**STUDY THE FLEXIBLE AND RIGID PAVEMENT BY CREATING VARIATION IN SUBGRADE STRENGTH AND TRAFFIC**

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***ABSTRACT***

Transportation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic development of any region since every commodity produced whether it is food, clothing, industrial products or medicine needs transport at all stages from production to distribution. It provides movement of passengers and goods from one place to another place. Main modes of transportation in our country are Roadways. Railways, Waterways, and Airways. Out of these, roadways allow movement of about 85% of passengers and 70% of goods because it is nearest to the people and also provides flexibility for movement of vehicles.

Pavements are generally classified into two categories based on the structural behavior:  
- Flexible Pavement

- Rigid Pavement

***Keywords:-*** *industrial development, flexible pavement, rigid pavement, California bearing ratio, village road*

**INTRODUCTION**

**Flexible Pavement**: Flexible pavement are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural actions under the loads. The flexible pavement layers reflect the deformation of the lower layers on-to the surface of the layer. Thus if the lower layer of the pavement or soil subgrade is undulated, the flexible pavement surface also gets undulated. Bituminous concrete is one of the best flexible pavement layer materials. A typical section of flexible pavement consists of four components:  
- Surfacing (Wearing Course + Binder Course)

- Base Course

- Sub-base Course

- Soil Subgrade

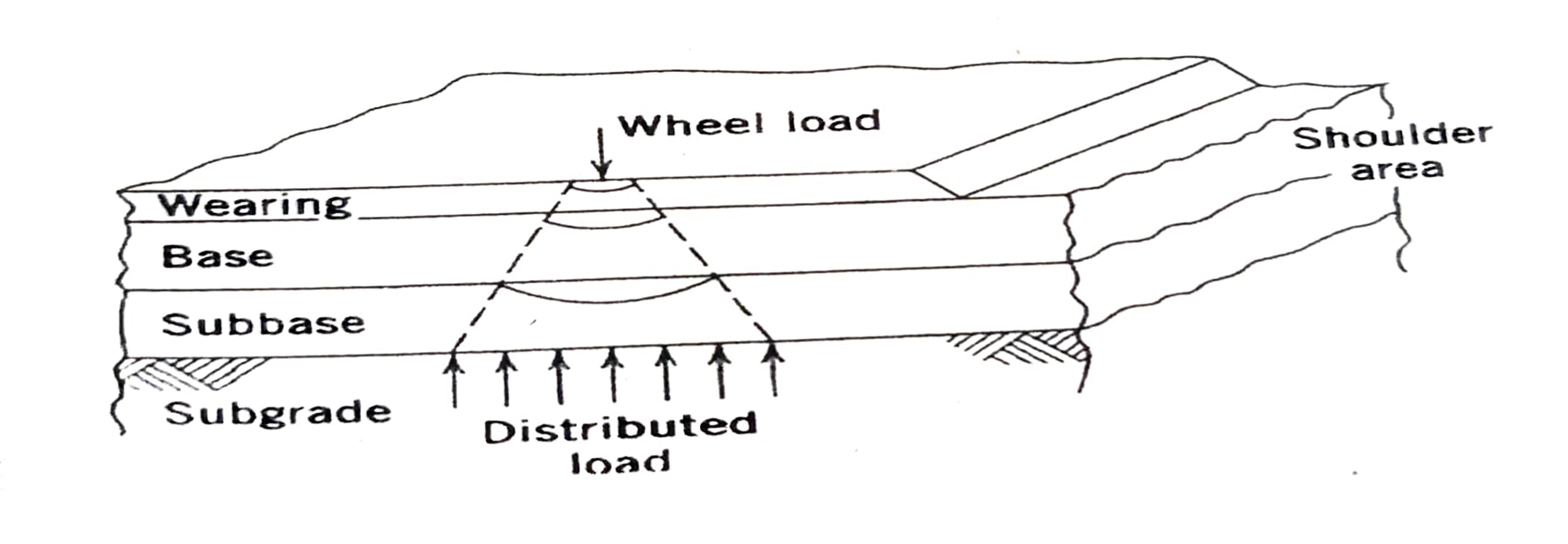


Fig. Section of a Flexible Pavement

The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure. The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel. Due to the ability to distribute the stresses to a larger area in the shape of truncated cone, the stresses get decreased at the lower layers. Therefore by taking the advantage of the stress distribution characteristics of the flexible pavement, the layer system concept was developed. According to this, the flexible pavement may be constructed in a number of layers and the top layer has to be the strongest as the highest compressive stress are to be sustained by this layer, in addition to the wear and tear due to the traffic. The lower layers have to take up only lesser magnitudes of stresses and there is no direct wearing action due to the traffic loads, therefore inferior materials with lower cost can be used in the lower layers. The service life of a flexible pavement is typically designed in the range of 15 to 20 years components.  
Rigid Pavement: Rigid pavements, as the name implies, are associated with rigidity preventing them to bend under loads like their flexible counterparts. The rigid pavements are made of Portland Cement Concrete (PCC)- plain, reinforced or pre-stressed concrete. The plain cement concrete slabs are expected to take up about 45 kg/cm² flexural stress. In case of rigid pavements, stresses are not transferred from grain to grain to the lower layers as in the case of flexible pavements. The rigid pavement has the slab action and is capable of transmitting the wheel load stresses through a wider area below. H.M Westergaard is considered the pioneer in providing the rational treatment of the rigid pavement analysis and his theory is used as the base for design of rigid pavements by IRC. The typical designed service life of a rigid pavement is between 30 and 40 years, lasting about twice as long as a flexible pavement. One major design consideration of rigid pavements is reducing fatigue failure due to the repeated stresses of traffic. Fatigue failure is common among major roads because a typical highway will experience millions of wheel passes throughout its service life. The Components of rigid pavement or cement concrete pavement structure (From to bottom) consists of:

* Pavement Quality concrete (PQC)
* Sub-base course (DLC)
* Granular Sub-base (GSB)
* Compacted Soil Sub-grade

A thin separation membrane is placed on the top of the base course before laying the PQC slab. The CC pavement is provided with the traverse and longitudinal joints. Three main types of concrete pavements commonly used are jointed plain concrete pavement (JPCP), jointed reinforced concrete pavement (JRCP) and continuously reinforced concrete pavements (CRCP).

**OBJECTIVES OF THE STUDY**  
The dissertation entitled "Economy of Flexible and Rigid Pavements with variation in Subgrade Strength and Traffic consists of designing a flexible and rigid pavement for the given values of design traffic and subgrade CBR, analyzing the cost of the designed pavement sections and study the effect of variation in CBR and traffic on their thickness and cost. The main objectives of the study are

1. To evolve the design of a Flexible and Rigid Pavement for varying values of subgrade strength and design traffic.  
2. To determine the effect of variation in subgrade strength on thickness of the pavement.  
3. To determine the effect of variation in design traffic on thickness of the pavement.  
4. To do the cost estimation of the designed sections of the Flexible and Rigid Pavements.

5. To discuss the effect of variation in Subgrade Strength on cost of the Pavement.

6. To discuss the effect of variation in traffic on cost of the Pavement.  
7. To discuss the economy of construction of flexible and rigid pavements.

**LITERATURE REVIEW**

Khan (1998) describes the Group Index Method and California Bearing Ratio Method for design of flexible pavements. In Group Index Method the thickness is obtained by first determining the Group Index value of the soil. The curves are plotted between Group Index of subgrade and thickness of the pavement for various traffic conditions. In California Bearing Ratio Method, the curves are plotted between California Bearing Ratio percent and depth of construction.  
Hadi and Arfiadi (2001) state that the design of rigid pavements involves assuming a pavement structure then using a number of tables and figures to calculate the two governing design criteria, the flexural fatigue of the concrete base and the erosion of the sub-grade/sub- base. Each of these two criteria needs to be less than 100%. The designer needs to ensure that both criteria are near 100% so that safe and economical designs are achieved. This paper presents a formulation for the problem of optimum rigid road pavement design by defining the objective function, which is the total cost of pavement materials, and all the constraints that influence the design. A genetic algorithm is used to find the optimum design. The results obtained from the genetic algorithm are compared with results obtained from a Newton-Raphson based optimization solver.  
Arora (2003) has reported that the Westergaard's analysis is used for design of rigid pavements. The stresses in the concrete slab are determined using Westergaard's theory. Westergaard considered the rigid pavement as a thin elastic plate resting on soil subgrade. The upward reaction at any point is assumed to be proportional to the deflection at that point. The slab deflection depends upon the stiffness of the subgrade and the flexural strength of the slab. Thus the pressure-deformation characteristics of a rigid pavement depend upon the relative stiffness of the slab and the subgrade.

Atalkilti [et.al](http://et.al/) (2009) did the Comparative study of the Flexible and Rigid pavements for different soil and traffic conditions. In their study they developed the mathematical models to estimate the ALD from individual vehicle counts. They designed around 90 flexible and 63 rigid pavements and calculated the costs of each pavement. From their study they concluded that flexible pavements show wider range of variation in cost with respect to design parameters of traffic and soil CBR. The overall variation on cost of rigid pavements is comparatively small. The design of a rigid pavement is highly influenced by the occurrence of small number of heavy axle loads. It is observed that flexible pavements are more economical for lesser volume of traffic.  
Tarefder [et.al](http://et.al/) (2010) present that reliability is an important factor in flexible pavement design to consider the variability associated with the design inputs. In this paper, subgrade strength variability and flexible pavement designs are evaluated for reliability. Parameters such as mean, maximum likelihood, median, coefficient of variation, and density distribution, function of subgrade strength are determined. Design outputs are compared in terms of reliability and thickness using these design procedures. It is shown that the AASHTO provides higher reliability values compared to the probabilistic procedure. Finally, the reliability of the flexible pavement design is evaluated by varying hot mix asphalt properties. Alternative designs are recommended for the existing pavement thickness by modifying material and subgrade properties to mitigate different distresses.  
Long [et.al](http://et.al/) (2011) addresses the structural performance of experimental rigid pavements constructed in California. The experimental study consists of seven Portland cement concrete pavement sections with various layer structures. Falling weight deflectometer was utilized ta conduct deflection testing for back calculation of layer moduli and subgrade reaction moduli. evaluation of joint load transfer capacity, and detection of voids under the slabs In addition, pavement distress condition was also evaluated as it relates to the integrity of pavement structure. The major findings in this study indicate that thick slab and lean concrete base lower the pavement deflection response and I prevent the formation of voids under the slab comers, but lean concrete base has no significant effect on subgrade reaction moduli values IRC 37 Guidelines (2012) the latest design method of IRC 37:2012 is based on Mechanistic Empirical approach of design. This guidelines used for the design of a flexible pavement on any highway (excluding low volume roads), in which bituminous surfacing is provided over (a) granular base and granular sub base, (b) a cemented base and cemented sub base with a crack relief layer of aggregate interlayer over cement base layer. (c) a cemented base and cemented sub base with SAMI layer between bituminous and base layer, (d) Reclaimed Asphalt Pavement (RAP) with or without addition of fresh aggregates treated with foamed bitumen/bitumen emulsion, and (e) bituminous base and granular sub base using the concept of long life deep strength bituminous pavements. Last four options are new additions over 2001 revision. There is no change in pavement design approach or in modeling of the pavement structure.

**GENERAL**  
The IRC: 37-2001 was based on a Mechanistic Empirical approach, which considered the design life of pavement to last till the fatigue cracking in bituminous surface extended to 20 per cent of the pavement surface area or rutting in the pavement reached the terminal rutting of 20 mm, whichever happened earlier. The same approach and the criteria are followed in these guidelines as well, except that the cracking and rutting have been restricted to 10 per cent of the area for design traffic exceeding 30 msa. These guidelines aim at pavement design by including alternate materials like cement and reclaimed asphalt materials, and subjecting them to analysis using the software IITPAVE, a modified version of FPAVE.

The Guidelines recommend that the following aspects should be given consideration while designing to achieve better performing pavements:

i. Incorporation of design period of more than fifteen years.

ii. Computation of effective CBR of subgrade for pavement design.

iii. Use of rut resistant surface layer.

iv. Use of fatigue resistant bottom bituminous layer.

v. Selection of surface layer to prevent top down cracking.

vi. Use of bitumen emulsion/foamed bitumen treated Reclaimed Asphalt Pavements in base course.

vii. Design of drainage layer.

viii. Design of drainage layer.

ix. Computation of equivalent single axle load considering (a) single axle with single wheel (b) single axle with dual wheels (c) tandem axle and (d) Iridem axles.

x. Design of perpetual pavements with deep strength bituminous layer

Traffic

General

* The recommended method considers design traffic in terms of the cumulative number of standard axles (80 kN) to be carried by the pavement during the design life. Axle load spectrum data are required where cement bases are used for evaluating the fatigue damage of such bases for heavy traffic. Following information is needed for estimating design traffic:

1. Initial traffic after construction in terms of number of Commercial Vehicles per day (CVPD).

2. Traffic growth rate during the design life in percentage.

3. Design life in number of year.

4. Spectrum of axle load.

5. Vehicle Damage Factor (VDF).

6. Distribution of commercial traffic over the carriageway.

* Only the number of commercial vehicles having weight of 30 KN or more and their axle- loading is considered for the purpose of design of pavement.
* Assessment of the present day average traffic should be used on seven-day-24-hour count made in accordance with IRC: 9-1972, "Traffic Census on Non-Urban Roads".

Traffic Growth rate

* The present day traffic has to be projected for the end of design life at growth rates ('r') estimated by studying and analyzing the following data:

1. The past trends of traffic growth; and
2. Demand elasticity of traffic with respect to macro-economic parameters (like GDP or SDP) and expected demand due to specific developments and land use changes to take place during design life.

* If the data for the annual growth rate of commercial vehicles is not available or if it is less than 5 per cent, a growth rate of 5 per cent should be used (IRC SP:84-2009).

Design Life

* The design life is the defined in terms of the cumulative number of standard axles in misa that can be carried before a major strengthening, rehabilitation or capacity augmentation of the pavement is necessary.
* It is recommended that pavement for National Highways and State Highways should be designed for a minimum life of 15 years. Expressways and Urban Roads may be designed for a longer life of 20 years or higher using innovative design adopting high fatigue bituminous mixes. In the light experience in India and abroad, high volume roads with design traffic greater than 200 msa and perpetual pavement can also be designed using the principles stated in guidelines. For other categories, a design life of 10-15 years may be adopted.
* If stage construction is adopted, thickness of granular layer should be provided for the full design period. In the case of cemented bases and sub-bases, stage construction may lead to early failure because of high flexural stresses in the cemented layer and therefore, not recommended.

Vehicle Damage Factor

* The guidelines use Vehicle Damage Factor (VDF) in estimation of cumulative msa for thickness design of pavement.
* The vehicle damage factor is a multiplier to convert the number of commercial vehicle of different axle loads and axle configuration into the number of repetitions of standard axle load of magnitude 80 kN. It is defined as equivalent number of standard axle per commercial vehicle. The VDF varies with the vehicle axle configuration and axle loading.
* The equations for computing equivalency factor for single, tandem and tridem axles given below should be used for converting different axle load repetitions into equivalent standard load repetitions. Since the VDF values in AASHO Road Test for flexible and rigid pavements are not much different, for heavy duty pavements, the computed VDF values are assumed to be same for bituminous with cemented and granular bases.

Single axle with single wheel on either side =(axle load in kN/65)4

Single axle with dual wheels on either side =(axle load in kN/80)4

Tandem axle with dual wheels on either side =(axle load in kN/148)4

Tridem axles with dual wheels on either side =(axle load in kN/224)4

Distribution of Commercial Traffic Over the Carriageway

Distribution of commercial traffic in cach direction and in cach lane is required for determining the total equivalent standard axle load applications to be considered in the design. In the absence of adequate and conclusive data, the following distribution may be assumed until more reliable dala on placement of commercial vehicles on the carriageway lanes are available:

A. Single-lane roads

Traffic tends to be more channelized on the single-lane roads than two-lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.

B. Two-lane single carriageway roads

The design should be based on 50 per cent of the total number of commercial vehicles in both directions. If vehicle damage factor in one direction is higher the traffic in the direction of higher VDF is recommended for design.

C. Four-lane Single carriageway roads

The design should be based on 40 per cent of the total number of commercial vehicles in both directions.

D. Dual carriageway roads

The design of dual two-lane carriageway roads should be based on 75 per cent of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four lane carriageway, the distribution factor will be 60 per cent and 45 per cent respectively.

* Where there is no significant difference between traffic in each of the two directions, design traffic for each direction may be taken as half of the sum of traffic in both directions. Where significant difference between the two streams exists, pavement thickness in each direction can be different and designed accordingly.
* For two way two lane roads, pavement thickness should be same for both the lanes even if VDF values are different in different directions and designed for higher VDF. For divided carriageways, each direction may have different thickness of pavement if the axle load patterns are significantly different.
* Computation of Design Traffic
* The design traffic in terms of cumulative number of standard axle to be carried during the design life of the road is calculated using the following equation:
* N = (365\*{(i + r) n - 1})/r \* ADF. …..eq (3.1)
* Where,  
  N = Cumulative number of standard axles to be catered for in the design in terms of msa
* A = Initial traffic in the year of completion of construction in terms of the number of commercial Vehicles Per Day (CVPD)
* D = Lane distribution factor
* F = Vehicle Damage Factor.
* n = Design life in years.
* r = Annual growth rate of commercial vehicles in decimal (e.g., for 5 per cent annual
* growth rate, r = 0.05 ) .
* The traffic in the year of completion is estimated using following formula:
* A = P (1 + r)x
* Where,  
  P = Number of commercial vehicles as per last count.
* x = Number of year between the last count and the year of completion of construction.

**CONCLUSIONS**

The dissertation entitled "Economy of Flexible and Rigid Pavements with variation in Subgrade strength and Traffic" has been taken up with the view to study the effect of CBR and design traffic on the cost of flexible and rigid pavements. The pavements have been designed for a two lane carriageway of width 7.5m assumed to be located in Kurukshetra, Haryana. The CBR of existing ground has been varied from 4% to 10% and design traffic on the road has been varied from 2msa to 150msa to determine its effects on the thickness of the pavement and ultimately on the cost of the pavement.

The main conclusions drawn from the study are:

The thickness of Flexible Pavement decreases gradually with increase in the value of CBR from 4% to 10%.

There is no significant variation in the thickness of Rigid Pavement with increase in Subgrade strength from 4% to 10%.

→ The cost of Flexible Pavement decreases with increase in the value of CBR from 4% to 10%.

There is no significant variation in the total Cost of Rigid Pavements with  
increase in the value of CBR from 4% to 10% for a given design traffic. Maintenance Cost for Flexible Pavements for entire design life is very high and may be 9 to 20 times costlier with design traffic varying from 2 msa to 150 msa as compared to the Rigid Pavements.  
  
→ Maintenance Cost for Flexible Pavements increases with increase in the design traffic but for Rigid Pavements there is little change in the Maintenance Cost.

As far as total cost including maintenance is concerned, for low design traffic the flexible pavements are more economical than the rigid pavements for any value of CBR. However, as design traffic becomes more, the Rigid Pavements are more economical than the Flexible Pavements due to their low maintenance cost.

The Rigid Pavements can sustain more design traffic with little variation in Pavement thickness.

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