23.02.16

Shamsul Haque Sir

Syllabus:

i) Material & Mix Design
ii) Pavement Design
iii) Construction & Maintenance of Pavement
iv) Railway Engineering.

Highway Pavement

History

- Elephant has relation with pavement.
In primitive society when men used to go to unknown places, then followed the defined path of a flock of Elephant.
Elephant has basic instincts to sense which road is stable as all soils can't take load of heavily loaded Elephant.
So, the road through which Elephants move, is the most stable even in wet season.
Elephants walk over sandy soil as it has good drainage property. Or they select silty soil.
Sand doesn't soak water & changes its property, rather sand drains water. But the problem is sand is unbound. So, there was not stability of sandy road. Then

mean started using boulders and other construction materials for making road. Men used to embed boulders in soil to ensure stability. Mostly natural materials were used initially.

Structural stability of pavement surface comes in 2 ways.

- When load is applied, the material should not be punched. Vertical depression must not be allowed.
- Later confinement is required.

Structural integrity is maintained from 2 confinements:

i) Vertical confinements.
ii) Lateral confinements

Geometry is also needed along with confinement. Side drain required for wet season. Damage occurs if water moves below soil and destroys its bearing capacity.

Gutter → raised curbs are present and water comes to edges and there are sag sumps so that water

is discharged away instead of letting it go below soil.

Wheel & human being should not be at same grade.

For roads, safety is 1st principle.

Geometric proportioning changed with volume.

Crown → is at the middle.
→ crown can also be depressed.
→ saucer drain were also used.

Drainage aspect is most important for stability and duration of road.

Drainage, Moisture, stagnant water are the causes of damage of road.

But yet, the riding quality was not much good initially as blocks were not at same level. So, if static load vibrates due to undulation, then dynamic load increases. Ensuring riding quality became a desire.

All the roads were at same level as soil.

But in Mahasthangarh of our country, roads are over embankment.

In our country it is not possible to drain as whole country is low lying area. So, road top was kept above highest flood point. Bricks were used to make retaining wall to confine inner materials and create an embankment below road. Inner filling material was not only soil, other things were also used.

Perpetual Pavement → shoul sustain at best 40 years.

But our present roads are non-engineered and hence sustains only 2 years.

In primitive times, some glue type material was required to connect together unbinding material like aggregates.

Lake ~~asphalt~~ asphalt → natural binding material.

Asphalt & Bitumen are same.

↓ USA

↓ British

Crude oil → if did fractional distillation, after extraction, we can get many lubricant resources.

Residue of Crude oil is asphalt (bituminous material).

Thus came bituminous pavement material.
Later, concrete pavement came and cement became the binding material.

Components of Flexible Pavement

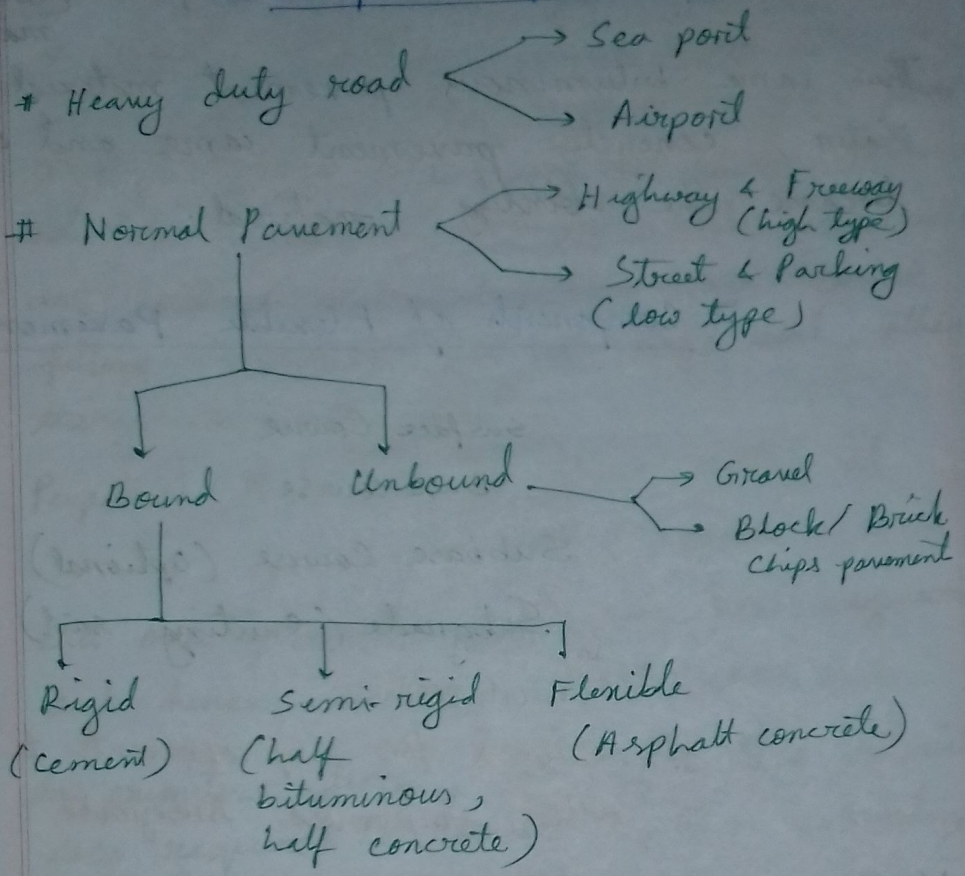
1. Surface Course
2. Base course
3. Subbase Course (Optional)
4. Subgrade (Existing soil)

Natural soil
If replaced for improvement, then called improved subgrade

Material richness should move from bottom to top. So, the upper materials in contact will be most costly. Size of top material is smaller. Shape is transmitted in Pyramid shape.

We'll use CBR method to know how much load soil can carry.

Classification of Pavements



Riding Quality of Bituminous pavement is very high.

Concrete pavement has a bit less riding quality but it has long duration and there is no need of maintenance. It is of a bit fair color.

Life cycle Cost = Installation Cost + Maintenance Cost.

Rigid Pavement is getting popularity all over the world → Fit & Forget.

In Rigid Pavement → Panels are required
In Bituminous " → Continuous pavement.

Identification
- Concrete Pavement → Grey color + Panels
- Bituminous " → Blacking + no panels

- In some cases, concrete pavement may be mandatory (near toll plaza).
- Rural road → low cost pavement (Gravel road)
- Paving block → brick made of earth
  → brick made of mortar (riding quality is good)
- Submersible pavement / Block Pavement.
- Boats give direct connectivity which roads cannot give.
- Heavy duty pavement → in sea port as there are huge vehicles. (more layers & thickness required)

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- Heavy duty pavement → Airport.
- Rural road → can gradually evolve, small layer.
- For parking areas → very low cost pavement.
- ILB → Interlocking Block

Performance increases than concrete pavement when interlocked.

So, the skin of sea-port and air-port is of ILB.

Critical load of airplane is when it is stationary for fueling. So, in these places the pavement will be of ILB.

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What is a Pavement

- Pavement is a multi-layer system
- With Pavement, by default, the layers will come.
- In Pavement design, shoulder is included.
- At grade → Shoulder
  Raised → walkway.

Functions of the Pavement

i) Reduce & distribute load to wider area
The load is spreaded in such a way that its within bearing capacity of soil.
Thickness cannot be insufficient.

ii) All-weather, riding quality is to be ensured.

iii) Safety, evenness and comfortable rides are to be ensured.

iv) Delay occurs due to pavement.

v) have to be aesthetically pleasant
(using marking or using plantation)

vi) Should not create extra noise & air pollution
↑ uneven pavement ↑ fuel waste due to congestion

(vii) Ensuring economy

Requirements of Pavement Structure

- Load is spreaded pyramidacally. Thickness is very important requirement.
- Due to snowfall, weathering load comes from bottom. When ice becomes water, volume increases. It causes upheaval.

Load from top → 

Load from bottom → 

Have to give such thickness that swell & frost are arrested.

- Has to be impervious.

Dense graded Top soil is required.

For dense graded → min^m void, max^m density.

($\frac{3}{4}$th Dowongraded) -

Sieve aggregate → max^m size of aggregate is obtained

Nominal size of aggregate → max^m size.

After taking max^m size, take enough next size to fill the void, then take next size to fill rest of the void → Go on like this.

In silt, cement is given.
To fill void of cement, silicon fume is used → Densest concrete obtained this way.

→ Have to give importance to foundation.
Even if pavement is ok, if support system is not proper, weakness of foundation will be reflected on pavement and undulation will be visible.

→ Punching can occur in flexible pavement but not in rigid pavement.

→ We want to keep foundation & pavement dry

→ Material should be non-frost susceptible & skid resistant.

Types of Pavement

Flexible Pavement
4 layers, (Multilayer)

Rigid Pavement:
Single layer

If soil is bad, use Rigid Pavement.
Make different designs to get least cost Option.
Have to be most careful in aggregate selection of Flexible Pavement.
We need Healthy aggregate..
↙
cubical in shape
with angularity
If flaky, won't take load.
If elongated, won't take load.

Rigid Pavement → Can use round aggregate as slab like action.
Whole slab acts as one.

(Q) Draw Load Distribution pattern of Rigid & Flexible Pavement.

Richness moves from top to bottom

◎ Surface Course

- Wearing coarse (top is most vulnerable)
- Intermediate or binding coarse (structural layer)

☒ Types of Flexible Pavement

-dense graded, open graded, gap graded

To provide vertical drain & to reduce cost → Open grade.

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(3)

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Types of Flexible or Hot Mix Asphalt (HMA) Pavement

Nearly $\frac{1}{2}$" (or 12 mm) gets worn This is wearing course; not structural layer

Binder course is structural layer.

HMA → Dense graded (min^m void)
→ Crap graded
→ Open Graded.

- Highest size → nominal size.
  $\frac{1}{2}$" downgraded aggregate.
  $\frac{3}{4}$" " "
- Void of sand is filled up with silt, dust → then cement → then silica fume.
- Petronous tower is made of concrete although tall buildings are of steel structure. They used 14,000 psi strength concrete so that col^m size doesn't increase. They used fume in concrete to densify.

Gap Graded → can do intentionally

Open Graded → For every size, a bit less than required is taken deliberately so that porous asphalt concrete is obtained. This is done for vertical drainage. In this case, there won't be crown; there will be asphalt.

(i) Full depth Pavement
(ii) Partial depth Pavement

- If uses bituminous material in all layers, then it is called full depth (in 3 layers)
- If only top is bituminous → then called partial depth pavement

Semi Rigid or Composite hybrid pavement.
If hybrid done, better performance

Black topping → top bituminous, underlying layer is concrete.

White topping → top is concrete, underlying layer is bituminous

* Flexible pavement finished

Rigid Pavement

(*) Flexible Pavement → multilayer system
Rigid " → single layer "

(*) Rigid / Concrete Pavement.

(*) Flexible Pavement →
- Interlocking, Cohesion, friction
- Stress distribution
- localized load; weakly bonded aggregate can punch

(*) Rigid Pavement →
- One layer takes stress concentration
- Integrated structure.
- no punching.
- no localized influence
- deflection mechanism is slab mechanism

(Q) contrast bet" rigid & Flexible Pavement.

(*) Flexible pavement is very much sensitive to ~~support~~ subgrade condition. There should be uniform ~~support~~ subgrade. Subgrade weakness is reflected on surface.

* Sensitivity of Rigid pavement depends on concrete quality. Subgrade condition does not matter here.
* Rigid Pavement has optional intermediate layers. If soil is not good, then instead of increasing slab thickness, can introduce intermediate layer.

Terms of Concrete Pavement:

- Bottom layer is to be kept spread 1 to 1.5 ft. Optional layer width is wider than topmost concrete layer.
- Panel by Panel construction
  There is 100% seperation in betⁿ two panels as during construction, there was formwork (wooden)
- Transverse & longitudinal joint
- Crowning → centre is higher than 2 outer edges.
- Weakness: If joint opens, water will enter inside & weakens foundation. So, tie bar reinf. is use. Joint fails; not concrete pavement.

- Tie bar → tightly keeps 2 adjacent panels longitudinally
  → deformed bar ; embedded in concrete
- 3 loadings of slab
  i) Centre loading (good)
  ii) Edge " (vulnerable) → like cantilever deformation
  iii) Corner "

- Dowel bar → In transverse direction
  → ~~32~~ starts from 32 mm size
  → round bar. so that
  ~~no~~ bonding in concrete
  → grease, epoxy coating given so that concrete won't come in contact with it.
  → it floats in concrete ; it doesn't obstruct actions of concrete.

(Tension → $\frac{1}{10}$ of compression) → Concrete

Arch, Col^{m} → compression member → Romans used it.

Masonry → without reinforcement
→ brick, mortar

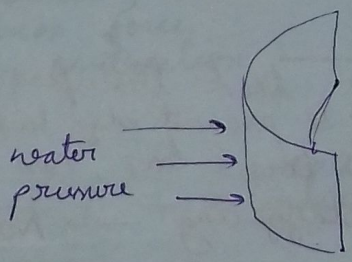
Rod → swells 3 times its dia in contact with water.

Roman design → not economical but philosophically excelled.

Philosophical difference → our structures have tension.
Roman structures had compression.

Dams → Crescent Shaped

because if convex, then gets water tight with pressure from load of water.



- but, side should be properly anchored.

F.R Khan → he didn't do much analysis; but he could feel for structures.

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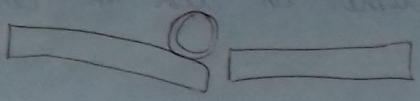
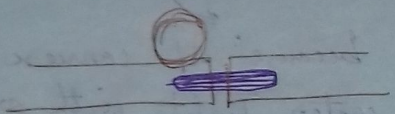


Clear water enters but turbid water comes out, bringing fine materials with it. Pore pressure developed. Loss of material. Tension crack is developed at joint.

So, have to give rod at joint.



The dowel is thick so that no shearing occurs

Dowel bar → load transferring device
→ to prevent edge loading action

Instead of Dowel bar, can skew, can do staggering → Non dowel joint

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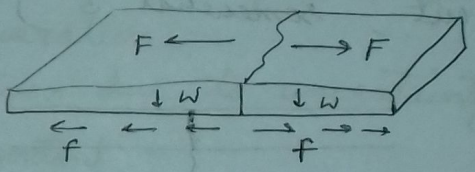
Length → more in longitudinal direction
Crack → in short direction
} Rectangular Panels of Rigid Pavement

Riding comfort increases is less joint.

Transverse crack → develops dispersedly.

● Soil Structure Interaction

Friction develops



Tension force is created & since concrete is weak in tension, crack is developed which releases tension force.

Induced by contraction → as much contraction was resisted, that much crack

If compression force is induced → due to change of shape → buckling occurs in upper direction.

→ becomes inclined & crack is developed while resisting expansion.

→ due to change of size

→ at high temperature (blow up → thus swelling)

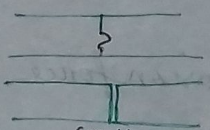
- We want dispersed crack

Regular joint is created using rod at joints. So, crack moves below and looks good. So, at top, people will see a line; not crack.

Man made Contraction Joint.

A predefined crack is produced which looks like a joint from above. (A little bit is cut; somewhat 3")

- Aggregate Interlocking Transfer Mechanism.
- Upto now, was contraction joint (a weak joint is deliberately created)
- i) Contraction Joint
  ii) Construction Joint
  iii) Expansion Joint
  iv) Isolation Joint



(100% seperation; dowel bar is mandatory)

- In construction Joint → load is not transferred by Aggregate Interlocking Dowel bar is used for load transfer.

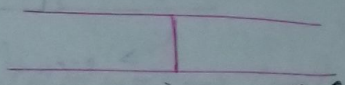
Aggregate interlocking is desirable.

- Construction joint is used because as there is discontinuity in work, constructing seperate panel & giving construction joint is suitable.

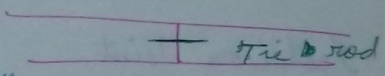
For ~~Dowel bar~~, Construction joint, Tie bar & Dowel bars are used.

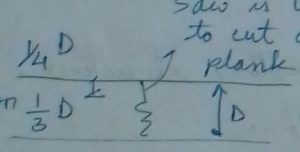
Construction joint is a planned joint. There is 100% seperation.
It is also given due to uncertainty.

Drawing is important:



give 1 straight line at middle - May give a tie rod at middle





(Thus section is made weak) → This is induced crack; not deliberate).

Expansion Joint:

Used in road; not in airport.

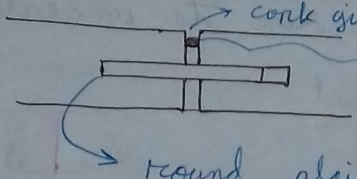
Dowel bar → Load Transferring device.

→ Must give a gap at the end of Dowel bar

→ round, plain & lubricated dowel bar with epony resin and cap.

→ a stopper on cap is used at the end.

→ no bond with concrete will be created.

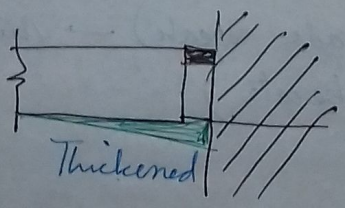


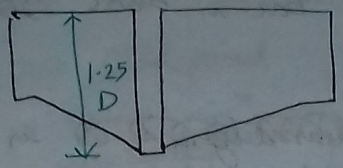
round, plain & lubricated dowel bar with epony resin & cap (write these.

Isolation Joint:

If a road end with another structure.

Can't use dowel bar here.





Q Drawing the joints comes in exam.

Formwise 2 types of Joints

i) key joint (not vertical) → a void is created

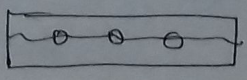
ii) Butt joint (vertical joint)

Chair is used to place dowel bar → Contraction Joint.
(on inserter or drilling)

Plank used to place dowel bar (tie bar) → Construction Joint.
(Formwork)
(Inserter is also used)
(Can also do drilling)

Contraction Joint & Construction Joint → VVI

- Contraction Joint → tension crack
  → dowel bar is coated with epoxy, grease etc. (no sticking on bonding with concrete).
  → dowel bar should not tilt in any direction.
- splitted formwork is used.



Sometimes, tie bar is bent 90° and later made straight.

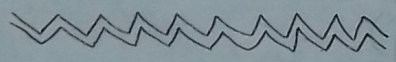
Coupler → ~~attended is~~ is also used.

Expansion joint → blow up

Faulty Expansion Joint.

(Compression is being released here by blow up).

Teeth Joint:



Expansion is allowed in long direction only.

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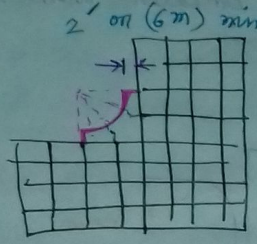
Aspect ratio must not be >1.25

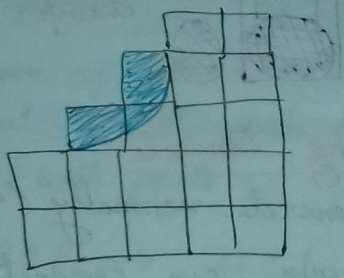
>1.25 → Odd panel

#



have to meet at 90° with radius

end point won't be sharp.

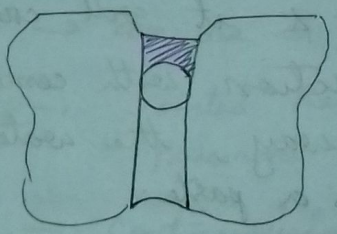


Joint Sealing

Concrete pavement fails at joint ; not at middle.

Joint has to be water proof or leak proof.

Q Draw Joint delail for sealing purpose.



can't flash with surface.

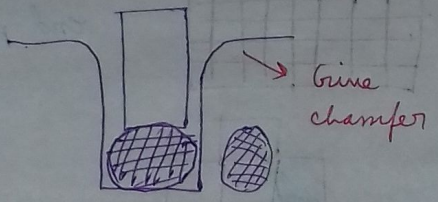
There will be lower meniscus ; not upper meniscus.

May use stopper

Q Show the procedure of sealing construction, expansion & contraction joint.

Oval shape indicates → it is in a tight condition.

Diameter should be greater than the reservoir dia.



Roller Compacting Concrete:

Can't compact concrete normally (wet mix)
In case of dry mix, can compact concrete.
Water is present in microscopic ~~bag~~ level.
No water given. With compaction, water will come out & it will create exothermic reaction with cement. When roller moves away, the water will return back as a paste.

Porous Concrete:

Deliberately made porous; in general concrete is impervious.
This is given when needed for drainage purpose.

Joints are given to reduce weathering effect, to control crack & to allow pavement movements.

Crack can be controlled by giving more joint but at the cost of riding quality.

(6) What are the ways of inserting dowel bar in concrete panel?

In case of sawed contraction joint, can avoid dowel bar as parts of cracks are shared by both parts.

JPCP → Jointed Plain Concrete Pavements.
- → panel length < 6 m or 20'
- → riding quality is being compromised
- → can use in residential area.

JRCP → Jointed Reinforcement Concrete Pavements.

CRCP → Continuously Reinforced Concrete Pavement.
- → L > 15 m or 50'

VVI

Comparison Between Flexible & Rigid Pavements

(will definitely come in exam)

↳ Multilayer pavement : Flexible
Single layered : Rigid

↳ Flexible : each layer carries some load using aggregate interlocking & friction. Aggregate carries load.

Rigid : (Single entity → Slab carries load in bending action.

↳ Aggregate Type & Requirement (most important in Bd perspective)

Flexible → more aggregate requirement (50% more than rigid)
(comes from Jaflong of Sylhet. there is high transportation cost)

Rigid → less aggregate required.

CT → next week

↳ Single is round small stone
Can't use it in Flexible pavement as it won't create interlocking. In Flexible pavement, load transfers by interlocking.
Can use single in Rigid.
Aggregate type is not so sensitive in case of Rigid.
∴ Concrete pavement is more desirable for our country.

↳ Concrete pavement → high modulus of elasticity
Flexible → low

↳ Mode of Failure:
Flexible: Rutting, Fatigue, Shear
Rigid: Fatigue, Temperature Cracks,

↳ Advantages:
Rigid → Offer stage construction (most important in perspective of BD as due to finance, construction is done in different stages).
→ like Bandage; patching work easier.
Concrete → no patching work.

दाँत : a wood plank is used to strike on concrete.
A ridge like pattern created.
It is a skill based work.
If thickness mentioned, workers can create ridge of that thickness.

Utility line → needed for urban areas
→ not done at same time
→ never recommend rigid pavement in urban area as can't cut road.
→ rigid pavement is for rural areas.

Can open for traffic immediately in case of flexible.
But in case of rigid, have to do curing for 14 days before opening.
So, in busy roads, can't use rigid

3R → Reduce, Reuse, Recycle
→ Flexible is easier to Recycle compared to Rigid.

Submerged Condition:

Our drainage system is not good; Tropical country
water logging.

Aggregate & bitumen

Bitumen coating is stripped off by water.

Bitumin is sensitive to moisture.

Water → enemy for flexible
→ friend for concrete.

For maximum utilization of resources, where water logs, must not give bitumen; must give concrete pavement.

Equipment Involvement:

- If aggregate superheated & bitumen is underheated, then binder will segregate.

So, aggregate & bitumen must be at same temperature. (Its a must).

While transporting, heat is lost & bitumen may set and then its porosity will decrease & will behave

like sponge.
So, after transportation, use a thermometer to check if temp. ok; otherwise discard the bitumen.

no roller needed for concrete pavement
Here, w/c ratio is very very important.
Curing is another compliance for concrete pavement.

• Competent, Sincere, Honest → person is needed in our country

Environmental impact is very high in case of ~~rigid~~ flexible pavement (pollutes a lot)
Professional Contractor needed.

Concrete pavement work is much easier.
Only, water-cement ratio and curing are to be done under expert supervision.

Concrete pavement is so better for narrow or low standard road.

27 page → compliances for bituminous pavement.

Concrete pavement is safer than bituminous pavement in respect of lighting or energy consumption ~~view~~ view.
Concrete reflects light more as it is fair color.

Concrete pavement is safer when hard break is to be applied.
Bituminous → less gripping; may skid in it; min^m stopping distance is more than concrete; texture is easily lost; gets polished with time; Rain water works as lubricant.

More carpeting required for bituminous pavement (more aggregate required).

Concrete pavement saves 20% fuel.

Inherent weakness of concrete pavement is it is difficult to lay utility line.

Bituminous pavement absorbs both light & heat & its temp. is at least 10° higher than ambient temp. So, at junction, where queue is formed should not keep bituminous pavement as it will be very hot.

Less equipments needed for Concrete Cylinders are needed to form for Quality control of concrete pavement.

For bituminous pavement, temp. check needed for quality concrete.

Where extra performance needed, use concrete pavement at those parts → like toll plaza, bus stop, junction etc.

Bituminous pavement can't take shear, it can take compression.

In remote areas (borders) use concrete pavement.

May give concrete under wheel path & middle is made green.

For Bituminous pavement, extra width at side is needed; can't keep vertical. But can do give vertical for concrete pavement.

CT Syllabus

- Rigid Pavement
- Differentiate bet^{n} Flexible & Rigid Pavement.

10-04-16

(6)

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Flexible Pavement

Direct load → wheel
Indirect load → weather.

Black top → one layer
Other layers → another layer } 2 layers.

If stiffness of 2 layers are equal, stress diminishes with increasing depth from top. But in reality, Black top has much more stiffness ($E_1 >> E_2$) than bottom layers.

If load applied on flexible things, it bulges at side.

This was for horizontal stress.

Deflection:

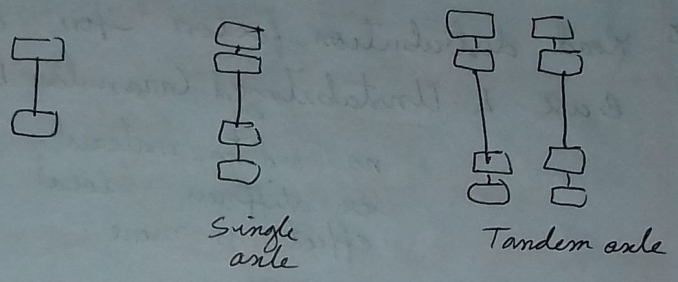
With increasing distance, deflection becomes horizontal.

Concave → Compression zone.
convex → Tension zone.

A reverse curve at transition depelops a tension curve & hairline crack is

developed & it fills & again develops when load comes.

- Semi-Trailer Truck:



more damage as closely spaced

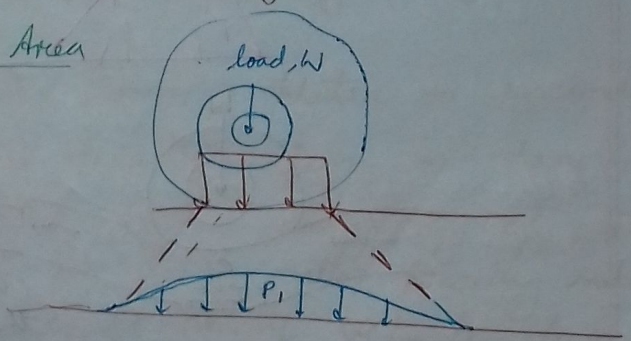
- Mechanism: Interlocking & Inter granular Friction

Due to rough surface, shear is developed.

- Load distributes in soil as Pressure bulb

With depth, intensity decreases.

- Influence Area



1 load factor for single wheel.
Other load factors for multiple wheel.
" " " tandem etc.

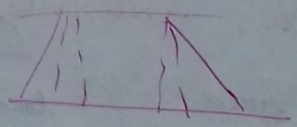
Load distribution factor for (Cement-Treated Base & Unstabilized Granular Base.

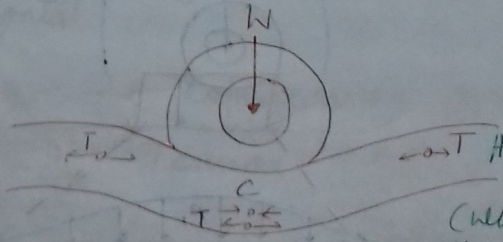
Unstabilized → no bonding material, less stiffness, local effect is more.

Cement-Treated → not used much

Aging reduces ductility
When aggregate to aggregate bond decrease, then all don't participate in load carrying and load transfer becomes more local.
So, small footprint of load distribution.

(2) Draw load distribution pattern for initial, intermediate & final state





Hair crack because of tension.
(When wheel comes here then compression comes here)

Water comes out of crack when compression comes with high speed. As a result, bonding bet^{n} aggregate breaks.
So, clogging water is bad.
Besides, water also give Buoyancy force.
More water, more buoyancy.
The water in fig is Flood water.
There is ~~occur~~ current called action of ~~running~~ running water.
Individual aggregate present but no pavement.
There won't be any black top
Aggregate → wash out
Bitumen → strip off
Due to successive tension - compression, pore water pressure etc.
↳ Have to improve drainage system to prevent this
↳ Even if water clogs. Water is secondary. Main ~~water~~ disintegration is done by heavy wheel load. Buoyancy of water only works on loose matter. During submergence have to prevent heavy vehicle from moving on flexible pavement.

If truck is loaded more at vertical direction, then C.G. moves up and if a little tilted, it falls under the action of gravity.

- Rigid pavement damage is from weathering effect; not from wheel load.

Soil-Structure Interaction:

When shape changes:

In contraction, tension force is induced

In expansion, compression force is induced (contraction)

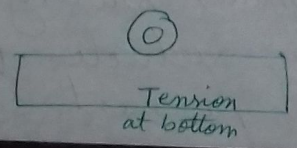
Frictional Force is developed by weight

If polythene sheet given, then slip will occur; no crack → non-restrained

Or may make smooth so that no friction developed.

Before sunset → Convex

After sunset → Before sunrise → cool / warm → Concave



Curling & warping is resisted by Thickness (increase it)

When uniform temperature → to resist → give joint spacing

Wheel load → Thickness
Weather action → Joint Spacing
If don't want to give much joint → Give Reinforcement

Design Principle (Rigid Pavement)

Critical condition of loading for Rigid Pavement:

- Corner loading
- Edge loading (cantilever action)
- Middle loading (safer) (slab action)

For long Lasting Pavement:

- Have to do strengthening
- Vulnerable sections have to be thickened (edge thickening)

→ Corner & edge (15") and middle (12")
→ won't become cantilever anymore.
→ For edge thickening, have to make trench while construction to thicken

peripheral thickening.

Q How to handle corner & edge loading?

→ have to adopth edge thickening.

24.04.16

Shamsul Hoque Sir

Pavement Distress

Flexible Pavement

Common mode of distresses:

(1) Fatigue (Alligator) Cracking.
- Repetitive in nature
- Induced by fatigue
- Interconnected block of crack.
- Bearing capacity decreases if water enters.
- Can't have high speed.
- At small cracks, → patch work (small bandage)
- " big " → overlay or carpeting.

Possible causes: ↳ irregular compaction
↳ bottom up or classical fatigue cracking (initiates at bottom as surface condition is weak at bottom).

(2) Bleeding:
- Thin film of excessive bitumen becomes visible
- In summer time, pavement is squeezed & bitumen comes up as paste in top.
- After bleeding, crack develops.
- 100% void should not be filled with aggregate; 4% of total mix should be kept as void.

Excess bitumen comes up at summer time.
Looks glossy. We can use sand (spray sand) in this case; then bruises will return.
If more glossy, then special vehicle with heater is used (technology based solution)
Mechanical Grader can also be used (ploughed)

(3) Block Cracking:

Bigger cracks of rectangular size.
If Finer material is more than coarse material, then this type of crack develops.
Should seal these cracks.
High pressure blower is used to clean.
If too big crack, then can use total over lay instead of joint sol^n

(4) Corrugation & Shoving:

Problem → no riding quality, more noise, more impact load.
Type → ridge, valley
Reason → if unstable pavement; if round aggregate is used; if compaction was not adequate

⑤ Depression

Some part subsides; local ponding occurs; Bitumen of that place oxidizes (age hardening).

* Those who eat more, take more oxygen & becomes old quickly.

for Adhoora, Emamee, Ripa, Rumpa

* Hydro planing → contact bet^n tyre & pavement is lost.

* Remove → dig → correct layer → compact again → patch work.

⑥ Joint Reflection Cracking

If Bituminous pavement is given on concrete pavement.

Cracks caused by weather are random

Concrete expands & contracts more compared to bituminous pavement.

Joint reflection comes up.

Have to seal.

As a preventive measure, concrete joints are stitched by polymers → Preventive maintenance technique.

⑦ Longitudinal Cracking:
not 100%. monolithic betⁿ old & new construction.
weakest point is where 2 structures overlap
Planar → a purpose built truck with heater at bottom (Infrared device)
To make monolithic, can fuse by heating
Tack coat → self adhesive glue.
These involve cost.

⑧ Patching
Not a mode of distress
After repair work, subsides (depressed)

⑨ Polished Aggregate:
- Slippery; hazardous issue in accident point of view; not structural problem
- Repair ~~techno~~ technique is to give slurry
- BST (Bituminous Surface Treatment)
DBST (Double " ")

⑩ Potholes:
mainly happens after rainy season.
1st allegated crack is formed; if bigger wheel load comes, a chunk may come off;

1 aggregate if moved, 4 aggregates are exposed

Occurs in Rainy season

Can't repair with water in pothole.

Even if water removed, can repair as water has already moved deeper.

Best convenient time of repair is winter season.

After winter comes, 1 or 2 months are waited before carpeting.

(11) Raveling:

At some points, there will be loss of aggregate from pavement surface.

Reason → aggregate ~~segregation~~ segregation

→ binder holds aggregate & prerequisite is aggregate must be clean before coating.

We need ——→ Healthy. Angular, Well graded aggregate

——→ have to wash properly so that no dust otherwise, coating will be on dust; not aggregate.

(12) Rutting :
↳ post consolidation
↳ more visible in western countries
↳ occurs in case of disciplined and guided traffic.
↳ hydroplaning happens if more depression

(13) Slippage Cracking
↳ torn out
↳ signature footprint is Crescent shape

(14) Stripping
↳ allegated crack but comes eventually (final stage).
↳ crack moves bottom to top.
↳ stripping means removing away bitumen by water due to affinity.
↳ probability is more in summer.

(15) Transverse (Thermal) Cracking
↳ not in our country
Upheaval created
Water molecules try to swell up
Probability of expansion

⑯ Water Bleeding and Pumping.

Water from bottom comes up due to difference in wheel load.

Correction → retaining wall may be given to cut of seepage (very expensive)

- Repair Techniques

Fog seals (not structural)

Slurry seals (emulsion + water + well graded aggregate + mineral ~~@~~ filler.

Micro-surfacing (Bitumen is very low cost binder; performance is worst at 2 ~~cases~~ conditions of extreme weather. Polymer is needed sometimes; a bit costly; Polymer works as additive for long lasting)

Crack Sealing (looks bad; not pleasant or soothing aesthetically).

Crack means came in equilibrium → good.

- Patch work Step: Cause oriented treatment Whatever may be the shape of distress, have to be removed as rectangular block (50% more volume)

Final finishing by roller.
At bottom, rammer or vibration is used.

(*) Must be in rectangular section.

(*) At least 50% greater; have to cover affected & influenced area.

(*) For Rigid Pavement – mode of distress, study by yourself.
- blow up
- corner loading
- edge loading.

CT → on distress of Bituminous & Flexible pavement
→ study those common for Bangladesh (specially)
→ reasons may come.
→ next week.
→ sir will take 3 CT

(*) A1 CT → Fatigue, Bleeding, Common distress in Bd, name of distress in rigid & flexible, Cause & Problem of distress, How to repair, sol".

(*) Q → Common mode of distress, Fatigue Cracking, Bleeding, Shrinkage Crack, Ravelling, Alligator, Rutting, Reflection, Corrugation & shoving,

10.05.16

(8)

Shamsul Hoque Sir

AASHTO Road Test

Loops : For both flexible & rigid pavement.

AASHO Test

Fig-2

Major Technical Findings of The AASHO Road Test

(Highlighted)

no need to study in detail.

(*) performance is defined as - - - unserviceable level

(*) Load Equivalency / Damage Factor

ESASs

(*) PSI: Performance / Serviceability Concept

PSI

International Roughness Index (IRI)

PSI & IRI are inversely related to one another

(*) Structural NO. Concept

(*) Value of Subbase to Reduce Pumping in Rigid Pavement:

Each layer is converted to a no.

(*) Effectiveness of Dowels for Load transfer

(x) Joint Spacing

(Just Read the headlines)

Limitations (Study) of the AASHO Road Test Findings:

Study the Objectives of AASHO test.

Pavement Design

↳ Mainly semi-empirical in nature

↳ Analytical part comes from AASHO Test.

Type of Pavements

Objectives of Structural Design of Pavements

Performance (life cycle) of pavement depends upon

Design considerations

Pavement Design consists of

Why structural design of pavement is a complex one?

Thickness → structural design

Material for providing thickness → Mix design

(*) Road is a heavy duty env. unlike bldg.

(*) Factor of Safety is factor of Ignorance

Pavement Design Guide for Roads & Highways Department

↳ nomograph based ; can be challenged

↳ Table 1: Required CBR for Pavement layers

Ground improvement by replacement method

For sustainability & durability, along with having bearing capacity, have to arrest settlement.
Settlement potential is to be examined by 'Boring test'.

Table 5: (Nomochart) Thickness Design Table for Flexible Pavements.
Traffic → in the form of load for design year
Should understand this table properly; might be given in exam.

- Can address upto 60 million load
- For 14 million, WC of ashphalt (in 2 layers for proper compaction) is 40+90=130
- Either Base course type I or Type II or Cement bound granular can be used.
- For base type II, 250
- Sub-base → depends on soil condition. Have to interpolate. In our country, usually not more than 5
- Improved Subgrade is to be done if CBR requirement of 5% is not fulfilled.
- For Subgrade → Table 6
- Table 3: Vehicle Equivalence factors.
- Road should be designed for large bus. small truck 18k is standard. Large Truck → 4-8 ESA
- Compound interest → for future forecast.
- Table 2: Pavement Design & Life & Traffic growth rates.

- Cumulative ESA $= \frac{(1+r)^n - 1}{r}$

  r = annual traffic growth rate
  n = design life in years

(OR)

National Road	57.3
Regional Road	41.0

(memorize)

(Math)

Design:

While designing, design for 1 direction is done but sample collected for both directions.

- If 2 direction data given, multiply with $\frac{1}{2}$
- Compound factor: either memorize or use eqn
- Use Nomochart.
- Improved Sub-grade from Table 6

(*) Next Class → won't take place.

Catalogue Method

Catalogue for Pavement Type 1

- T → Traffic
- S → Subgrade (bearing capacity)
- A matrix
- Design is already given
- Very effective & simple method

(Q) What is the beauty of Catalogue method.

↳ different designs, costings are given (Rate of Schedule)

05.16

Shamsul Hoque Sir

- Rigid Pavement.

→ PCA method (Portland Cement Association)

PCA Thickness Design Method

↳ Fatigue Failure

↳ Erosion Failure

➤ Main concept of Erosion analysis → every load generates tension in pavement & compression in subgrade.

➤ Slab can deflect & impact the soil.

➤ A trial thickness is assumed.
If 50% damage comes, it means overdesign.
Cumulative damage % 300% → underdesign.
no need to trial more, rather change thickness.

➤ In Concrete pavement design, Modulus of Subgrade Reaction (k → pci → psi/inch) is needed, not CBR value.
Modulus of Rupture is strength characteristics of concrete to be used.

We'll design only for Truck. We don't want volume (as geometrical design is not needed).
We'll be doing structural design

- Axle load spectrum is used.
- 2 tables
  - ↳ Treated Subbase
  - ↳ Untreated Subbase
- Design Truck Volume (correct it in sheet)
  - $V = 365\ (ADT)(T)(D)(L)(G)(Y$

- Pavement design is done in full scenario
  - ↳ Lane distribution factor for wandering.
    - $G = (1+r)^{1/2}$
  - ↳ 2 closely spaced axle with group action is called tandem axle

- Based on Miner's Hypothesis,

$$D = \sum_i \frac{n_i}{N_i} \leq 1$$

(n_i: actual, N_i: factual)

Example (1)

4" untreated subbase → modified $k = 130$

Doweled Asphalt Shoulder (not concrete)
- → lateral confinement
- → better design
- → costly

- L is found from graph
- 52 → static load → can't use it

For getting dynamic load (it has impact) →
multiplied by 1.2 (Load safety Factor)

- Always start with max^m.
  More load → more damage.

Axle Load kips : 30
LSF : 1.2

Fatigue Analysis
Erosion

↳ Single axle
↳ Tandem axle

Equivalent Stress Table → for S.
Stress ratio if known, allowable repitition will be known

no concrete shoulder will be used.
In Table, Tandem axle → 2nd row.
Enter table using k.
Assume a trial thickness (Let 9.5")
Interpolate.

Stress Ratio Factor = $\frac{\text{Equiv. Stress}}{MR}$

- Use Nomochart → Stress ratio & load magnitude are needed
- Pivotal point is at same position.
- When line goes out of graph, write - 'This load cannot create damage'.
- For Tandem, 1st one is already greater So, the 2nd one will be unlimited
- Total Fatigue contribution = 62.9

Erosion factor → doweled, not doweled (2 parameter)

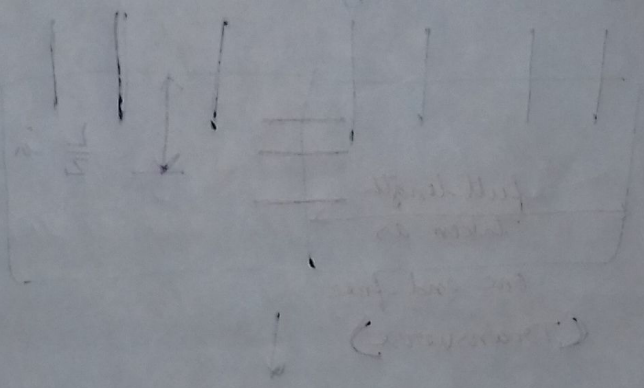
Here, pivotal line is vertical
For fatigue, " was inclined

Can consider any thickness. Sir will observe what type of comments we write. Marks will depend on the comments.

The empirical knowledge of this method came from USA; yet we'll use this.
Load spectrum might be given in chart (graph) or Table.

- Do 2nd math also.
  It becomes easier if programming is done.

Next class: Design calc. by Catalog Method.
Reinf. calc. of rigid pavement.



9.05.16

(10)

Shamsul Hoque Sir

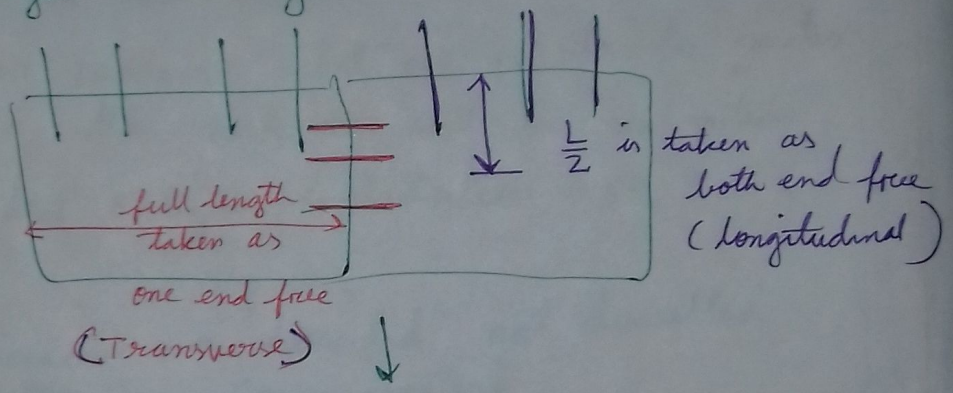
Reinforcement Details of Rigid Pavement

Calculation of Temperature Reinf:

$$A_s = \frac{Wf}{f_s} L$$

f, W, f → constant.

Length will change.



Math Draw reinf & joint details.

Contraction joint → predefined → saw cut
→ weakest plane
→ crack means tension is developed.

Less dowel bars in contraction joint
More " " Expansion " (less spacing and more length)

Distributed Temp- Reinf.

Here, # 4 bar is use. Can also use # 3

Tie bars:

Bigger size used.

Length of tie bar: if bigger size is used, more bonding

27.11 in on 2 ft c/c → correct in sheet.

✓ ×

- Transverse joint → 100% seperate.
- See the table in 121 page
- dowel bar → industry standard at manufacturing is 2"
  - → it takes shear.
  - → no design (tie bar needs designing)

Fig → correct: 39 slide no.

5(16 mm)@ 36" (900 mm) c/c → correct.

Both plan & side view.

1993 AASHTO Flexible Pavement Structural Design

(slide : 4)

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.52 \times \log_{10}(M_R) - 8.07$$

PSI ⟶ Initial Serviceability
(Deteriorated) Terminal Serviceability

M_R → modulus of resilience

We'll get SN (structural No.)

SN → an indicative no.
→ converted to thickness

Layer Concept of Structural Design

a_1 → layer coeff.

$$D_1 \geq \frac{SN_1}{a_1}$$

SN → from nomograph → 5 lines (of which 2 are pivotal lines)

- $\Delta PSI \rightarrow (IS - TS)$

Example 1 > Design example

Determine ESAL for following axle load distribution Survey data.

↳ 1000 trucks
↳ one day both directions
↳ Pt = 2.5
↳ SN = 6.0 (assume) → Then check by Trial & error

Table 1

There is another method.
↳ no factor from Table

Q Why SN is assumed ?
to connect to axle before going to table

↳ After getting load, find thickness.
↳ 3 thickness
↳ layer coeff will be given
↳ Have to use Nomochart thrice for 3 SN.
↳ Nomograph: Probability → tilting point → 18 kip → 2nd pivotal line → MR value of soil base on subbase → ΔPSI same; MR different for 3 layers

- $a_1 D_1 = SN_1$ ← from nomograph; given

$$D_1 = \frac{SN_1}{a_1} = 7.88'' \approx 8''$$ (0.5" rounding)

- $a_1 D_1 + a_2 D_2 = SN_2$

use 8" not 7.88" (SN_1 will also change)

↳ $= 8''$

↳ $= 10.5''$

- Check:

$SN_3 \approx SN \approx$ assumed SN (Give a comment if this is not satisfied)

SN_3: Total thickness on soil; SN: total SN

↳ ESAD & Design ⟶ AASHTO (empirical)

▨ Catalog method calc → next class.

Always assumed, drainage layer = 1

If m is not 1:

$$\begin{cases} a_1 m_1 D_1 \geq SN_1 \\ a_1 m_1 D_1 + a_2 m_2 D_2 + a_3 m_3 D_3 \geq SN_3 \end{cases}$$