

Introduction to Civil Engineering Profession
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Lecture – 15
Scope for Highway Engineers in Civil Engineering Profession-2

(Refer Slide Time: 00:11)

DESIGN OF PAVEMENTS

- Flexible Pavements
- Rigid Pavements
- Composite Pavements

**Choice Of Pavements Based On Life
Cycle Cost Analysis**

32

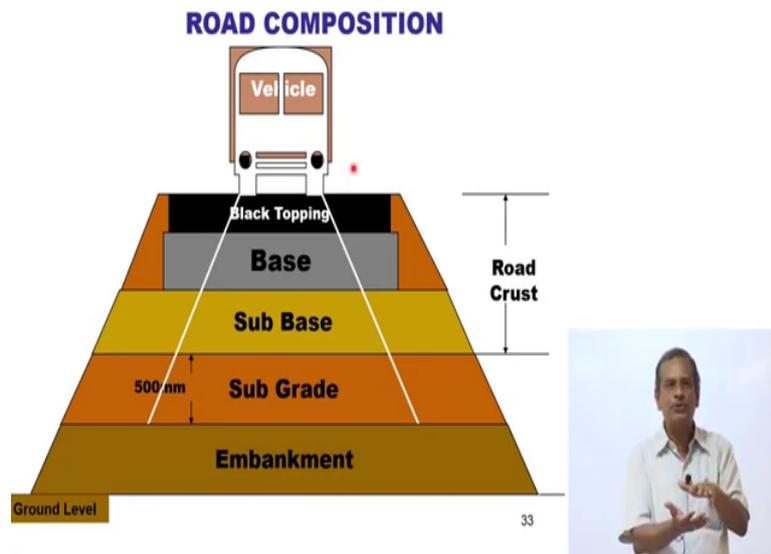


We found that there are about 54 lakh kilometers or 5.4 million kilometers of roads in the country. The national highways contribute only to 1.2 lakh kilometers less than 2 percent of the country's road network, but carry nearly 40 percent of the traffic. Majorities of the roads in the country are rural roads low volume roads. So, the challenge before us is whether they invest the money to provide a connectivity to a low volume roads connecting the villages or use the money for national highways.

So, when you want to decide these roads as I was questioning in the last class, the major problem that we face is non-availability of materials or construction in the country today. So, there are different choices for you to construct the pavements. So, one is we have flexible pavements or bituminous pavement; second is a concrete pavement or a rigid pavement; third is a composite pavement. I will take you over what are these types what is the load carrying mechanism and how they are effective in in constructing a sustainable road infrastructure in the country.

The issue at this point of time is that I can spend less initially, but spend more on maintenance later vis-a-vis spending more initially and spending less on maintenance subsequently. So, which is the lowest in terms of life cycle cost? So, lifecycle is a value is a parameter that we consider for a period of 20 years, 25 years, 30 years which of those road way components or a type of pavement will result in the lowest life cycle cost is something that we need to talk about.

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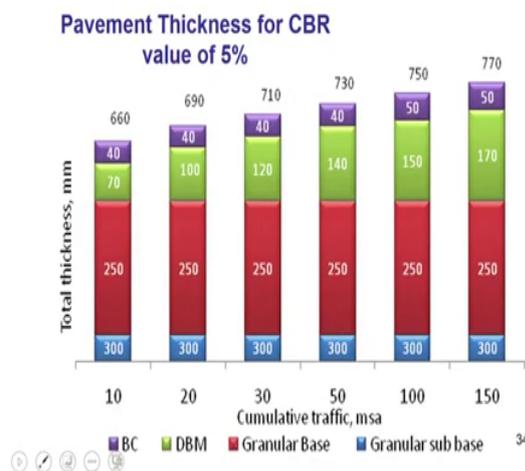
What we saw in the last class was that conventionally a bituminous pavement will consist of different layers. It can be in filling or it can be in cutting, it has got an embankment on which the entire load is to be carried. The sub grade is the lowest layer which consists of soil. Normally for national highways the thickness of the sub grade is around 500 millimeters, for rural roads it is around 300 millimeters.

So, this is the layer soil layer system, we support the entire load that is coming on the pavement. What you are seeing on top is only the black top, but what has been buried below is the bituminous black top, a base course, a sub base course, and a sub grade. So, out of this the bituminous layer thickness is less, maybe around 150 millimeters and 200 millimeters, but that will cost nearly 40 percent of the total pavement layer cost.

So, if you want to reduce the material consumption then what are the options before us? So, the thickness of the pavement layers what I means what do you see here at the sub base, base course, binder course and a wearing course that depends upon the strength or the sub grade soil. If sub grade is weak, traffic is high, then thickness of a pavement layer is large. If the sub grade is strong then the thickness of the pavement can be reduced significantly.

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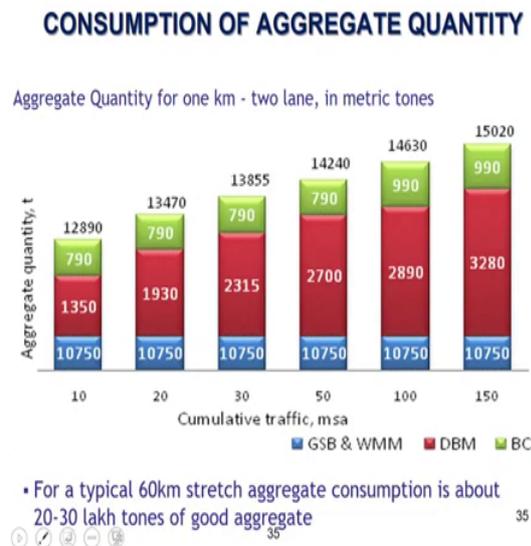
CONVENTIONAL PAVEMENT DESIGN – IRC37



As can be seen in the last class we saw that if the sub grades strength is for example, 5 percent is the strength of sub grade quantified in terms of CBR which is a California Bearing Ratio. So that is the parameter that we consider for the design of the pavement. If sub grade CBR is 5 percent the traffic is around 150 million standard axles, the thickness of pavement is of the order of 77 centimeters here sub grade strength is not 5 it is 4, 3, 2 then thickness will go up to even 1000 millimeters. So, weaker the sub grade, higher the traffic, thicker is the pavement.

Out of this the bituminous layer is around maybe 220 millimeters, we have got 250 millimeters of a granular layer and about sub base layer of 300 millimeters. So, how do I reduce the material consumption is the first challenge before you when you graduate.

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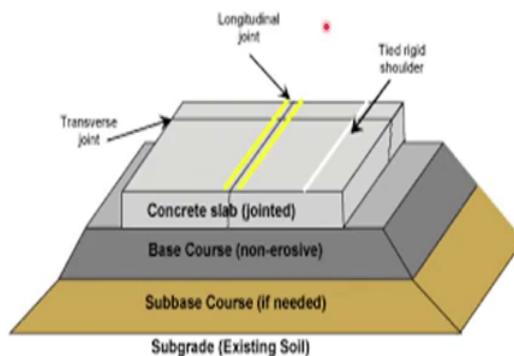
So, how much material do we require for constructing these roads? For construct of a typical 60 kilometer of a road stretch, I require about 20 to 30 lakh tons of good aggregates. I will come to the issue of sustainability in due course, but remember for constructing 1 kilometer of a two lane road I require nearly 15020 metric tons of aggregates.

Now when you have 1 lakh 20000 kilometer of national highways you can compute how much material do we require when you convert your single lane into a 2-lane, 2-lane into a 4-lane or

a 6-lane or a 8-lane huge quantity of materials are required, but we do not have good quality aggregates. So, how do we construct sustainable long large pavements is the first challenge.

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CONCRETE PAVEMENTS



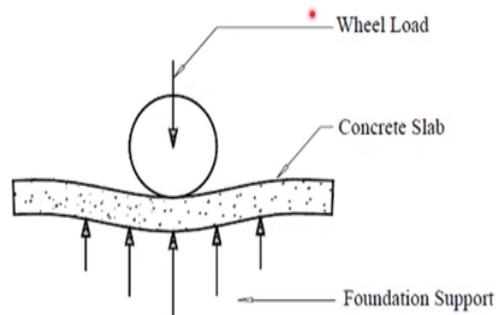
36



So, here again comes I can go in for a concrete pavement. So, in the case of a bituminous pavements the road is taken up by the entire all the pavement layers. So, I require a thicker layer if you want to distribute the load to a the subgrade level so that the pavement does not fail prematurely. Alternatively, I can go in for a concrete pavement. The concrete pavement take up the load by the slab action that are it can be seen here there are consist of different layers again. The concrete pavement takes up the load by a slab action.

(Refer Slide Time: 05:19)

TRANSFER OF WHEEL LOAD TO FOUNDATION IN RIGID PAVEMENT STRUCTURE



37



So, even if the weak sub grade is weak, I can provide a ready layer and reduce the thickness of the pavement layers. So, I need only one layer of concretes maybe over a base course. So, total thickness of the pavement is much much lesser. This concrete pavement will last for 30 years without major maintenance, but initial cost is higher than a conventional bituminous pavement.

So, as I was mentioning earlier should you spend more initially and spend less subsequently or spend less initially, but spend more subsequently. But, as you can be seen the quantity of material require in a bituminous is huge, the quantity of material required for concrete pavement is less. So, one way of reducing the grade consumption is by construct considering alternate materials in construction in the construction like a concrete pavement where the load is taken up by the slab action.

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MATERIALS

□ Road development programmes in India require **150 million cu.m of aggregate per annum** - Environment Problem.

□ NHDP Project of **60 km** road improvement requires **20 Lakh tonne of material**. For a lead of **200 km** (which is common in North India) it will require **180,00,000 litre of diesel for transportation alone**

38



So as I was mentioning, we require about 150 million cubic meter of aggregates every year. If you go to northeast, you will not get a good quality aggregates at all for road construction. If you go to Andaman Nicobar islands, all the aggregates Andaman Nicobar will absorb the moisture the water absorption may be more than 2 percent, we permit up to 2 percents. If it absorbs more water, it will lose its load carrying capacity if it is use for bitumen construction the binder will strip off from the aggregates. So, you will find potholes, cracks and rutting failures.

So, if we require about 150 million cubic meters of aggregates one hand, other hand if you look at state like West Bengal where aggregates are not available you have to transport the aggregates from Bihar. If you have to transport the aggregates for over 260 kilometers about 20 lakh tones of material for over 200 kilometers I require nearly 180 lakh liters of diesel, on

one hand material non-availability, on other hand I had to transport the materials to a longer distances again it is not sustainable.

So, the question before us before you when you graduate will be how do I construct a pavements which will result in the lowest life cycle cost at the same time, we will also reduce less quantity of materials not only for initial construction, but this an life of 30 years.

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NEW MATERIALS & DESIGN

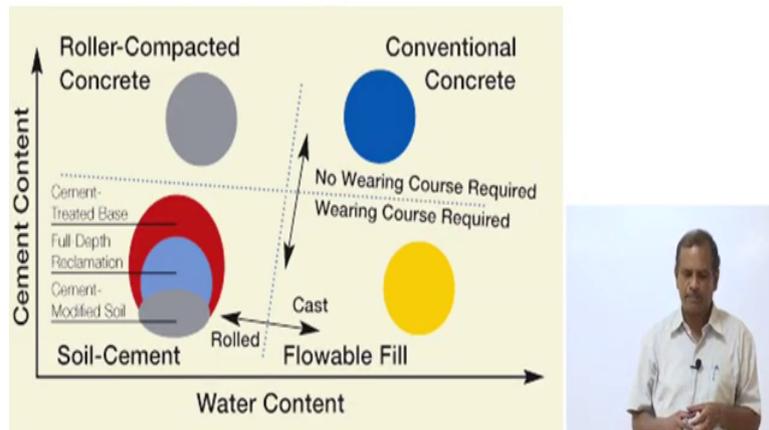
39



We will look at this. We have to introduce new materials when I want to introduce new materials in the design. How do I introduce these materials which will improve the performance, reduce the thickness of the pavement and reduce the cost is something that we have to talk about.

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CEMENT BASED PAVEMENT MATERIALS



So, one way of reducing the aggregate construction can be you can introduce cements. What I am talking about is that is sub grade is weak. As I was mentioning CBR of the sub grade is 2 percent 3 percent. Can I improve the strength of sub grade soil? Yes, you can do that. I can add cement to the soil, I can add lime to the soil I am try to modify the properties of soil, reduce the plasticity improves the less moisture induced damages. So, if I can improve the strength of the sub grade soil by stabilization, then I can use cement. So, that is called as soil cement layers.

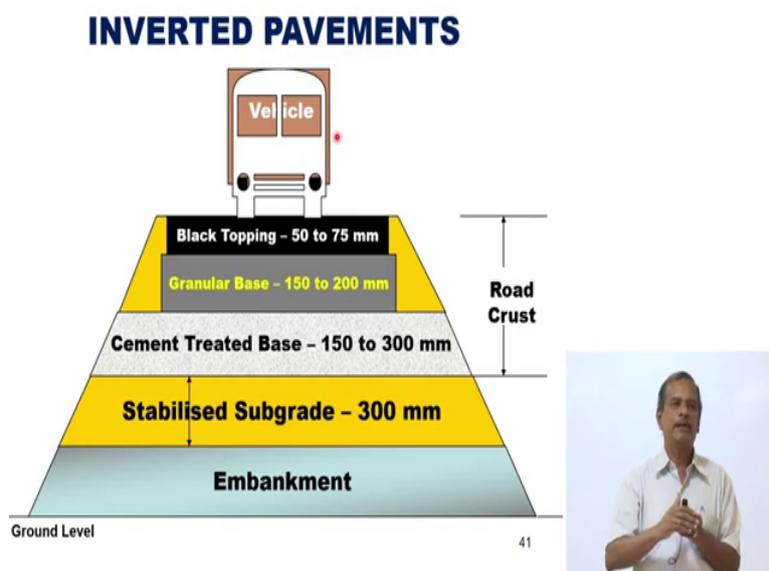
So, now, earlier what we were talking is that this is a strength of sub grade what should the thickness of the pavement? Now, I can tell you what strength do you need 5, 10, 15, 20 I can give I can try to modify the soil. Now, these soils are called as engineered soils. You can get what all strength you that you need. So, I can use a soil cement. So, if the cement content

becomes more I can also use a roller to compact the concrete to compact the pavement that is called as the roller compacted concrete.

You just see water content is more and if cement content is low, it cannot form your wearing course and the repeated applications of abrasion the concrete pavements so called concrete pavement will abrade. So, we need to provide a bituminous layer above that. On the other hand, if the cement content is more and the water content is also more, it is the conventional concrete pavement. If as I was mentioning about 77 centimeters thick bituminous layer, on the other hand if I have a concrete pavement the thickness of concrete pavements can reduce to as low as 300 millimeters.

I can have yeah hard shoulder or a concrete shoulder and I can reduce thickness even to 270 millimeters. From 770 I can bring down the thickness to less than 55 millimeters by having a concrete pavement. So, one way of contracting sustainable concrete pavement is by reducing the thickness, by stabilizing the pavement layers or by having improved materials in the lower layers.

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Alternatively I also go in for an inverted pavement. So, this is a third type of pavement that we have started adapting in the country today. What I am trying to do as an inverted pavement is that? In the conventional pavement when we talk as a bituminous pavement I have bituminous layer, a granular layer, a sub grade soil. The strength of the granular layer will be more than that of the soil. The strength of bituminous layer will be more than that of the granular layer. So, the strength will increase as you go from bottom to top.

Whereas, in the case of an inverted pavement above the blacktop I introduce the cement treated layer where a introduce a cement treated layer the thickness of bituminous layer can be drastically brought down. The aggregate (Refer Time: 10:37) can be drastically brought down. From 200 millimeter 170 millimeter I can bring down to 50 millimeter to 75 millimeters. Out of the 54 lakh kilometers or 5.4 million kilometers of roads in the country less than 1 lakh

20000 kilometers are national highway majority of the roads do not require such thick bituminous pavements.

I can go in for an inverted pavement with the cement treated base, I can introduce a granular base and a blacktop and you can reduce the thickness drastically to for example, 350 millimeters. So, this is the alternative that we have started adapting in the country today. Most of the pavement that we have constructed today have got a cement treated base. The recent one is the Amaravathi city being constructed. The entire network of roads that are being constructed in Amaravathi will have a cement treated base. So, that may be long lasting, sustainable with a thin bituminous layers.

So, the pavement conventionally can be a bituminous pavement, can be a concrete pavement, can be an inverted pavement. So, there are three choices. So, you have to now decide what pavement type will last longer depending upon the material availability, depending upon the traffic, climate, environmental factors you have to define the thickness of the pavement.

Now, as I was mentioning most of the roads projects that are taken up are under the category of build operate and transfer the concessional invest his money and construct the pavement. So, he would like to know which is the pavement type that he should select that will result in the longer life. So, as a high civil engineer you have to recommend to him this for this traffic, for this sub grade soil type, for this climatic condition this is the pavement type. You should be able to predict the performance and then tell that this type of pavement will result in the lowest life cycle cost.

Many many express ways have been taken up in the country today. Many airports are being renovated rehabilitated newly constructed. For example, a taxi way – your runway should it be flexible, should it be concrete, should it be compensate again only a civil engineer can tell what is the pavement type that will result in the lowest life cycle cost.

(Refer Slide Time: 12:55)

SOIL STABILIZATION

The soil stabilization means the improvement of stability or bearing power of the soil by the use of controlled compaction, proportioning and/or the addition of suitable admixture or stabilizers.

Basic Principles of Soil Stabilization....

- Evaluating the properties of given soil
- Deciding the lacking property of soil and choose
- Effective and economical method of soil stabilization
- Designing the Stabilized soil mix for intended stability and durability values



42

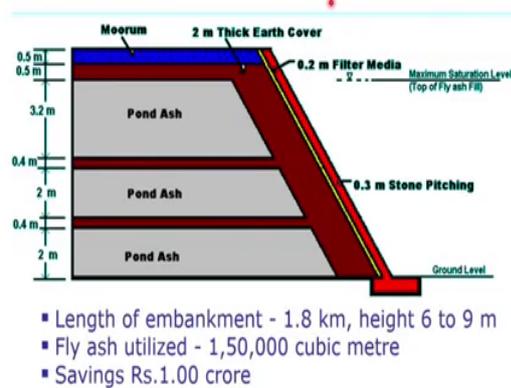
So, having seen about these inverter pavement we have to introduce soil stabilization. So, now, there are many many materials available to stabilize the sub grade soil. What I am try to do is you have want to find out what are the property of the sub grade soil which is available at the site, find out the missing properties or lacking properties it may be the swelling maybe more fines maybe more. So, if you find that the property lacking property I can try to modify the properties by having chemical stabilizers; many stabilizers are available in the market today. I can get what are the strength that you need.

So, you can design the stabilize soil mix. So, again the job of civil engineer is to design your stabilized mix, find its properties use that material property to design the thickness of the layers, predict the performance and then work out the life cycle cost that is a challenge before you. When you are spending nearly 5 crores to 10 crores to 15 crores where the single lane or a two-lane or a four-lane; you have to careful in selecting the type of the pavement. Wrong

types of pavement will result in a higher maintenance cost. So, soil stabilization one method that we are started adapting across the country today in many of that national highway projects and rural roads.

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APPROACH EMBANKMENT FOR SECOND NIZAMUDDIN BRIDGE AT DELHI



43



You look here I can also use industrial waste. Again, this is job of civil engineer is to make use of this industrial waste in construction. Huge quantity of material can be used in road construction. For example, the outer ring road which I talked about for Chennai we use more than a lakh cubic meter of fly ash. So, this is one for a embankment in Nizamuddin Bridge at Delhi. The length of the bridge embankment is 1.8 kilometer 8 kilometers, height varies from 6 to 9 meters. We have used nearly 1.5 lakh metric tons cubic meter of fly ash here.

The fly ash by itself will not have cohesion so, it has to be confined you soil layers there. But, the point here is that, you can use industrial waste in road construction and that way you can

preserve the environment. We can use the material in road construction when materials not available, fly ash can be used for road construction.

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**Lime stabilisation
of (Orissa)**

**View of finished road
surface**



We can also try to use stabilization using lime. These are some roads whose constructed in Orissa. Their sub grade is weak, it have got more swelling. You can try to modify the sub grade soil by using lime the road is finish. So, this road will last longer. So, you can use either industrial waste or you can try to stabilize a sub grade soil using cement, using lime, using fly ash you can also do your double civil stabilization lime and cement, lime, cement, fly ash. Any of the combinations can be tried to improve the properties of sub grade soil.

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HIGH PERFORMANCE BITUMEN

- ❑ Withstand higher resistance to deformation and cracking
- ❑ better adhesion with aggregates
- ❑ higher fatigue life under heavy axle load
- ❑ better resistance to ageing
- ❑ Improved road performance



45

Alternatively, you can also use high performance bitumen. Normally, we use bitumen in the top layers. It is called as asphalt in America, is called bitumen in British. We since we follow British terminology, we use call it as bitumen. So, this bitumen when use in a in a top layer it has to withstand high resistance to deformation and repeated application of loads. It should not rut, it should not crack. So, if can I modify the binder that is used in the top layer? Yes, you can use that.

There are a number of modified binders or high performance bitumen that are available which will ensure better bonding between the aggregates and the binder. They will have higher fatigue life under repeated applications of the loads, they will not crack, they will not rut. So, we can use a high performance bitumen. They when it is expose to atmosphere it will not

undergo aging, cracking. So, it will have an improved performance, but again all comes with cost. If you want a better performance longer life, less distances, spend more.

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So, you can use a high performance bitumen like this, it can take up repeated applicable loads without any failure. So, again the challenge before you is that what type of modification needed for the bitumen, what will be the increased cost, what will be the performance of this highly high performance bitumen. As I was as you know the cost of bitumen will be around 30,000 rupees to 35,000 rupees for metric tonne.

When I try to modify the binder the cost will go up to 40,000 to 45,000 to 50,000 rupees. So, should I spend more money? Yes, you can perform better, but again you have to find out different there are different types of modified binders which one to select this again the recommendation based on the recommendation of the civil engineer.

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**USE OF
GEOTEXTILES FOR
CONSTRUCTION OF
EMBANKMENT WITH
STEEP SLOPE**

**LAYING OF
GEOTEXTILE OVER
SOIL SUBGRADE
(AS SEPARATOR)**

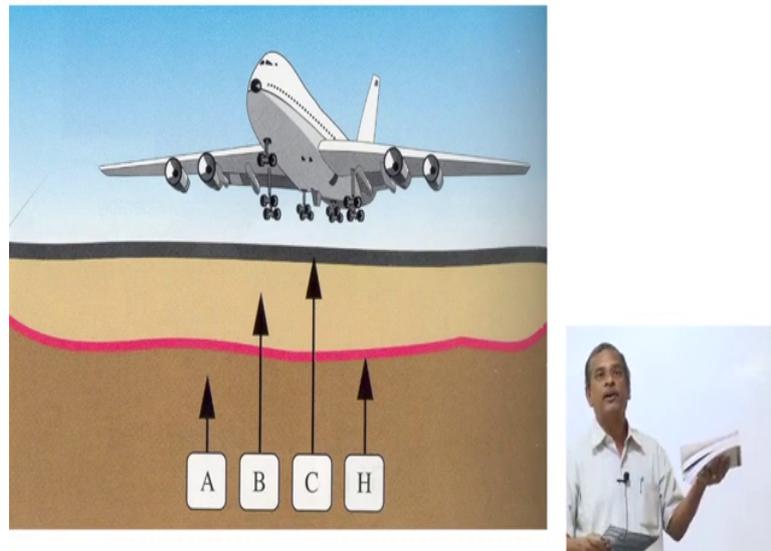


Again, we have got better materials. I think it is time that we use new materials. One new material that can be used can be a geotextiles. I think after recent last year floods many of roads in Kerala were cut off cut off because of landslide. So, what should I do now? This geotextiles can be used for embankment with the steep slopes to prevent, to ensure a better slope stability. You can have also a geo synthetic layers in the pavements, you can also use them as a separation layer.

For example, these materials are available in the form of a grid or in the form of fabric. You can use them as a separation layer. This will prevent entry of water saturating the upper layers. So, it is time that as a civil engineer, you use these materials in road construction. I will come take you forward as how they can be better utilized in road construction. So, they can be used

for slope stability and slope stability; they can be use a soil separation layer that will prevent the entry of fines for sub grade to the upper layers.

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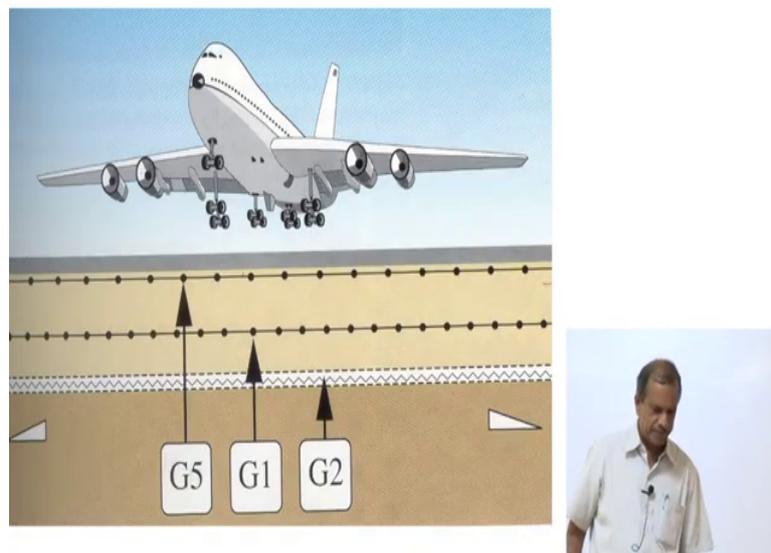
They can also be used in the case of runway pavements and taxiways. For example, if you are going to construct a runway and a taxi way in the soil which is weak. If the soil is weak if we construct a runway and taxi way and because of the repeated applicable loads the pavement will deform that will result in early failure and unsafe for the passengers.

The question is that how do I improve the strength of the sub grade soil? So, when I have got a weak soil which has to be strengthened what I can try to do is that I can try to reinforce this by introducing geogrids into that. So, the strength of the layer improved significantly. So, the question now is that what is the strength of this soil without any reinforcement, what is the type of reinforcement that I should choose there are different types of reinforcement it can be

geofabric like this, it can be like this, it can be different types like this. So, what is the type that I have to choose?

The next question is that in a given pavement layer system where should I keep this? At one third from bottom? mid-depth? Where should I keep? And, what will be the input strength of this layer system with the geo grid. So, this again have to be done only by a civil engineer. So, everything cost money if you introduce a new material that is the improved performance at, but what cost. So, I can improve the strength of the sub grade soil by introducing a geo grids here.

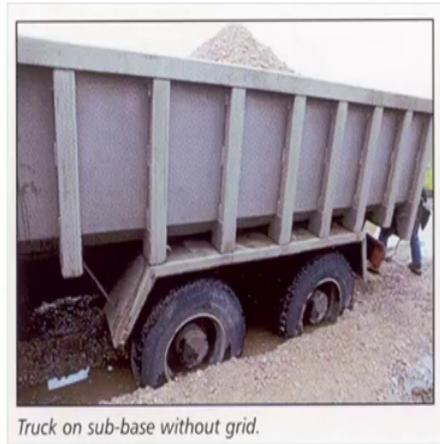
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So, you can find the two layers of geo grids laid there run way or a taxi way can last longer without a deformation, no rutting, no cracking will occur.

(Refer Slide Time: 20:02)

Truck on Sub-Base without Geogrid



Truck on sub-base without grid.

50



Alternative there are new other materials that are coming. For example, either surface is sub grade is weak a truck cannot run on that.

(Refer Slide Time: 20:09)

Truck on Sub-Base with Geogrid



Truck on sub-base with grid.

51



Alternatively if they introduce the geo grid into the layer, the sub grade gets more support, a truck can move.

(Refer Slide Time: 20:18)



**USE OF
GEOTEXTILES FOR
CONSTRUCTION OF
EMBANKMENT WITH
STEEP SLOPE**

**LAYING OF
GEOTEXTILE OVER
SOIL SUBGRADE
(AS SEPARATOR)**



So, that is another application of geo synthetics.

(Refer Slide Time: 20:19)



STRETCHING OF THE GEOCELL LAYER ON THE GROUND



The third application which I have seen is that you can use geo cells. So, these are geo cells which can be used for construction of the pavement layers. So, in a pavement as I was mentioning the load gets distributed over a wider area. So, if I can fill these layers with aggregates, there is a confinement in between the layers, there is a possibility of water draining off from here. So, the layer can support the load better the stresses coming at the bottom will be much much lower and the performance will be improved.

Thirdly, because there is the confinement here the thickness of pavement can be drastically reduced. We tried this. This is again at a location in Maharashtra. We use a geo cell for construction of a road.

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GEOCELL LAYER SPREAD ON THE PREPARED FOUNDATION BED



What we did was that we laid this geo cell layers, filled that with aggregates and then rolled with the conventional roller.

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STONE AGGREGATE FILLED IN GEOCELLS



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COMPACTION



What are the advantages of having this geocells in road construction?

(Refer Slide Time: 21:16)

PAVEMENT THICKNESS Traffic - 150 msa; 2% CBR

Combinations	IRC- Un Reinforced	Geocell at Subgrade	Geocell in base and subgrade	Geocell only in base
BC	50 mm	50mm	50 mm	50 mm
DBM	215 mm	185 mm	170 mm	215 mm
WMM	250 mm	0	Geocell with GSB-200 mm	Geocell with GSB-200 mm
GSB	460 mm	500 mm	100 mm	400 mm
UBGRADE	500 mm	200mm Geocell with soil infill	200mm Geocell with soil infill	500 mm
Total cost	2635/m ²	2490/m ²	2450/m ²	2800/m ²
Thickness	975 mm	735 mm	520 mm	865 mm
Traffic	100 msa	150 msa	150 msa	150 msa
Design Life	16 years	20 years	20 years	20 years



The use of geocell is that for example, if a require about 975 millimeter thickness of a pavement for a load which has got a strength of 2 percent CBR. I can bring down the thickness from 975 to 520. From 975 to 520 millimeter by introducing geo cells both at the base course as well as sub grade soil. So, you have to now decide and recommend where this can be utilized, what will be the reduction in the thickness of the pavement layers, what will be the cost.

So, you look at the cost again. The cost will around 2450 rupees for per meter whereas, current will pavement is 2635. This cost is not the issue. The issue is that availability of materials for construction. So, I can drastically reduce the thickness of the pavement layers improve the performance and you can see that the performance of pavement is around 20 years to 16 years in the conventional pavement. So, improved life, lesser grade consumption,

lower cost and so, it is time that you as a civil engineer when you graduate apply such new materials in road construction.

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PRECAST CONCRETE PAVEMENTS



So, again another thing which I have want to introduce is that you can try to have a concrete pavement. As you know the concrete pavement, you should cure it for 28 days. You can open the road to traffic only at the end of the 28 days. Now, those of you from Bangalore will know number of roads have been taken up under as a white topping a concrete overlay over a bituminous pavement. So, I can construct around 300 meters, 400 meters per day. If I have to have around 200 kilometer, 300 kilometers of roads, it takes number of days to construct these roads.

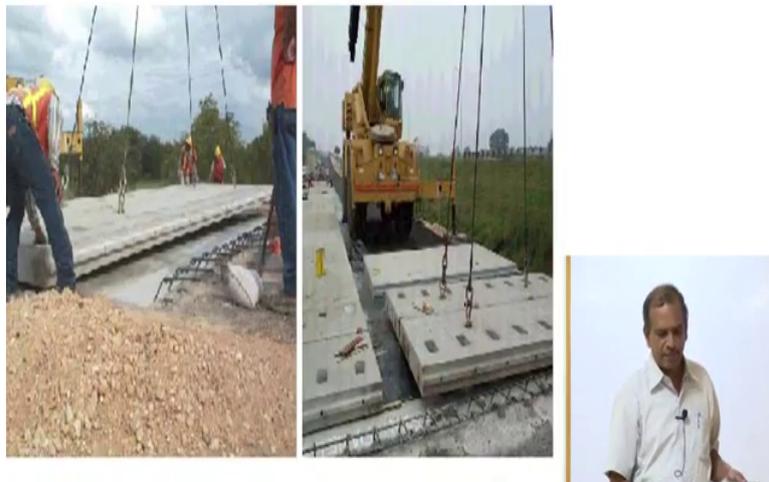
Alternatively, it is time that we look at precast concrete pavements. Can I fabricate this concrete pavements elsewhere? Bring it to a site, I can make fabricate slabs like this; bring it

to a site, assemble them and then open the door to traffic. You can do a post tensioning after you and fabricate all this, arrange them in a specification and do this. We have started this adapting this for the first time in the country for the outer ring road at Nagpur. A research works is being under progress in NIT, Nagpur today.

So, concrete pavements were it is time that some of you can become an entrepreneur can have a company for a precast concrete pavement. You will find that this technology will be adapted when wherever you would not have a faster construction. The road should not be there today, tomorrow morning when you come there should a concrete (Refer Slide Time: 23:46) should be available. So, that is a challenge that is before you.

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PRECAST CONCRETE PAVEMENTS



So, concrete pavements can be brought in, assemble in the site and then open the road to traffic.

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PRECAST CONCRETE PAVEMENTS



So, these are some technologies that we have to now adapt.

Now, having talked about this construction, bituminous pavement, concrete pavements composite pavement – use of new materials in terms of binder, geo synthetic, stabilizers, precast concrete pavement. So, we have created the infrastructure today or we are creating the infrastructure today.

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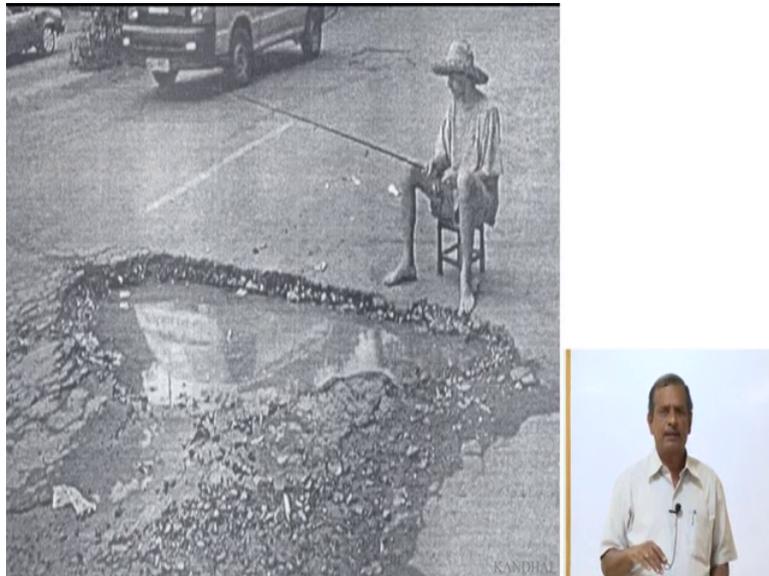
MAINTENANCE



The challenge before you is that how do I maintain this infrastructure that is to be a going to be huge tasks before you. Many of the projects as I was mentioning yesterday many of the projects road projects are available for sale. These projects come under the category of what is called as the TOT – Toll Operate and Transfer. The road constructed road is available for sale, you can buy the road project for the project for 60 kilometers, 100 kilometers, 200 kilometers, but you can you have to toll the road, you have to operate and maintain the road and then we can transfer at the end of 30 years; which means you have to evaluate the condition of the road and find out what is the lacking performance requirements.

So, when the road is constructed, every road any road that you construct for that matter will deteriorate.

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So, more the road you construct when you do not maintain the road the road will develop potholes, but I cannot compare the pothole to other countries in India because there are big craters. So, when these potholes form I think this one is a issue of maintenance other is the issue of safety.

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Beaten, battered and bruised. So, why the roads deteriorate like this? Is the problem with the design? What has gone wrong?

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Remember major problem is because of water. It is not that we are walking on the moon, we are walking on the roads. Potholes are there, it is become a shame. You go to Bangalore every year they will count the potholes. They will say that today I counted 10000 potholes. Today, I counted 20000 potholes. It is a shame that civil engineers are not able to construct a long lasting durable road effects.

We can go to Moon and Mars, but we do not know how to construct the roads. So, that is a challenge before is what have gone wrong.

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WATER IS ENEMY NO.1 TO ROADS...



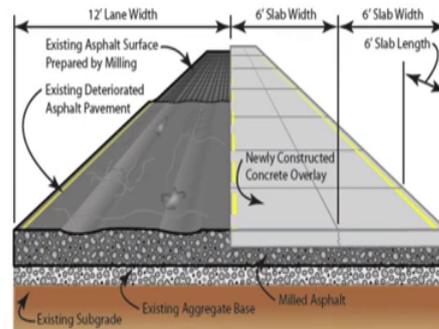
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So, when we look at these roads that are being constructed the road, the enemy is water. For a civil engineer water is enemy number 1, enemy number 2 and enemy number 3. So, if you do not care water at the time of construction, the water will remain there I am here. You never cared me at the construction I am here. So, issue is that how do you take care of this.

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WHITE TOPPING



The existing pavement is utilized as a subbase in a CDOT TW; the asphalt is simply milled and the new concrete overlay is constructed on the milled asphalt surface.



One way of solving this problem is having a white topping. On a given bituminous pavement which I was talking earlier on this bituminous pavement, it has become deteriorated I can provide a concrete overlay on the top. So, majority of the problem of water induced damage can be reduced. I cannot mill this layer, reduce the thickness and promote a concrete layer on this.

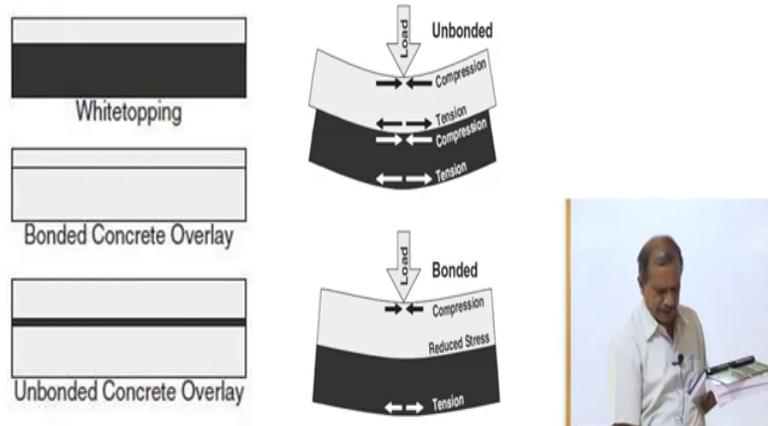
So, one of the major problem that we are facing in urban location is that the road was at a higher level the lower level, house was constructed at a higher level. Today a road level has gone up houses remained the same level and all the water from the road comes to the houses and then that is why flooding occurs in majority of the locations in Chennai.

So if I construct the white topping wherein I mill a pot in between bituminous layer and construct the concrete pavement above that that can last longer. So, Bangalore they have

realized the importance of white topping; several 100 kilometers of roads in Bangalore are being white topped. They are trying to do that in many of the locations city, even in Chennai if we done some locations where the white topping.

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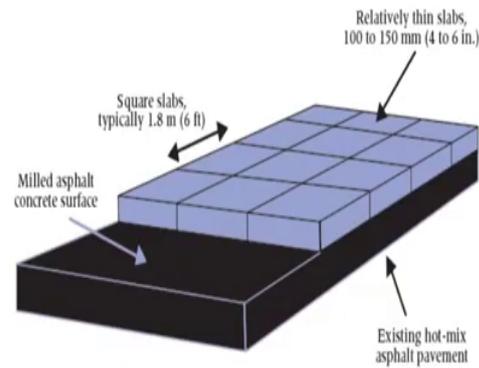
BONDED AND UNBONDED OVERLAYS



So, again these thickness of white topping can be vary from 100 millimeter to 250 millimeters or 220 millimeters. So, if the thickness of bituminous layer if I have a layer above this layer is very thin then that is called as ultra-thin white topping. If I provide a thin layer on the top, then it is possible that the layer may crack. So, I have to ensure a bond between this concrete pavement and this bituminous layer. So, how do you ensure the bond between this layer is the question here.

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WHITE TOPPING



So, I have to mill the surface to ensure a better bonding and provides a concrete pavement. At this point of time there are three types of white topping one is thin white topping where thickness varies from 100 millimeter to 200 millimeter; ultra-thin white topping which is less than 100 millimeters. So, here again if you want have thin layers, you have to ensure a bond between the bituminous layer.

So, here again as a thickness becomes less the size of the panel also becomes less for as can be seen here the size of panel will be around 1.8 meters by 1.8 meters or 1 meter by 1 meter; thinner the pavement smaller the slab size, but if you can have this if you also from Bangalore will know the Nandi highway the outer a part of the preferable road of Bangalore is constructed with white topping. The thickness of the white topping is only 180 millimeter, but

it has been last a last the last 5 years without any major maintenance. So, sustainable, long lasting pavement one possibility is having white topping over a bituminous pavement.

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CONSTRUCTION STEPS

Milling

- Provides removal of rutting
- Roughened surface to enhance the bonding

Repair to existing pavement

- Repair / Seal the cracks
- Overlay when cracks are extensive

Preparation of existing pavement surface

- Cleaning, drains/ man-hole covers to be raised
- Camber correction
- Utility lines – shift old lines or lay new lines



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Again, it provides a removal of the rutting, I can mill the surface. Now, milling machines are available.

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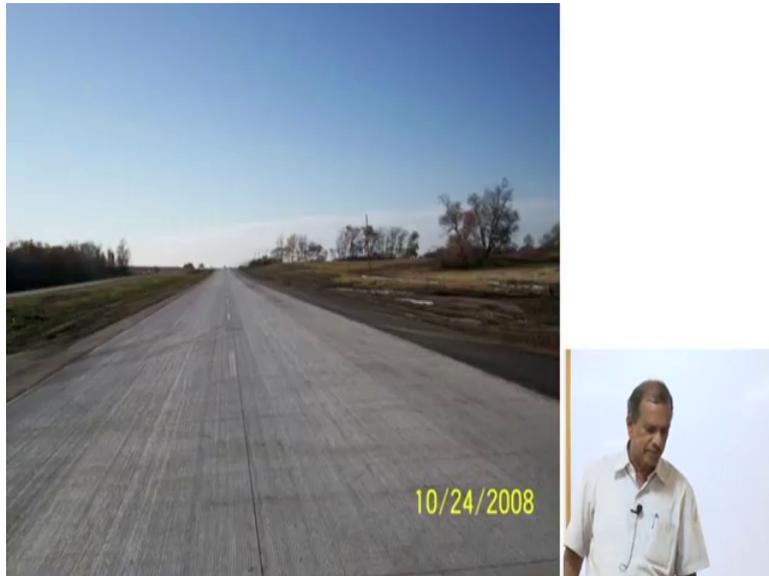
I can mill the surface which will ensure a better bonding. This is how a milled surface will look like.

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Or this milled surface, you can have a white topping or a concrete pavement.

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And, but you have to cut this to the size to one third depth using milling machines, cutting machines.

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Cutting machines – so, more cutting machines are required in a slab size surface small.

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So, you can have white topping on a deteriorated bituminous pavement and forget about the road for 20 to 30 years. So, bituminous pavement can also be made sustainable by constructing concrete pavement.

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NEED FOR MAINTENANCE

- Deterioration with Passage of Time due to
 - Action of traffic – HCV
 - Environmental Factors – Ingress of water, oxidation of Binder, loss of volatiles
 - Inadequacies in the initial design, specifications and construction standards
 - Lack of adequate support from lower pavement layers

77



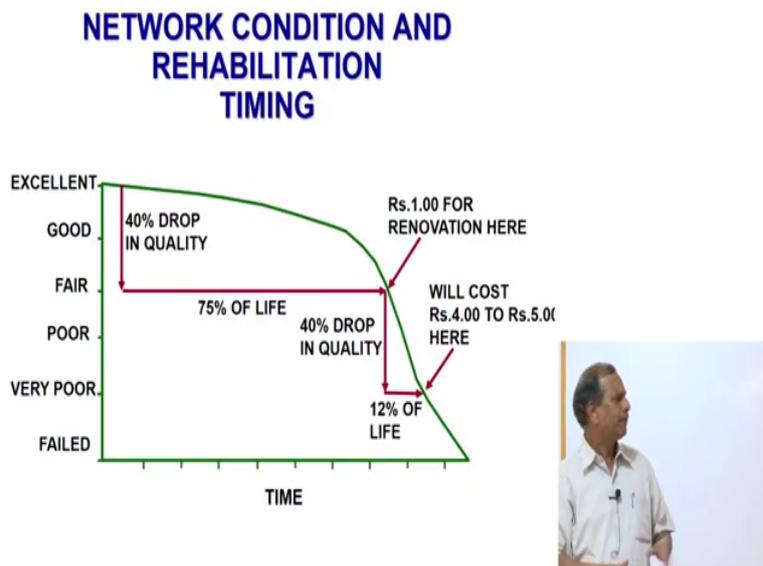
The other issue that you are to face is that all the roads will deteriorate when there are different types of vehicles on the highway cars, two wheelers, auto rickshaws, trucks, buses. The majority of a distress on a pavement is only from the concrete pavements sorry from the commercial vehicles. So, more the commercial vehicles, fast is the deterioration if you are not accounted it in the design. So, one factor is the heavy commercial vehicle which causes the deterioration of the pavement.

Second is environmental factors – water will get into the layers. Thirdly, this surface when this exposed to atmosphere there will be oxidation of the binder, loss of volatile matter, the top bituminous layer like a more rigid, stiff and may crack. Once it cracks water will enter into the pavement system. Once the water enters into the pavement system, it strips the binder from

the aggregates and potholes form. So, a second reason is a environmental factors, third is inadequacies in the design.

The last can be about the lack of support sub grade getting weak because of moisture induced damages. So, if that is the case how do I design the pavement?

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As the pavements are deteriorating the pavement is very good initially, it will be excellent initially so, this will start deteriorating with the passage of traffic. So, if I do the maintenance here, it is called as the preventive maintenance. More and the more I delay the maintenance, the cost of maintenance will go up. If the thickness of bituminous layer required maybe around 20 millimeters, here the thickness of the layer will be 200 millimeters here.

Number 1 – I am increasing the cost of maintenance by delay; number 2 – I am increasing the thickness of bituminous layer by delay; number 3 – I am requiring more material for maintenance if I delay. So, we have stitch in time we will save nine. So, this is how a pavement deterioration will take place and if you do early the cost of maintenance will be maybe 1 rupee more and more delay, the cost will go up to for 4 to 5 rupees.

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SUSTAINABLE MAINTENANCE



Other is that how long we can do then overly over overly over overly it is time that we have to need should relook as how do we construct the sustainable pavement. One way we having sustainable road is for example, this is a Tilak near Bangalore where every time I come to the airport I just take a photograph. It was full hillock became half and now over a period of time the hill will lost. We have to now look at that for your grandchildren perhaps.

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If you want to show a hill you want to show only on a paper, a hill will look like that because we had used all the hill material for road construction that is not sustainable. So, what should they do now?

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The option before us to use is that this is a case of a Chennai Tada road we can find the road has deteriorated with full of cracks.

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Top Down Cracking



Many roads because of the repeated application of loads develop cracks. The cracks may be only the top; the paddy cracks occur from the bottom, but this is a top group crack because of the aging, because of increase loads, over loading, because of the increase tire pressure. What I can try to do is because of a crack I need not provide an overlay over this. I can mill the layer up to the depth to which cracker propagated reuse the material. In a nutshell sustainability talks about reduce, reuse and recycle. It is time that we you adopt recycling technologies in road construction.

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So, we will look at this I can mill the entire material. Now, milling machines are available. If the road has deteriorated I need not pardon overlay above that. You mill the material, use the material again and again and again.

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So, milling is the first step when you want to reuse the materials.

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COLD IN-PLACE RECYCLING (CIR)

- ❑ Process in which
 - ❑ Portion of existing AC pavement is milled
 - ❑ Reclaimed material is sized and mixed with new binder, additives, and sometimes virgin aggregate
 - ❑ Remixed material is placed back on the pavement
 - ❑ New wearing course placed later
- ❑ Construction options:
 - ❑ Single machine process
 - ❑ Single-pass equipment train



84



Once you reuse mill the material, I can do a cold recycling. In the case of cold recycling, I mill a part of the bituminous layer, I use a reclaimed material, I can use a foamed bitumen. What is the foamed bitumen here?

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COLD MILLING

Removal of pavement surface using carbide-tipped cutting bits

Purpose

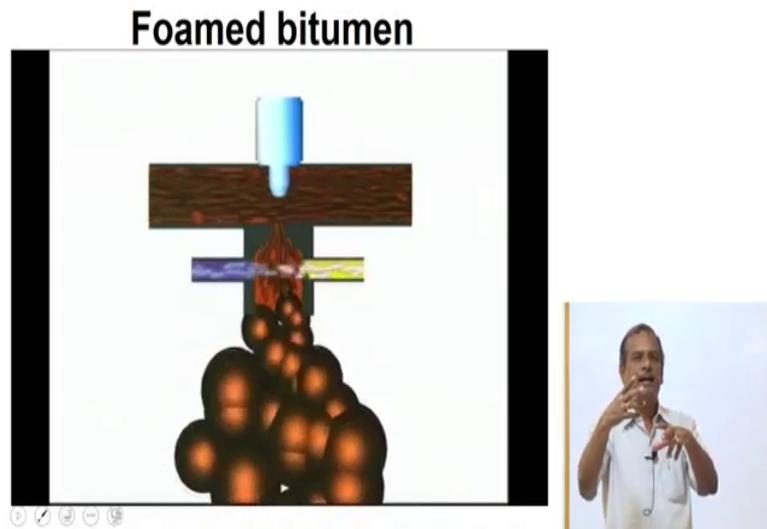


- Restore profiles and slopes
- Re-establish surface friction
- Remove layer for recycling
- Prepare for an overlay

85



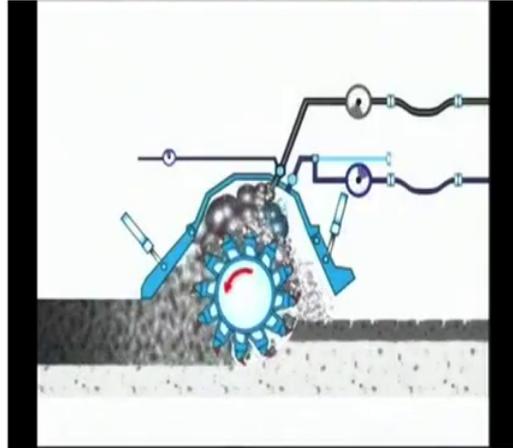
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So, I can do your cold milling here. I can try to inject a hot bitumen water on one side air on the other side. So, the volume of bitumen increases by 14 to 17 times. This will try to spot well the milled particles and use that material in road construction.

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COLD IN-PLACE RECYCLING



I can mill the material mill the material, I inject the foamed bitumen. So, this layer is called as a bitumen stabilized material or called as a BSM. So, I do not I have not thrown out the wall deteriorated pavement material. I am trying to reuse it again because the material has deteriorated, I am trying to strengthen the material properties by using a foamed bitumen, I can reduce the thickness of the layers.

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COLD IN-SITU RECYCLING



In the case of cold recycling this how the material is look like.

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COLD IN-SITU RECYCLING



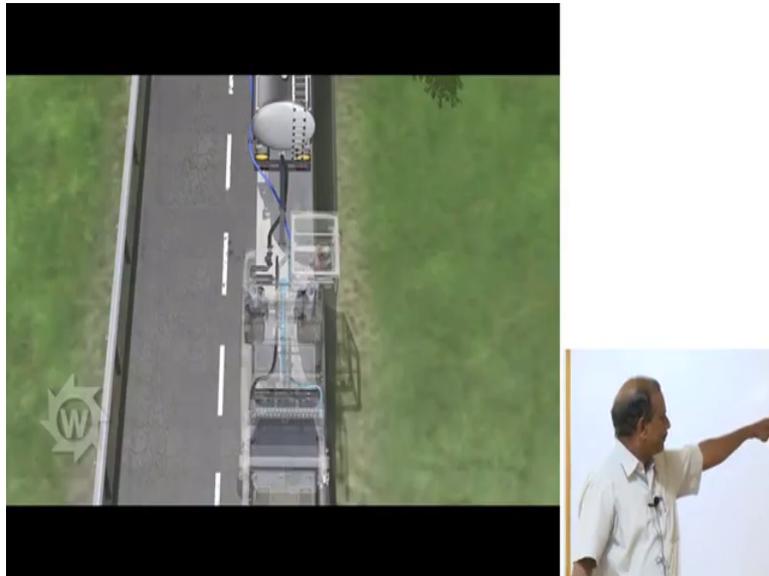
I can use that as a one of a excellent binder course, I can reduce thickness of bituminous layers.

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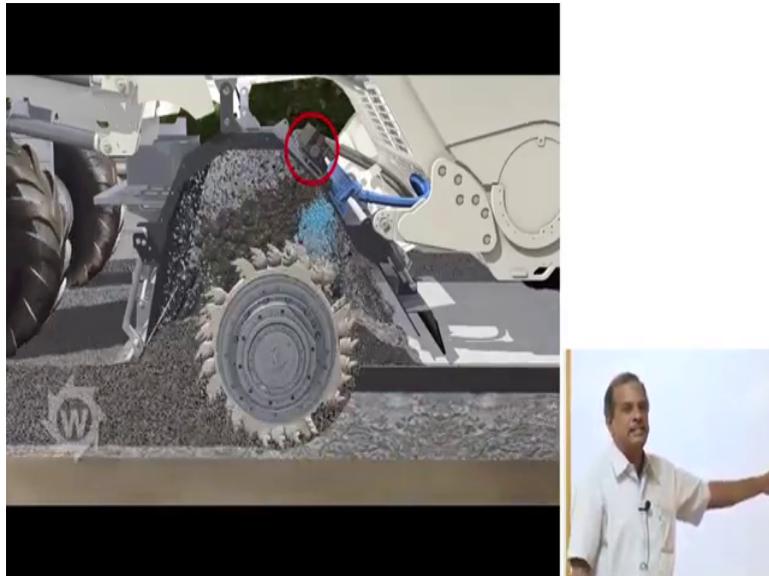
What I try to do here is that. What I try to do is I add cement to the layer to increase the stiffness. I mill the material to I have got here tanker of bitumen.

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I have tanker of water.

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I try to mill the material to the milled material I use the foamed bitumen and lay it and compact. So, this will result in reuse of the material, stiffening of the aged materials I try to rejuvenate the oxidized aged bitumen and by the process I can reduce the thickness of the bituminous layers.

So, this is the one way of reusing a material and this technology we have started adapting in several highway projects in the country today.

(Refer Slide Time: 35:29)

HOT IN-PLACE RECYCLING (HIR)

□ Process in which the upper 25 to 50 mm (1 to 2 in) of the existing pavement is heated, mixed with a recycling agent (and perhaps virgin materials), and relaid on the pavement

□ Addresses surface distresses such as:

- Corrugations
- Bleeding
- Minor cracking
- Low surface friction
- Rutting



91



The other way by which we can do this is a hot in place recycling. So, what do you know second technology that we are adapting today is that I can try it when the surface got corrugations, bleeding, minor cracking, low friction, low rutting.

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HEATER-SCARIFIER



I try to heat the layers. So, this is a process that we are adapting today I can heat the layers. I can scarify the material.

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Once I try to scarify the material I you have a pugmill where I bring in virgin material aggregates, mix the material and lay it back. So, with the result the finished road surface will be approximately similar to that of the old deteriorated pavement. I am reusing you material with the result the requirement of virgin aggregate will be marginally very very less.

So, the technology that has to be adopted in the years to come or number 1, you have to reduce the construction either by stabilizing a upgrade using geocells, geogrid, geosynthetics, use modified binders or in the case of recycling adopt the case white topping, or recycle a the material either hot recycling or a cold recycling, any of the technologies can be adopted. So, all these choices again depends upon the proficiency of the civil engineer who is in-charge of the project.

So, you should not only be able to select the type of pavements, select the type of material at the same time you should also be able to predict how it will perform, what will be the maintenance requirement, how is the maintenance cost. So, that is a challenge in a nutshell life cycle cost analysis, road asset management, pavement preservation these are the technologies a techniques that we have to you have to adopt when you graduate.

So, construction is one hand, the maintenance is the on the other hand. Maintenance challenges are like a doctor diagnosing a disease you have the road is an deteriorated for example, campus roads. The campus roads are deteriorated these roads we are constructed in the year 2009. Now, they are 10 years old, now what should I do now?. So, as a civil engineer you should be able to tell should I recycle? Should I use a modified binder? Should I do adopt the white topping? What type of binder to be adopted? Again, the choice depends upon the performance and, the performance depends upon the choice of material, again your proficiency in selecting and recommending the right material for the right pavement at the right time.

(Refer Slide Time: 37:54)

**DESIGN OF RUNWAYS, TAXIWAYS,
APRONS AND TERMINALS.....**

94



The other issues are that runways and taxiways will be the challenge that you had to do it. There are several runway pavements that are to be rehabilitated, reconstructed. The challenge before you is that how do you do that.

(Refer Slide Time: 38:03)



For example, the airbus that has been constructed; seating capacity is more.

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TECHNICAL DETAILS

- ❑ Length: 73 m
- ❑ Height: 24.1 m
- ❑ Wingspan: 79.8 m;
- ❑ Typical Operating Empty Weight: 252,200 kg
- ❑ Maximum takeoff Weight: 590,000 kg
- ❑ Maximum fuel: 310,000 l
- ❑ Capacity: 555 in 3 classes or 853 passengers in 1 class, with up to 66.4 tonnes (146,400 lb) of cargo
- ❑ Normal cruise speed: 0.85 Mach (approx 903 km/h)
- ❑ Maximum cruise speed: 0.89 Mach
- ❑ Range: 15,000 km (8,000 nmi)

97



The challenge before you as a transport engineer is that the capacity of these as 555 in 3 classes or 853 passengers in 1 class. But, the issue that you should see is that the maximum takeoff weight is 590 tons. Now, you have to design a pavement, a runway and a taxiway such that it does not deform, crack, ruts under this huge load. The empty weight is 252 tons, but the full takeoff weight is 590 that of takeoff weight is more because of it is fuel is full, the landing weight is less.

So, the challenge before you is that how do I design a sustainable pavement for a load of 590 tons. So, unlike a highway, where the traffic vendors in the case of a runway pavement they follow a particular path so, wheel rutting will be along a particular path. In a duration of the road application your runway is only a fraction of a second because a aircraft lands are 200 to

250 kilometers per hour speed, but it reduces speeds when you go through exit taxiways and cross the low speed in the taxiway.

So, the deterioration in a taxiway will be more than the deterioration in a runway. So, how do we design a sustainable taxiway? What material, what type of pavement, what are the combination of different layer is again a challenge. So, this is a not only this suppose if I have thousand assume that 853 passengers are to be carried by one aircraft. To see of this 850 passengers at least 1500 people will come visit this. So, you need the terminal to be designed for this 853 passengers you have to now design the all the terminal facilities starting for sitting arrangements to the security clearance to the all other facilities till boarding.

So, again a job of civil engineer is not only designing the runway and the taxiway, but all the terminal facilities including parking, access all the facilities are to be designed by a civil engineer. This as far as the airport taxiways are concerned.

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ROAD CONSTRUCTION IN DIFFICULT AND INHOSPITABLE TERRAINS



98

The other challenge before you will be construction of roads in inhospitable and difficult terrain.

(Refer Slide Time: 40:17)



For example, I want to have for road for strategic importance. I want to construct the roads in Himalayas. How do I construct the concrete pavement? Can I consider bituminous pavement?

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WEATHER CONDITION

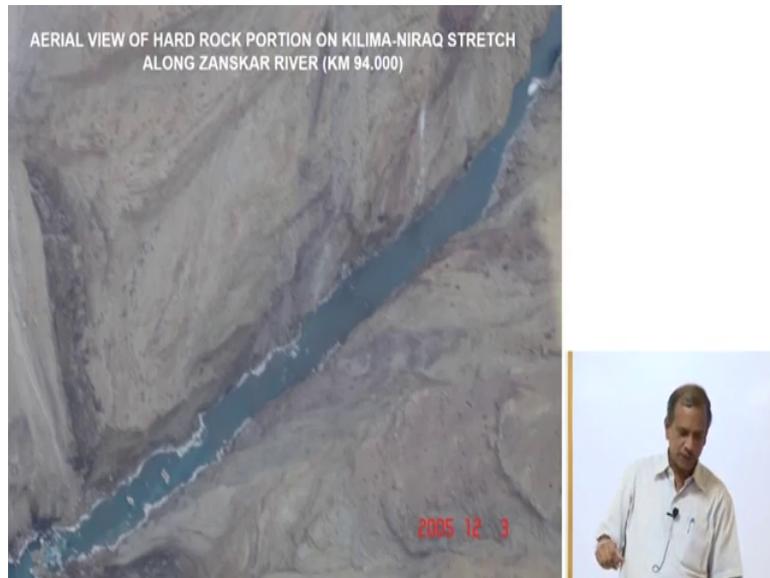
- ❑ CLIMATE IN LADAKH REGION IS IN EXTREME.
- ❑ MAX TEMPERATURE RECORDED IS 38.4°C AND MIN - 40°C IN THE REGION.
- ❑ JANUARY IS THE COLDEST MONTH.
- ❑ CLIMATE IS MORE OR LESS OF THE TYPE PREVAILING IN TIBET.

101



When the temperature is low for example, I want to construct of roads here, the temperature a recorded is minimum minus 40 degree centigrade. How do you construct a road there? What machinery can I take it there? Unless you form a road it is a challenge before us before the enemies how do I protect the country. So, how do I construct the road? What should be the pavement type? Should I recycle the material? Should I have a concrete pavement? Again, a challenge before us. So, the climate is more important. The window for you to work maybe 3 months in a year; in a 3 months you should construct the pavement.

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So, here again for example, this aerial view are the hard rock portion in the section of Himalayan region.

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You have to construct the road there. Because of the requirements of oxygen is less there you will find it difficult for the working efficiency for these machines. So, how do we construct is a challenge. Again, landslides will be there. Once you try to destroy the nature.

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VALUE OF TIME

- ❑ Cost of project is highly sensitive to time of completion.
- ❑ One year early completion/delay in completion means 25 % of project cost made up of 10% by interest on loan, 10% loss of toll revenue and 5 % by escalation.
- ❑ Cost of road crust is usually 25 % of project cost and hence even if the cost increases due to a new material/technique by 25 % but reduces the time of completion by six months, still it will be economical



So, the other challenge before you as a civil engineer is that the value of time. In all highway projects time is running. If a highway project delays by 1 year, the cost will go up by 25 percent. You look the cost of the material increases, you lose toll revenue, you are taken loan from banks and financial institutions, you have to repay with the principal and the interest. So, time is money. So, not only selection of material and the design of the pavement, you should also be proficient in project management.

How do I construct the facilities the quickest possible time? Can I adopt precast technology? How do I do even for example, a flyover in a city, how do I do that? So, challenge before is that project management, time management and select of appropriate type of materials and design. So, that we are able to complete the infrastructure in the quickest possible time. So, there are several challenges before you as a civil engineer.

(Refer Slide Time: 42:25)

INDIAN HIGHWAYS TODAY....

105



(Refer Slide Time: 42:27)

MUMBAI-PUNE EXPRESSWAY



To summarize all this, the Indian highways today we are able to see highways comparable to any of the country of the world these are Mumbai – Pune expressway.

(Refer Slide Time: 42:32)



We have the other highways which are comparable to any other developed country in the world.

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YAMUNA EXPRESSWAY



The recent one is a Yamuna expressway.

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YAMUNA EXPRESSWAY



One thing which I have not talked about is about the safety issues because I could not cover within these 2 hours of time. Nearly 1 lakh 50,000 people get killed on Indian roads every year. So, better roads, higher speed, more accidents. So, again the challenge is how do you construct a sustainable and forgiving highways is the challenge before you. Even driver wants to travel a 200 kilometer per hour he should not be able to travel. How do I design the facility to meet that is a challenge.

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YAMUNA EXPRESSWAY

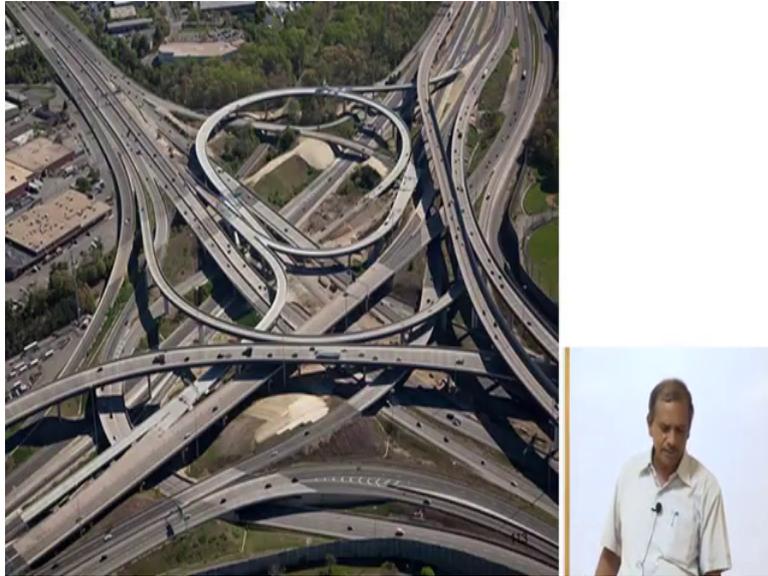


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So, a challenge before you is the Yamuna expressway here. So, I think more and more traffic in urban areas you will design more and more interchanges. So, this will be a challenge before you more the traffic you are happy as a civil engineer because job opportunities are more, challenges are more. You have to design; it is not just a single level.

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If you go to Velachery we are going to see the 2 level flyovers, I think that that will come in the years to come more and more interchanges will could be there. So, you have to design these interchanges again a challenge before you for different categories of vehicles.

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More congestions these are the normal scenario how to solve this in a democratic country like that where a Singapore is easy. You cannot buy a car with a unless you pay a hefty fees licensing, but here anybody can have a car. So, they including everyone is the in the same group.

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So, again by a Delhi 8-lane highways. You can make 20-lanes also, but 20-lanes will be in congestions like this. So, challenge before you as a civil engineer is that how do I solve this problem of congestion, delay and accidents is the challenge before you.

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More and more you construct I think it is time I think the time is not far away when you find railways which are like this.

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We need roads become bad; we need new facilities new way of thinking of how to take the people above the bad roads.

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So, this again a challenge how to rehabilitate this road. What has gone wrong, how to repair the road?

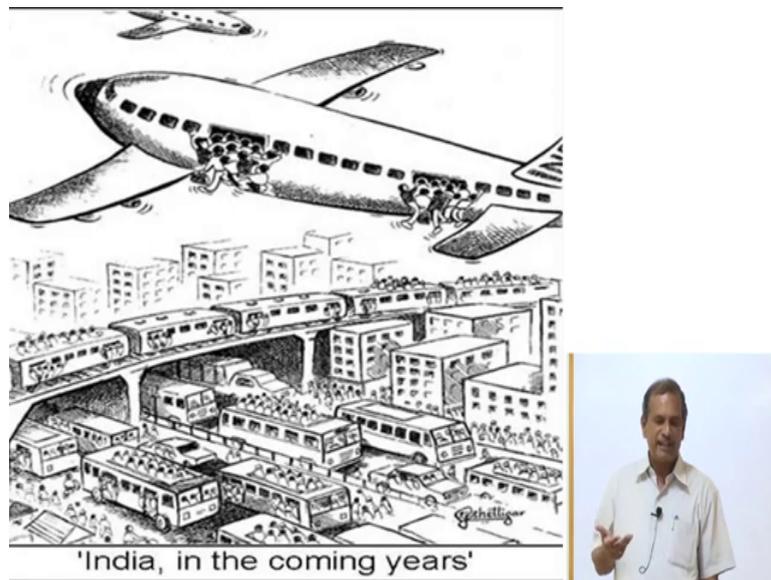
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Student: [Laughter].

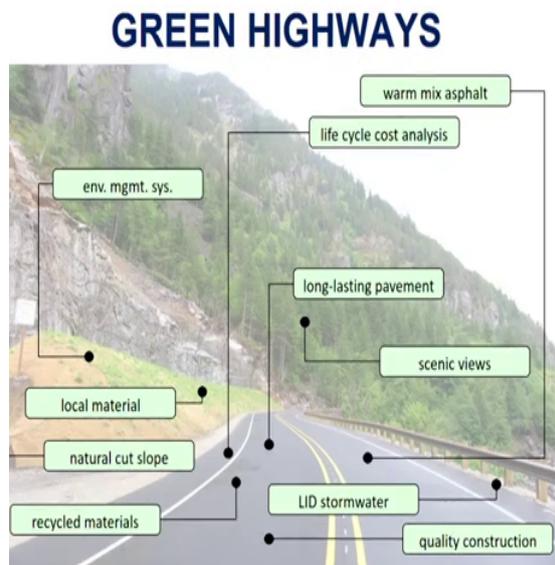
That becomes more and more challenges before you.

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I think time is not far away when you find roads in the country like this. So, this is going to be the future of Indian traffic in the years to come, not only the highways, railways, airplane as well. So, more and more problems I happy, that there are more opportunities before you.

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So, what you have learnt is that we need a green highways materials are available.

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CHALLENGES

- ❑ Use of New materials in Highway Construction
- ❑ Conservation of available resources
- ❑ Design of Long lasting pavements
- ❑ New technologies in Construction and Maintenance
- ❑ Recycling of Pavement Materials
- ❑ Green Highways
- ❑ Highway Drainage
- ❑ Urban Pavement Management
- ❑ Highway Asset Management
- ❑ Research and Development – new materials, life and performance prediction, optimal maintenance strategies

123

So, something that you have learnt is that is time that you talk about new materials in design and construction, how to conserve the material by reducing, reusing and recycling the materials; how to design a long lasting pavements; new technology in construction like a precast construction; recycling the materials; try to construct green highways; improving the drainage of the facilities; urban pavement management; having white topping; how to manage a road asset is something that you have to face in the years to come.

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SCOPE FOR HIGHWAY ENGINEERS IN CIVIL ENGINEERING PROFESSION

- ❑ Highway Planning
- ❑ Highway Design – rural roads, urban roads, inter-city highways, border roads
- ❑ Highway Construction – all above
- ❑ Highway Maintenance Management
- ❑ New Materials for improved Performance
- ❑ Road Asset Management

124

And, the scope for highway engineers is that you have huge potential for as a highway planners, highway designers construct of rural roads, urban roads, inter-city highways, inter changes border roads. Construction using new materials, new technologies; maintaining the road asset that you have created, improved performances using new materials and how do we as manage these road asset is a challenge before you.

I think this no death for job for a civil engineer in the highway engineer profession I am happy that your chosen the profession branch either compulsion or be choice does not matter. I feel that over all if you look I always tell in my class we can always say that I was engineer for this building; I was engineer for this flyover, bridge you can tell. Ask any computer sciences engineer; let him tell that this software is written by me. You can be proud that your being a civil engineer.

So, and moreover more than anything else I personally feel that civil engineer can enjoy the life. He will have the money he can enjoy the life overall if a win - win situation. So, you will not repent for having chosen civil engineer as a profession, definitely over the period of time you can enjoy the profession working like this in several challenging projects. So, I wish you all the very best.