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 V

Lecture 39

Highway Maintenance

Types of Failures in Flexible Pavements and their Causes and Repair Techniques

Failures in flexible pavements can be due to failure of its component layers which undergo distress due to various causes. Types of failures in flexible pavements and repair techniques are discussed.

In general, the flexible pavement consists of the following component layers:

Sub-grade

Sub-base course

Base Course

Surface Course

Instability in any of the layers will result in the complete failure of the pavement system. This makes it necessary to construct each layer with utmost care and precision.

There are different types of failures in flexible pavements. Determination of this failure and its reasons is necessary to facilitate correction in mix design and construction for the future projects.

Types of Failures in Flexible Pavements and their Repair Techniques

Types of Failures in Flexible Pavements due to Exposure

The exposure that affects the flexible pavements adversely are:

Weather conditions

Change in weathers imposes distress in flexible pavements.

Use of chemical and salts in colder climates

The frost heave and the stripping of asphalt due to snow and ice will result in potholes and other distress.

Ultraviolet rays

The ultraviolet rays make the pavement to undergo oxidation and bring it to a brittle state. On a hot sunny day, the pavement temperature can be up to 140 degree Celsius. This is the softening point of liquid asphalt. This will make the pavement to expand and move.

The reduction of temperature will make the pavement to contract. This expansion and contraction are the main reason for initial cracking.

Water (natural rain and irrigation)

Through the cracks, water can enter to the base and the subgrade, which will result in the structural damage

Vehicle loads and petroleum

The fuel spillage coming from the vehicles deteriorates the integrity of the pavement. This increase the softening point of the binder.

A parked vehicle has chances to leak gasoline or brake fluid that make the asphalt to liquefy. This makes the binder to separate from the rock that may create softer areas. Hence sudden treatment of oil spots on parking area should not be ignored.

Aging of Flexible Pavements

Aging is a life cycle deterioration of the pavement. This results in highly accelerated oxidation and cracks formation. Small deterioration determined at the initial stages will help in reducing the intensity of the aging effect. As the exposure to temperature and ultraviolet increases the rate of deterioration.

Types of Failures in Flexible Pavements due to Distress

The distress faced by the pavement can be of two types:

Environmental distress, and

Structural distress

Environmental Distress in Flexible Pavements

The outside influence that affects the pavement performance are categorized under environmental factors. These include snow, the chemicals, water and problems with aging.

These types of distress are observed from the top down. The remedy for such problems is a surface application. These include crack sealing, seal coating, chip seals, skin-parching. In certain situations, a hot mixed overlay is added to the surface as part of treatment.

Structural Distress in Flexible Pavements

The structural are categorized as the physical failures that are found on the pavement and the sub-base. These structural failures are occurred due to overloading, wet subgrade, frosting effect or lower standards of design. This kind of distress is found from bottom up.

The only remedy for these is removal and their replacement, mentioned as (R & R) of the area that is affected. Or repaving that includes total removal, milling, pulverizing the area and then paving back.

Types of Failures in Flexible Pavements due to Structural Distresses

Some of the structural distresses which can cause failures in flexible pavements are:

1. Alligator Cracking of Flexible Pavements

Alligator cracks are also called as map cracking. This fatigue failure caused in the asphalt concrete. A series of interconnected cracks are observed due to such distress.

The tensile stress is maximum at the asphalt surface (base). This is the position where the cracks are formed, i.e. the area with maximum tensile stress. A parallel of longitudinal cracks will propagate with time and reaches the surface.

Repeated loading and stress concentration will help the individual cracks to get connected. These will resemble as a chicken wire or similar to the alligator skin. This is termed as the alligator cracking. It is also known as the crocodile cracking.

These cracking is observed only in areas that have repeated traffic loading. Alligator cracking is

one of the major structural distress. This distress is later accompanied by rutting.

2. Depressions in Flexible Pavements

There are certain areas in the pavement that are localized and have a lower elevation compared to the surrounding pavement level. These lowering are depressions found on the pavement. They are mainly noticed only when they are filled with water (After rain).

Depressions in flexible pavements are a very common distress found in parking lot construction as well as in overlays. These depressions can be caused either by the foundation soil settlement due to continuous loading or it can be formed during the construction.

There are different severity levels that are considered for the depression in the flexible pavement that is constructed for airfield purposes.

3. Corrugations in Flexible Pavements

The corrugations are distress seen in the pavement at regular intervals in the form of ridges and valleys. These are usually less than 5 feet, along with the direction of the pavement.

The ridges form of corrugations will be perpendicular to the traffic direction. Unstable pavement plus traffic will create such distress. Where the traffic starts and stops, this distress are observed.

4. Shoving

A form of plastic movement that is seen in the form of the wave is called as shoving distress. These are also observed perpendicular to the direction of the traffic.

5. Potholes

In road surfaces where a portion of the same has broken away, cause a disruption by forming a pothole. These are also called as a kettle. In the Western United States, these are known as chuckhole.

The pavement fatigue is the main reason behind the formation of potholes. The occurrence of fatigue cracking will interlock to form alligator cracking. These chunks between the cracks formed in the pavement will become loose and will be picked out under continuous loading and stresses.

This will leave a pothole on the pavement.

In cold temperatures, the water trapped in the pothole will carry out the freezing and thawing action that leads to additional stresses and crack propagation.

Once the pothole is formed, the distress grows resulting in the continuous removal of pavement chunks. Water entrapped will increase this rate of expansion of distress. The pothole can expand to several feet in width. They don't develop too much in depth. The vehicle tires are damaged due to large potholes.

6. Rutting of Flexible Pavements

The depression formed in the surface is called the rutting. This is formed in the wheel path surface. This depression will make the other sides of the wheel to undergo uplift as shown in the figure-6. This pavement uplift is also called as shearing.

These ruts like depressions are evident after rain. Where these depressions would be filled with water. There are two types of rutting that can occur;

Pavement Rutting

Subgrade Rutting

7. Swelling of Flexible Pavements

These are distress that long and gradual wave. These can be ten feet long. The swelling distress is characterized by the upward bulge in the pavement surface. Surface cracking is the next series of distress that is seen after swelling.

The main reason behind swelling in flexible pavement is the frost action in the subgrade. Where frosting results in the swelling of the soil.

Types of Failures in Flexible Pavements due to Environmental Distresses

1. Bleeding in Flexible Pavements

The phenomenon of formation of a film of asphalt binder over the surface of the pavement surface is called as bleeding. The occurrence of bleeding will give a shiny glass like reflecting surface. The

layer will have bubbles which are seen as blisters. The asphalt binder formed will be sticky in nature.

The filling of asphalt binder into the aggregate voids during hot weather conditions and their expansion in later situations will result in bleeding. As the process of bleeding cannot be reverted in cold temperatures, they remain on the top of the pavement as such. The bleeding can be caused due to the following factors:

Excessive asphalt binder in the mix

Excessive application of the binder during surface treatment

Lower air void content – no adequate voids for the bitumen to penetrate

2. Block Cracking in Flexible Pavements

This is also called as thermal cracking. The cracking is happening in the form of blocks. These cracks are interconnected making the pavement to divide into rectangular pieces (almost rectangular).

The size of each rectangle may vary from one foot by one foot to ten foot by ten foot. This is spread over a wide pavement area. But these are observed in areas of no traffic. This is an after effect of environmental exposure, hence it is called thermal cracking. The temperature effects and aging are the possible reasons.

3. Bumps and Sags

Pavement surface that is localized, small in area that has undergone an upward displacement will be named as bumps. These are caused due to the instability factor of pavement.

Several factors contribute to bumping formation. They can be caused even due to buckling or the bulging of the concrete slabs. Areas, where an asphalt pavement is laid over a concrete pavement, observes such failures.

Another contribution to bumps are the frost heaves that creates bumps due to expansion. Oxidation

will result in the spelling of the crack edges. Any plant roots growing under the pavement too can cause bumps in the pavement.

The sags are mainly caused due to the settlement or the displacement of the pavement surface. Sags are small, abrupt and localized. Large or long dips in the pavement can be created by the sags.

4. Edge Cracking in Flexible Pavements

In unconfined asphalt pavements, edge cracking is found to occur. During the compaction process of the pavement, the edges will start to yield, especially when there is no sort of confinement like curbs or edge barriers.

The edges will yield with age, undergo oxidation and becomes brittle. The edge cracking is observed in the shape of 'C' formed along the edges of the street, parking lot or the roads.

5. Joint Reflection Cracking

These are cracks that are observed in the flexible overlay over a rigid pavement. The rigid pavement joints that are an underlying experience these cracks.

6. Raveling

The dislodgement of aggregate particles will result in the disintegration of the hot mixed asphalt progressively from the surface to downward direction. This failure is called as raveling. This dislodgement is the loss of bonding between the aggregate particles and the asphalt binder.

The aggregates are sometimes coated with dust particles that result in lack of bonding. This will make the aggregate to bind with the dust rather than the binder.

7. Cold Joints in Flexible Pavements

These are longitudinal joints which are formed in the asphalt pavement. This failure occurs when a hot mix asphalt is poured adjacent to an existing pavement. This kind of failure is mainly common in parking lots, inverted crowns and areas with lower traffic.

The difference in temperature and the plasticity variation will bring a different between the two

layers. This will cause a longitudinal joint to occur between the asphalt mats that are laid.

The longitudinal joint possesses a lesser density compared to other pavements. These longitudinal joints called the cold joint, with time will let intrusion of water. It increases the roughness and hence limits the life of the pavement.

Longitudinal and Transverse Cracking Distress

This distress can be considered as either a structural or an environmental distress. The longitudinal cracks are formed parallel to the pavement alignment or the center line of the pavement.

This is a fatigue cracking. Here, the cracking occurs in the direction of traffic flow. The transverse cracking is formed perpendicular to the pavement centerline. This is caused as a thermal cracking.

Lecture 40

Types of Failures in Rigid Pavements and their Causes and Repair Techniques

Failures in rigid pavements are caused by distresses due to various causes. Repair techniques these types of failures in rigid pavements are discussed.

Types of Failures in Rigid Pavements

The different types of distresses responsible for failures in rigid pavements are:

Joint Spalling

Faulting

Polished Aggregate

Shrinkage Cracking

Pumping

Punch out

Linear Cracking

Durability Cracking

Corner Break

Joint Spalling in Rigid Pavements

Excessive compressive stress causes deterioration in the joints, called as the spalling. This may be related to joint infiltration or the growth of pavement, that are caused by the reactive aggregates.

Poor quality concrete or construction technique will also result in joint spalling. Small edges to large spalls in the back of the slab and down to the joints can be observed.

Main causes of joint spalling in rigid pavements are:

Joints subjected to excessive stress due to high traffic or by infiltration of any incompressible materials

The joint that are constructed with weak concrete

Joint that is accumulated with water that results in rapid freezing and thawing

Joint Spalling in Rigid Pavements

The joint spalls can be avoided by using good construction techniques, or by sealing the joints.

Faulting in Rigid Pavements

The difference in elevation between the joints is called as faulting. The main causes of failures in rigid pavements due to faulting are:

Settlement of the pavement that is caused due to soft foundation

The pumping or the erosion of material under the pavement, resulting in voids under the pavement slab causing settlement

The temperature changes and moisture changes that cause curling of the slab edges.

Polished Aggregate in Rigid Pavements

The repeated traffic application leads to this distress. These are the failures in rigid pavements caused when the aggregates above the cement paste in the case of PCC is very small or the aggregates are not rough or when they are angular in shape, that it cannot provide sufficient skid resistance for the vehicles.

Shrinkage Cracking in Rigid Pavements

These are hairline cracks that are less than 2m in length. They do not cross the entire slab. The setting and curing process of the concrete slab results in such cracks. These are caused due to higher evaporation of water due to higher temperature cracks. Improper curing can also create shrinkage cracks in rigid pavements.

Pumping Effects

The expulsion of water from the under a layer of the pavement is called as pumping. This distress is caused due to the active vehicle loads coming over the pavement in a repetitive manner. This will result in the fine materials present in the sub base to move along with water and get expelled out with the water.

Larger voids are created under the pavement due to repeated expulsion. The stains on the pavement or on the shoulder surface are the method through which this type of failure of rigid pavement is evidenced.

Pumping can be avoided by prevention of water accumulation at the pavement sub-base interface. This can be achieved by reducing the deflection to a minimum value and by the provision of a strong well constructed sub-base.

The constructed sub-base must have sufficient drainage facility so that the subgrade below is not saturated. Modern pavement construction makes use of underground drainage system that is the best solution for pumping distress.

Corner Breaks in Rigid Pavements

These are the failures in rigid pavements that is caused due to pumping in excessive rate. When the pumping completely remove the underlying support that no more support exists below to taken the vehicle load, the corner cracks are created. The repair method is either full slab replacement or the repair for the full depth must be carried out.

Punch-out in Rigid Pavements

A localized area of concrete slab that is broken into pieces will be named as punch out distress. This distress can take any shape or form. These are mainly defined by joints and cracks. The joints and cracks will mainly keep 1.5m width.

The main reason behind punch outs is heavy repeated loads, the slab thickness inadequacy, the foundation support loss or the construction deficiency like honeycombing.

Linear Cracking in Rigid Pavements

These types of failures in rigid pavements divides the slab into two or three pieces. The reason

behind such failures is traffic loads at repeated levels, the curling due to thermal gradient and moisture loading repeatedly.

Durability Cracking in Rigid Pavements

The freezing and thawing action will create regular expansion and contraction which will result in the gradual breakdown of the concrete. This type of distress is patterns of cracks on the concrete surface as layers that are parallel and closer to the joints.

Joints and cracks are the areas where the concrete seem to be more saturated. Here a dark deposit is found and called the ‘D’ cracks. This failure of rigid pavement will finally result in the complete disintegration of the whole slab.

References

1. Khanna, S. K., & Justo, C. E. G. (1991). *Highway engineering*. Nem Chand & Bros.

2. Mathew, T.V., & Rao, K.V.K. (2007). Introduction to transportation engineering–NPTEL.

3. http://www.vssut.ac.in/lecture-notes.php?url=civil-engineering