Pavement Materials
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Lecture 41
MARSHALL AND SUPERPAVE MIX DESIGN (Part 2)

Hello friends. In the last presentation, we were discussing about the steps that are involved in the MARSHALL AND SUPERPAVE MIX DESIGN PROCESS. And we completed our discussion.

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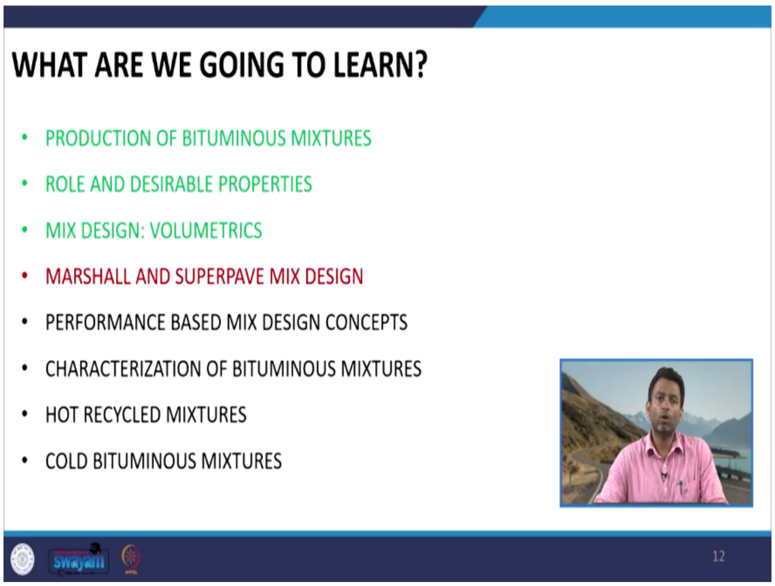

On design aggregate gradation, which we discussed that is an important step to choose an appropriate aggregate gradation out of various options that satisfy the upper bound and the lower bound criteria given by the highway agency for any given bituminous mixture. So, let us continue our discussion and let us see the further steps involved in the mix design process.

And we are especially talking about the steps involved in the MARSHALL AND MIX DESIGN process and we will keep discussing about these steps simultaneously for both the process. So, that we can understand what are the differences between the steps involved in the MARSHALL AND SUPERPAVE MIX DESIGN method.

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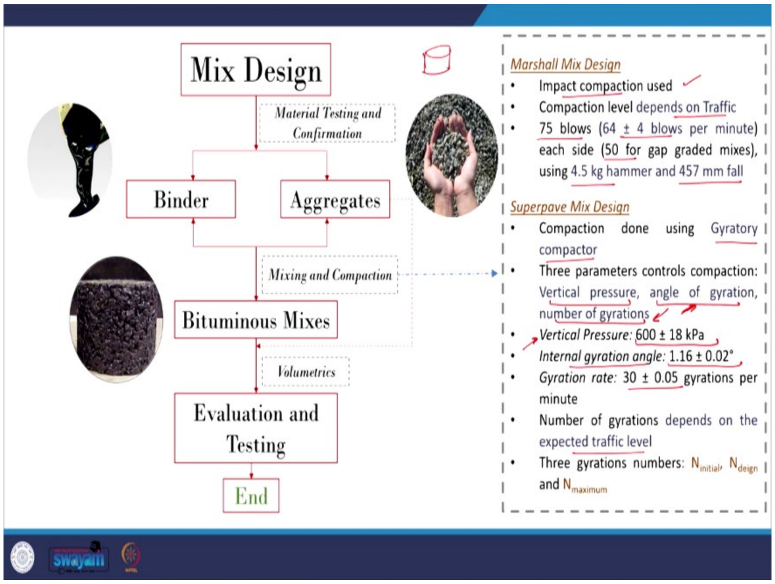

We have selected the material including the Binder and Aggregates we have performed the design aggregate gradation, we have selected the final gradation to be used, then comes the mixing and compaction of making the mixture and mixing the binder and aggregates together and compacting it to produce a cylindrical bituminous mixture for laboratory investigation.

So, talking about the preparation, let us see what we do to prepare the sample in case of MARSHALL MIX DESIGN and what we do in case of SUPERPAVE MIX DESIGN. Ultimately we are going to prepare a cylindrical bituminous mixture, the difference being in MARSHALL MIX DESIGN method we are using an impact compaction whereas, in SUPERPAVE MIX DESIGN we are using a gyratory compactor.

So, the mode of compaction is different in both the methods. Therefore, using a similar aggregate gradation and similar binder, when we make mixes using these two methods, they can have different properties because the aggregate orientation while making the mixture in both the methods will be different.

Few literature's have indicated that gyratory compactor produces a mixture, which has aggregate orientation, very similar to what we get from the infield mixes which are compacted under rollers. But, as I mentioned, these are very few literature's that have actually evaluated and validated the results.

In the MARSHALL MIX DESIGN we use a impact compaction, the amount of compaction to be given which means the number of blows to be given to produce the final mix, it depends on the traffic level, we will see the number of blows corresponding to the traffic level after a few slides. The standard method which we use, it uses 75 blows of compaction on both sides, which means once you have the mixture I will show you the mold and the collar here.

So, if you can see in my hand I have this mold and I have the mold and then I have the collar. So, this mold is seated on the base plate and over this we put the collar and finally the loose mixture is kept here. So, this collar is basically included to accommodate some extra mixture or extra height.

Because we are putting loose mixture here and after compaction it will be the depth will be reduced. So, we will put the loose mixture here and then here we will put our hammer and apply the impact compaction as I mentioned that we are going to give the compaction on both the sides.

So, first on this side we will give 75 blows and then we will remove the collar we will reverse the sample put it on the base plate again put the collar back and again give 75 blows on this side. So, this is how we will finally prepare the compacted bituminous mixture and as an example, I have I think I have previously shown you a bituminous mixture.

So, we will have a cylindrical bituminous mixture of this form. Again some of these additional specifications include at the rate of impact. It should be, in the range of 64 plus minus 4 blows per minute. The number of blows also depends on the type of mix for example, if you are using a stone mastic asphalt, which is a gap graded mixes.

Then the collar specification specified it only 50 blows are required additional blows can cause breakage of the aggregates. So, 50 blows is sufficient in the standard compaction we use a 4.5 kg hammer with a 457 mm fall, we also have a modified compactor for mixes in which the maximum aggregate size is more than 25 mm.

I will discuss about that probably in one or after one or two slides, coming to the SUPERPAVE MIX DESIGN as I mentioned, we use a gyratory compactor in the gyratory compactor the compaction is controlled using three parameters. These include the vertical pressure, the angle of gyration. And the number of gyration which means how much pressure I am applying on the mixture because we are not a playing a contract, which means, the loose bituminous mixture is almost in contact with the gyratory compactor. And there will be some gap between them which is basically controlled by the angle of gyration.

So, this angle of gyration is also very important and finally, how many number of gyrations we are giving this will control the finally, the final density of the mixture, the standard which is used in the SUPERPAVE MIX DESIGN it says that the vertical pressure should be in the range of 600 ± 18 kPa.

The internal gyration angle should be in the range of 1.16 $\pm$ 0.02 degrees and the gyration rate which is given to compact these specimens should be in the range of 30 $\pm$0.05 gyrations per minute, and how many gyration has to be given it depends on the expected traffic level.

Similar to the number of blows which is required in MARSHALL compaction that also depends on the expected traffic level, in the SUPERPAVE MIX DESIGN method, there are three different gyrations which are used as a standard during the mix design process, it includes an initial and design and maximum we will discuss about these also.

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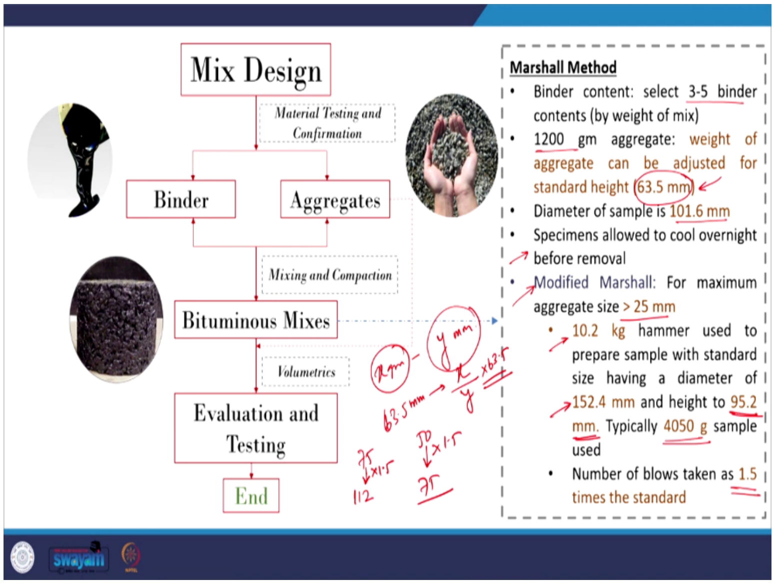

So, these are some images just to familiarize you with the different compaction process. So, this is a Marshall compactor you can see this is the compactor and this can be moved up and down this is the mold with the collar which I just showed you and using this machine we can produce the bituminous mixture.

This pictures these three pictures, it tells us about the SUPERPAVE gyratory compactor, it says that what is the internal angle so, this is the internal angle the gap which it makes with the sample, this is the vertical pressure and this is the rate of gyration which is used. And finally, this picture shows that how a gyratory compactor actually looks like, or this gives us some idea about the compaction method.

Now, once we have the compaction method, let us also understand that how many samples we are going to make, what should be the weight of the sample, how much material we are going to consume and so, on. So, in the MARSHALL method and also in the SUPERPAVE MIX DESIGN method typically the mixes are made at 3 to 5 different binder contents and binder content is represented by the weight of the mix.

So, typically we use 1200 gram of aggregate. Now, the weight of aggregate can be adjusted for standard height. So, standard height is 63.5 mm let us say, you are using x gram of aggregate and the thickness which you got is y mm but our standard height is 63.5 mm. So, if you find that the value that is y is going much beyond the standard height, then we can change this x gram of aggregates and we can alter it.

So, how we will do that? So, you see that if you have y mm of height you have to use x gram of sample which means for 63.5 mm height. How much sample will be required, $\frac{x}{y} \times 63.5$. So, this can be the amount of aggregate which we use can be adjusted so that we have the sample of standard height the dia of the sample is constant it is 101.6 mm.

And once we prepare the sample using the Marshall method the samples are usually allowed to cool overnight though they can be removed once we feel that the sample has cooled down we can remove it from the mold but typically we allow it to cool overnight before removal. As I mentioned we also have something called Modified Marshall.

And Modified Marshall method is used when we have aggregates in the mixture whose size is more than 25 mm. In that case the impact process remains same, but we will use a 10.2 kg hammer and the standard and the size of the sample will be also larger than the conventional or the standard size. So, the dia of the sample is 152.4 mm and the height is 95.2 mm.

So, this is the standard height, whereas, for Standard Marshall 63.5 mm is the standard height and typically, we will use around a 4 kg of sample to prepare the Modified Marshall also the number of blows will change for the Modified Marshall as I mentioned that we use either 75 blows or 50 blows in Standard Marshall if you are using Modified Marshall then these blows has to be multiplied by a factor of 1.5.

So, the sample which we are compacting at 75 should be compacted at 112 blows just a multiplication factor of 1.5, whereas simple which was compacted at 50 blows will be compacted at 75 blows now, on both the sides. So, this is some of the salient features of the compaction process in the Marshall Mix Design method.

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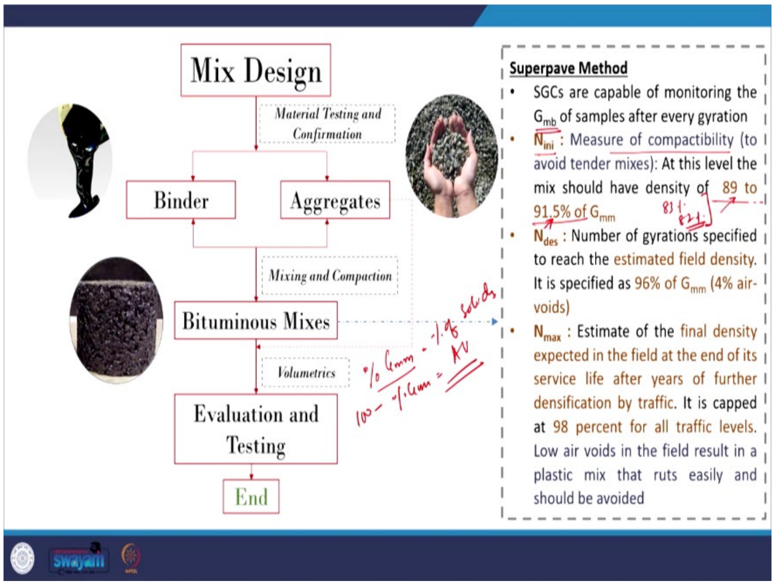

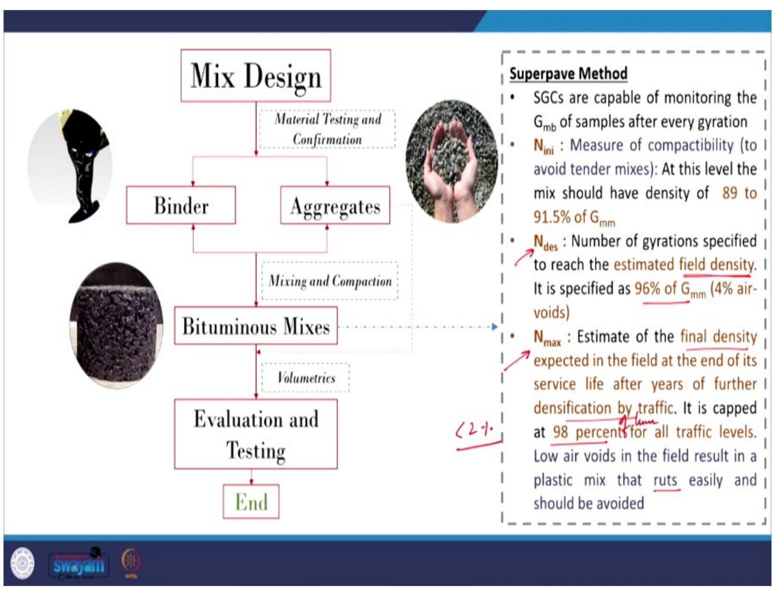

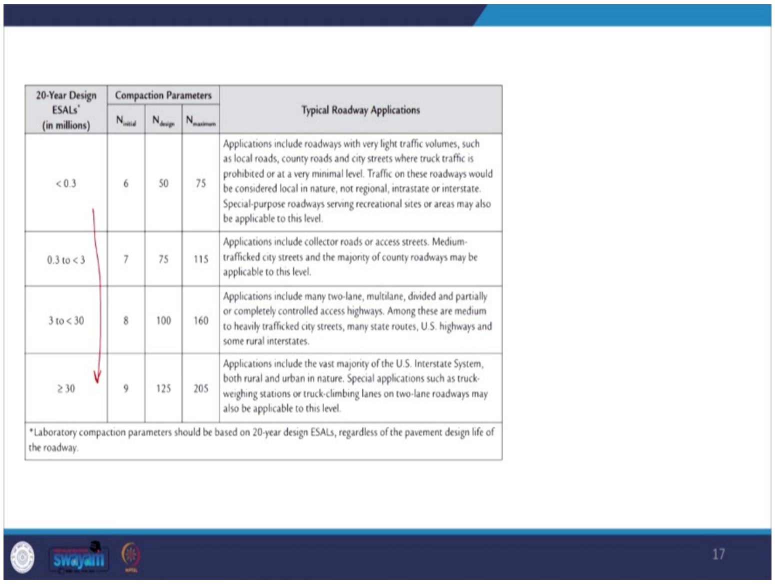

20-Year Design ESALs* (in millions)	Compaction Parameters			Typical Roadway Applications
	$N_{initial}$	N_{design}	$N_{maximum}$	
< 0.3	6	50	75	Applications include roadways with very light traffic volumes, such as local roads, county roads and city streets where truck traffic is prohibited or at a very minimal level. Traffic on these roadways would be considered local in nature, not regional, intrastate or interstate. Special-purpose roadways serving recreational sites or areas may also be applicable to this level.
0.3 to < 3	7	75	115	Applications include collector roads or access streets. Medium-trafficked city streets and the majority of county roadways may be applicable to this level.
3 to < 30	8	100	160	Applications include many two-lane, multilane, divided and partially or completely controlled access highways. Among these are medium to heavily trafficked city streets, many state routes, U.S. highways and some rural interstates.
≥ 30	9	125	205	Applications include the vast majority of the U.S. Interstate System, both rural and urban in nature. Special applications such as truck-weighing stations or truck-climbing lanes on two-lane roadways may also be applicable to this level.

*Laboratory compaction parameters should be based on 20-year design ESALs, regardless of the pavement design life of the roadway.

Coming to the SUPERPAVE Method as I mentioned, we use a gyratory compactor and we have a automated system which means we can continuously monitor the bulk density of the mixture. So, we have N initial number of gyration and this initial number of gyration is given or the criteria should be satisfied. And it is a measure of the compatibility of the mix.

So, let us say if we have a mixture, which compacts too easily, which means that can be a tender mix, so we have to prevent the mix from being tender. And that is why a criteria, is imposed that at this level of compaction that N number of N initial number of gyrations after N initial number of gyration. The mix which we have should have a density in the range of 89 to 91.5 percent of Gmm.

So, we know that percent Gmm is nothing but it tells us about the percentage of solids in the mix. So, if I just subtract 100 form percent Gmm, it will tell me about the air voids. This we have discussed when we talked about the volume metrics of the bituminous mixture. So, this means that the mix will have 11 percent to 9.5 percent air void at this level.

Here again, you can try to understand that if after N initial the air void is very high, let us say 83 percent of Gmm or 82 percent of Gmm. This mix will be very difficult to compact in the field, so, those mixtures should also be avoided. So, N initial the check N initial, it helps us to reject those mixes, which can be very difficult to compact or which are more, tender in nature. So, this is an important criterion, in the SUPERPAVE MIX DESIGN.

Coming to the N design this number of gyrations, it specifies the infield density and when I say field density, it means after years of traffic when sufficient traffic is moved and the mixes finally come to a stage where we are expecting that no further compaction will take place. So, the number of gyrations to reach the estimated field density, which means the design number of traffic, has moved over it.

So, this is same in case of Marshall as well as SUPERPAVE MIX DESIGN that we are targeting 4 percent air void and that is why it is 96 percent of Gmm. So, when we are making the mixes in the lab using the SUPERPAVE method, and we are giving N design a number of gyrations at this gyration the air void should be 4 percent.

Then one more important criterion is N max and this criteria, it helps us to identify those mixes, which can be prone to rotting or shoving in the field. This is an estimate of the final density expected in the field at the end of service life after years of further densification which means let us say the sufficient number of traffic has moved over it and still the mix has a tendency to densify.

So, N max will tell us what will be the maximum level of densification in this particular aggregate structure or this particular mix. And this is capped at 98 percent, when I say 98 percent of Gmm it means that the mix should not have lower than 2 percent air voids. So, if the air void in the mixture becomes too low, then these mixtures can result in plastic flow or it can ruts easily and these mixes should be avoided for construction.

So, these three checks helps us to finally identify a most suitable bituminous mixture to be used for field construction, this is the criteria as I said we have five different levels of traffic. So, for each level of traffic the value of N initial, N design and N maximum has been suggested by suggested in the SUPERPAVE MIX DESIGN process and add these, number of gyrations the level of air void should be made by the mixture. And you can also see that the, what are the roadway applications corresponding to different levels of traffic here.

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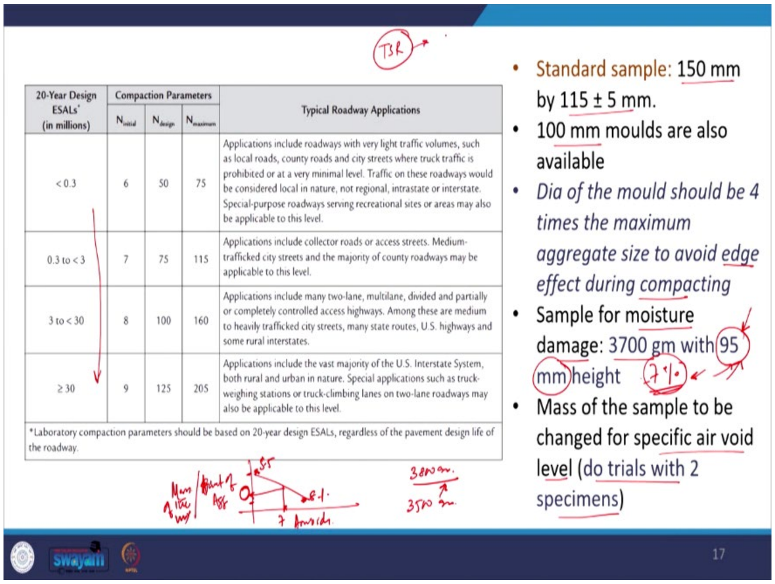

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Some other salient features of the SUPERPAVE compaction process is that in contrast to Standard Marshall which is 100 mm in dia approximately the standard sample here is 150 mm in dia and 115 mm in height these days, we also have samples in the SUPERPAVE gyratory compactor we can produce mixes with 100 mm dia also. Typically, the dia of the mold irrespective of the mix design process is chosen based on the maximum size of the aggregate and the dia of the mold should be approximately you can say 4 times the maximum size of the aggregate, so that we can avoid the edge effect during compacting.

So, in addition to the samples that are prepared for determining the optimum binder content, in the SUPERPAVE MIX DESIGN method, we also prepare samples to evaluate the moisture sensitivity of the mixes and for this typically 3700 gram of aggregate is used and the samples are prepared to meet a criteria of 95 mm height, this 95 mm height is basically selected.

So, as to get a mix which can have air void of 7 percent which is required to evaluate the moisture sensitivity. Now here when I say that the height is fixed, which means that we have to change the amount of aggregate which can be used to have 7 percent air void corresponding to 95 mm height. So, for this what typically is done typically let us say this is amount of aggregate or the mass, mass or a mass of the mix and then we have air voids. So, we are selecting a first a higher wait around later said 3800 grams.

So, for 3800 grams we will use the gyratory compactor we will continue the gyration until 95 mm height is reached. So, at 95 mm height we will see what is the air void in the sample let us say this is the air void in the sample. And this is 3800 then we will make a mix let us say at 3500 gram they will keep giving the gyration until the height of again 95 mm is reached. this is a air void which we get approximately 5.5 percent.

And this is something which we get around, 8 percent. So, we will just plot a straight line our standard air void is 7 percent. And we will know how much material we have to finally use to prepare the mix, which will give us 7 percent air void. So, therefore, it is written with the mass of the sample to be changed for specified air void level.

So, we will do trials with two different specimen and then we will perform the tensile strength ratio test I will discuss about this test maybe after towards after few slides and I will also show you the standard mold to using which will we do the indirect tensile strength test. So, TSR is basically derived from the indirect tensile strength of the specimen.

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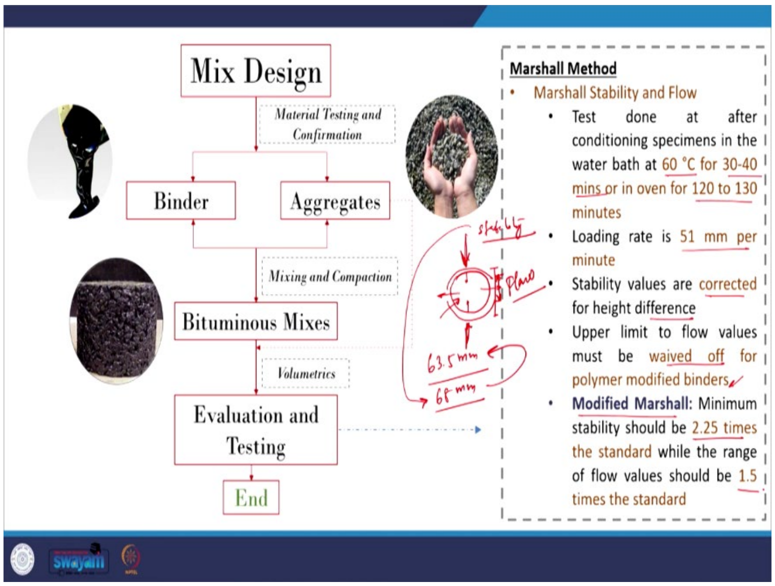

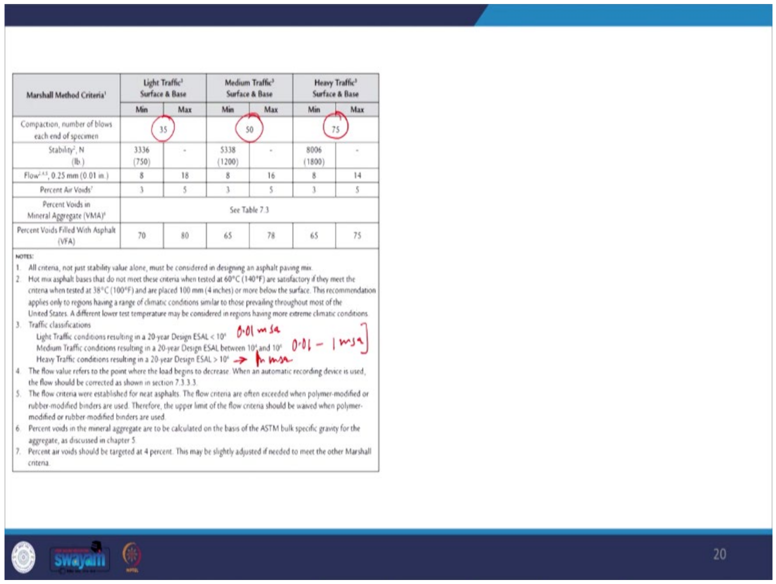

Marshall Method Criteria[1]	Light Traffic[3] Surface & Base		Medium Traffic[3] Surface & Base		Heavy Traffic[3] Surface & Base	
	Min	Max	Min	Max	Min	Max
Compaction, number of blows each end of specimen	35		50		75	
Stability[2], N (lb.)	3336 (750)	-	5338 (1200)	-	8006 (1800)	-
Flow[2,4,5], 0.25 mm (0.01 in.)	8	18	8	16	8	14
Percent Air Voids[7]	3	5	3	5	3	5
Percent Voids in Mineral Aggregate (VMA)[6]	See Table 7.3					
Percent Voids Filled With Asphalt (VFA)	70	80	65	78	65	75

NOTES:

1. All criteria, not just stability value alone, must be considered in designing an asphalt paving mix.
2. Hot mix asphalt bases that do not meet these criteria when tested at 60°C (140°F) are satisfactory if they meet the criteria when tested at 38°C (100°F) and are placed 100 mm (4 inches) or more below the surface. This recommendation applies only to regions having a range of climatic conditions similar to those prevailing throughout most of the United States. A different lower test temperature may be considered in regions having more extreme climatic conditions.
3. Traffic classifications
   Light Traffic conditions resulting in a 20-year Design ESAL < 10^4
   Medium Traffic conditions resulting in a 20-year Design ESAL between 10^4 and 10^6
   Heavy Traffic conditions resulting in a 20-year Design ESAL > 10^6
4. The flow value refers to the point where the load begins to decrease. When an automatic recording device is used, the flow should be corrected as shown in section 7.3.3.3.
5. The flow criteria were established for neat asphalts. The flow criteria are often exceeded when polymer-modified or rubber-modified binders are used. Therefore, the upper limit of the flow criteria should be waived when polymer-modified or rubber-modified binders are used.
6. Percent voids in the mineral aggregate are to be calculated on the basis of the ASTM bulk specific gravity for the aggregate, as discussed in chapter 5.
7. Percent air voids should be targeted at 4 percent. This may be slightly adjusted if needed to meet the other Marshall criteria.

In the MARSHALL MIX DESIGN method, we have something called mechanical testing of the bituminous mixtures which we do not have in SUPERPAVE MIX DESIGN. In SUPERPAVE MIX DESIGN, we have the criteria of N initial, N design and N max and moisture sensitivity using the criteria of N design and N initial we and the volumetric parameters, we will determine the optimum binder content and at the optimum binder content we confirm or we will check the values of moisture sensitivity and the air void at maximum number of gyration.

But in the Marshall Mix Design method, in addition to the volumetric analysis, we will also perform some strength test on the mix and this is done using the Marshall stability and flow machine.

So, here what we do we have a mold which looks something like this in my hand if you see I have a mold here and the sample is placed here. So, this is the breaking head and this is how the sample is kept diametrically inside this particular breaking head and then what we do we apply a vertical load on the top of the sample.

So, the load is applied at a rate of 51 mm per minute and this Marshall stability and flow test is done at a temperature of 60 degrees Celsius. So, once we prepare the sample, we will condition the sample at 60 degrees celsius inside a water bath and typically it is done for 30 to 40 minutes, in case you do not have a water bath and you intend to use a air draft oven and then the conditioning period should be increased to 120 to 130 minutes.

So, if you put the air draft oven in 120 to 130 minute it will give you a similar sample which we will get after conditioning the sample within the in the water bath for 30 to 40 minutes. So, we will perform the test we will see that what is that particular load at which the sample breaks and we will note down the load.

And then we will also see now try to imagine this that you have the sample kept here you are applying a load noting down the maximum load at which this sample breaks and that load is the stability value of the mix try to imagine that when you are putting this load the sample will be coming down, the sample will compress.

So, the sample this particular height will now let us say become will reduce to this particular height. So, there will be reduction in height from both the type of the sample because the sample will try to flow outside. So, this particular vertical deformation at the peak value of the load is noted down and that is denoted as the flow value of the sample.

So, flow value represents the vertical movement of the sample at the breaking point there is stability is the maximum load in order to break the sample. So, and once we have the Marshall stability values these values has to be corrected for height difference because as I mentioned 63.5 mm is the standard height.

Let us say the sample has a height of 68 mm then these the value of stability for 68 mm sample will have to be converted to the stability value corresponding to 63.5 mm sample and we have correction factors for the same.

In flow value we do not have any specific correction factor but one important point in flow value is that in case the sample is made using a polymer modified binder, so, polymer modified binder can flow more even after breaking. So, in that case, the flow value should actually be waved off as is suggested by Asphalt Institute when we are using a polymer modified bituminous mixture.

So, in case of modified Marshall method, everything remains the same the procedure remains the same, but the minimum stability criteria which is outlined by the highway agency should be multiplied by 2.25 times and the check should be made corresponding to this particular value. Similarly, the range of flow values as is suggested by the highway agency for standard MARSHALL should be multiplied by 1.5 and the check of for flow values should also be made corresponding to the corrected value of Marshall flow.

So, this is just an a picture of a standard Marshall machine and you can see that this is the breaking head, these are the dial gauges, this is the load cell and this is how we will give the load to the sample.

Moving further, this table shows the criteria given in MS2 corresponding to the number of blows corresponding to the minimum stability values minimum flow values and the other volumetric parameters.

So, an important point to note here is that you see in Marshall Method we have three different levels of compaction corresponding to three different traffic levels. So, 35 blows is given when we are expecting very light traffic less than 0.01 MSA, 50 blows is given when the traffic ranges from 0.01 to 1 MSA and 75 blows are given when we are expecting the traffic to be more than 1 MSA.

In contrast, in SUPERPAVE MIX DESIGN we have five levels of traffic and use and as we saw that the levels of traffic are as high as 30 MSA. So, this is again one of the major differences in the traffic levels used in the Marshall Mix Design and the SUPERPAVE MIX DESIGN process.

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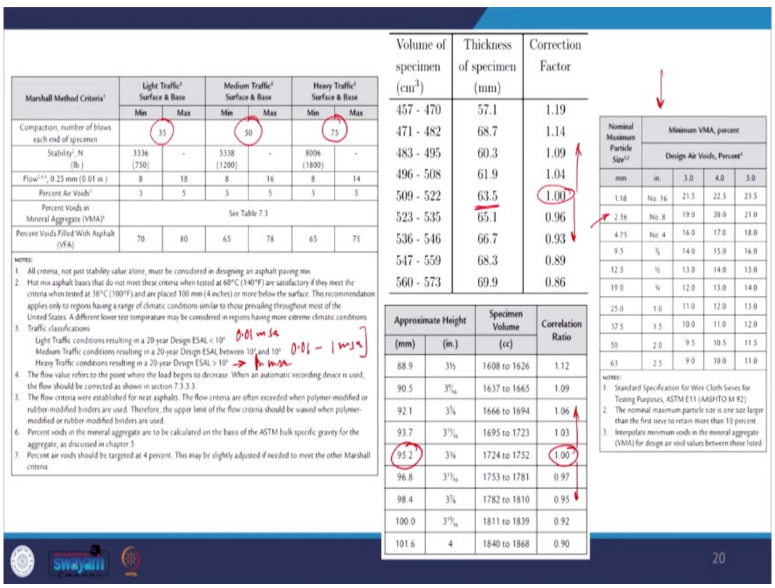

These are the correction factors as I mentioned you can see that corresponding to 63.5 the factors is 1 which is the standard value, and for modified Marshall corresponding to 95.2 mm height the value is 1, and if we have different heights of the sample which we have prepared, then the corresponding factors has to be used to correct the stability values after the Marshall test.

And this table it just shows the minimum VMA criteria and we have already discussed that this VMA criteria is dependent on the nominal maximum aggregate size of the aggregates we are using in the particular mixture.

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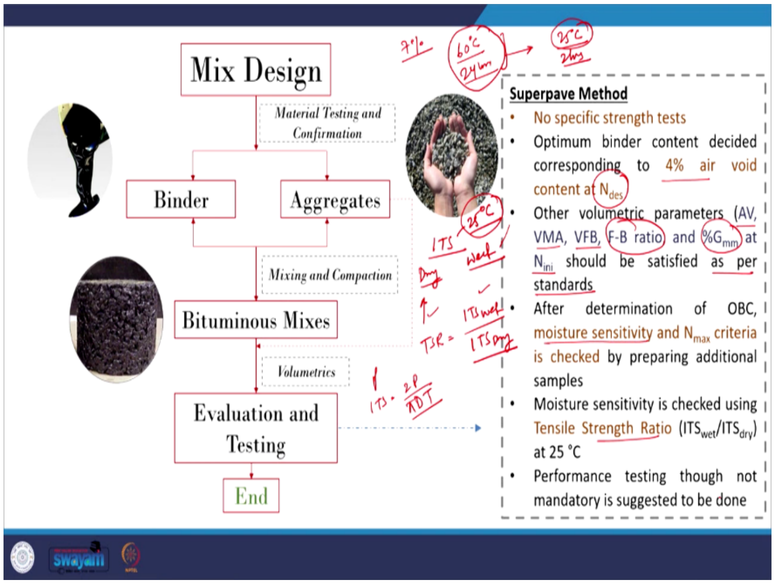

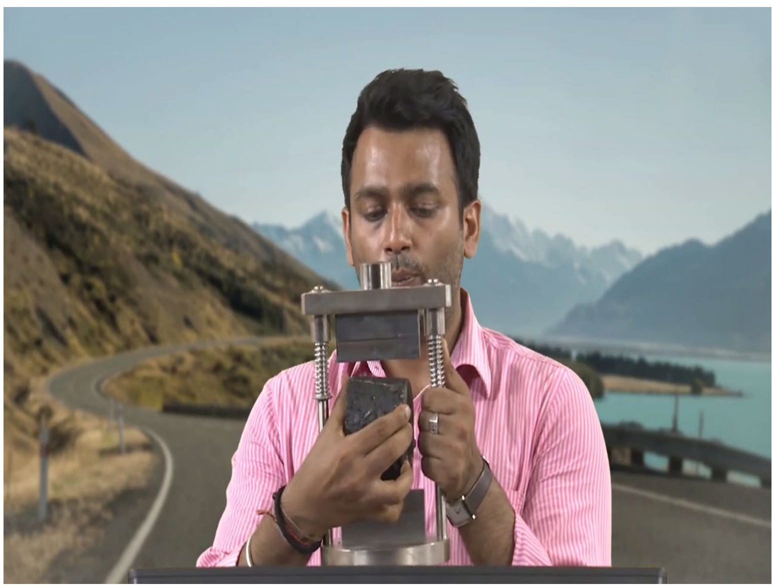

So, this was about the mix design process or the steps to do the strength test in the Marshall method. Now, coming to the Superpave method, as I mentioned, we do not have any specific strength test. What we do? We will determine the optimum binder content corresponding to 4 percent air void at the value of N design gyration and then we will see that the other volumetric parameters such as air void, voids in (())(26:28) aggregate, voids filled with bitumen filler to binder ratio this is again taken in Superpave mix design and percent Gmm at N initial when I say percent Gmm at N initial, it means that I am talking about air voids at N initial it should be satisfied as per the standards.

Once we determine the optimum binder content, then at the optimum binder content, we will prepare additional mixes the first set of mixes will be subjected to moisture sensitivity check and this we will do using this tensile strength ratio. So, we will perform an indirect tensile strength test on dry specimens and wet specimen.

This test is done at 25 degrees Celsius the conditioning process includes preparing the sample at 7 percent air void then the dry specimens will be kept in the water at 25 degrees Celsius for 2 hours and then we will do the dry test here. After we have the uniform temperature in the sample and the conditioning the moisture conditioning is done by keeping the sample at 60 degrees Celsius for 24 hours, then we will remove the sample and then 25 degrees Celsius for 2 hours.

So, the standard temperature to do the test is 25 degrees Celsius and this period and temperature corresponds to the conditioning period to induce moisture damage, artificial moisture damage within the mixture. So, we have dry ITS we will do wet ITS. And then we will calculate the tensile strength ratio which is ITS wet by ITS dry.

Indirect tensile strength is done using the same Marshall machine which we have discussed applying the load at a 51 mm per minute, but the braking head is different. So this is the braking head which you see that we have rectangular strips at the top and the bottom. And then we will again place the sample diametrically like this, in this way, and then we will give load from the top.

So, when we give load from the top here, top and bottom here, using a rectangular strip, there will be a cracking which will be induced in this particular phase, and this is what we are trying to measure. So, once we have the load the value of p, we will calculate the ITS using a simple formula that is $\frac{2P}{\pi Dt}$.

And then, we will do the same for wet specimens and dry specimens and finally, we will take the ratio, in the Superpave Mix Design method we specifically do not do any performance testing, which is not mandatory. But Asphalt Institute's suggests that performance testing can be done to gain confidence on the mix design and this performance testing can include a series of tests to check the properties such as permanent deformation failure or fatigue cracking within the bituminous mixture.

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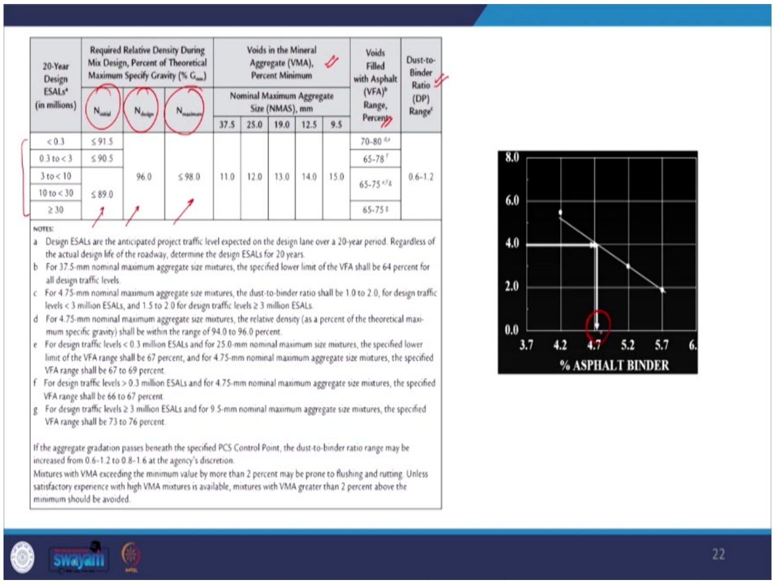

And this is the final criteria, which is outlined in the Superpave Mix Design method, which you can see that we have different criteria's corresponding to N initial, N design and N max and what should be the percent Gmm values. And then we also have criteria's corresponding to volumetric which we have already discussed does to binder ratio.

And does to binder ratio is basically filler to effective bitumen ratio and also voids filled with bitumen corresponding to different levels of traffic. So, the steps finally, once we have prepared the mix set N design at 4 percent air void, we will see what is the binder content. So, this we will consider as the optimum binder content.

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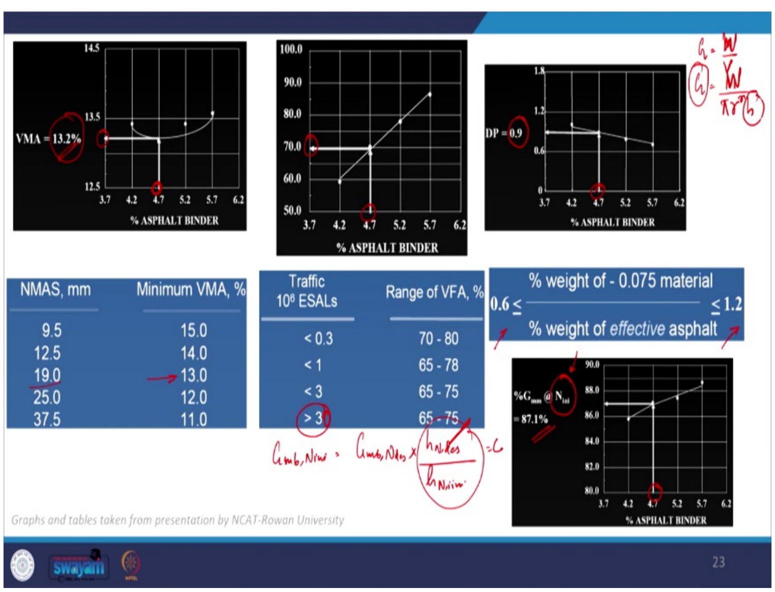

And then what we will do at this binder content, we will find out what is the value of VMA? And then we will check whether this VMA criteria meets the design criteria for example, here they have taken 19 mm as the nominal maximum aggregate size and you can see that the minimum VMAs 13 percent and VMA at the optimum binder content is 13.2 percent which satisfies the criteria then, we will also check the voids filled with asphalt.

So, add the optimum binder content here the value which you get is 70 percent. And for the corresponding traffic let us say we are targeting for greater than 30 MSA traffic. In that case, you see the VFA value ranges from 65 to 75 percent which is again within the limits you will check the dust to binary ratio here at optimum binder content they are getting the value as 0.9 and the actual design value should range from 0.6 to 1.2 which is again within the specified criteria.

And similarly, we will calculate the percent Gmm at N initial and this is done using a correction factor. So, what they do, they keep on monitoring the height of the sample at N initial and N design. At N design they will take out the sample they will measure the actual Gmb using this Gmb and using this particular Gmb.

They will make a correction factor corresponding to the height because if you see G is equal to mass by volume, and if the weight or you can see weight remains the same volume of cylindrical specimen is $\pi r^2 h$, but we have surface irregularities. So, we cannot use this formula directly.

But one thing is for sure that the value of Gmb is inversely proportional to the height of the specimen. So, using this proportionality factor, you can take out the sample after N design measure the GMB and then back calculate the value of Gmb at N initial just by using the height factor which means that Gmb at N initial will be equal to Gmb at N design multiplied by height at N design divided by height at N initial. So, this is basically the multiplication factor which is se. So, using this you calculate that at 4.7 percent binder content what will be the person Gmm or the air void and this also should satisfy the minimum criteria the range of criteria.

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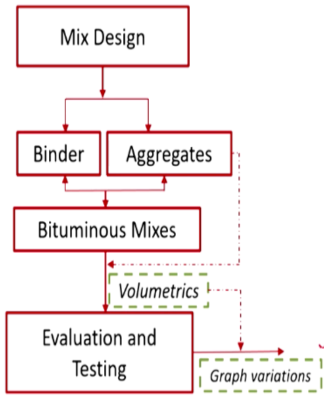
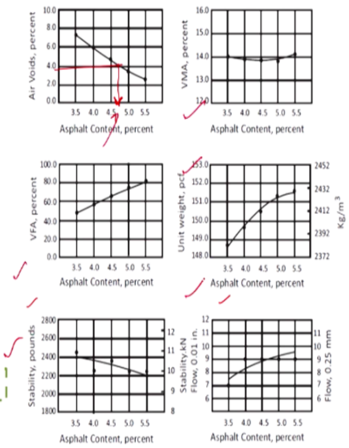
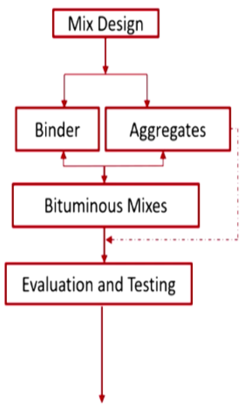
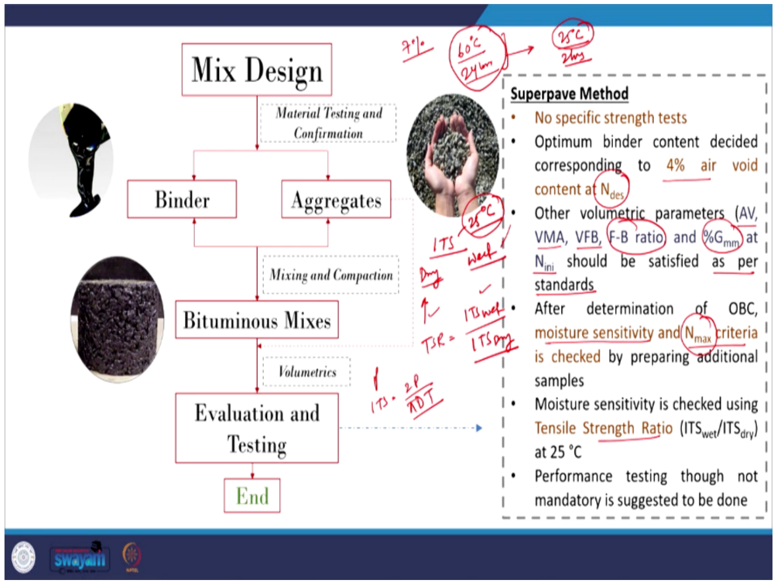
Marshall Mix Design







Find the binder content corresponding to 4% AV and check if all other parameters (Stability, Flow, VMA and VFB) are within the permissible range



So, we are just completing so, I hope the previous explanation was clear how to do the complete the steps of Superpave Mix Design, coming to the Marshall mix design we have to plot the variations again here. But here in addition to the volumetrics, we are also looking at the stability and flow values which is plotted here.

The step here includes that corresponding to 4 percent air void, you find out the bitumen content. And at this bitumen content you check all the other criteria, similar to what we are doing in the Superpave Mix Design method. So, find the binder content corresponding to 4 percent air void and check if all the other parameters are within the permissible range.

I think one step which I missed here was that I did not explain about the N max criteria, which is also required in the Superpave Mix Design. So, after finding out the optimum binder content, as I mentioned, we have to do a check for moisture sensitivity. In addition to this, we will prepare two more samples and then subject that mix to N max number of gyration. And then we have to ensure that after N max number of gyration that sample should not have air void less than 2 percent. So, this is the final check and then we complete the mix design process.

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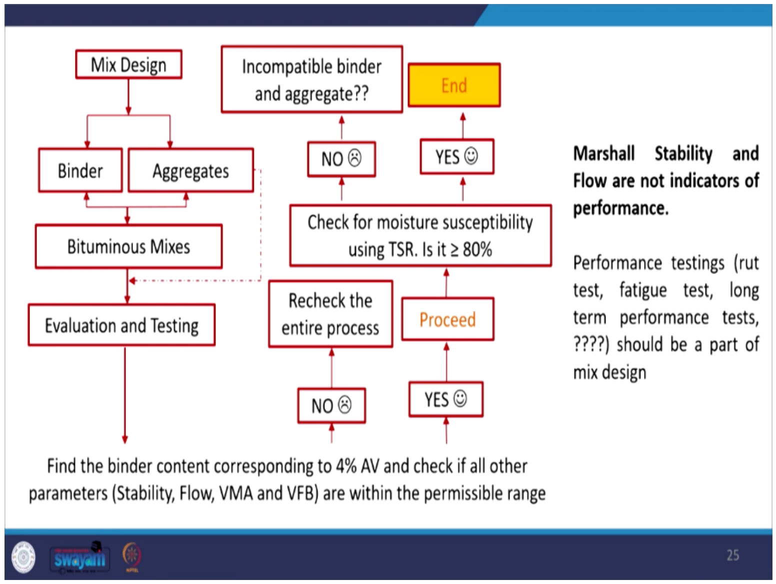

Coming to the Marshall Mix Design process as I said that, we will check all the other criteria's if these criteria's are not met then we have to recheck the design process. If it is met, then we will proceed, though usually not mandatory, but as per the guidelines of the ministry, we also perform a moisture susceptibility check using tensile strength ratio.

And it should be more than 80 percent if it is not more than 80 percent which means that the aggregates and the binder are not compatible. So, you can add a anti-stripping agent or you can use some other technique to reduce the moisture sensitivity. And once it is met, then we are done we are, we finally select the optimum binder content.

Before concluding because we have completed discussing the mix design process, there are a few important things which I would like to put forward and this will be our discussion this will be our base for starting our discussion in the next presentation that Marshall stability and flow they are not actual indicators of performance.

And though previously, there was a belief that the volumetric parameters are sufficient to tell us about the performance of the mixture, which is actually true that volumetric parameters play a very important role. But since these days, we are using different materials different types of mixes, the volumetric parameters may not give us sufficient information about the performance of the mixtures.

So, we have to do some additional performance test or we have to relook at the mix design process and adopt methods such as performance based mix design, which will be discussing briefly in the next presentation. So, that we will have more confidence we can produce most durable mixtures and our mixtures will perform finally in the field.

With this I will end here and today we have completed our discussion on the mixed design methods and we have discussed about the Marshall and the SUPERPAVE MIX DESIGN. In the next class we will start discussing briefly about the concepts related to performance based mix design. Thank you.