Chava Anvesh* et al.
(IJITR) INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND RESEARCH
Volume No.4, Issue No.5, August – September 2016, 3797 – 3802.

Comparative Study on Analysis and Design of Flexible and Rigid Pavements

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Abstract: **A highway pavement is really a structure composed of superimposed layers of processed materials over the natural soil sub grade, whose primary function would be to distribute the applied vehicle loads towards the sub-grade. To create the street stretch like a flexible pavement by utilizing style of flexible pavement by CBR method like a rigid pavement for that collected design upon given black cotton soil sub-grade and also to estimations the development price of designed pavement. The primary purpose of this research would be to develop an approach to choose the most inexpensive pavement design method to handle for that parts of a highway network also to find out the cost analysis of pavement designs. Various grades of concrete under similar condition of traffic and style concrete road are located to more appropriate than bituminous road. Because the whole existence cycle cost arrives to become reduced the plethora of 30% to 50% however for streets getting traffic under 400 cv/day and road is within good shape, the main difference between whole existence prices of concrete overlay is 15% to 60% greater than the flexible overlay. The best goal is to make sure that the sent stresses because of wheel load are sufficiently reduced, so they won't exceed bearing capacity from the sub-grade.**

Keywords: **Pavement Design; Superimposed Layers; Vehicle Loads; Flexible Pavement; Rigid Pavement**

I. INTRODUCTION

The transportation by road may be the only mode that could give maximum plan to everyone. This mode has additionally the utmost versatility for travel with regards to route, direction and speed of travel. You'll be able to provide door-to-door service only by road transport. Concrete pavement a lot of advantages for example lengthy life time minimal maintenance, user and atmosphere friendly minimizing cost. The pavement structure should have the ability to give a surface of acceptable riding quality, sufficient skid resistance, favorable light reflecting qualities, and occasional environmental noise. Two kinds of streets are usually acknowledged as serving this purpose, namely flexible streets and rigid streets. Pavement grants or loans friction for that automobiles thus supplying comfort towards the driver and transfers the traffic load in the surface towards the natural soil. Streets are mainly for use by automobiles and people on the streets [1]. Storm water drainage and ecological the weather is a significant concern within the creating of the pavement. The very first from the built streets go as far back to 4000 BC and comprised of stone paved roads or timber streets. The streets from the earlier occasions relied exclusively on stone, gravel and sand for construction and water was utilized like a binding agent to level and provide a finished turn to the top. A highway pavement is structure composed of superimposed layers of processed materials over the natural soil sub-grade, whose primary function would be to distribute the applied vehicle load towards the sub-grade. The pavement structure should have the ability to give a surface of acceptable riding quality, sufficient skid resistance, favorable light reflecting qualities, and occasional environmental noise.

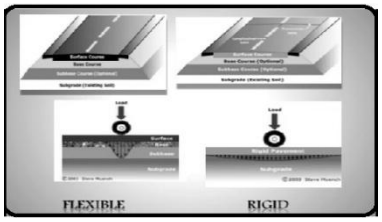

Fig.1.Variation in load distribution of flexible and rigid pavement

II. ESSENTIAL REQUIREMENT OF PAVEMENTS

Structural performance: pavement ought to be, sufficiently strong to face up to the stresses enforced onto it. Thick enough to distribute the exterior loads around the earthen sub-grade. Functional performance: a pavement must have, riding quality, surface friction for skid resistance,

low noise and, and good geometrics. Pavement layer thickness incase & sub-first layer combinations: total thickness: Min: 380 20(mm) to Max: 850(mm). GSB thickness: 100-380(mm). Wmm thickness: 225-250(mm). Layer below putting on course thickness: 30-170(mm). Putting on course thickness: 20-50(mm). Streets are usually categorized into five types they're: flexible pavement: Flexible streets are individuals, which overall have low flexural strength and therefore are rather within their structural action underneath the loads. The flexible pavement layers reflect the deformation from the lower layers onto the top of layer. An Average Flexible Pavement includes four components: Surface Course, Base Course, Sub-base course, Soil Sub Grade. Rigid pavement: Rigid streets are individuals possess significant flexural strength. The stresses aren't moved from grain towards the lower layers as just in case of flexible pavement layers. The rigid streets are constructed with Portland cement concrete-either plain, strengthened or pre-stressed concrete. The plain cement concrete foundations are anticipated to consider to around 40 kg/cm flexural stresses. The rigid pavement has got the slab action and is capable of doing transmitting the wheel load stresses via a wide area below. An Average Rigid Pavement includes three components: Surface course, Base or sub-base course, and Sub-grade [2]. The putting on span of the pavement is built by distributing bricks or pre-cast rectangular cement concrete blocks, or interlocking concrete blocks. The joints together are full of mud of normal gradation. These bits of blocks behave as a little rigid plate. An amalgamated pavement includes cement concrete or cement-treated granular and bituminous layers. A perfect pavement should satisfy the following needs: Sufficient thickness to distribute the wheel load stresses to some safe value around the sub-grade soil, Structurally strong to resist all kinds of stresses enforced on there, Sufficient coefficient of friction to avoid skidding of automobiles, Fine surface to supply comfort to road customers even at high-speed, Produce least noise motionless automobiles, Dust proof surface to ensure that traffic safety factors are not impaired by reduction of visibility, Impervious surface, to ensure that sub-grade soil is properly protected, and Lengthy design existence with low maintenances cost.

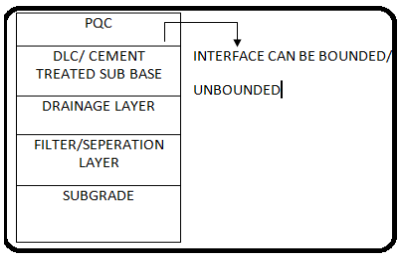

Fig.2. Typical cross-section of concrete pavement

III. VARIABLE PAVEMENT DESIGNS

Pavement design comprises thickness resolution of different layers for forecasted amount of traffic, in situ and weather conditions. The designed pavement should serve visitors to the presumed degree of service for that design period. Throughout the service duration of the pavement, there are lots of factors associated with traffic, nature and engineering factors which need to be taken into cost-economy and sturdy service. The standards affecting pavement design receive below. Material Qualities: Pavement materials contain various kinds of sub-grade soil, fine aggregates, granular materials, folders, viz. bitumen, tar, cement, emulsions, lime etc. Traffic Volume: Traffic volume is among the primary factors which decide pavement thickness. Traffic count articles are carried out at road junctions or imaginary parts of streets to find out passage of numerous automobiles per unit period of time. Estimate of future traffic volume for any design period is calculated when it comes to cumulative standard axles each year (csa/year). TRAFFIC Rate of Growth: This value can be used to estimate future traffic (A) after n period of time according to present traffic volume (P). The speed of development of visitors are generally calculated in the rate of growth of car registrations, fuel consumption and socio-economic developments inside a locality within the last couple of (ten or twenty) years. Design Existence: The word "DESIGN LIFE" signifies the cumulative quantity of standard axle load repetitions that a pavement should really supply the preferred degree of service before requiring strengthening procedures. For flexible streets, the look period (n), might be taken as 10 t0 two decades. For rigid streets, design service period varies-just in case of high and low traffic volume streets; it might be taken as 20to 3 decades correspondingly. Lane Distribution Factor: [LDF] Lane distribution factor is really a decimal value which signifies the power of positioning of wheel load repetitions along a road stretch. The lane distribution factor (LDF) ought to be determined from realistic and appropriate field surveys according to special repeatability of wheel pathways of various automobiles within the transverse direction of the pavement surface. Standard Axle Load: The entire weight of the vehicle is transported by its axles. The burden around the axles is moved towards the wheels which load is ultimately moved onto the top of pavement in touch with the tires. Load Equivalency Factor: [LEF] Load equivalency factor (LEF) is really a number which relates the quantity of equivalence damage the result of a given load of axle towards the standard axle load. According to field test data, AASHTO has suggested specific load equivalency factors for single and tandem axles [3]. Truck Factor: Truck factors would be the

heavy vehicle factors which are employed to convert the volumes of automobiles categorized under different heavy vehicle classes into ESALs of 80 KN, with the load equivalency factors (LEF). Legal Axle Load Limit: To guard streets against overloading, different agencies in numerous nations have recommended maximum allowable limits of axle load based on their approach to compaction, materials, and factors associated with mix design in addition to pavement crust thickness. Vehicle Damage Factor: The harm brought on by different automobiles is calculated while using vehicle damage factor which is often used for performance modeling, design and upkeep of streets. Load Safety Factor: It's a factor of safety. To take into consideration unpredicted loads or possible periodic overloading or versions in the level of commercial traffic loading especially on expressways or important streets, the burden safety factor can be used like a multiplication factor for growing measured axle loads [4]. Steering wheel Pressure and Phone Pressure: Pressure within an inflated rubber of the tire is known to as tire pressure or inflation pressure. Equivalence Single Wheel Load: Dual wheel with single axle or tandem set up of axle-loading configuration is really a broadly used practice of moving gross weight of car to the pavement surface, on the greater contact area. According to this idea, the automobiles transporting greater weight are put together with tandem axle-dual wheel set up and also the resulting concentration of load is going to be stored inside a specified allowable limit. Equivalent single wheel load (ESWL) is really a single tire that is calculated with different standard configuration of dual wheel set up.

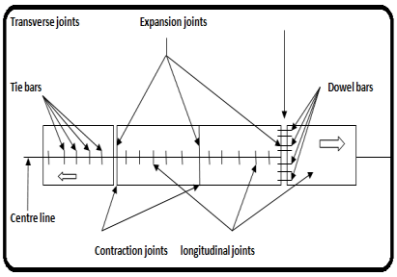

Fig.3.Details of joints used in a dual-lane concrete pavement

IV. PAVEMENT DESIGN PROCEDURE

Any mixture of traffic and pavement layer composition may be attempted using IITPAVE. The designer may have full freedom in both pavement materials and layer thickness. The traffic volume, amount of layers, the layer thickness of human layers along with the layer qualities would be the user specified inputs within the program, which gives strains at critical locations as outputs. The adequacy of design is checked using the program by evaluating these strains with allowable strains as predicted using the fatigue and rutting models, in built-in this particular program. An acceptable pavement design is accomplished through iterative process by different layer thickness or, as needed, by modifying the pavement layers materials. Whatever the design procedure, it is important the material qualities are adopted after transporting out relevant tests across the materials. Where all test facilities aren't available, a under people tests needs to be moved out, that may validate the assumed design qualities [5]. The kind of tests needed combined with selection of values for material qualities receive according to typical testing and knowledge about other nations. The as recommended might be adopted for pavement design as default whilst not without validation by posting materials to such tests which may be easily moved in any laboratory to validate the assumed design values.

V. DESIGN OF RIGID PAVEMENT

Given Data:

A cement concrete pavement will be created for a four-lane divided national highway with two lanes in every direction within the condition of Telangana. Style of pavement for that duration of 3 decades lane width=3.5m transverse joint is anticipated that Spacing =4.5m.

Solution:

a) SELECTION OF SUB-GRADE REACTION

- Effective CBR of compacted sub-grade =8percent.
- Modulus of sub -grade reaction = 50.3Mpa/m(form table 2)
- Provide 150mm granular sub-base
- Provide a DLS sub-base thickness 150mm with minimum 7days compressive strength of 10Mpa
- Effective modulus of sub-grade reaction of combined foundation of sub-base +granular sub-base and DLS sub-base(by table 4 by interpolation)=285Mpa/m
- Provide a de-bonding layer of polythene sheet of 125 microns thickness between DLS and concrete slab.

b) SELECTION OF FLEXURAL STRENGTH OF CONCRETE

- 28-day compressive strength of cement concrete =40MPa
- 90- day compressive strength of cement concrete =48MPa
- 28-day flexural strength of cement concrete =4.5MPa
- 90-day flexural strength of cement concrete =4.95Mpa

c) SELECTION OF DESIGN TRAFFIC FATIGUE ANALYSIS

- Design period =30years
- Annual rate of growth of commercial traffic(expressed in decimals)=0.075
- Two way commercial traffic volume per day=6000 CVPD
- % of traffic in predominant direction = 50 percent (3000cvs in each direction
- Total two-way commercial vehicles during design period,
- C = $\frac{365*6000\{(1+0.075)^{30}-1\}}{0.075}$ = 226,444,692 CVs
- Average number of axles (steering /single /tandem /tridem) vehicle = 2.35
- Total two-way axle load repetitions during the design period,

  = 226,444,692*2.35

  = 532,145,025 axles
- Number of axles in predominant direction = 532,145,025*0.5

  =266,072,513
- Design traffic after adjusting for lateral placement of axles (25% of predominant direction traffic for multi-lane highways) = 266,072,513*0.25

  = 66,518,128
- Night time (12-hour) design axle repetitions = 66,518,128*0.6 (60% traffic during night time)
  = 39,910,877
- Day time (12-hour) design axle repetitions = 66,518,128*(1-0.6)

  = 26,607,251
- Day time (6-hour) axle load repetitions = 26,607,251/2

  =13,303,626
- Hence, design number of axle load repetitions for bottom-up cracking analysis

  = 13,303, 626
- Night-time (6-hour) axle load repetitions = 39,910,877/2

  = 19,955,439
- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit = 55 percent
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m) = 19,955,439*0.55

  = 10,975,491

VI. DESIGN OF FLEXIBLE PAVEMENT

DESIGN CALCULATIONS:

- Lane distribution factor = 75% = 0.75
- Initial traffic = 3000 CVPD assuming 50% in each direction
- Vehicle damage factor [VDF] computed for the traffic = 4.5
- Cumulative number of reputations of standard axles to be catered for in the design,
- N = 365*3000*[{(1+0.075)30-1}/0.075]*0.75

  = 84916759.3
- Effective CBR of sub-grade = 8%
- Design resilient modulus of the compacted sub-grade = 17.6*(CBR)0.64, CBR > 5

  = 17.6*(8)0.64 = 67Mpa
- Thickness of granular layers: WMM =250mm, GSB =230mm
- Resilient modulus of granular layer = 0.2*(h)0.45*MR sub-grade

  = 0.2*(480)0.45*67 = 216Mpa

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  = 0.2*(480)0.45*67 = 216Mpa

Cumulative fatigue damage analysis has to be done for single, tandem and tridem axles respectively, taking flexural strength of cemented base as 1.4Mpa.

Modulus of rupture of cementitious base = 1.4Mpa.

VII. CONCLUSION

The pavement was created like a flexible pavement upon a black cotton soil sub grade, the CBR technique is most suitable method than available techniques. The pavement was created like a flexible method that pavement was created based

on their design thickness that cost analysis of the section is calculated, CBR according to IRC is most suitable when it comes to cost analysis. The pavement was created like a rigid pavement, the technique is most appropriate. It's observed that flexible streets tend to be more economical for lesser amount of traffic. The existence of flexible pavement is near about fifteen years whose initial price is low requires a periodic maintenance following a certain period and maintenance costs high. Whereas the existence of rigid pavement is a lot more compared to flexible pavement of approximately 4 decades roughly 2.5 occasions existence of flexible pavement whose initial cost is a lot more compared to flexible pavement but maintenance price is very less.

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AUTHOR's PROFILE

Chava Anvesh Born in 1992 at KHAMMAM, KHAMMAM district, Telangana. He received his bachelor of technology degree in civil engineering from **SARADA** institute of technology & science, Jawaharlal Nehru technological university Hyderabad in 2014, M. Tech**.COMPARATIVE STUDY ON ANALYSIS AND DESIGN OF FLEXIBLE AND RIGID PAVEMENTS**. From JNTU Hyderabad in 2016**.**

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Dr. S. Sreenatha Reddy is well known internationally for his outstanding research in .Mechanical Engineering. He has also proposed a model using first principles of Thermodynamics to predict the complex Diesel Engine. In particular, he has made important contributions to the analysis and design of Internal Combustion Engine. In his work, **Dr. S. Sreenatha Reddy** combines modern process modeling concepts with advanced experimental techniques. He has also developed new technologies like **Exhaust Gas Recirculation (EGR) and Magnetic Fuel Conditioning system** for reducing harm emissions**.** It promotes the exchange and mutual enrichment of knowledge in international dialogue via conferences, like the Frontiers of Research Symposia and other meetings.

Dr. S. Sreenatha Reddy Earlier worked as Principal, Head of both the Aeronautical & Mechanical department, coordinating R&D cell for Mechanical Research and Development Board (MRDB) & Aeronautical Research and Development Board (ARDB) projects, TPO, NSS Coordinator, developing courseware and implementing ISO 2001 and NBA Accreditation.

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