was design as shown using the following input parameter

- Modulus of Subgrade Reaction, K_{eff} = 70 psi
- Traffic, W_{18} = 0.3×10^6
- Design Reliability, R = 80%
- Overall Standard Deviation, S_0 = 0.40
- ΔPSI = 2.5
- Elastic Modulus, E_c = 3,000,000 psi
- Modulus of Rupture, S_c = 650 psi
- Load Transfer Coefficient, J = 3.3
- Drainage Coefficient, C_d = 1.0

Comparative Cost Computation Analyses: The cost for both pavements where computed from the various thicknesses obtained from design using a 1km length and 7.3m width of road, typical sections of both pavements as presented in Figures 3.2 and 3.3. The costs of the pavements are obtained by multiplying the volume the various materials by their unit rate. The rates used were obtained from comparing rates used for award of contracts by Federal Ministry of Works (FMOW) and Niger Delta Development Commission (NDDC).

RESULTS AND DISCUSSION

Flexible Pavement Design Thickness

The results of the Flexible pavement design are presented in the Figure. 4.0 The result revealed an outright variation in thicknesses at 2% soil capacity with respect to the different traffic loadings however for soils with CBR 4-12%, though the variation thus still exists but was not as distinctive as it were in 2%. While the results for the Rigid Pavement revealed that the variation in thicknesses with respect to the traffic load and soil CBR of the pavements were more pronounce at 2% soil CBR while that of 4%-12% were not very pronounce as shown in Figure 4.1The variation in the cost elements are from 66.384 to 172.755 Million Naira for a kilometer length of road depending on the traffic load and soil CBR, the cost however is inclusive of 20% Annual Maintenance Cost (AMC) which was uniformly added to all the 36 no. pavement designed.

Conclusion

From the results and analysis, the following conclusions can be drawn:

- The flexible pavement shows wider range of variation with respect to design parameters of soil CBR and Traffic load as compare to rigid pavement.
- The study found out the cost of constructing and maintaining of rigid pavement on the long run is cheaper than that of flexible pavement.
- The Pavement cost increases with an increase in Traffic Load and decreases with an increase in soil CBR conditions. Hence, Rigid should be chosen with high Traffic Loads or even low Traffic Loads with high soil CBR.

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