Pavement Materials
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Lecture: 33
Production of Bituminous Mixtures

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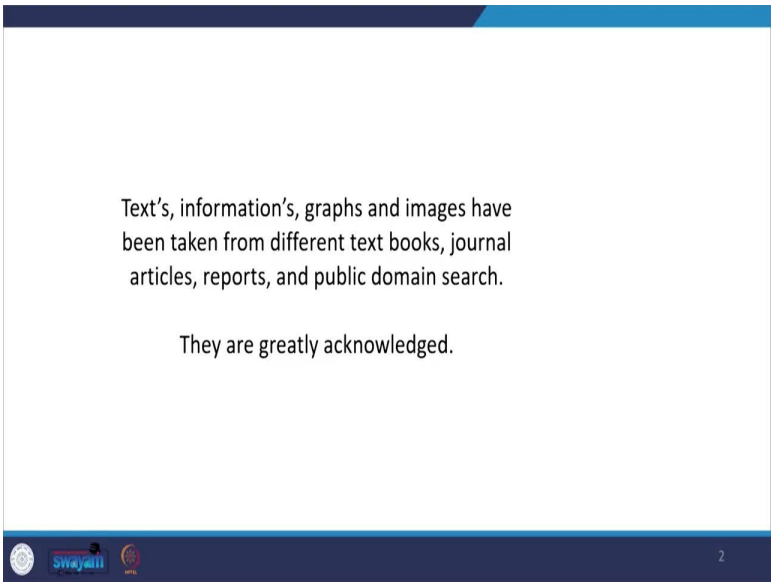

Hello friends, today we are going to start another module, which is Module 4 and here we will be discussing about Bituminous Mixtures. So, before we begin, I wish to inform that various text information graphs and images that have been used in this presentation have been taken from various textbooks, various reports, various specifications, journals, and the general public domain search and they are greatly acknowledged.

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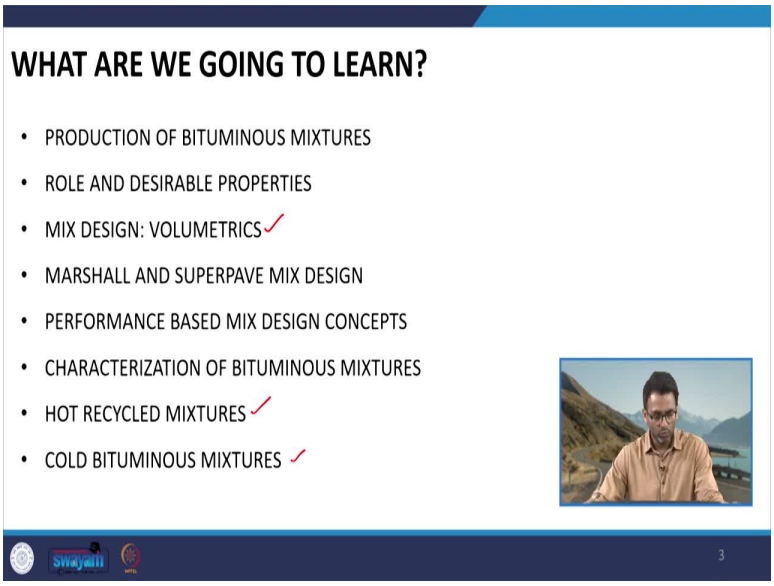

So, in this module we are going to learn various aspects related to bituminous mixtures and we will start our discussion by understanding about the production of bituminous mixtures by looking at a bituminous mixture. We will then talk about the role and desirable properties which is required from a bituminous mixture as a paving material because it has to finally be laid in the pavement and it has to give satisfactory performance. We will talk about the mix design aspects, where we will be talking about the Marshall mix design process and Superpave mix design process.

And before we look into the steps of these mix design process, we will spend some time discussing about the volume metrics of bituminous mixtures which basically will form a very critical or an important part of this module. Then, we will briefly touch upon some advanced concepts which are more popular in recent times that is development of performance based mixed design.

We will also talk about various laboratory investigations, which are carried out to characterize the bituminous mixtures to characterize the performance of the bituminous mixtures. Then, we will also discuss about the mix design concepts related to hot recycled mixtures, again, a very important topic to be discussed. And we will also briefly discuss about the mixed design process of cold bituminous mixture, so where cold indicates that we will be using emulsions and foam bitumen for the production of these mixtures.

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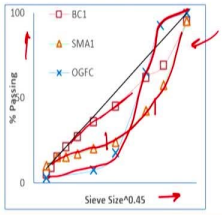
Introduction

What is an Asphalt/Bituminous Mixture?

Asphalt Mixture/Bituminous Mixture is a *"heated mixture of aggregates uniformly mixed and coated with asphalt binder"*

- Dense graded
- Open graded- *(AV 18-22%); OGFC/ATPB*
- Gap graded- *High contents of coarse aggregate (70-80%), high binder content (>6%) and high filler content (nearly 10%). Excellent stone to stone contact and resistant to rutting*



So, let us start today by discussing about the production of bituminous mixture. So, before I discuss about the production of bituminous mixture, let us first understand what is in asphalt or bituminous mixtures. So, both the terms are used interchangeably let us understand the definition of this mixture.

So, in simple terms, we can define a bituminous mixture as a heated mixture of aggregate. So, aggregates are heated before it is mixed, so, heated mixture of aggregates. Uniformly mixed and coated with asphalt binder. So, here we have a binder which is the bitumen or the asphalt binder, which will be mixed with heated aggregates and in fact, this binder will also be in heated state because bitumen is a viscoelastic material and to make it fluid to make it workable, to mix it with aggregates properly, we have to heat it to elevated temperatures.

So, we have bitumen, we have mineral aggregates, which are graded because there is a specific gradation which we are targeting for and once we will mix them it will appear like a loose mixture and this mixture will be further laid, it will be spreaded on the surface of the pavement and it will be compacted using specific type of rollers. Before I move forward I will just try to visually show you bituminous mixture, which I have also showed in a previous module where we discussed about bitumen that this mixture is made up of graded mineral aggregates and bitumen.

So, you can see this is a very dense mixture which I am showing here today and but we can have mixture with various gradations various surface characteristics or and various volumetrics as well, we will discuss more about it. So, depending on the aggregate gradation, which we are choosing for making the bituminous mixture for example, so this mixture which I am holding in my hand this is a dense mixture you can see the surface is very smooth, so, depending on the gradation, we can have different types of mixture for example.

I have another mixture, which is a bitumen rich mixture more of gap graded in nature. I am holding it using a paper just to save my hand from getting dirty here. You can see that this is a coarse graded mixture and you can see that we have coarse particles and very high bitumen content, if you can see the shine in the mix. So, this is a gap graded mix which is produced. So, depending on the gradation, we can have different types of mix, we can have dense graded mixtures, where the design air wide is approximately in the range of 3 to 5 percent.

We can have open graded mixtures such as open graded friction courses or asphalt heated permeable bass and these mixtures have higher void content of around 18 to 22 percent. Now, these are very special mixtures which are designed either to facilitate high permeability of water or it is also used to absorb sound in the surface layer. We can also have gap related mixtures, I have already discussed about different types of aggregate gradation.

So, in gap graded mixtures, we have coarse aggregate and we have fine aggregate the intermediate size is usually missing. So, we have high content of coarse aggregate, high binder content, and high filler content. So, these mixes usually have very excellent stone to stone contact and give good resistant to rutting. So, these mixtures are plotted corresponding to the maximum density line, here as you can see in the y axis you have percent passing and this is the normalized sieve size raised to the power 0.45.

And you can see that this black dark line is the maximum density line, this brown line which I have drawn this one, this is a well graded structure, so this indicates a dense gradation. We have a graded mix which is shown here and you can see the intermediate size is not very prominent we have aggregates from lower sizes and higher sizes. And then we have open graded friction course, which is more of a poorly graded mixture, which shows that there are aggregates mostly of single size in this particular gradation.

So, how are these mixes actually produced? We have two different types of production which we have to discuss, which we have to understand. One production is something which we do in the lab, and we expect that similar mixture can be produced in the plant and it can be compacted in the field.

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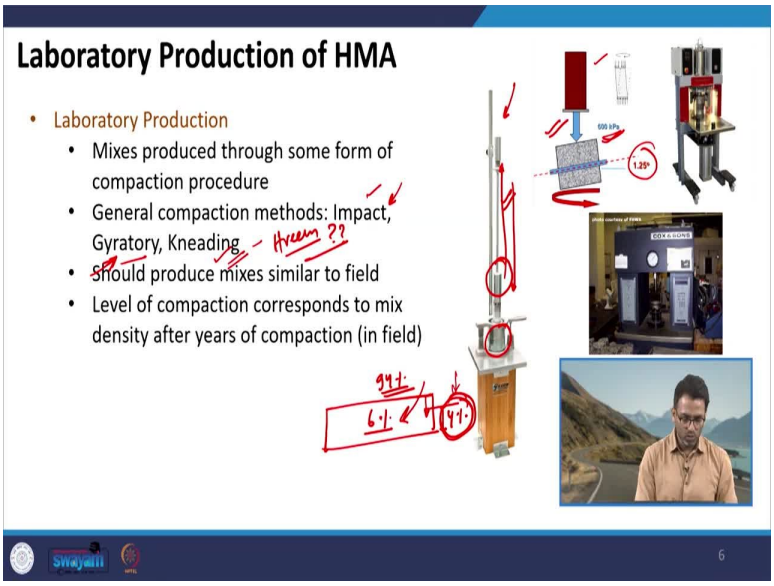

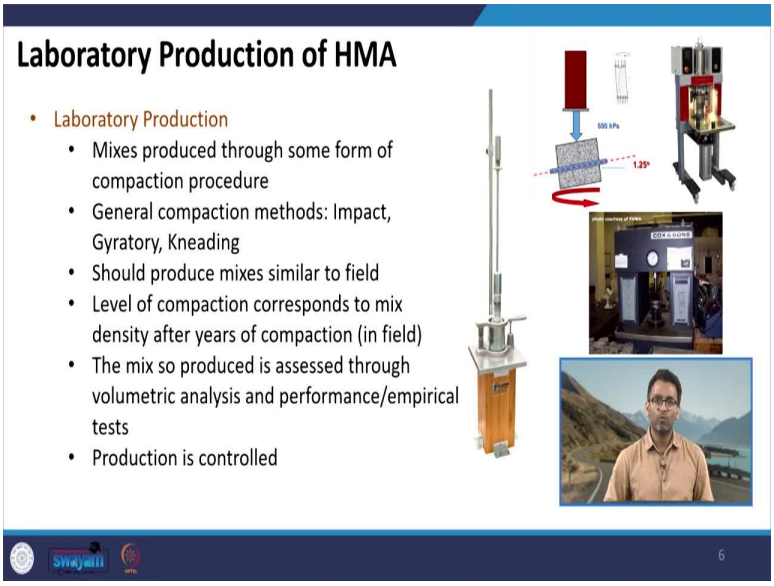

So, we have laboratory production of HMA in which mixes are produced through some form of compaction process, because if you see this mix, this is a cylindrical mixture and this occupies some volume which means that we have to compact it so, that it achieves the desired volumetric characteristics. Mixes in the laboratory are produced to some form of compaction. Various forms of compaction can be there depending on the type of mix design we are using and this is also interesting because here is one question that if you are going to produce a mix which is to perform in the field, then why are we adopting different forms of compaction?

The reason is because the mix design methodology or the process of compaction have evolved over a period of time. During the earlier days, one type of compaction was more popular and mix designs were developed based on that form of compaction. Later, when more researches were carried out, new mix

design methods developed and in the mix design they developed a new process of compaction. And of course, there are reasons why these new process of compaction were developed I will talk about them. But generally, there are three forms of compaction, impact compaction, gyratory compaction, and kneading compaction.

Impact compaction as the name suggests, we are going to produce a mix by giving the impact to the mixture, there will be a weight which I will throw from some height to impact the mixture which will be present in a cylindrical mold and due to this impact force this mixture will be compacted within the mold. So, that is impact compaction. So, normally we use a Marshall compactor which is shown here, this image has been taken from a random search in the internet.

So, you see we have cylindrical mold here and this is the compactor and this is basically the hammer. So, this can be lifted up and it can be thrown down. So, we have a specific process, specific weight of the hammer, specific height of fall, which we will discuss during the mix design process. So, today we are just looking at the process of compacting. Then we have gyratory compactor, this is used in the Marshall Mix design, which is popularly used in India. Then we have gyratory compaction, which is used in the Superpave mix design.

So, here we are not giving any impact load for complexion of the mixes, what we are doing on the loose mixture, let us say if this is a loose mixture on the loose mixture, we will have a load here, which will be in contact with the surface of this loose mixture and then it will apply a gyratory action at some angle, if you can see in this picture, that there is some angle at which the gyratory action or the force to compact is applied that will be applied to again compact the mixture to a given density.

Now, few limited research have indicated this form of compaction is better than the impact compaction in the sense that the asphalt mixture which is produced using this form of compaction is found to be a close replica of what is being produced in the field under the action of the rollers, but because in the field after we lay the loose mixture, we are using roller compactors to compact it.

So, then under this roller compactors because of the energy which we are applying the aggregate particles will have certain form of orientation. So, when you try to see that orientation and compare it with the orientation of the laboratory under different types of compaction, researchers have found that gyratory compaction gives a better representation of that aggregate orientation and therefore, is a better representation of the actual field mix which is produced, we will discuss more about it.

And then we have needing compaction which is typically used in heavy mix design, but this mix design we are not going to discuss in detail because this is no longer in use presently. So, the Kneading mix design kneading compaction is used. In the kneading compaction we have temper foot. So, the compaction is not

from a significant height, but from some height, we have a temper foot which applies a kneading action to compact the mix.

So, again the idea of kneading compaction was to produce a mix which could better replicate the mix which is produced under the rollers. Whatever be the compaction process, which we use the final idea or target should be to produce mixes, which are similar to what can be produced in the field.

Now, how much we are going to compact the mix, what should be the final density of the mix which we compact. Now, usually the mixes are compacted to achieve a level of density which will be present in the field after years of compaction which means that when I am doing the construction, I am compacting the mix to a particular density.

Let us say that the initial density at which I am compacted the mix in the field is 6 to 8 percent, this is the air void within the mixture, I am just giving 94 percent of compaction. So, which means 6 percent air voids are there, this is not a design mix, which I am going to produce in the laboratory.

After I compact the mix in the field, when I open it to traffic, there will be further secondary compaction of the mix. So, the air void of the mix will reduce over a period of time under the action of the moving traffic and then it will stabilize to a particular level beyond that there will be no reduction in the density ideally.

Let us say that the final density is air void which is reached this 4 percent. So, this is the mix which I am going to produce in the laboratory. So, this is always a confusion that students ask that we are producing the mix at 4 percent air void in the laboratory, but in the field, I am getting a mix which is having 6 to 8 percent air void, why is the case and what is the reason?

The reason is that our performance depends on the mix after it has undergone the secondary compaction. So, I am looking for that particular mix. So, that is why I am interested to produce the design mix which I will achieve in the field after years of compaction. So, this is again one point which we have to remember.

Now, the mix which we produced in the laboratory will be assessed through volumetric analysis and in addition to that, we will also conduct some mechanical tests and also some performance tests to understand the response of the mix under different conditions. In laboratory in contrast to what we see in the field and the plant the production is more controlled.

For example, even if you talk about batching the aggregates we do more fractionation than what is typically present in the mixing plant. In mixing plant let us say you have 2 to 3 stockpiles or 3 to 4 stockpiles which has to be blended in the laboratory we usually go for more number of fractionation so that we can control the mixture and study the actual property of the design mix.

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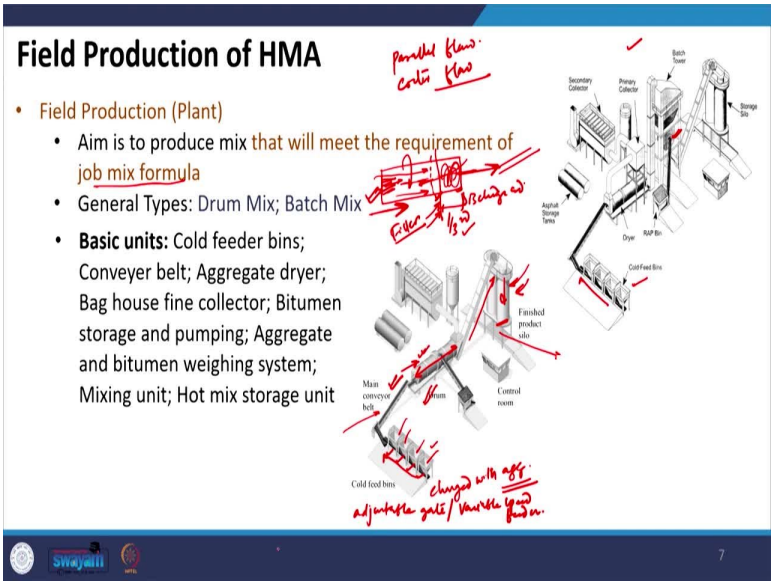

So, as we have now discussed about the production in the laboratory, let us see how the asphalt mixtures are produced in the field. So, when I say feel it comprises basically of two parts, the first part is the production of the loose as far as mixture in the hot mix plant followed by the transportation of this hot mix asphalt using trucks to the site and at the site we compact it using rollers and then paver and screed so that we will discuss as we move forward.

So, let us start our discussion with what happens in the plant. In the plant the aim is to produce a mix that will meet the requirements of the job mix formula. Now, this job mix formula is the mix design the final mix design which we complete in the laboratory. So, once we have done all the analysis through laboratory testing, through laboratory measurements, we will supply the mix design sheet and the same sheet has to be followed accurately in the plant to obtain or to produce the same mixture, because the performance of the mixture which is produced depends a lot on the volumetrics of the bituminous mixture. And that is why it is important that the values of various parameters which we have achieved in the lab should also be present in the final mix which is going to be laid in the field.

There are generally two types of plant using which the hot mix asphalt can be produced. One is the drum mix plant and the other is the batch mix plant. So, these are two pictures showing the drum mix plant, this one, and this picture is an outline of batch mix plant. So, in the drum mix plant the ingredients they are added, they are dried, and they are mixed in a single drum. So, this is the drum which you are seeing on

the screen now. So, only one drum the aggregates will be dried it will be added with the binder, it will be mixed with the binder, and actually it also will be weighed in the same drum.

Whereas, in batch mix plant the ingredients they are pre-weighed and they are added in a separate pug-mill. So, there is a pug-mill here to mix the aggregate particles with the bitumen, different sizes and quantity of aggregate with the bitumen. So, again we will talk about the details, these are two types of plant which can be used for the production of asphalt mixture, some of the basic unit of this plant it includes the cold feeder bin.

Now, cold feeder bin will be present both in the drum mix plant and the batch mix plant. So, these cold feeder bins they are charged with aggregates using a front loader, using a truck, they will charge these bins with different sizes of aggregate. So, these bins they have slanted sides with vibrators, which will keep constant supply of aggregate.

So, you can see here that the aggregates are supplied below the bin and there are vibrators so, that aggregates are not stuck in the bin, the bins also have an adjustable gate and variable speed feeder to control the quantity of aggregate that comes at the bottom of the bin and it is gathered in the conveyor belt.

So, there is a conveyor belt which will run below the bin which you can see here and from this gathering conveyor belt, the material is brought to the cold feed elevator. So, in which the material will be brought together of different sizes and in the drum mix plant this cold feed elevator also have an automatic weighing system.

So, the cold feeder elevator they have an automatic weighing system and using this weighing system appropriate quantity of aggregate will be further moved to the drum for drying. And in fact, this conveyor this measurement of the aggregate weight it can be controlled remotely using a system because before entering the drying drum, the aggregate will also have moisture. So, the adjustment of moisture is also made when the aggregates move from the cold feeder bins to this elevator. So, then the aggregate goes inside the drum which you see here, this is the drum.

In the drum mix plant there can be two types of movement of the aggregate inside the drum one is called as the parallel flow and the other is called as counter flow. So, before I explain parallel flow and counter flow, let me just tell you that in this drum, we have a heating system. So, the primary purpose of the drum is to dry the aggregates and since it is a drum mix plant the mixing of the aggregate with the bitumen will also take place in the same drum, let us say can be considered as two part system.

What happens in a typical drum one thing is that this drum will continuously rotate about its horizontal axis and then there is gas system which is provided the flame and the flame can be from one side and the aggregates can either move from here to here or it can come against the flame it can be of both the type.

So, in the parallel flow the aggregates are made from the burner side. So, if this is the burner side, then the aggregates are fed from the burner side and then the aggregate moves through this drum and let us say if this is the discharge end so, at approximately one third distance from the discharge end we have the bitumen feeding system.

So, the bitumen will be feeded here, so, the aggregates move here at this location the bitumen is feeded and then it is mixed with the aggregate in this location and then finally, the entire mixture will get discharged from here. And at the same location very near to the bitumen, we also will add filler.

Now, one of the reason of adding filler in the close proximity of the binder is to trap the fines because the fines will keep on moving due to the action of the heat inside and it is important to trap this filler, so, this filler will be trapped by the bitumen which will coat it. So, finally, the mix will come out from the discharge end and after coming from the discharge end it can be taken by a conveyor belt which you can see here, conveyor belt and it can be stored in this silo.

So, silo is basically the storage unit because finally, the mix has to be transported to the site. So, it is transported using trucks.

So, it may happen that truck will take some time to go to the site and come back and of course, there are several number of trucks. So, depending on the movement time and what whatever situation is at the field, the speed at which the construction is going on depending on that there can be some waiting time and but the production in the mixing plant is continuous. So, in order to store the mix to facilitate this time gap, we can store the mix inside this tower which is called as silo and as the trucks arrive we have gates beneath the silo, it will open it will load the truck with the hot mix asphalt and then the truck will go to the site, so, this is the process.

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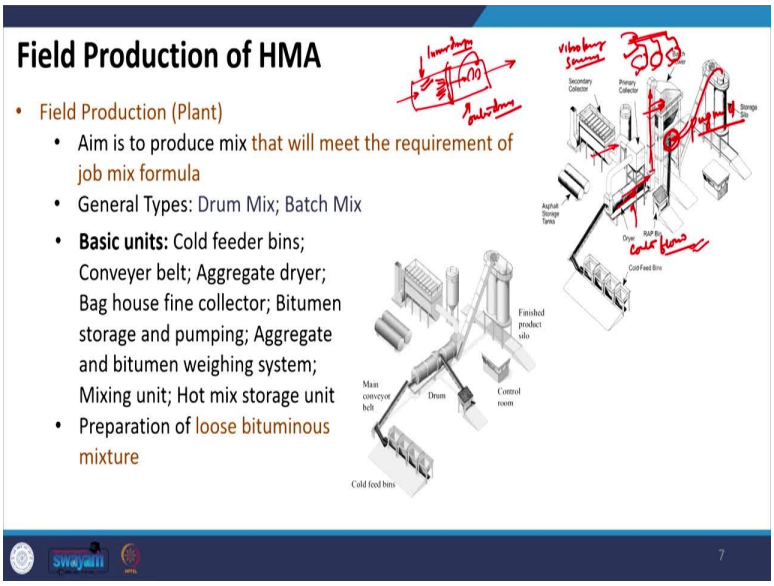

On the other hand, if you talk about the counterflow drum, in the counterflow drum, it is generally a double barrel type drum when I say double barrel, which means the drum itself is divided into two parts, the drum is divided into two parts. So, the aggregate first enters against the exhaust gas. So, if the aggregate is entering here, so, the exhaust gases provided on this side. So, the aggregate enters against the exhaust gas it is heated inside the inner drum.

So, this is the inner drum and then it travels to the outer drum, where it is mixed with the binder and we can have some paddles inside which will move along with the drum. So, the drum is also moving the paddles are facilitating the mixing of aggregates and binder. And again, similarly to what we have discussed it will come out from the discharge and it can be either sent to the truck or to the storage silo. This is the simple process of explaining what happens in a drum mix plant.

Whereas, in a batch mix plant which you are seeing here the outline the initial part is same that we have cold feeder bins from their aggregates go to the dryer. So, and this dryer, this is usually a counter flow system. So, aggregate is moving against the exhaust gas, this dryer is usually called has a counter flow system and after coming out, because we are not adding bitumen in the drum bitumen is added separately. So, after coming out from the discharge end it is sent to the hot elevator. So, aggregates will be sent in the hot elevator to the top of the batch tower.

And here the I will show you probably in the next slide that here we have different slots and we have a vibratory system and we have screens placed here, so we have a we have vibratory screens which will divide the aggregate which is coming in into different sizes. So, we have sieves here, different sizes of sieves. So, it will finally store the aggregates of different sizes. And we can apply a remote control here to decide how much aggregate has to come out and has to be mixed with the bitumen. So, all the weighing

system is controlled remotely, the weighing system of the aggregate, the weighing system of the binder, the weighing system of the filler.

So, in the same tower at some point the filler and bitumen are also added and again further we can as I said we can control the weights. So, depending on the job mix formula, the respective weight of different sizes will be allowed to move further, where it will come in contact with the bitumen and the fines and it will be mixed.

So, this mixing unit it is called as pug-mill, so, in pug-mill the bitumen, aggregates, and the fine material, they will come in contact with each other and they will be mixed for a few seconds that depends from case to case that how long we are allowing the mixing to take place and that also affects the cost of the entire operation of the batch mix plant.

And finally, we do the same thing we will transfer this mix which is produced here to the storage silo and then it can further be transferred to the trucks this is clear that how things what are the different units of drum mix plant and batch mix plant, I will try to explain it again using different picture in a different slide, so, I hope this is clear.

So, in the plant what we are basically doing we are preparing loose bituminous mixture. So, up to loose bituminous mixture everything happens in the plant that is proportioning of aggregates and mixing of hot drying of aggregates and mixing of aggregates, bitumen, and fillers. One more thing which probably I missed is that in that the filler is the movement of the filler or the amount of filler is also controlled to the bag house which is placed here and this also controls the pollution system which may arise because of the movement of the fine particles. So, that also is controlled in separately in the plant.

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These are some pictures are taken from one of the site visits which we did a few years back, I have a video also which I will play. The first picture which you see here, this is basically a the cold feeder being part and you can see that how the from the cold from beneath the cold feeder up in the aggregates are traveling through the conveyor belt and it will be taken further to the elevator which will is connected to the drying drum.

And there can be number of cold feeder bind depending on the number of stockpiles and from the cold feeder been the aggregates are further transferred to this from this elevator to the event you can see in the second picture that the aggregates are traveling and it is it goes to the drying drum.

Now, again in this picture you must be wondering that there are multiple a conveyor belt here. So, sometimes in the batch mix plant what we do for example, if some specific let us say rap has to be added then they are not added directly with the normal movement of the aggregates they are added separately. So, for that we can have separate conveyor belt system.

Then, finally, after coming from the I mean through the elevator, the aggregate will be we will come to this drying drum which you see here in the third picture and this drying drum as you can see, you have a specific length and you have a specific diameter. So, this length to diameter ratio it varies depending on the type of plant and typically let us say the length to diameter ratio is approximately around like 4 is to 1 to maybe 6 is to 1 typically. So, it depends from it varies from plant to plant.

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And I also have a video here just to show how the drum keeps rotating about the horizontal axis. So, this is I am just trying to play it here. So, you can see that how this drum is rotating here and we have a discharge end and from the discharge end, these heated aggregates will be taken to the hot elevator which you can see here this is the hot elevator and above the hot elevator here. Basically, we will have vibratory screens which will separate the aggregates into different sizes and it will be stored there. And then we can control the movement of these aggregates depending on the job mix formula.

And beneath that, we have a system where the bitumen will further be fitted along with the fines and the aggregates which come from the top and they will be sent to this pug-mill here for mixing. And from the pug-mill it can be directly discharged to the truck here which will be standing here otherwise it can also be you know sent further to the storage silo if there is a delay in the a movement of the trucks.

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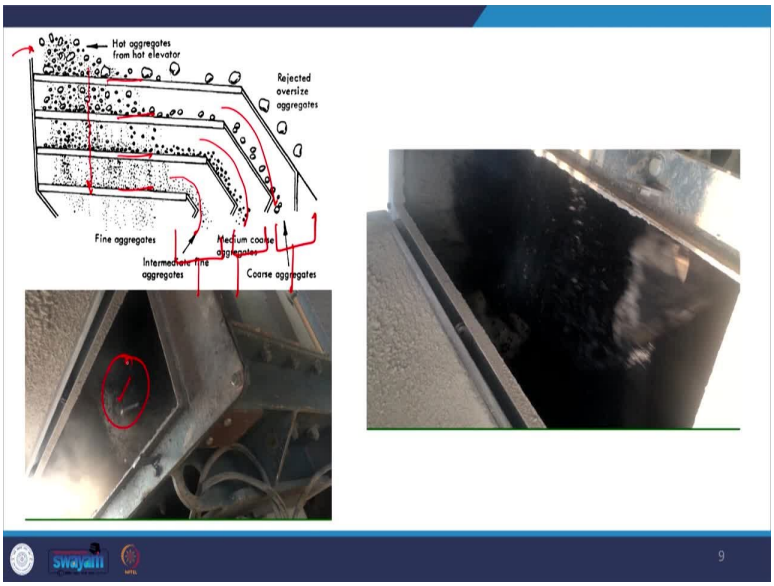

So, when I was saying that I will try to explain the what happens at inside the hot elevator. So, you can see that the hot aggregates enter here and these are different screens of or sieves you can see. And when this keeps on vibrating of course, you can understand that aggregates of different sizes will travel and it will be retained in the respective sieves depending on the size and from each sieves we have a different unit from where to where it can be collected separately and it can be kept.

And then we can further allow the movement of these aggregates depending on the job mix formula. And then it will meet the bitumen and the fine bitumen and the fillers it will be then mixed in the pug-mill. This is a video so, I will try to play the video to explain just to try to visually explain how what happens inside the pug-mill.

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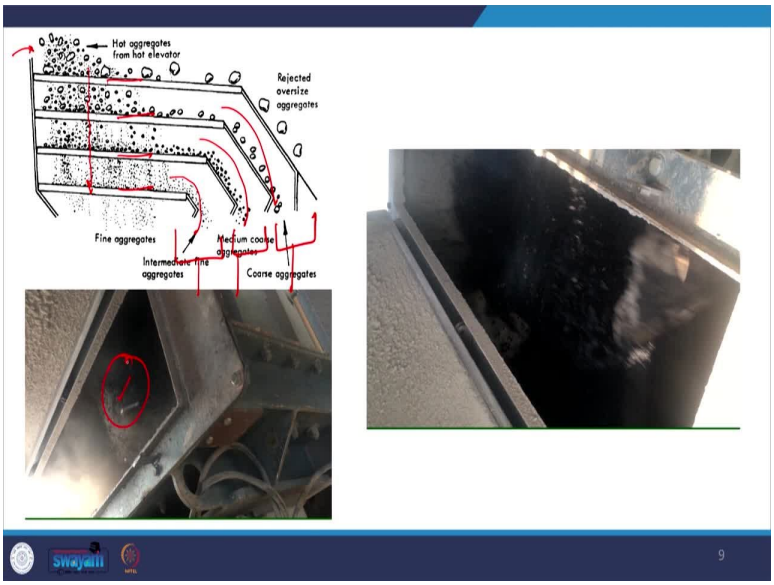
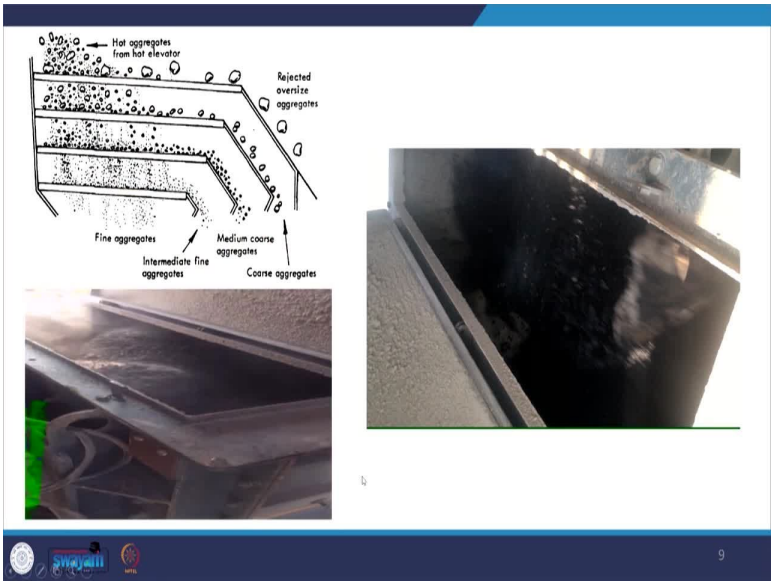

Hot aggregates from hot elevator
Rejected oversize aggregates
Fine aggregates
Medium coarse aggregates
Intermediate fine aggregates
Coarse aggregates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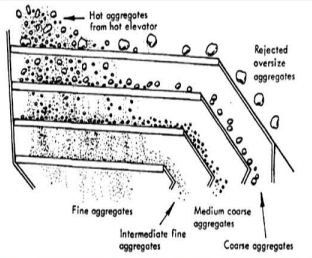
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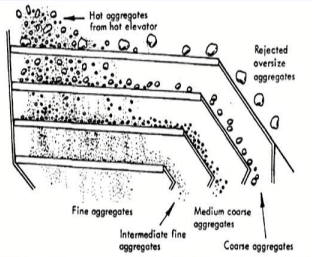
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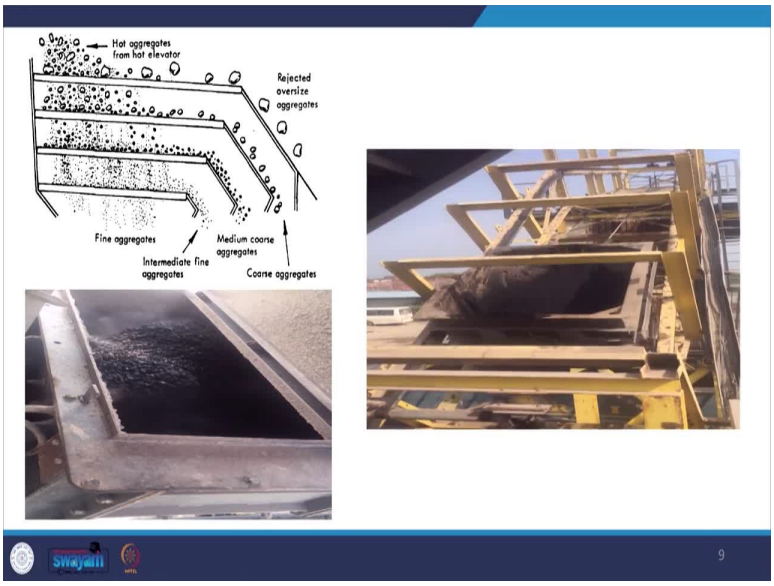

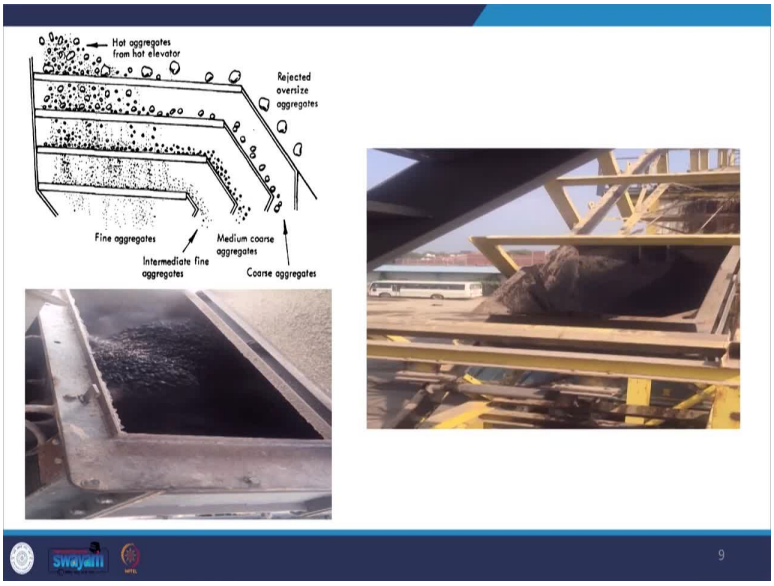

So, you can see that how the aggregates are being are moving inside and it is being mixed with bitumen. So, initially it will appear to be dry, but after a few seconds, you can see a very smooth mixture which is ready which will be very clear in the second video. So, I think now, it is pretty clear how the color has changed to more of uniform black in nature.

And after a few seconds of mixing here you can see how things are happening. So, this mixture has been prepared it is now finally traveling in it will be sent to the storage silo here. And then it will first discharge the entire material and it will come back again to collect further material. So, I hope that it is clear that how things are happening during the production of hot mix asphalt and the plant.

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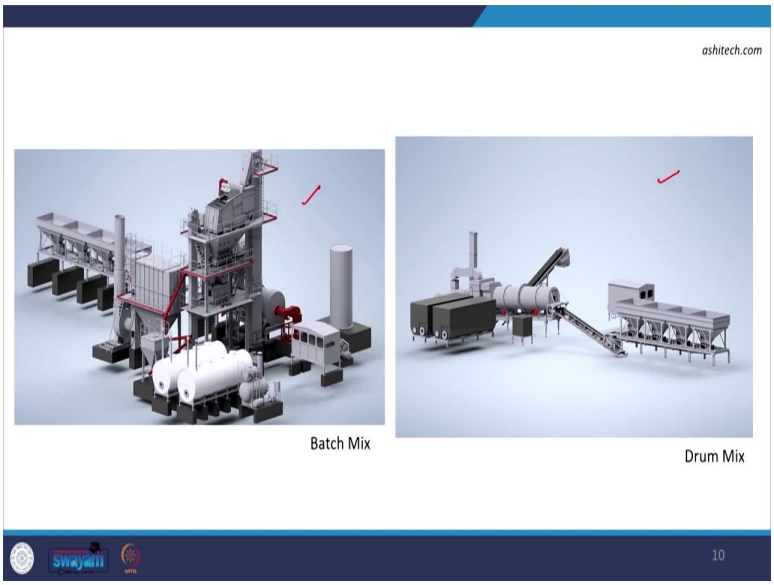

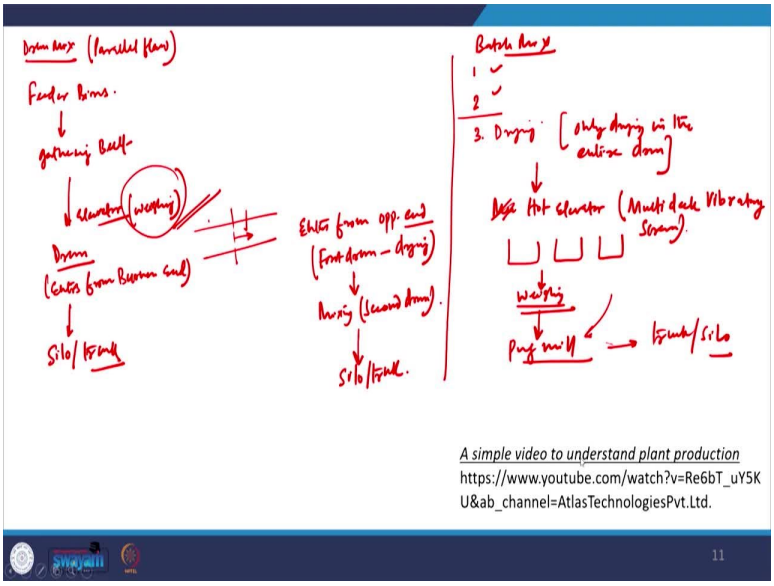

Well these are again two pictures taken randomly from internet search with clear indication about different units of a of a drum mix plant and the batch mix plant. So, here I will just try to repeat few things which we have discussed about the drum mix plant and the batch mix plant. So, in the drum mix plant let us say I am talking about the drum mix plant here and I am talking about the parallel flow system.

So, in the parallel flow system we what happens that the feeder bins will store the aggregates separately. So, we will have feeder bins to store the aggregates separately and the aggregates will be collected by the gathering belt. So, we will have a gathering belt to collect the aggregates and then and into the vibratory screen. And then we have a single deck vibratory screen that removes oversized material before the aggregates reach the charging conveyor. So, it will reach the elevator here.

So, the charging conveyor it will transfer the aggregates after weighing, so we will have a weighing system here. So, after weighing it will transfer the aggregate to the drum and aggregates will enter the drum from the burner end, so enters from burner end, because this is a parallel flow system and first half of the drum does the heating.

So, as I said the drum has can be considered in different sections. So, the first half of the drum typically it will facilitate the heating and the mixing will take place in the second half of the drum and the hot mix asphalt will come out from the other end and it will be discharged either into the truck or into the silo. So, from here it will go either to the silo or to the truck directly. So, this is about the parallel flow.

Whereas, in the counter flow the first part remains the same, the second part remains the same, the third part also remains the same, so up to here everything is same. Then here the aggregate enters the first drum from the opposite end, so it enters from opposite end, opposite to the burner and only drying takes place in the first drum so, this is a two-drum system.

So, first drum only drying will take place and the mixing takes place in the second drum or second chamber. Then finally the hot mix asphalt now that the next process is same that it will come out from the discharge end and it will be either stored in the silo or sent directly to the truck. So, this is about a drum mix.

If we just have to recap about the batch mix plant. So, here also the first part is same that the feeder bin will store the aggregate separately and aggregate will be collected by the gathering belt below the bins and into the vibratory screen. Then the second part also remains the same that we have single deck vibratory screen that will remove the oversized material before it enters the charging conveyor and the dryer. Now, here so point one and two it remains the same.

Now, here we are not concerned about the weighing part. So, this weighing which we have discussed this is this does not happen here in the batch mix plant. So, here then aggregate enters the drum so, the third part is basically drying so, aggregate will enter the drum from the opposite side counterflow and only drying will take place, only drying in the drum, in the entire drum. So, from here the heated aggregates are taken to the multi deck vibratory screen. So, here it is taken to the from hot elevator to multi deck vibratory screen. So, here the weighing will take place.

So, after the aggregate past the vibratory screen they are stored in separate bins. So, which I showed you in the previous slide that they can be stored in different bins as per their size and then the weighing will be weighing will take place and it will be weighed separately and it will be led it will be fed into the mixing unit which is the basically the pug-mill. So, bitumen minerals and other materials for example, if we have wrapped they are weighed separately before it is added to the mixing unit so, which I have already

explained. So, and then after mixing it is further sent to truck or to silo. So, I hope again this process is clear to you.

Now, usually in the pavement material class this is something which is always confusing for the students because they are not able to visualize what happens in the plant for mixing during the production of hot mix asphalt. I also have a video here are taken from Atlas technologies Private Limited, it is a three 3d animated video. So, I will just try to play this it will be a few minute video and this will also clarify whatever we have discussed verbally. So, I think visually it will be more comfortable for you to understand what happens in the mixing plant. So, let us just play this video and try to understand.

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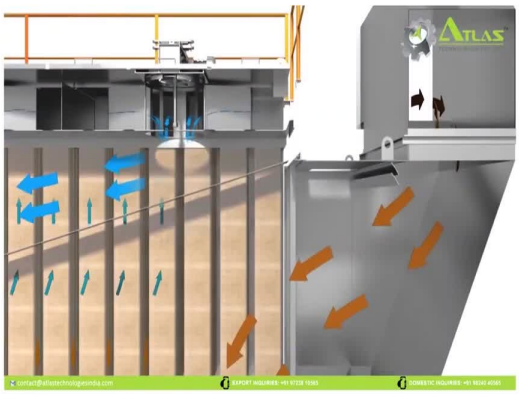

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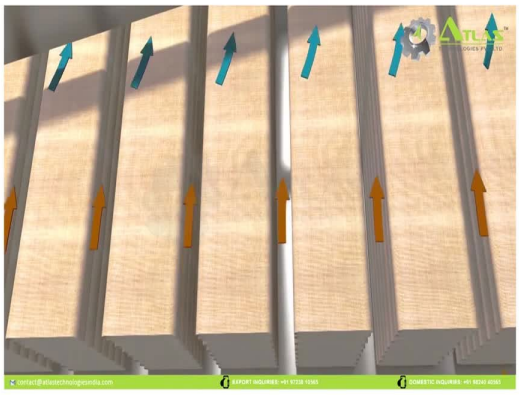

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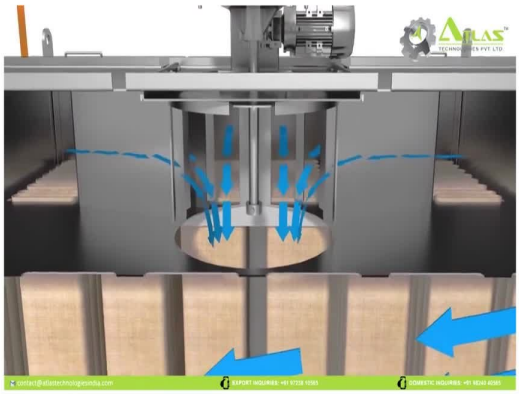

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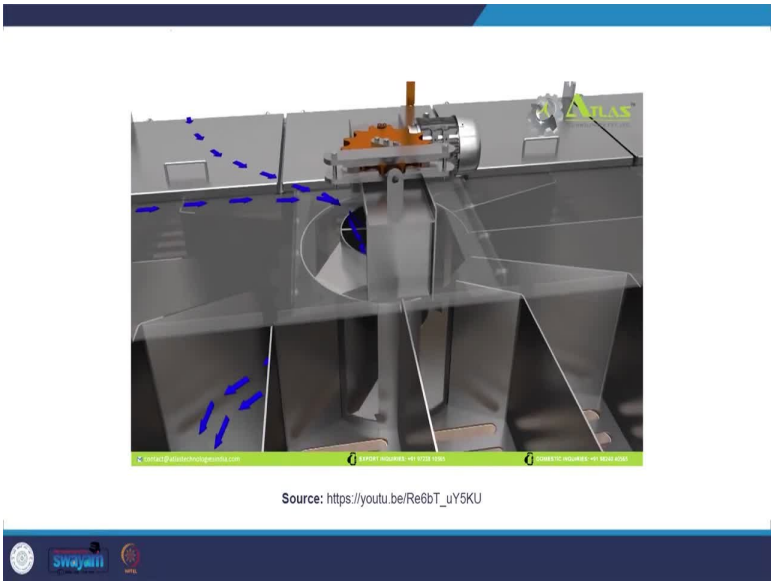

So, here you can see a complete picture of the batch mix plant, so, this is a batch mix plant basically with different units. So, these are the cold feeder bins from the feeder bin goes to the conveyor belt and we have vibratory screens here to control the movement. So, this is what happens inside the drying drum.

So, you can see that on the front side we have the burner and the aggregates are moving against the burner. So, this is what I was saying about the bag house finds. So, they have a system of not wasting the fines. So, these fines can be collected and they can also be reused again. So, this is how the air will move out.

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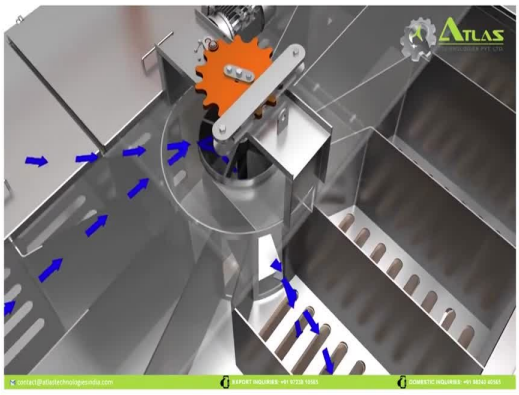

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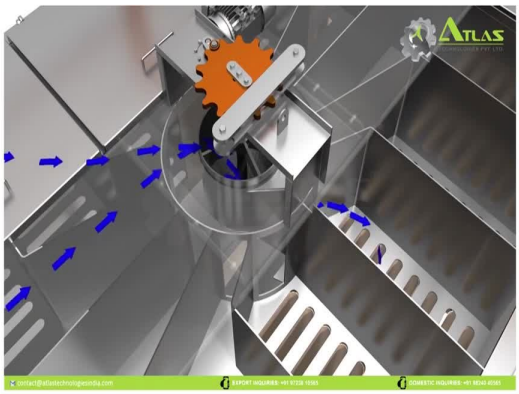

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So, this is how where the fines will be collected and it will be stored and will be later added with the in the mix. And you can see that it will be later taken to the elevator and it will be added with the aggregates at the top of the tower.

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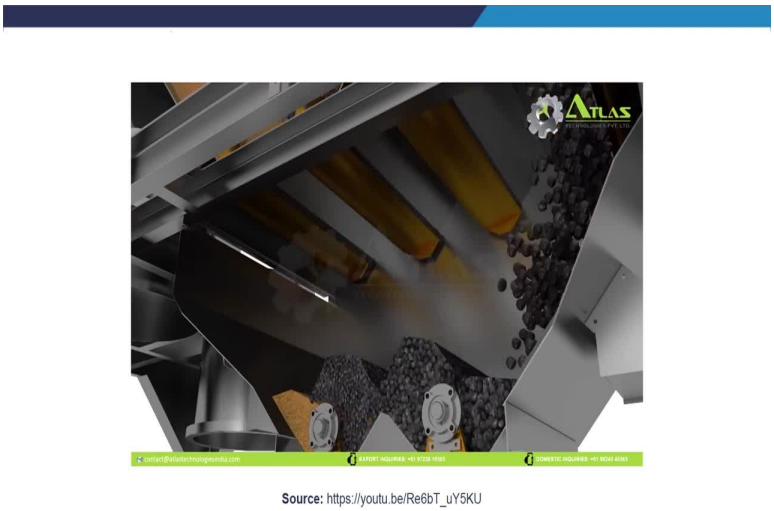

So, these are the aggregates which comes out from the drying drum. So, this is what I was showing you in the picture that we have different sizes of sieves and depending on the size of the aggregates it can be collected and stored in different bins which you can see here that there are different how it goes to different bins. So, you can see that there are gates which will be controlled remotely depending on how much aggregates we want to be mixed per volume of the mix. So, this depends on the mix design which has been done.

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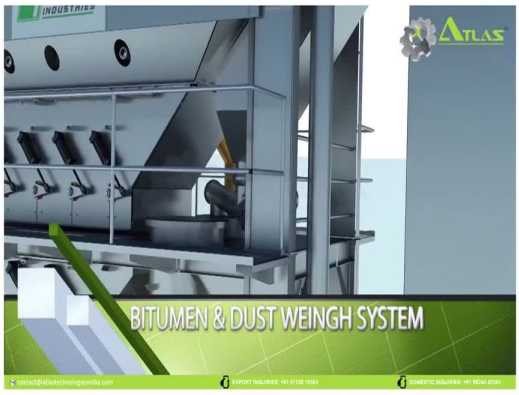

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So, now it shows what happens inside the pug-mill and finally, the gates will be opened and it can go either to the storage silo or it can be loaded to the trucks. So, I hope that this video makes it pretty clear of the different actions or the different steps which are followed in the mixing plant.

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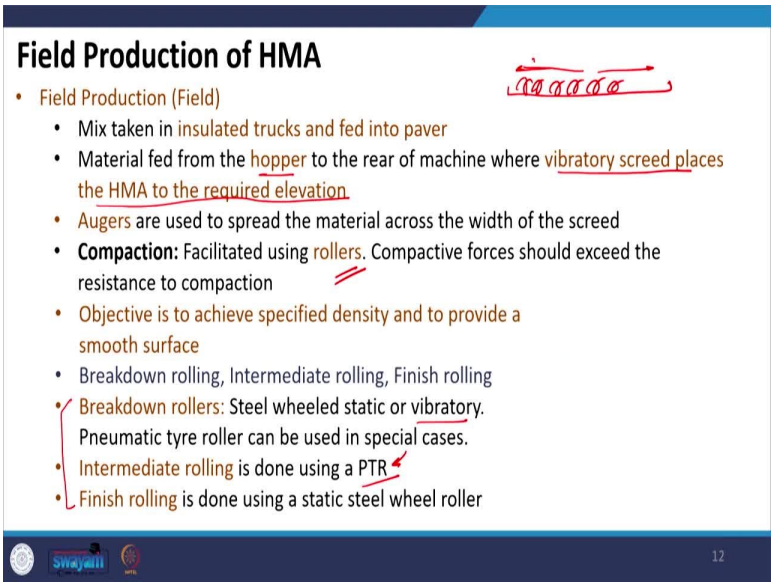

So, now we will move forward and we will go to the second step that now we have prepared the mix in the plant and we will see that how this produced mix is compacted in the field. So, this mix is taken in insulated trucks and it is fed into the paver, I will show you in the next slide how a paver looks like. Here the material is fed from the hopper to the rear of the machine where the vibratory screeds it places the HMA to the required elevation.

So, in the paver we have a system where using augers we can spread the material. So, there will be some auger system I will show you in the next slide where and these augers will continuously keep on moving and it will spread the loose mixtures laterally and to the required lose elevation and it will apply some a little compaction to the mix. Again, an example I will show you in the next slide.

So, once this loose mix has been spreaded laterally to the required met, then we will start the compaction and the compaction is done using rollers. So, here we have to ensure the primary objective here is that the competitive forces because of the rollers, it should exceed the resistance to compaction by the mixture.

So, the roller should be capable enough to compacting the mix to the required density now that is the main purpose. And here also one more important thing is that the temperature is very important, because the compaction effort required and the level of compaction or density which will be achieved is also a function of the temperature at which the compaction is being done.

So, as I mentioned the final objective is to achieve the specified density and to provide a smooth surface. So, these two objectives are fulfilled using different steps of rolling, this rolling are usually termed as breakdown rolling, we have intermediate rolling, and we have finished rolling. Now, what is a breakdown rolling that is the initial rolling that aggregates are in loose state now, so, I will do a breakdown rolling so, that the aggregates can be allowed to move about each other and to orient itself properly within the in the mix, so that can be done using breakdown rollers.

So, breakdown rollers can are usually steel wheel rollers or and it can be either static or it can be vibratory, it is usually a vibratory type roller, sometimes pneumatic tire roller are also used only in special cases, but generally still wheel rollers are used. And as I mentioned that the breakdown rolling is usually done using a vibration. So, you we have to set a specified frequency at which the vibration will take place and it will compact the mat which is being laid using the paver.

The main purpose of intermediate rolling is to achieve the required density. So, here a pneumatic tire roller is used. So, this is called as a term denoted as PTR. So, the intermediate roller is done using PTR. So, the advantage of using PTR is we can achieve a very dense surface, I mean the appropriate density can be achieved and that to within a shorter period of time in comparison to steel wheel roller, where the uniformity and density is not very accurate.

And finally, we do the finish rolling which is done using a steel wheel roller which is a static steel wheel roller and the main purpose of doing finished rolling is to remove the tire marks of the PTR which will occur after the intermediate rolling and also to remove if there are any further surface undulations in the

pavement, so that is done using a finisher. So, you can see that there is a three step process breakdown rolling, intermediate rolling, and finished rolling.

So, again just a recap that breakdown rollers are used to orient the aggregate particles properly, to facilitate compaction. Intermediate rolling we want to achieve our target density, so we use a pneumatic tire roller and the main purpose of doing finished rolling is to remove any irregularities from the surface and also to remove the marks of the PTR from the surface. So, this will ensure a smooth riding surface in the pavement.

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This picture is showing that how the aggregates and we have also seen in the video, so it is loaded into the truck. So, here you see again there can be different ways of loading in the truck, but usually the mixes are loaded in something like this, which you can see here. So, this form of loading it ensures that the segregation is not very high, instead of loading everything at one place here the segregation of the material will be high.

So, therefore, a multiple step discharge is used typically for loading the truck. So, after loading this truck you can see here that the material is discharged. So, this is the paver, it is discharged on the rear side of the paver and here this this paver has screed system and auger system which will place the loose mixture to the required height and also will laterally spread this mixture. So, I have a small video here to just show you how the auger system actually works.

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Now, here you can see that how after the discharge and it is it goes to the front side and then here you will see the auger system moving and how it spreads the mix. So, you can see the augers moving here and it is moving the mix laterally so that the lose mixture can be properly laid. And then finally, the surface will look something like this after the paver has spreaded the mix.

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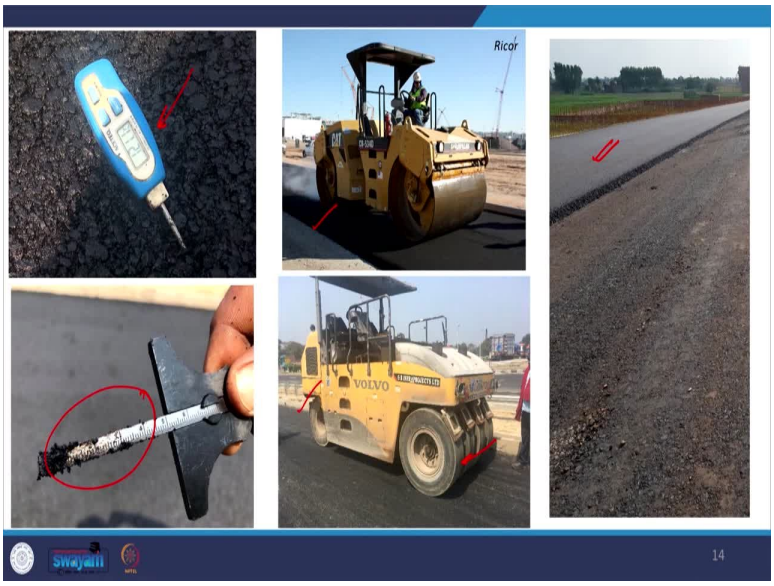

And then we will start compacting you can see that there is a this is the breakdown rolling and after that we will do an intermediate rolling using a pneumatic tire roller which you can see here, and again we will use a static wheel roller to complete the surface. So, this is a finished surface which you can see on one side.

So, as I mentioned temperature is very important during compaction though, so, this should be continuously monitored and we should also check the final thickness as per the design specification. So, after compaction, we have to ensure that the required depth is reached. So, these are some of the steps which gives us an idea about the production of the bituminous mixtures in the plant and then in the final complexion in the field.

So, we will stop here today. So, just to recall that we have discussed about the production of bituminous mixtures, we have talked about the production steps in the laboratory, the importance of production in the laboratory and then the production in the plant and subsequent compaction in the field. And we have also discussed about the different types of plants, drum mix plant and batch mix plant, and we have briefly discussed about the procedure which are adopted corresponding to different units in these mixing plants. And we have also tried to talk about the difference in the production process.

So, in the next presentation we will talk about the mix design process we will try to understand the important properties which are desired from hot mix asphalt and based on these desirable properties how we aim towards doing a rational mix design for the bituminous mixtures. Thank you.