TRANSPORTATION ENGINEERING

COURSE CODE- RCI4C002

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SYLLABUS

Module-I (10 hrs)

Modes of transportation, importance of highway transportation, history of road construction. Principle of highway planning, road development plans, highway alignments requirements, engineering surveys for highway location. Geometric design- Design controls, highway cross section elements, cross slope or camber, road width, road margins, typical cross sections of roads, design speed, sight distance, design of horizontal and vertical alignments, horizontal and vertical curves.

Module-II (10 hrs)

Highway Materials:- Properties of subgrade , sub-base , base course and surface course materials , test on subgrade soil, aggregates and bituminous materials. Traffic Engineering:- definition , fundamentals of traffic flow , traffic management, prevention of road accidents , elements of transport planning , highway drainage

Module-III (9 hrs)

Design of Highway Pavements: Flexible pavements and their design, review of old methods, CBR method, IRC:37-2012, equivalent single wheel load factor, rigid pavements, stress in rigid pavement, IRC design method (IRC:58-2011).

Module-IV (9 hrs)

Highway Construction: Construction of various layers, earthwork, WBM, GSB, WMM, various types of bituminous layers, joints in rigid pavements, Hot Mix Plants, Construction of Rigid Pavements

Module-V (7 hrs)

Highway Maintenance: Various type of failures of flexible and rigid pavements.

Books:

- Highway Engineering, by S.K.Khanna and CEG Justo, Nem Chand & Bros.
- Transportation Engineering-Highway Engineering by C Venkatramaiah, Universities Press.
- A course in Highway Engineering by Dr. S.P. Bindra, Dhanpat Rai Publications.
- Principles of Highway Engineering and Traffic Analysis by Mannering Fred L., Washburn Scott S. and Kilaresk Walter P., Wiley India Pvt. Ltd
- Traffic Engineering and Transportation Planning by Kadiyali, L.R.,Khanna Publishers
- Transportation Engineering and Planning by Papacostas, C.S. and Prevedouros, P.D.,Prentice Hall.

ACKNOWLEDGEMENT

I would like to acknowledge various sources from which this lecture note was prepared. Especially I would like to mention that the lecture note has been prepared in the light of material available with NPTEL, Transportation-I prepared by Prof. Tom V. Mathew and Prof. K.V. Krishna Rao of IIT Bombay and also, from lecture notes available in VSSUT, Burla site.

Module III

Lecture 31

Flexible pavement design-I

Overview

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives loads from the above layer, spreads them out, and passes on these loads to the next layer below. Thus the stresses will be reduced, which are maximum at the top layer and minimum on the top of subgrade.

Design procedures

- Empirical design
- Empirical design

Traffic and Loading

- Fixed traffic
- Fixed vehicle
- Variable traffic and vehicle

Equivalent single wheel load

To carry maximum load within the specified limit and to carry greater load, dual wheel, or dual tandem assembly is often used. Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth.

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$$\log_{10} ESWL = \log_{10} P + \frac{0.301 \log_{10}\left(\frac{z}{d/2}\right)}{\log_{10}\left(\frac{2S}{d/2}\right)}$$

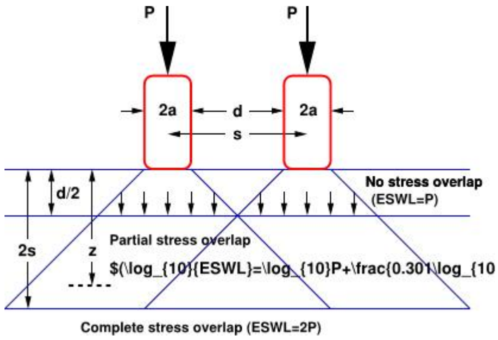


Fig. 31.1 ESWL-Equal stress concept

Equivalent single axle load

- Legal axle load
- Standard axle load

Repetition of axle loads

Equivalent axle load factor

$$\text{Equivalent single axle load, ESAL} = \sum_{i=1}^{m} F_i n_i$$

Lecture 32

Flexible pavement design-I

Material characterization

It is well known that the pavement materials are not perfectly elastic but experiences some permanent deformation after each load repetitions. It is well known that most paving materials are not elastic but experience some permanent deformation after each load application.

Resilient modulus of soil

The elastic modulus based on the recoverable strain under repeated loads is called the resilient modulus.

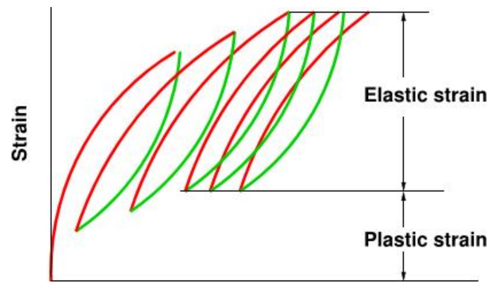


Fig. 32.1 Recoverable strain under repeated loads

Dynamic complex modulus

This is one of the way of explaining the stress-strain relationship of visco-elastic materials.

Correlations with other tests

Determination of resilient modulus is often cumbersome. Therefore, various empirical tests have been used to determine the material properties for pavement design.

Mechanistic-empirical analysis

Mechanics is the science of motion and action of forces on bodies. In pavement design these phenomena are stresses, strains, and deflections within a pavement structure and the physical causes are loads and material properties of the pavements structure.

Advantages

The basic advantages of the Mechanistic-Empirical pavement design method over a purely empirical one are:

- It can be used for both existing pavement rehabilitation and new pavement construction
- It can accommodate changing load types
- It can better characterize materials allowing for better utilization of available materials accommodation of new materials improved definition of existing layer proportion
- It uses material proportion that relates better with actual pavement performance
- It provides more reliable performance predictions
- It defines role of construction in a better way
- It accommodates environment and aging e ect of materials in the pavement

Mechanistic model

Mechanistic models are used to mathematically model pavement physics.

Inputs

A layered elastic model requires a minimum number of inputs to adequately characterize a pavement structure and its response to loading. These inputs are:

Material properties of each layer, like modulus of elasticity (E), Poisson's ratio,

Pavement layer thicknesses, and

Loading conditions which include the total wheel load and load repetitions

Output

The outputs of the layered elastic model are the stresses, strains and de ections in the pavements.

- Stress.
- Strain.
- Deflection.

Lecture 33

IRC Method of Flexible Pavement Design

Overview
Indian roads congress has specified the design procedures for exible pavements based on CBR values. The Pavement designs given in the previous edition IRC:37-1984 were applicable to design traffic upto only 30 million standard axles (msa).

Scope
These guidelines will apply to design of exible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/ MOST standards. These guidelines apply to new pavements.

Design criteria

- Vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
- Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
- Pavement deformation within the bituminous layer.

Failure Criteria

- Fatigue Criteria
- Rutting Criteria

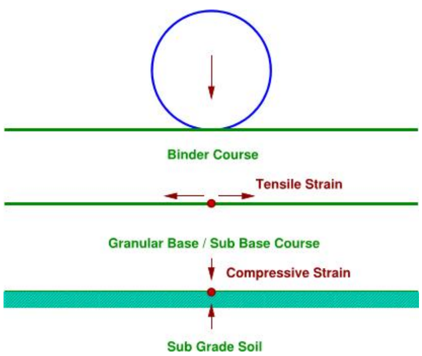


Fig. 33.1 Critical Locations in Pavement

<u>Design procedure</u>

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code.

Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

- Design traffic in terms of cumulative number of standard axles; and
- CBR value of subgrade.

Design trffic

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information:

- Initial traffic in terms of CVPD
- Traffic growth rate during the design life
- Design life in number of years
- Vehicle damage factor (VDF)
- Distribution of commercial traffic over the carriage way.

<u>Pavement thickness design charts</u>

For the design of pavements to carry traffic in the range of 1 to 10 msa, use chart 1 and for tra□c in the range 10 to 150 msa, use chart 2 of IRC:37 2001.

<u>Pavement composition</u>

- o Sub-base
- o Base
- o Bituminous surfacing

Lecture 34

Stresses in Rigid Pavement

Overview

As the name implies, rigid pavements are rigid i.e, they do not flex much under loading like flexible pavements. They are constructed using cement concrete. In this case, the load carrying capacity is mainly due to the rigidity ad high modulus of elasticity of the slab (slab action).

Modulus of sub-grade reaction

Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil sub-grade, which is assumed as a dense liquid. The upward reaction is assumed to be proportional to the deflection.

Relative sti ness of slab to sub-grade

A certain degree of resistance to slab deflection is o ered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure.

Critical load positions

There are three typical locations namely the interior, edge and corner, where di ering conditions of slab continuity exist. These locations are termed as critical load positions.

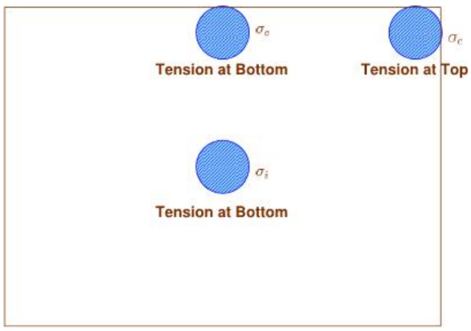


Fig. 34.1 Critical stress locations

Temperature stresses

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. This is caused by

(i) Daily variation resulting in a temperature gradient across the thickness of the slab and

(ii) Seasonal variation resulting in overall change in the slab temperature.

Combination of stresses

The cumulative effect of the different stress give rise to the following thee critical cases

- Summer, mid-day: The critical stress is for edge region
- Winter, mid-day: The critical combination of stress is for the edge region given by
- Mid-nights: The critical combination of stress is for the corner region given

Lecture 35

Design of joints

Expansion joints

The purpose of the expansion joint is to allow the expansion of the pavement due to rise in temperature with respect to construction temperature.

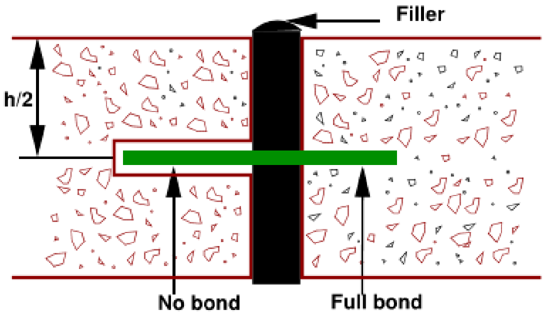
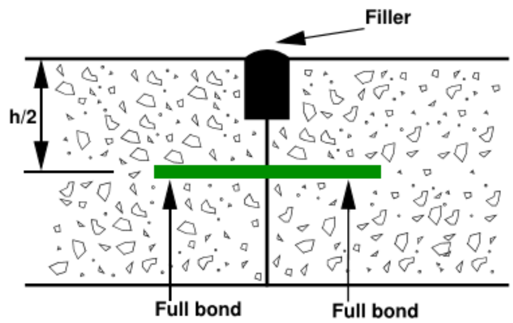


Fig. 35.1 Expansion joint

Contraction joints



35.2 Contraction Joint

Dowel bars

The purpose of the dowel bar is to e□ectively transfer the load between two concrete slabs and to keep the two slabs in same height.

Tie bars

In contrast to dowel bars, tie bars are not load transfer devices, but serve as a means to tie two slabs. Hence tie bars must be deformed or hooked and must be firmly anchored into the concrete to function properly.

Lecture 36

Low Volume Roads

Overview

Low Volume Road is considered a road that has relatively low use (an Average Daily Traffic of less than 400 vehicles per day), low design speeds (typically less than 80 kph), and corresponding geometry. Most roads in rural areas are low-volume roads.

Steps

The basic steps of road panning are:

- Planning
- Location
- Survey
- Design
- Construction
- Maintenance

Importance of Rural Roads

Rural road connectivity is a key component of rural development in India since it promotes access to economic and social services and thereby increases agricultural income and productive employment opportunities. As a result, it is also a key ingredient in ensuring sustainable poverty reduction.

Aspect of Road Design

- General Design
- Materials
- Slopes
- Drainage
- Erosion Control

Lecture 37

Highway Drainage

Overview

Provision for adequate drainage is of paramount importance in road design and cannot be overemphasized. The presence of excess water or moisture within the roadway will adversely affect the engineering properties of the materials with which it was constructed. Cut or fill failures, road surface erosion, and weakened subgrades followed by a mass failure are all products of inadequate or poorly designed drainage. As has been stated previously, many drainage problems can be avoided in the location and design of the road: Drainage design is most appropriately included in alignment and gradient planning.

Importance of Drainage

Water has a number of unhelpful characteristics which impact on highway performance.

- It is a lubricant reducing the effectiveness of tyre grip on the carriageway wearing surface which can increase stopping distances.
- Spray from rainwater being thrown up by car tyres can reduce visibility which can lead to delays in reacting to events on the carriageway.
- Drag on car tyres from local rainwater ponding can alter the balance of vehicles travelling at speed which can be alarming or cause skidding.
- It is incompressible therefore standing water effectively acts as a jackhammer on the wearing course right through to the sub-base when vehicles pass over head.
- It expands when frozen pulling apart the carriageway construction which then falls apart when it warms up
- In extreme storms, rainwater can simply wash away roads on embankment should the culvert become blocked or lack capacity.