CARD International Journal of Science and Advanced Innovative Research (IJSAIR)
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 2, Number 4, December 2017
http://www.casirmediapublishing.com

Rigid Pavements: An Alternative Durability against Flexible Pavements for Nigerian Roads

Gana A. J., Osuolale O. M. & Okigbo S. N.

Department of Civil Engineering, Landmark University, Omu-Aran, Kwara state
Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso
Department of Civil Engineering, Federal polytechnic Bida, PMB 55, Bida, Niger State
Email: Phildebo123@gmail.com, Omosuolale@lautech.edu.ng
Corresponding Author: Gana A. J.

ABSTRACT

The performance of many flexible pavements also called Asphaltic Bituminous roads are not satisfactory, bearing in mind that the major highways in Nigeria were designed for a life span of between 10-15years. Based on estimated traffic volumes not exceeding 10tones exile loads, and the minor truck roads designed for a life span of 5-10 years. It has been observed that majority of the Nigerian roads failed before their designed life is attained, as a result of mis-use by over loading of vehicles. This paper examines historical background on rigid pavements, types of pavement, differences between rigid pavements and flexible pavements, Nigerian present Asphaltic pavement roads, recommendation and conclusion.

Keywords: Rigid pavements, flexible pavements

INTRODUCTION

What is a pavement?

A pavement is a multilayered structure which usually supports the vehicle load on its surface and transfers the load to sub- grade soil. The ultimate aim of any pavement structure is to ensure that the transmitted stresses are sufficiently reduced such that they will not exceed the supporting capacity of the sub- grade soil, the basic idea of building a pavement for all weather use by vehicles is to provide a suitable sub-grade, provide necessary drainage and to construct pavement that will provide the following:-

(i) To have the sufficient total thickness and internal strength to carry expected traffic loads
(ii) To have the adequate properties to prevent or minimize the penetration or internal accumulation of moisture.
(iii) To have a surface that is reasonably smooth and skid resistant at the same time as well as reasonably smooth and skid resistant to wear,

distortion and deterioration by any existing weather.

Historical Background understanding on Rigid Pavements

When someone visit the courthouse in Bellefontaine, Ohio (USA) he can see a concrete pavement still in place and partly in use after almost 110 years of service, which history noted that it is the first successful and long lasting rigid pavement constructed by two visionary men called:- George Bartholomew and James C. wonders. The concrete pavement built was with an attempt to solve the dust and mud problems in their town by a new material called artificial stone (at that time) or concrete. It was however recorded that a little earlier in 1879 in Scotland, a concrete was used with Portland cement for binding, though it had deteriorated rapidly and was not considered as a pioneer.

As innovative as their idea was, it was humorous and skeptical the way the then city council handled the case by asking them to donate the cement for the construction of the city which was later built. The report further went on that few thousand miles of highways were later paved with concrete before rigid pavements were first used at Airports

The Global Pictures

(i) In USA, often cited as the benchmark for Rigid pavements, the Dwight D. Eisenhower Federal-Aid Highway Act of 1956 created a 66, 000km interstate highway system, out of which sixty-percent of the system was paved with concrete (ACPA 2006). To date, there is about 260, 000km long

(ii) In the province of Quebec, Canada, concrete pavements makes up 1,239 two-lame km of the 29, 000km road network, only about 4. Percent carried about 75 percent of Quebec's traffic.

(iii) In Germany 26.7% of the motor ways are rigid pavements and accommodates about 49,000 vehicles per day.

(iv) In china, rigid pavements are currently finding a wider application with a total completed mileage of about 70,000 km long at present.

(v) Rigid pavements are common in highways of many developing countries

General Requirements of Pavements

i. Pavements should possess sufficient thickness spread the surface loading to a pressure intensify which the sub-grade is capable of withstanding
ii. Pavements should be sufficiently strong enough to carry the stress imposed upon them
iii. They should have sufficient thickness to prevent damages to frost susceptible sub-grade
iv. The surface of pavements should be impervious to the penetration of surface water, which would weaken both the pavement and the sub-grade.
v. Pavements surfacing should have a skid resistant texture.

Characteristics of Pavements

i. They should be structurally sound enough to withstand the stresses imposed on them
ii. They should be sufficiently thick to distribute the loads and stresses to a safe value on the sub-grade soil
iii. They should provide a reasonably hard wearing surface, so that the abrading action of the vehicle wheels does not damage the surface
iv. They should be dust- proof so that traffic safety is not impaired
v. The riding quality should be good they should be smooth enough to provide comfort to the road users at the high speeds at which the modern vehicles are driven
vi. The surface of the pavements should develop as low a friction with the tyres as possible. This actually enable the energy consumption of the vehicles to be low
vii. The surface of the pavements should have a texture and adequate roughness to prevent skidding of vehicles
viii. The surface of the pavements should not produce excessive levels of sound from moving vehicles.
ix. The surface of pavements should be impervious so that water does not get into the lower layers of the pavements and the sub-grades and cause deterioration.
x. The pavements should have long life and the cost of

maintaining it annually should be low.

Choice of Road Pavements

The choice of road pavements depends on the availability and the cost of the materials required, and on the operational requirement for the road construction.

Factors for Pavements Design

Pavements design is generally governed by a number of design factors. Some of them are illustrated below:

Design life: The design life or performance period refers to the period of time for which the initially designed pavement structure will last before any rehabilitation is needed. It is also described as the time elapsed as a new, reconstructed or rehabilitated pavement structure deteriorates from its initial level of service. The analysis period is the number of years that any design strategy for any pavement must cover the table below illustrates this.

Table 1

Highway conditions	Analysis period in years
High volume-urban	30 to 50
High volume-rural	20 to 50
low volume-paved	15 to 25
low volume aggregate surface	10 to 20

Source: AASHTO

Reliability: The term reliability refers to the probability that any particular type of distress or combination of distress manifestations will remain below or within the permissible level during the design life. The performance prediction error developed for different pavements are as follows:-

i. Rigid pavement=0.25
ii. Flexible pavement=0.35
iii. **Traffic factors**: The following are considered during the design period
    a. Wheel load
    b. Impact
    c. Repetition of wheel loads
    d. Position of wheel load across pavement
    e. Iron tyred vehicles
iv. **Climate factors**: The factors for consideration are:
    a. Rainfall
    b. Frost
    c. Temperature.
v. **Road geometry**
    a. Horizontal curves.
    b. Vertical profile.

vi. **Sub grade strength and drainage**
   a) Sub grade strength
   b) Drainage.

Types of Pavement

Pavements are generally divided into two types

(1) Rigid pavements: These pavements are structures constructed of cement concrete slabs, which derive their capacity to with stand vehicle loads from flexural strength or beam strength due to high modulus of electricity. Due to high flexural strength the vehicle loads on cement concrete slab is distributed over a relatively wider area of the soil than flexible pavements.

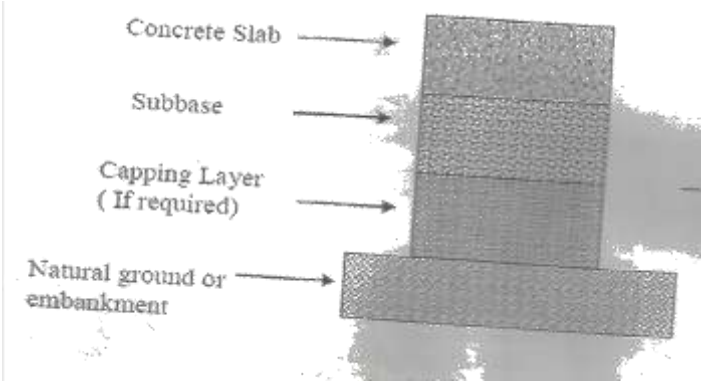

Figure (1)

Source: Girima Birhanu (2005) High way Engineering (ii)

Types of Rigid Pavements

Depending on the level of the reinforcement, the rigid pavements are sub-divided into:

(i) **Jointed unreinforced Concrete Pavement (JUCP):** This type of pavement consists in an unreinforced concrete slab cast in place continuously, and is divided into bays of predetermined dimension by the construction of joints. The bays dimensions are made sufficiently short as to ensure that they do not crack. The bays are linked together by tie bars, with the main function to prevent horizontal movement.

(ii) Jointed Reinforced Concrete Pavement (JRCP): this pavement consists generally in a cast in place concrete slab divided in reinforced concrete bays separated by

joints. The reinforcement is made to prevent developing cracks from opening.

(iii) **Continuously Reinforced Concrete Pavement (CRCP):** These types of pavement are made up of a cast in place reinforced concrete slab without joint. The expansion and contraction movement are prevented by a high level of sub-base restraint. The frequent transverse cracks are usually held tightly close by a parge amount of continuous high tensile steel longitudinal reinforcement.

(iv) **Prestressed Concrete Pavements (PCP):** These are pavement that are usually constructed with the application of prestressed reinforcement into the pavements. Prestressed concrete pavements as been used more frequently for airport pavements than for highway pavement, because the saving in thickeness for airport pavements is much greater than that for highway pavements.

(v) **Composite Pavements:** Composite pavements are composed of cement concrete as a bottom layer and with hot-mix asphalt. An ideal slab usually provides a strong base and the hot-mix asphalt provides surface. Composite pavements include rehabilitated concrete pavement using asphalt overlays, and asphalt pavement with stabilized bases.

Factors affecting Design of Rigid Pavements

The structural design of any rigid pavement is governed by many factors. Of some these factors are listed below:

(A) Loadings
- (i) wheel load and its repetitions
- (ii) Area of contact of wheel
- (iii) Location of load with respect to slab

(B) Properties of sub-grade
- (i) Sub-grade strength and properties
- (ii) Sub-base provision or omission

(C) Properties of concrete
- (i) Strength
- (ii) Modulus of elasticity
- (iii) Poisson's ratio
- (iv) Shrinkage properties
- (v) Fatigue behavior

(D) External conditions
- (i) Temperature changes
- (ii) Friction between slab and sub-grade

(E) Joints

(i) Arrangement of joins

(F) Reinforcement

(i) Quantity of reinforcement

(ii) Continuous reinforcement

Flexible pavements: Flexible pavements are usually constructed with asphaltic cement and aggregates, and usually consist of several layers. The lower layer of the subgrade is usually scarified and blended to provide a uniform material before it is compacted to a maximum density. The next layer is the sub-base, which usually consist of crushed aggregates (rocks). The next layer is the base layer and is also often made of aggregates. The top layer of a flexible pavement is the wearing surface. It is usually made of asphaltic concrete, which is a mixture of asphaltic cement and aggregates. The purpose of the wearing layer is to protect the base layer from wheel abrasion and to water proof the entire pavement structure.

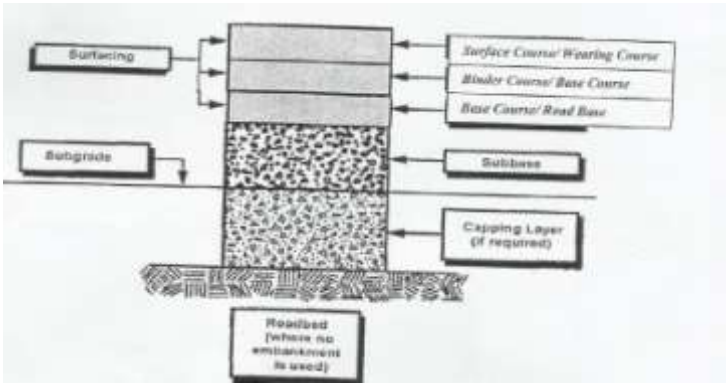

Figure (ii): Flexible pavement
Source: Abraham Enagaw (2006) Highway Engineering (ii)

CONSTRUCTION TYPES OF FLEXIBLE PAVEMENTS

Generally, there are two types of construction of flexible pavement Methods

(i) **Conventional Flexible Pavements**: Constructional flexible pavements are multilayered structures with better materials on top, where the intensity of stress is high and inferior materials at the bottom where the intensity is low. The design principle melees it possible to use local materials and usually result in a most economical design.

(ii) **Full dept asphalt pavement**: Full dept asphalt pavements are constructed by placing one or improved sub-grade.

MATERIALS USED FOR FLEXIBLE PAVEMENT

Flexible pavement construction uses a relatively Thin-Layer of Tar or bituminous bond surfacing material with a thicker base of crushed stone or lean concrete, beneath of which there is often a sub-grade of granular material or stabilized soil. The other materials are:-

(i) Hot-rolled asphalt, which is made by mixing binder of low penetration with a graded aggregates, consisting of crushed rocks.
(ii) Dense tar surfacing:- this is a hot process material consisting of a mixture of course and fine aggregates, filler, and high viscosity tar.
(iii) Tar-macadam and bitumen macadam.
(iv) Fire cold asphalt.
(v) Mastic asphalt.
(vi) Compressed natural rock asphalt

Sub-base Materials

Crushed rocks, crushed concrete, crushed slag or well burnt non plastic shale. These materials will remain stable over a much wide range of moisture contents. All sub-base materials are always place and spread evenly in layers hot exceeding 9 inches compacted thickness, and also compacted by smooth, wheeled or pneumatic tyred rollers or by vibrating compacting plant.

Base Materials

Generally, any materials which has a California bearing ratio (C.B.R) value of not less than 80% compacted can be used for road pavement construction, provided that it remain stable in water and is unaffected by frost. The suitable materials for main pavement base construction material includes crushed stone or blast furnace slag, dry lean concrete, cement bound granular material, and also bituminous bound material

Others are:

(i) Dry- bound macadam
(ii) Pre- mixed water bound macadam
(iii) Dry lean concrete
(iv) Cement bound granular base material.

DIFFERENCES BETWEEN RIGID PAVEMENTS AND FLEXIBLE PAVEMENTS

1) The manner in which they support vehicle loads and transmit to the sub-grade

differs. in case of rigid pavements a relatively thin pavement slab distributes the load over a wide are due to its high rigidity. Localized low strength sub-grade materials can be overcome due to this wider distribution area.

2) Rigid pavements must be designed and constructed precisely and good quality of concrete must be used, otherwise, they tend to be more troublesome and reconstruction or repair is more difficult.
3) It is feasible to design rigid pavements for longer design lives up to 60 years
4) Flexible pavements require more frequent maintenance, in every4 years, while rigid pavements require little
5) The initial investment of rigid pavement is often more costly.
6) Flexible pavements are convenient for stage constructions.
7) Rigid pavements are more impervious than flexible pavements
8) The rigid pavements take relatively short time for construction since the curing time of concrete might take up to 28 days, therefore the duration of traffic dislocation at the time of construction will be less
9) Unlike with flexible pavements rigid pavements do not suffer deterioration from weathering; neither their strength nor their stiffness is materially affected by temperature changes.
10) The main weakness of rigid pavements is glair, not comfortable, slippery, and noisy which are mainly due to the development of friction between the wheel and the surface of the pavement, while it is better in that no significant deformations of the pavement occurs due to traffic load, and is very resistant to abrasion. Flexible pavements, as compared to the rigid ones, have better surface characteristics or quality, i.e not noisy, slippery, and comfortable, because they undergo plastic deformations through the occurrence of bleeding or corrugation due to low compaction.
11) Design precision:- cement concrete pavement is amenable to a much precise structural analysis that a flexible pavement. This is because of the fact that the flexural strength of concrete which is used as the main

basis for design is well understood. On the other hand, flexible pavement designs are mainly empirical

12) Life span :- cement concrete slabs of a thin section (i.e about 10cm)last longer in life than that of flexible pavements generally varies from 10 to 20 years, even with this shorter life , it can only be achieved only with extra maintenance input .rigid pavements can last up to 40 years or even more.
13) Maintenance:- A well designed cement concrete pavement needs very little maintenance . The only maintenance needed is in respect of joints continuously, reinforced concrete pavements (CRCP) have reduced the number of joints to be attended to. The hard surface can withstand the abrasion caused by iron – tyred vehicles. Flexible pavements need a lot of maintenance input.
14) Initial cost: The argument raised so far against a cement concrete slab is that it is much more costly than a flexible pavement the argument that a cement concrete specification is costlier than a flexible pavement should also no longer be valid. While the cost of cement has increased very much in recent times, the cost of bitumen has also increased.
15) Stage construction: - Road construction is generally done by adopting a policy of stage construction especially for low volume roads. For example, a new road can be constructed with the barest minimum specifications, which may involve a little thin bituminous surfacing with a partially designed thickens. As traffic grows, additional layers in the form of water bound macadam bitumen – bound bases and superior surfacing are added this is a great advantage when dealing with new roads in an atmosphere of austerity and economic crisis. Cement concrete slabs do not fit into such a scheme of stage construction.
16) Availability of materials: Cement bitumen, stone aggregates gravels, and sand are the major materials involved in pavement construction. Cement has been in serious short supply several times bitumen also is a source material. In locations where stone aggregates are scarce , cement concrete may have no advantage, since the

total construction thickness may be less than that for a flexible pavement.

17) Surface characteristics: Usually, a good cement concrete surface is smooth and free from potholes and corrugations. Therefore, the riding quality of a cement concrete surface is always assured with a bituminous surface, it is only the asphaltic concrete surface that can give comparable readability.
18) Penetration of water: A cement concrete slab is practically impervious, except and well maintained, water will not penetrate and soften the subgrade. A bituminous surface of flexible pavement is not impervious. Water can find its way into the lower layers through cracks and pores. Such water can damage the stability of the pavement.
19) Traffic dislocation during construction: A cement concrete pavement requires 28days before it can be thrown open to traffic on the other hand; a bituminous surface can be thrown open to traffic immediately after it is rolled.
20) Environmental considerations during construction: During the construction of flexible pavements, where bituminous layers are to be provided, the process of heating of bitumen and aggregates and mixing them together in hot-mix plants can prove to be much more difficult and hazardous to the environment than cement concrete construction where no heating of any material is involved. The use of bituminous cut backs can also prove to be environmentally dangerous due to the evaporation of volatile constituents into the atmosphere.

Nigerian Present Asphaltic Pavement Roads

The country's asphaltic pavement roads have failed to reach the expected life span they were designed to be, because they have been generally over – stressed by over loaded axle loads. The typical examples are Lagos – Ibadan express way built in 1978, and the Benin – ore road commissioned in 1980. Many sections of the country's roads are in a very bad state due to excessive loadings.

RECOMMENDATION

The construction of rigid (concrete) Pavements for Nigeria

Roads, especially Inter – State is huge capital intensive. The project is federal government Business, and it can be executed if proper planning is carry out in terms of Budget allocation

Other organizations such as the World Bank, whose main purpose is to promote Economic and social progress in developing and social progress in developing Nations can be contacted. The world bank consists of the following:

(i) International Bank for reconstruction and development (I.B.R.D)
(ii) International development Association (I.D.A)

The international Road federation (I.R.F), which was founded in 1948 to encourage better Road and Transportation systems worldwide – It is a none – profit, non- political service organization that helps to update Technology and management practices and to produce the maximum economic and social return from National Road Investments. The I.R.F is also working hard to identify new sources of financial supports for roads construction and maintenance projects world – wide.

CONCLUSION

A good pavement road is costly to construction especially with financial implications, but once construction, such a road requires in savings for human's lives and vehicles operation costs. Keeping these considerations in mind, various investigations carried out on the comparative Economy of a flexible pavement and a rigid pavement on overall economic considerations, a rigid pavement is far more Economical them flexible pavements for Nigerian Roads.

REFERENCES

Fredo L. Mannering, walther. P. kilareski, scott. Washburn (2007) third Edition. Principles of Highway Engineering and Traffic Analysis, published by John wiley and sons, New Delhi, India

L.R. kadyali, N.B.Lal (2008) fifth Edition, principles and practices of Highway Engineering khanna publishers, Nath market, Nai sarak, Delhi, India

EACE (2004) Bulletin, vol 7, No 4, Ethiopian Association of civil Engineers Addis Ababa

Girima Birhanu (2005) High way Engineering (ii), Jimma university, Technology

faculty Department of civil Engineering

Abraham Enagaw (2006) Highway Engineering (ii) jimma university, Technology Faculty, Department of civil Engineering

B.L. Gupta, Amit Gupta (2010) Highway and Bridge Engineering, Published by A.K. Jain standard publishers Distributors Nai scerak, Delhi, India

K.S. Rakshit (2008) Construction maintenance Restoration and rehabilitation of Highway bridges, published by new central book agency Ansari road, New Delhi India.

ASHTO Guide for Design of pavement structures (1993)

Principles of pavement Design, Second Edition, by E.J. yoke and M.W Witczak.

Guild lines for the Design of plain jointed Rigid pavements for Highways, second Revision, Indian Road congress manual No.58. (2002).

Concrete pavement Design, construction and performance by Norberr Delate (2008)

Pavement Analysis and Design, second Edition by yang H.huang.