Architectural Acoustics
Prof. Sumana Gupta
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Lecture – 24
Introduction to Auditorium Design Balcony and Ceiling Design

We are going to start lecture 24 today. It is again Introduction to Auditorium Design which will be specifically discussing on Balcony and Ceiling Design. So, earlier we have discussed on the shape of the auditorium the stage area etcetera and all the concepts.

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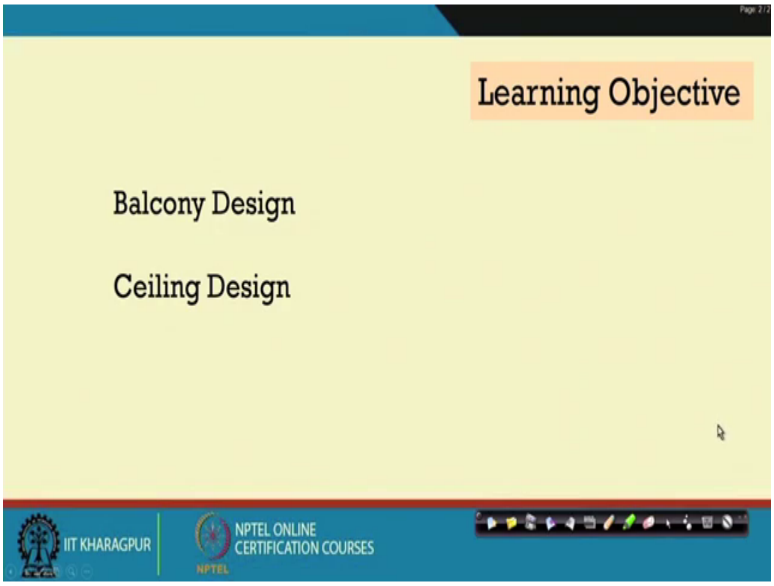

And, now we directly come to the ceiling design and the balcony design.

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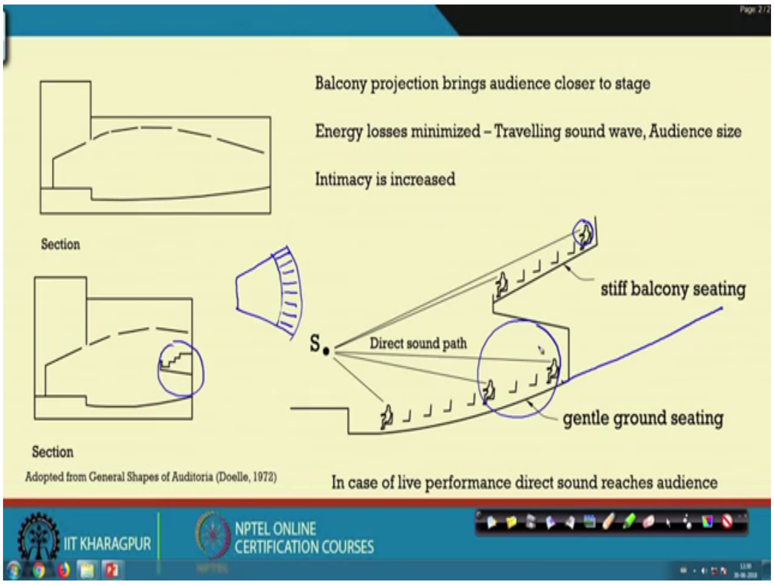

So, this profile has been adapted from Doelle in 1972 who had, actually who is also an acoustician, he has told that the balcony projections being bring the audience closer to the stage.

So, this is very important, because once you bring the people closer to the stage, what happens is the distance traveled by the sound is reduced. So, the reflected path which is more important, while getting into such big spaces the energy loss gets minimized and the reflected sound gets emphasized. So, loss of energy is minimized is one of the reason and the other reason is it makes brings the people more closer to the stage. So, in that case the concept of intimacy which we already discussed is much more achieved and this intimacy has been given 40 percent of the weightage.

So, once we bring the balcony into the system of auditorium design, where we can accommodate more number of people in may be a very compact volume then we can achieve a better efficiency of the auditorium. So, if we see in plan you will see that an additional projected space is reserved, which is the balcony. So, this additional reserved space, which is the balcony, will have some effect or some impact on the audience who are sitting directly below it.

So, we have to be very careful in looking into the aspects of sound moving into this particular space, where the balcony is an addition or a projection which you see here. So, if there is a source sound which is standing that is in case of lectures or a theatre, where people is standing or a music. We can see that the direct sound path is moving till the end of the audience, where in the ground for, ground floor seating as well as it is reaching to the last point of the audience, who is raised at a height because of the balcony.

We will also look into the viewing conditions from these particular locations, when in the next slides, but this is giving you a direct sound path to the entire hall. And achieving the distance, which is achieving a lesser distance of it is reflected path, which it would have achieved if it would be far extended. At the same time we have to remember that the there is a visual connection between the source and the last seat which is better achieved from a nearer location, but at a raised location.

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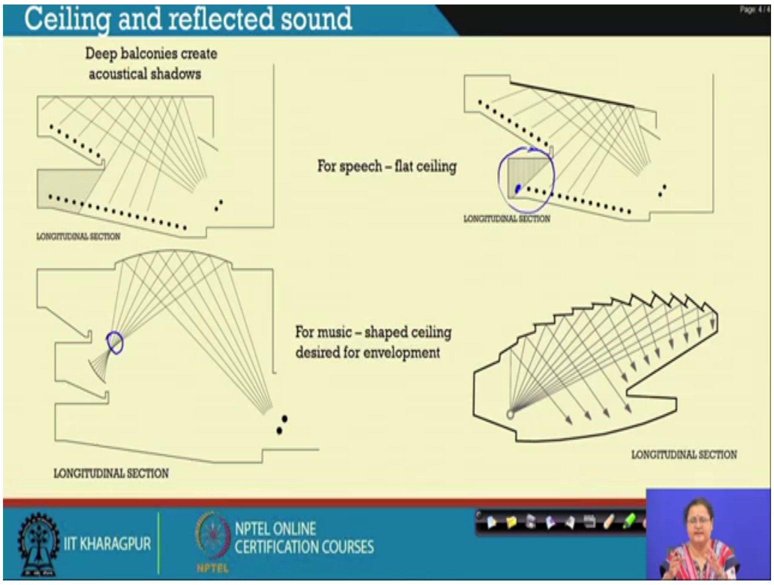

So, we see the ceilings how they can help? Because, we have seen the direct path in the previous slide, if we have a flat ceiling what we see here? The sound is getting reflected, whether it is a sitting position of a source or a standing position, the sound gets directly reflected and it is falling into the audience area. So, the balcony is getting lot of reflected sound, but this part of the audience is or the seating is receiving less amount of sound and is under the sound shadow area.

Yes, some will be reaching if some of the sound is getting reflected here and then following the principle some will be entering, but not far. So, the dimension of the seating area below the balcony should be gauged or should be measured or looked into. For speech we prefer flat ceiling and this was one of the alternative versus a slanting flat sloped ceiling flat ceiling, where here also we can see the sound shadow area has been reduced. Here you see the sound shadow area has been reduced, because the sloping surface is allowing in more amount of sound and almost reaching the last person sitting here.

So, in that case last person sitting here. So, in that case you can solve the problem, which was happening in this case. So, with a flat ceiling which is preferred for speech, because you are going to direct the sound or get reflected sound in all points. Then for speech this kind of flat ceiling is effective. Now, coming to case of music and multiple number of balcony projections, you see a concave surface will be more desired and even if they are converging at some point, they can again scatter into the balcony spaces.

At the same time these are all direct or if direct sound at the first reflections. The they are the direct sound and also the first reflections, which are reaching the balcony. We can also achieve this kind of section particularly for music. This is segmented you can see that the ceiling is continuously changing the profile with concave surfaces, short concave surfaces. So, this is also allowing the sound till the last point in both the cases and giving a better envelopment for a better music condition, for getting a better quality of music played in this particular space.

So, the lateral reflections which help in envelopment are happening here better from the sidewalls as well as from the ceilings. So, this special impression of this particular profile is better in case of music, if you compare over 1 or 2 of compare over the different shapes.

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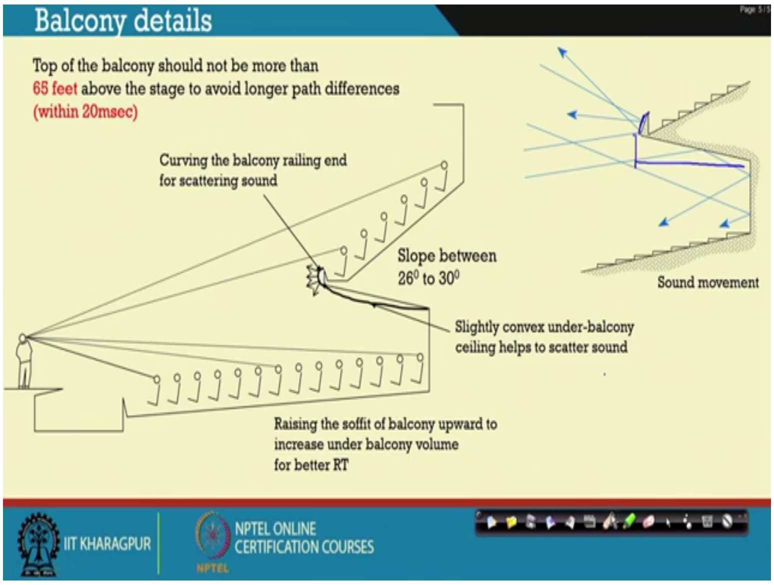

Now, coming to the further details within a balcony, we have already talked about the direct distance. Now, particularly when we have these particular areas that is this projected part which is the guard of the balcony. We can, we could have made it a straight thing, but it is played these are all to allow more amount of sound. So, the sound we are allowing sound inside this just by making the shape open making the balcony open. So, the soffit of the balcony is slanting. So, that allows more amount of sound that increases the localized volume too. So, amount of sound which is coming the V the localized RT, which is happening in that below the balcony has to be looked into while, we are taking up or planning or proposing for a balcony.

We see the through calculations it is it comes like the slope is of the upper part of the balcony is around 26 to 30 degree desired and maximum up to 35 degrees. And, you can raise the soffit of the balcony as it is written and already told to increase the volume below the balcony and increase the reverberation time. If, we look into further details, which we will cover in different examples, you can actually add up this kind of shape curved surfaces on the balcony railing. Where the sound gets scattered into the rest of the hall, below the soffit of the balcony you can have a concave, convex profile towards the sitting here.

So, that can actually help in scattering the sound in that particular area instead of direct sound, direct reflected sound. So, that helps in bringing in a better quality of the sound as well as in reaching the sound till the last point. So, these are some of the details which one can adopt, while doing a balcony or proposing a balcony at the same time looking into the acoustics of it.

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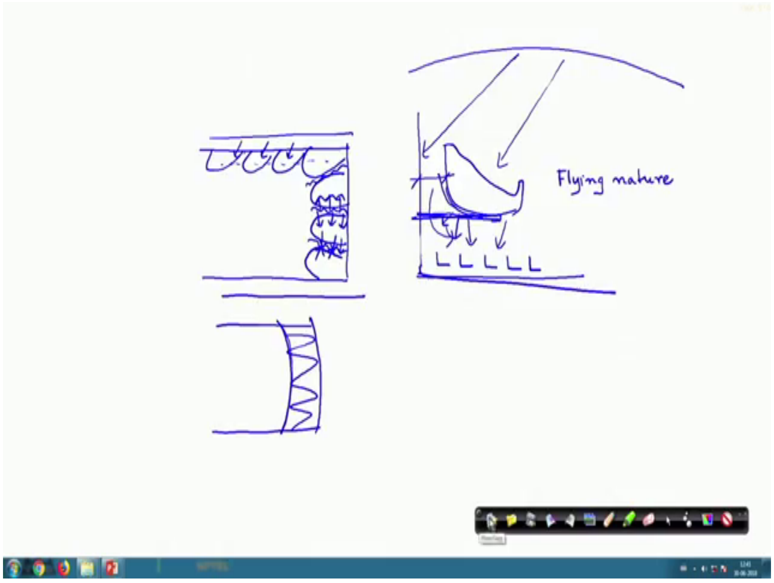

There is a concept of this has been tried out, hanging balcony. So, if you can hang the balcony away from the edge wall, then what happens the sound that is whatever be the profile the sound that is coming to this area can actually pass into this area. These areas the soffit being concave in nature, it can actually reflect sound in these particular areas below the balcony. So, if you have a seating here they will get sound till this point, because of this hanging nature or the flying nature of this balcony, but what is the drawback?

If, you look into the structural system it will be very difficult to achieve such thing. So, we as a architects can think of this and also at the same time have to look into the structure, how this can be supported, how this kind of structure can be supported over here? So, this kind of floating things can actually allow sound to pass into the lower part of the balcony or below the balcony taking care of the problem of the acoustical problem that may happen here.

Another way you can solve it. Say, this is your auditorium. You can have balcony in a segmented profile, where sound can actually pass through these particular areas reaching some portions of the audience, below balcony from other directions. So, it is not always true that you have to have a balcony exactly continuous here; you can adapt your shape. You can have other balconies here having sight corridors to have access to these areas and you can actually improve the sound quality for those people those people who are sitting here.

So, these have been adapted in big halls where the number of number of audience is high and where fund is not a constraint, but for our cases for simplicity cases we can add up this kind of balconies, which will accommodate more number of seats and in a closer location or in connection to the stage. And, it will improve the intimacy of the audience intimacy of the hall, which is of primary importance to achieve an acoustical quality the oneness within the feeling that I am within the hall. So, this distance matters and you are solving that out of it.

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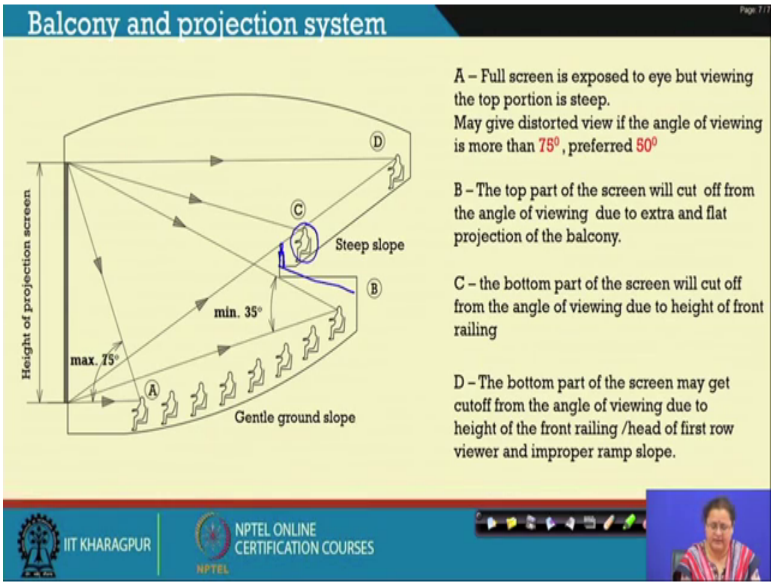

Now, coming to when there is a projection system. Till now we were talking that when a person is standing or a theater is happening where it is a live performance, but sometimes we also need to know how to take care of the visual things and the acoustics, when it is a projection system. See the person who is sitting at the very front seat that is at location A, what can happen to him?

So, he can see the bottom of the projection whereas, the top of the projection is bit steepy for him. So, he has to actually move his head up and down to see the entire screen, if not he is at a very comfortable angle of 50 degree. So, it is preferred to have 50 degree, but what happens once you want to achieve a 50 degree angle your audience the A position will shift back. So, maximum of 75 degree is proof is take is allowed, but beyond that it is not allowed, but if you go for 50 degree you lose a number of seats. So, you can plan for a lower costing seat in this particular location, if it is the purpose of this auditorium is for projection.

Coming to point B, which is at the last of the floor level, at the floor level so, you can see this last portion if there is a balcony. This end point is a difficulty for him to view. So, in the earlier plan, where you had seen that it is proposed to splay this is equally advantageous when a person at the back is sitting and seeing. So, more it is open the balconies of it is raised, the viewing angle from this point is increased. So, from this point the bottom is seen and at the same time the top is seen. So, this minimum of 30 degree has to be maintained and based on that the soffit can be arranged.

So, these are the tools I am helping you with these information. So, that you can start your plan considering the acoustics and not ending up into a hall having a bad sound system and then making corrections by putting absorbers or diffusers or reflectors. From the very start if you take care of these aspects, while you design an auditorium as an architect you will achieve a better sound quality in the system. Now, coming to point C where the person is sitting at the front part of the balcony.

So, if this is a solid railing it might obstruct his view. So, if there if you go by the heights anthropometry with the railing height, if you have a guard wall, which is transparent made of glass or made of pipes I will show you picture, then there is very less chance of the view being obstructed for the lower point, but the upper point is free. Similarly, from the point D; from the point D this slope is maintained such that from point D the lower part is seen with after crossing the height of the first person sitting over here.

So, if you solve this geometrically. The entire projection screen is visible. If the projection screen is pushed back then this drawing should where the projection screen is has to be decided first and then the drawing has to be done. So, if you start doing this way hopefully you will end up in a better or solvable design.

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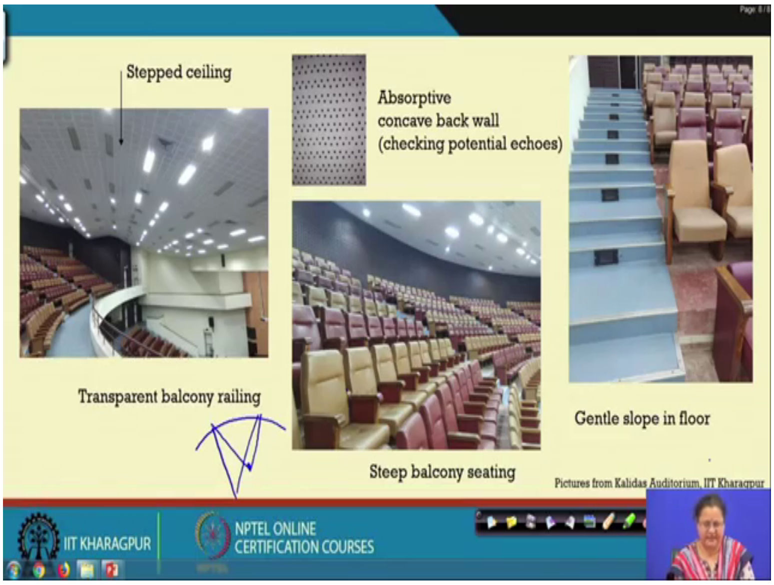

Let us see this picture. Here, you see this transparent balcony railing. So, this is a curve on which the railing has been put in. So, that it does not disturb the view of the first row neither from the back seat. So, this is the balcony you can see the stepped ceiling on top.

So, this has reduced the volume as well as helped the sound to move to these particular areas. The back of the wall at that is at the end of the balcony, you can see absorptive concave wall which checks potential echoes. We had already told that this concave profiles concave profiles can lead to sound concentrations lead to sound concentrations. So, focusing of sound can be avoided by absorbing sound at these back walls. So, these are some pictures; now here you see in the ground floor that is at the ground level you see the stage the seats are not that steep, what you can see in these 2 pictures.

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As, I have talked about the projection room I show you a projection room which is taken from the Netaji Auditorium of IIT Kharagpur. You can see the projection window from where the projection is being done and this is the system inside that is within the room, and this is placed at the back of the auditorium this is a old system of projection which was there. So, I have just clipped it for you, I have. So, this is the old projection system and this is the new projection system.

So, this is the side where you can see the, which is the back wall of the auditorium the Netaji Auditorium. So, this is more or less a straight profile, but they are also filled with absorbers. So, these are all panel absorbers here and they are actually absorbing sound. So, that the echoes are not happening.

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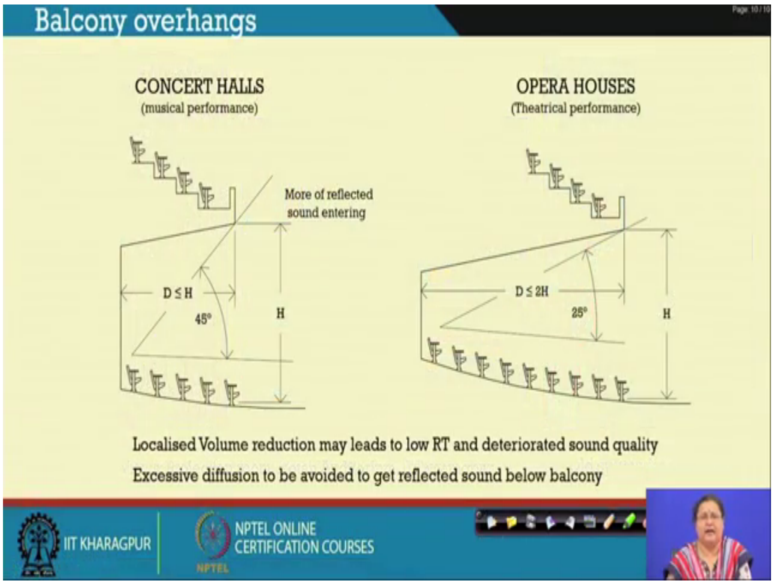

Now, coming to the dimensions of the balcony overhang how much, how big? So, me we must give you some clue for that or help for that, see here if it is a musical performance; that means, you need prolonged or you need higher RT in that case the depth is less.

So, more of reflected sound energy is allowed till the end so, that the people can get the sound. So, localized volume reduction may lead to low RT and distortion of sound quality beneath it. So, you are reducing the volume here. So, the depth has been reduced or suggested to be kept as less than equal to the height. And, height refers to the opening at the very front where the balcony is starting, where from the balcony is starting. For opera houses that is for theatrical purposes, where speech is of primary importance you can see the depth proposed is greater than less than equal to twice the height. So, here reverberant sound is not very important, because clear sound is to be reached because it is a theatrical performance.

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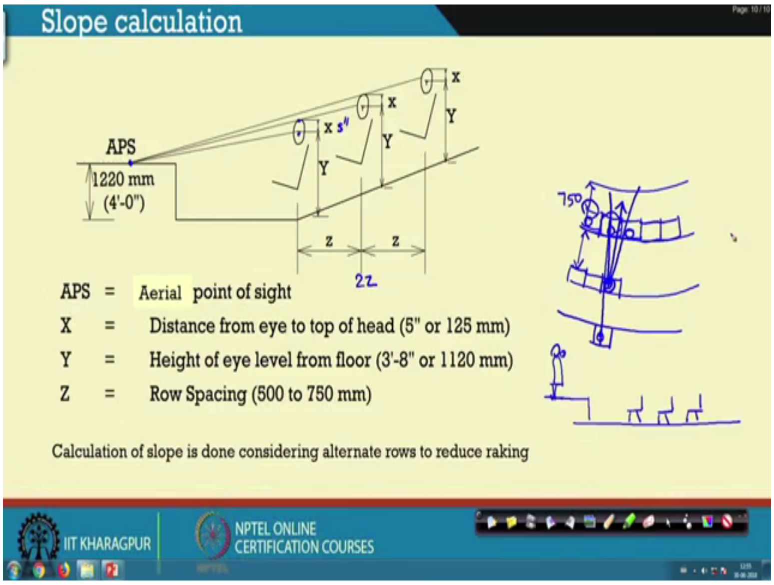

Coming to the slope calculation, how you can find out the slope? As, you all know we need some distance here for people to move. So, we have to keep the seat size and the person sitting here concerned and the leg space, where from people can move and that decides the distance Z. It can vary to give a comfortable space 750 is minimum, 750 even 500 is adequate, but 750 900 you can be generous.

But, 750 you have to maintain. So, if you are maintaining a distance of 750 here, if you see here that the persons are raised one after the other. If, they were not raised, what would have happened? If this is the stage and the persons are sitting here as was in the case of a classroom. People could not could see the person here, but not the feet, but not his feet movement, but in case of performances you need to see the lowest point of the stage where things may happen.

So, if we find out from the eye level, what is the top of the head, which is on an average 5 inch then if you get this 5 inch and this Z, you can actually have calculate the gradient. And from every point you can see the lowest point or the aerial point of sight that is the floor of the stage.

So, once you can see the floor of the stage from all the points your purpose is solved. And, that slope is achievable by raking the floor slope. Sometimes, this Z is considered as twice Z considering that seat the person sitting here will sweep in between these 2 persons. And, then the next overlap will be with the person here.

So, this persons head and this persons head are in one line, but these persons head is can see in between these 2. So, you can have a even a gentler slope, by locating the seat or arranging the seat. So, that it is bit staggered. The next row the peoples head persons head can see through the other 2 head in the front. So, in that case you can get a even gentler slope.

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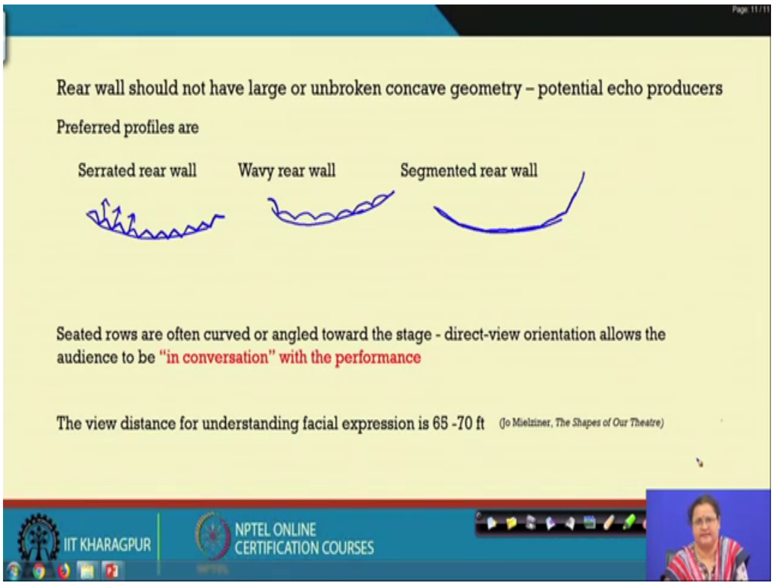

Now, coming to the rear wall; rear wall as I have already shown it should be in the example that it should have lot of absorptive surfaces. Other than that if you have an unbroken geometric concave geometry. So, it is a potential point of echo which we had already shown. And, how that has been taken care? It has been taken care with a putting quite amount of good amount of absorptive material of after calculation.

So, other ways you can do it, just by creating a serrated rear wall. So, if it is if your rear wall is of this profile you could have serrated it or broken it with such kind of a profile, that could lead to no convergence of sound or a of delayed reflected sound towards the hall. At the same time this could provide diffused sound to the last part of the audience. So, audience who are at the rear seat could get reflected sound from this serrated rear wall and that could improve the sound quality at the back.

Next is wavy rear wall, you can have even by managing in this concave shape you can have convex wavy rear wall you can also have segmented rear wall. So, this way in these ways you can treat your back wall. So, that no convergence of sound is happening or echoes are happening. And you can avoid putting lot of reflector rod lot of absorbers and even can take help of those delayed reflections to the bit lesser to the backer back side of the audience.

So, why are we looking into seeds arose are often curved or angled towards the stage, direct with that gives direct view or orientation towards the stage and allows the audience to be in conversation with the performance, this helps in achieving intimacy and that is why we always go for we always go for a curved sitting. Again, at the same time we must also keep in mind the view distance for understanding the facial expressions. Say, it is a theatrical performance you have to see the person's expressions for that there is a viewing distance. It is said within 65 to 70 feet you can notice the facial expressions the movement of the eye etcetera, but beyond that it is not possible.

So, it is not only acoustics, but viewing how far you can view? How detailed you need to view? How, what area you need to view? That is whether the footsteps of a dancer or a projection screen from top to bottom all these will control your design. And along with all these parameters, you now on think starting how the sound wind will behave, then only you can achieve a very good design; coming to the seat absorption.

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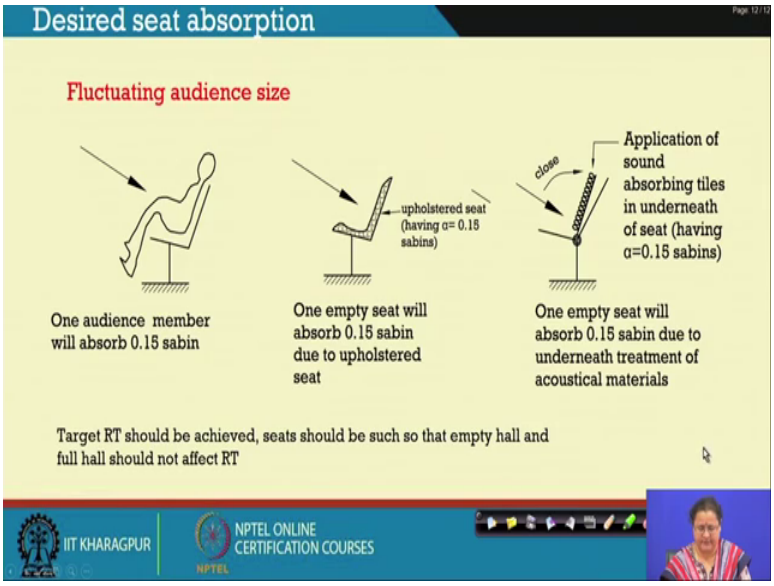

Now, audience eyes can fluctuate. If it is a 1000 seat all and 500 people come, you calculated the entire thing with audience absorption per person 0.15 Sabin and then people do not come.

So, in that case an open seat must be having equivalent sound absorption. Then only the target RT, which should have been achieved in a full hall or an empty hall, can never be defeated. You can even plan for closed seats with putting absorber beneath the seat. So, that will be also having equivalent absorption coefficient; equivalent absorption as that of a human being sitting over there. So, if you keep these things small things in mind, these become a very good help for achieving better acoustics.

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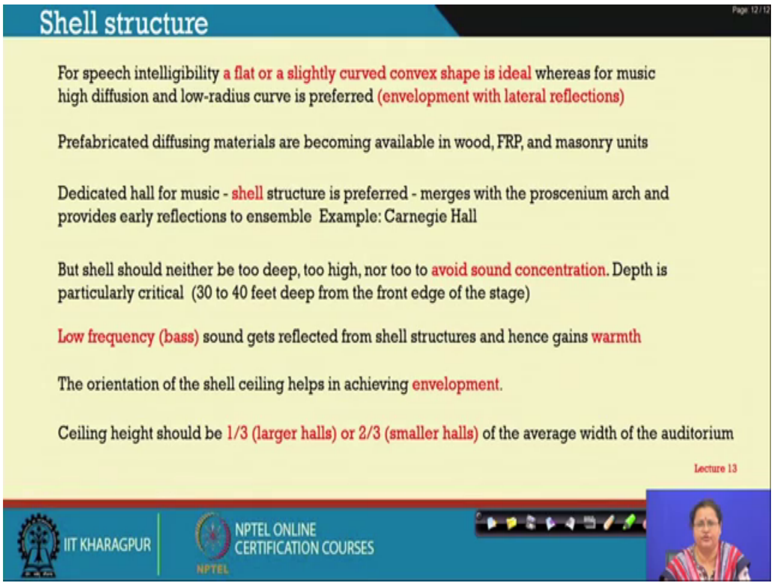

Now, coming to shell structure, which I have already shown in the ceiling for speech intelligibility have told that flat ceiling is better and for music it is a curved curvature or radius of the curvature should be there low. So, that there is no sound concentration, which helps in envelopment with lateral reflection.

You can get lot of prefabricated diffusing materials, which are becoming, which are becoming available day by day with having the having the characteristics acoustical characteristics given on it. So, you have FRPs you have wood you have masonry units, and you can actually make choice from the commercial items available, but for hall or music if you go for a shell structure, which has been adapted in various very renowned halls. And, the those are a very big sizes shell structure is preferred and this merges with the stage area.

Usually these halls are having surrounded seats. So, the shell structure covers the entire facility. And, there is no particular flight hour for the stage. So, this entirely helps in ensembling the sound it reflects back to the or to the players or the musicians in the stage area, at the same time it reflects to the entire hall and that helps in a very good sound quality.

So, I am just touching upon, because this also should be known to you as a acoustics as architects. And, here it is told that shells should neither be very deep and deep to avoid sound concentration and some critical values are also being given.

Low frequency is being reflected from shell structures in a better way and that gives warmth which is very much important for musical performances. And, this particular shape as I already told helps in envelopment or the special impression is better for such shapes. It is recommended that ceiling height should be one-third of large auditoriums, should be one-third in case of large auditoriums and two-third in case of small auditoriums compared to the as compared to the width of the auditorium. So, these are recommendations for shell structures and these are recommend and the width versus height relationship.

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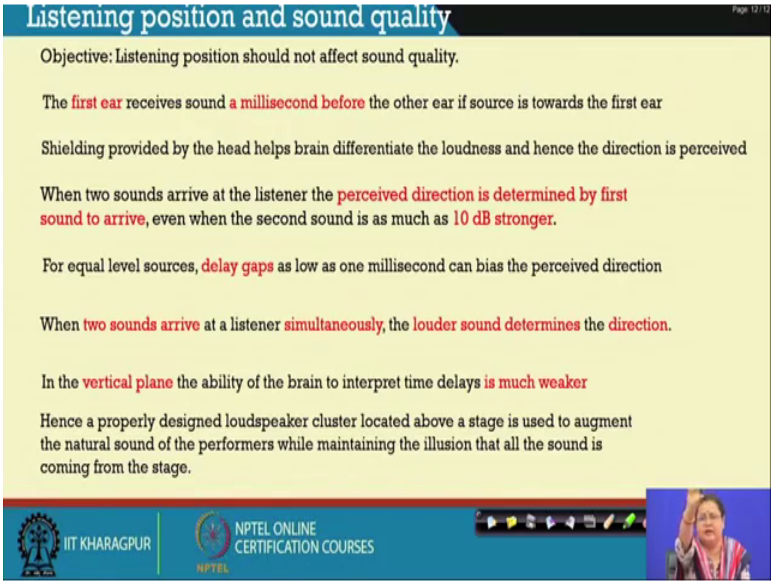

And with this we come to the last part that is listening position and sound quality. So, when you are in the hall? It is expected that your listening position should not affect the quality of the sound. The first ear receives a sound a millisecond before the other if the source is in this direction. So, if the source is in the direction of the first ear, then you receive the sound 1 millisecond before this ear. Shielding is done by the head. So, this 1 millisecond difference is caused by the head, when 2 sounds arrive at the listener the perceived direction is determined by the first sound.

Even, when the sound of the second sound is 10 decibels higher or stronger so, the first sound which is received is giving the direction, even if the second sound is stronger. For equal levels of sound, say equal levels of sound are coming to your ear the delay gap. Even 1 millisecond can bias the perceived direction, that has that happens when the first ear and the second ear receives the sound from one particular direction and not directly straight. When 2 sounds arrive to a listener simultaneously, the louder sound determines the direction.

So, if you are getting sound from the stage simultaneously, the sound louder determines the direction. When 2 sound when you know when you are in a vertical plane, if they are from the same point the sounds are in a vertical plane our brains ability to interpret the direction or the delay is much weaker. And taking advantage of this, you will always see in front of the stage at the top there are a number of speakers tipped, to help or enable the audience to listen the sound as if it is coming all from the stage.

So, this vertical difference between the stage performers and the top does not really make any difference that is we cannot make that difference, we human beings cannot make the difference we are weak in that. So, now, you can understand the shape of the people, if it is circular they their view converges towards the stage, the sound also comes out and towards the stage equidistant. At the horizontal plane and that gives a better listening.

So, the effect of intimacy the effect of all these things are a combined effect, when you are viewing you are in a circular way, you are viewing the stage center. So, hopefully these are enough food for thought before you step into an auditorium design.

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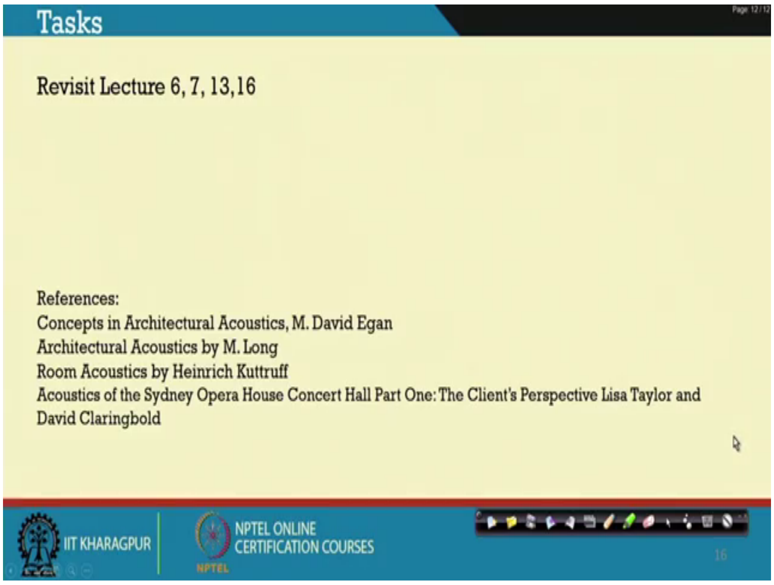

So, you can revisit the earlier lectures number particularly number 6, 7, 13, 16 and try to go through what all has been discussed till now. So, the next lecture will be more on will be on showing some examples of some good auditorium.