IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3 Ver. VII (May- Jun. 2016), PP 84-88
www.iosrjournals.org

A Comparative Study on Rigid and Flexible Pavement: A Review

Milind V. Mohod [1*], Dr. K.N.Kadam [2]
[1] **Assistatnt Professor, Department Of Civil Engineering, PRMIT&R,Badnera.*
[2] *Assistatnt Professor, Applied Mechanics Department, GCOE,Amravati.*

Abstract: *The last century has seen an intensive process of urbanization in rural as well as metro cities. This has led for a need of rapid construction of roads and transportation infrastructure. The demand for better roads and services required researchers, designers and builders to explore innovative and cost effective engineered products to satisfy increasing demand that would economize the construction as well as increase durability. Pavements are essential features of the urban communication system and provide an efficient means of transportation. Flexible pavements are preferred over cement concrete roads because of their certain advantages like they can be strengthened and improved in stages with the growth of traffic. The flexible pavements are less expensive in regards to initial cost and maintenance. The concrete pavements are now a day's becoming more popular in India because of steep rise in the cost of bituminous pavement. The largest advantage of using rigid pavement is its durability and ability to hold a shape against traffic and difficult environmental conditions. Although concrete pavement is less expensive but has less maintenance and good design life. The main objective of this study is to present a comparative review on suitability of pavement depending on various parameters such as material, loading, longer life, cost effectiveness etc.*
Keywords: *Flexible pavement, rigid pavement, life cost analysis, durability*

I. Introduction

Transportation has been one of the essential components of the civil engineering profession since its early days. From time immemorial, the building of roads, bridges, pipelines, tunnels, canals, railroads, ports, and harbors has shaped the profession and defined much of its public image. As cities grew, civil engineers became involved in developing, building, and operating transit facilities, including street railways and elevated and underground systems [1]. The role of civil engineers is to providing transportation infrastructure to accommodate a growing population. The transportation by road is the only road which could give maximum service to one all. This mode has also the maximum flexibility for travel with reference to route, direction, time and sped of travel. It is possible to provide door to door service only by road transport [2].

Pavement is the actual travel surface especially made durable and serviceable to withstand the traffic load commuting upon it. Pavement grants friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil. In earlier times before the vehicular traffic became most regular, cobblestone paths were much familiar for animal carts and on foot traffic load. Pavements are primarily to be used by vehicles and pedestrians. Storm water drainage and environmental conditions are a major concern in the designing of a pavement. The first of the constructed roads date back to 4000 BC and consisted of stone paved streets or timber roads. A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade [3]. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub grade. The roads of the earlier times depended solely on stone, gravel and sand for construction and water was used as a binding agent to level and give a finished look to the surface. All hard road pavements usually fall into two broad categories namely

1. Flexible Pavement
2. Rigid Pavement

Flexible Pavement

Flexible pavements are most commonly used for low to medium volume roads with significant usage also found in high volume interstate highways and airfield runways, taxiways and aprons subjected to heavy aircraft gear/wheel loads. As the demand for applied wheel loads and number of load applications increases, it becomes very important to properly characterize the behavior of subgrade soils and unbound aggregate layers as the foundations of the layered pavement structure [4]. Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure. The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic of flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system [3]. Flexible pavements suffer generally from rutting which results from heavy traffic and severe environmental condition [5]. Flexible pavements are those having negligible flexural strength and are flexible in structural actions under the loads. [14]

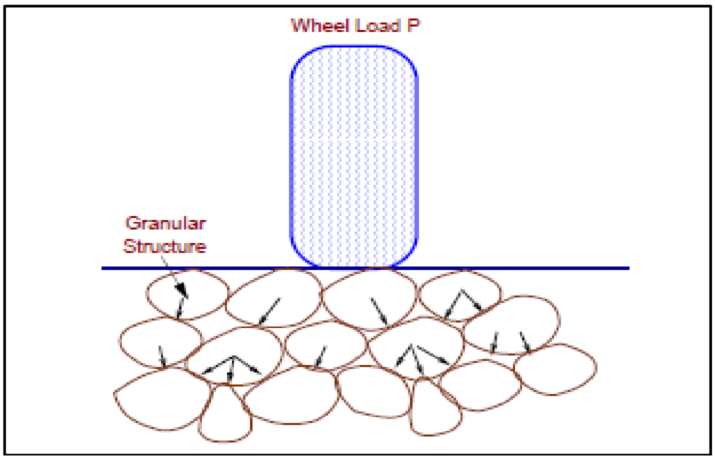

Figure 1: Load Distribution of Flexible Pavement

Categories of Flexible Pavement

There are mainly three categories of flexible pavement are as follows:

1. Conventional layered flexible pavement
2. Full - depth asphalt pavement
3. Contained rock asphalt mat (CRAM)

1. Conventional layered flexible pavement

Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

2. Full - depth asphalt pavement

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub grade. This is more suitable when there is high traffic and local materials are not available.

3. Contained rock asphalt mat (CRAM)

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water

Failures of Flexible Pavement

The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue test on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path.Rutting in flexible pavements is a major distress mode, relatively difficult to simulate in computational analyses, mainly for the following reasons.

1. The constitutive relations of the materials are nonlinear and complex. Most pavement materials are very difficult to characterize under repeated and moving loads.
2. The asphalt concrete material is viscoelastic and viscoplastic, i.e., strongly loading time and temperature dependent. The other unbound materials base, subbase, and subgrade are only slightly time dependent.
3. The temperature and moisture of the materials vary with every load repetition. Yet we need to be able to predict the expected rut depth, for various materials, structures, traffic, and environmental conditions. [9]

Rigid Pavement

Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course [3]. In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium Rigid pavements are constructed by Portland cement concrete (PCC) and should be analyzed by plate theory instead of layer theory, assuming an elastic plate resting on viscous foundation. Plate theory is a simplified version of layer theory that assumes the concrete slab as a medium thick plate which is plane before loading and to remain plane after loading. Bending of slab due to wheel load and temperature variation resulting tensile and flexural stress. Stress condition of rigid pavement analysed by using finite element analysis [12]. The cement concrete pavement slab can very well serve as a wearing surface as well an effective base course. Therefore usually the rigid pavement structure consists of a cement concrete slab, below which a granular base or subbase course may be provided [14].

Concrete pavements, often called rigid pavements, are made up of Portland cement concrete and may or may not have a base course between the pavement and subgrade. As a general rule, the concrete, exclusive of the base, is referred to as the pavement. The concrete pavement, because of its rigidity and high modulus of elasticity, tends to distribute the applied load over a relatively wide area of soil; thus, the major portion of the structural capacity is supplied by the slab itself [18].

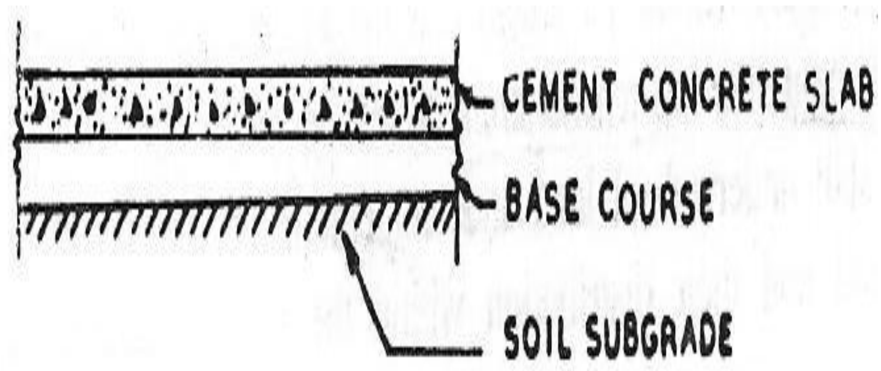

Figure 2: Cross section of Rigid Pavement

Categories of Rigid Pavement

There are mainly four categories of rigid pavement are as follows:

1. Jointed plain concrete pavement (JPCP)
2. Jointed reinforced concrete pavement (JRCP)
3. Continuous reinforced concrete pavement (CRCP)
4. Pre-stressed concrete pavement (PCP)

1. Jointed plain concrete pavement

Jointed Plain Concrete Pavement is plain cement concrete pavements constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints. They normally have a joint spacing of 5 to 10m.

2. Jointed reinforced concrete pavement (JRCP)

Although reinforcements do not improve the structural capacity significantly, they can drastically increase the joint spacing to 10 to 30m. Dowel bars are required for loadtransfer. Reinforcement's help to keep the slab together even after cracks.

3. Continuous reinforced concrete pavement (CRCP)

Complete elimination of joints are achieved by reinforcement in continuous reinforced concrete pavement.

4. Pre-stressed concrete pavement (PCP)

Pre-stressed concrete pavements are made up of pre-stressed concrete.

Failures of Rigid Pavement

Traditionally fatigue cracking has been considered as the major or only criterion for rigid pavement design. The allowable number of load repetitions to cause fatigue cracking depends on the stress ratio between flexural tensile stress and concrete modulus of rupture. Of late, pumping is identified as an important failure criterion. Pumping is the ejection of soil slurry through the joints and cracks of cement concrete pavement, caused during the downward movement of slab under the heavy wheel loads. Other major types of distress in rigid pavements include faulting, spalling, and deterioration.

Comparison between Rigid and Flexible pavement

There are many points with the help of those points we compared rigid and flexible pavement are as follows:

Flexible Pavement
1. Deformation in the sub grade is transferred to the upper layers
2. Design is based on load distributing characteristics of the component layers
3. Flexible pavement carries low flexural strength
4. Load is transferred by grain to grain contact
5. Have low completion cost but repairing cost is high
6. Have low life span (High Maintenance Cost)
7. Surfacing cannot be laid directly on the sub grade but a sub base is needed
8. No thermal stresses are induced as the pavement have the ability to contract and expand freely
9. An expansion joints are not needed
10. Strength of the road is highly dependent on the strength of the sub grade
11. Rolling of the surfacing is needed
12. Road can be used for traffic within 24 hours
13. Force of friction is less Deformation in the sub grade is not transferred to the upper layers.
14. Damaged by Oils and Certain Chemicals

Rigid Pavement
1. Deformation in the sub grade is not transferred to subsequent layers
2. Design is based on flexural strength or slab action
3. Rigid pavement carries high flexural strength
4. No such phenomenon of grain to grain load transfer exists
5. Have low repairing cost but completion cost is high
6. Life span is more as compare to flexible (Low Maintenance Cost)
7. Surfacing can be directly laid on the sub grade
8. Thermal stresses are more vulnerable to be induced as the ability to contract and expand is very less in concrete
9. An expansion joints are needed
10. Strength of the road is less dependent on the strength of the sub grade
11. Rolling of the surfacing in not needed
12. Road cannot be used until 14 days of curing
13. Force of friction is high.
14. No Damage by Oils and Greases

Cost Analysis of Rigid and Flexible Pavement

Initial cost is generally the major factor in deciding the type of the pavement in design. The planners often think that the flexible pavement is cheaper than the rigid pavements. In fact this is not always the case. Many researchers perform cost analysis of pavements. Initial cost of rigid pavement is high but by considering serviceability, life of rigid pavement it is found that it is economical than the flexible pavement. Construction cost for rigid pavements are cheaper than flexible pavements, in contrast to what is generally thought. However with the strength increase in sub grade the asphalt pavement costs and rigid pavement costs get closer. With increasing petrol prices the cost of asphalt pavements will be even higher. So concrete pavement should be highly considered in choosing the pavement types [16]. Cost analysis of pavement performed by Grameen Samapark it is found that rigid pavement is economical and cheaper [17].

II. Conclusions/ Summary

As per the above discussion of pavements (rigid and flexible pavement) by many researchers some conclusions or summary is drafted which are as follows:
1. Rigid pavement carries higher flexural strength than flexible pavement i.e. it carries bending and deformation without rupture under wheel axial load.
2. In flexible pavement load is transferred from grain to grain and because of that many failures occurs such as fatigue cracking, rutting and thermal cracking. But in rigid pavement no such phenomenon of grain to grain load transfer exists, hence there is fewer amounts of failure.
3. Life span of rigid pavement is more than the flexible pavement with low maintenance cost. Life cycle cost of flexible pavement will be about 19 % higher than the rigid pavement after 20 years.
4. Initial cost of rigid pavement is higher but when comparing total cost of pavement through life span rigid pavement is more economical than flexible pavement.
5. Initial cost of rigid pavement (concrete pavement) is reduces by replacing cement by fly ash at some percent or by using other alternatives.

From above conclusion we can say that rigid pavement is economical than flexible pavement and there is a need to developed it and used in transportation infrastructure in future.

References

[1]. Kumares C. Sinha, Darcy Bullock, Chris T. Hendrickson, "Development of Transportation Engineering Research, Education, and Practice in a Changing Civil Engineering World", ASCE, JTE, July/ August 2002.128:301-313.
[2]. Saurabh Jain, Dr. Y. P. Joshi, S. S. Goliya, " Design of Rigid and Flexible Pavements by Various Methods & Their Cost Analysis of Each Method", Int. Journal of Engineering Research and Applications, Vol. 3, Issue 5, Sep-Oct 2013, pp.119-123.
[3]. Tom V. Mathew and K V Krishna Rao, "Introduction to Transportation Engineering", NPTEL May 3, 2007.
[4]. Minkwan Kim, A.M.ASCE, ErolTutumluer, M.ASCE and Jayhyun Kwon, "Nonlinear Pavement Foundation Modeling for Three-Dimensional Finite-Element Analysis of Flexible Pavements", International Journal of Geomechanics © ASCE / October 2009.
[5]. ArvoTinni, "Introduction to Concrete Pavements", Introduction to Concrete Pavements, EestiBetooniühing – March 2013.
[6]. Belekar Y. &Irsha M. Effect of Dynamic Load on Rigid Pavement. *IJERT*.2015,04(03):287-290p.
[7]. Bassem Ali, MarwanSadek and IsamShahrour, "Finite-Element Model for Urban Pavement Rutting: Analysis of Pavement Rehabilitation Methods", Journal Of Transportation Engineering © ASCE / April 2009.
[8]. Daehyeon Kim, M.ASCE, Rodrigo Salgado, M.ASCE and Adolph G. Altschaeffl, "Effects of Supersingle Tire Loadings on Pavements", Journal Of Transportation Engineering © ASCE / October 2005.
[9]. Jacob Uzan, "Permanent Deformation in Flexible Pavements", Journal Of Transportation Engineering © ASCE / January, February 2004.
[10]. Michael S. Mamlouk, Fellow, Asce, John P. Zaniewski, Member Asce, And Wei He, "Analysis And Design Optimization Of Flexible Pavement" , Journal Of Transportation Engineering / March/April 2000.
[11]. Jacob Uzan, "Rigid-Pavement Evaluation Using NDT—Case Study", Journal of Transportation Engineering,©ASCEVol. 118, No. 4, July/August, 1992.
[12]. Yu T. Chou, M. ASCE, "Comparative Analyses Of Rigid Pavements", Journal of Transportation Engineering©ASCE,Vol. 109, No. 5, September, 1983.
[13]. Chou Yu T. Comparative Analysis of Rigid Pavement. *ASCE-JTE*.1983, 109 (05):669-688p
[14]. ArvindDewangan, Dr. D.P.Gupta, Dr. R.K.Bakshi, "Analysis of Pavement for National highway".International Journal of Computer Technology and Electronics Engineering (IJCTEE) , Vol 2, ISSN 2249-6343.
[15]. AASHTO. Guidelines for Design of Pavement Structures. American Association of State Highways and Transportation officials. 1993.
[16]. T. Akakin, Y. Engin, S. Ucar, " Initial Cost Comparison of Rigid And Flexible Pavements: Under Different Trafic And Soil Conditions",*ASCE-JTE*.1983, 109 (05):669-688p.
[17]. "Cement Concrete Road Vs Bituminous Road : A Cost Analysis" , Grameen Samapark.
[18]. Mohd. Imran Khan, Harwalkar A. B., "Mechanistic Analysis of Rigid Pavement for Wheel Load Stresses Using Ansys", IJRCE, Vol -4, ISSN 2248-9649.
[19]. IRC: 58:2011 (2011). Guidelines for the Design of Plain Jointed Rigid Pavements for Highways.IRC. New Delhi.