Architectural Acoustics
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Lecture – 23
Introduction to Auditorium Design
(Contd.)

So, in we start with lecture 23, we have covered in the previous lecture, how to start with the plan? First you need to convince yourself what shape you will take, yes we would not design alone or design the acoustics of huge halls say; 2500, 2800, but yes as an architect you will have to come across, you may come across halls multipurpose halls of sizes 500, 700, 1000 capacities. That is that could be in schools, that could be any institutional complexes that is quite often encountered.

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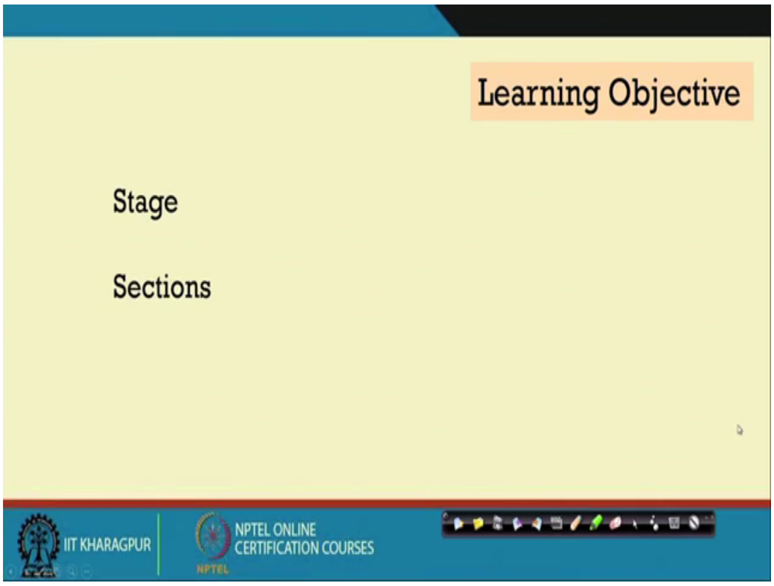

So, in this lecture, we will try to look into how to take care of stage and the sections, how those are important in developing the acoustical quality of the space or the auditorium which is under consideration. So, stage is the place where the performance is happening. And, we have already discussed during class room that if it is capacity is beyond 50, we need to raise the stage. And, gradually we saw how much like it should make a certain angle with the back seat. So, that around 5 to 7 degree angle is formed with the raise of the stage. So, all these dimensions are already discussed and you can revisit those classroom slides, and you can come back.

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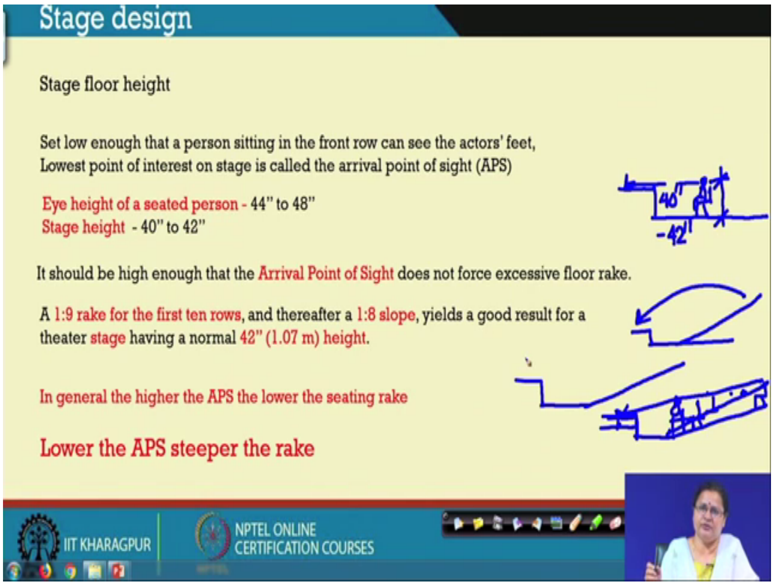

So, coming to the stage floor height, it should be low enough that a person sitting in the front row can see the actor's feet that is of interest. This interest is where our sight goes and arrives. So, arrival point of sight is the lowest point of interest on stage. So, if you have a stage and then a flat totally flat floor, the performer's feet is here should be visible by the person who is sitting here.

So, this eye level and this level of the lowest point of the stage that is the height of the stage should have a relationship. So, if this height is known which is basic anthropometrics, we see for male and female it is like 48 inches to 44 inches. So, this stage should be at a level lower to it so, that you can see what is happening at the lowest point in that level.

So, stage heights are preferred to be around 40 inches to 42 inches. Now, once this arrival point is determined which is almost at the center of the stage, the people behind the first row should be capable of seeing that floor that foot level. So, it should be high enough that it should be high enough that the arrival point of sight does not require a high raking or high inclination. So, that the last point last persons here at the end are capable of seeing what is happening here.

So, if this is there and if you start raking; obviously, the person here should be capable of seeing the leg here. Now, we will come to those calculations etcetera, how you get? So, if you have your seats one after the other, it is the eye level or the head level of all these which should cross and give view of the last percent in this point. And, the first point first viewer position has been set by setting the height of the stage. It could have been further low, if it is further low the raking would be further high.

So, an optimum is 1 is to 9 rake, for the first 8 to 10 rows and thereafter 1 is to 8 slope, that can yield a good result for theater stage starting at a height of which is at a height of 42 inches or 1.07 meters. So, the higher the apes aps the lower is the sitting rake, lower the aps higher is the sitting rake, what I showed here, lower is the stage height you have to rake it further. So, that the last person can see higher the raking higher the floor stage lower is the raking because you are already elevated at a point. So, keeping these in mind we will go into other details, when we come to the audience side, but for now we move to the other components of the stage the floor.

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The floor of the stage is usually preferred to be wooden, vinyl floors, and you can see the sockets are also there to take in power and that also shows, that over the structural floor, gap is there and the wooden battens the wooden battens are seen. So, the battens are fixed on top of it over the structural floor with a structural wooden framework that absorbs sound and gives a good sound good quality of original sound or the performer sound towards the audience.

So, unwanted sound is actually absorbed here. You can also see several other elements, which are the fins, which are the fins, you can see the curtain, you can see the reflecting wall we will come to it next slide.

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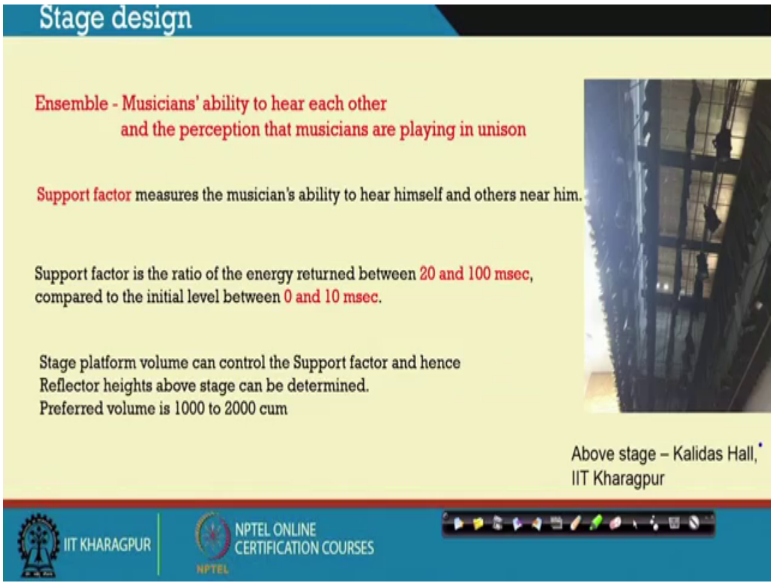

Now, coming to stage design, we I introduce you another term called ensemble, which means musicians ability to hear each other. Say it is a concert by few performers, when one is performing, some other also some others also are performing. And, they have to have coordination amongst them otherwise the whole purpose will be lost.

So, it is also the audience, who should receive the sound as if the musicians are playing in unison. So, to play in unison, the performers need to hear each other. And, that can be measured and that is called ensemble, that can be measured by support factor. That measures the musicians ability to hear to himself and others near him.

Because, in stage they are also getting reflected sound from the ceiling. And, also from the sides and if the ratio of the energy which is returned between 20 100 milliseconds, you remember clarity was c 80 80 milliseconds towards the audience. Here it is between 20 to 100 millisecond, the energy which is returning and it is compared with the initial energy, between 0 to 10 milliseconds when the all the sounds were originated had originated.

So, this ratio is called the support factor and that is also measured in decibels some minus 11 to minus 15 in a comparative scale is required though you need not calculate all these, but need not get into all these details, but you need to know that s ensemble that is getting the sound by the performers within themselves to work in unison. And, the audience feeling that yes everything is happening in the stage is in unison is very much important.

And, I give you the thumb rule like preferred volume is 1000 to 2000 cubic meter. Now, I here give you a small example Sidney opera house. The main auditorium designed by John Anderson, you must be all our of it. It is a hall of to 6 some 7 9 audience capacity. It has a stage of 17 meters by 11.5 meters and you are all our of the shell structure, the stage was below a shell, stage is below a shell structure. And, that was of a very high volume. And the performers actually raised complaints that they are getting much delayed sound and if you think the shell was 25 meters.

So, if you think of the volume of that stage visa stage considering that height of 25 meters. So, 25 cross 11 cross 5 cross 11.5 cross 17 will give you something with the shell structure, you may not get exact same exact cylindrical kind of volume on a rectangular volume. Even, if you cuttle down the volume will be something around 5000 cubic meters, but other good preferred halls performing halls good performing halls have a volume around 1000 to 2000 cubic meter.

So, that was the point when, the acoustician started experimenting how that could be brought down and how that sound that will delayed reflection could be cuttled? So, that the performers does not get confused. There were clouds or reflected ceilings, which were hanged from the top, but yes a lot of experiments are still dead going on.

So, stage area ceiling height is important, the volume I give you as a key or a thumb rule for your calculations. Because, you will be calcu you will be knowing your seat stage dimension when you start and then you try to achieve this volume, and then you can come up. See the stage above the stage of the Kalidas auditorium, where you can see the ceilings the lights the folds which all help for acoustical quality gain.

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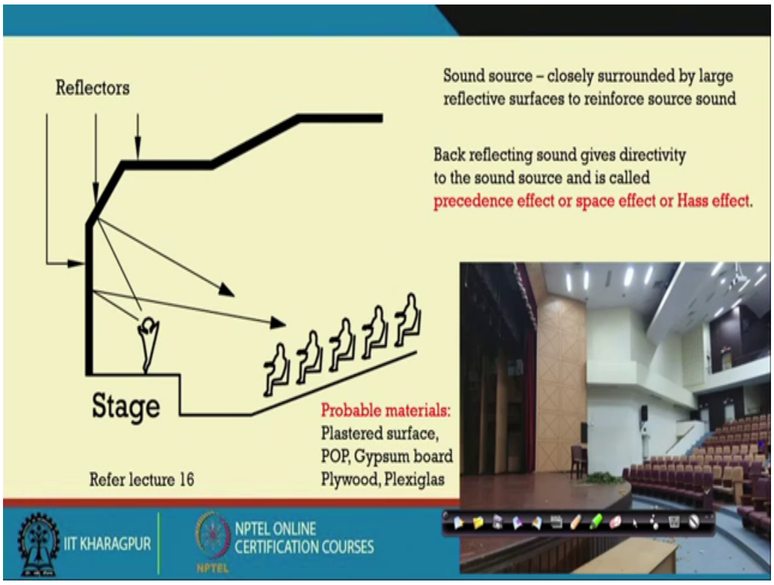

In the stage area closely surrounded by reflective surfaces help to reinforce sound. We have already discussed that in earlier lecture I think lecture 16, where we had talked of precedence effect or space effect or Hass effect. So, the back reflecting sound gives directivity to the sound source and that gives the audience a feeling that all sound is coming from the source.

So, these reflecting surfaces along the stage across the stage area and little beyond should be always angular and facing towards the audience, it must be split and it must push the sound more towards the audience floor. Probable materials, if you try to give plastered hard plastered surfaces, which are highly reflective plaster of Paris surface, Gypsum board, Plywood, Plexiglas all these are being applied as very high reflectors.

Here is a picture of Kalidas auditorium, where you can see that plywood has been applied on the side, on the splayed side, you can see hard wall surface here also these are all splayed. So, that the sound from this stage can actually move towards the audience, you can see this play continues on the top. So, that the balcony also receives reflected sound. First reflections or the early reflections from the stage or the source where the sound is you can also see these fiends in the earlier slide you could see, this also direct sound towards the audience or towards the floor.

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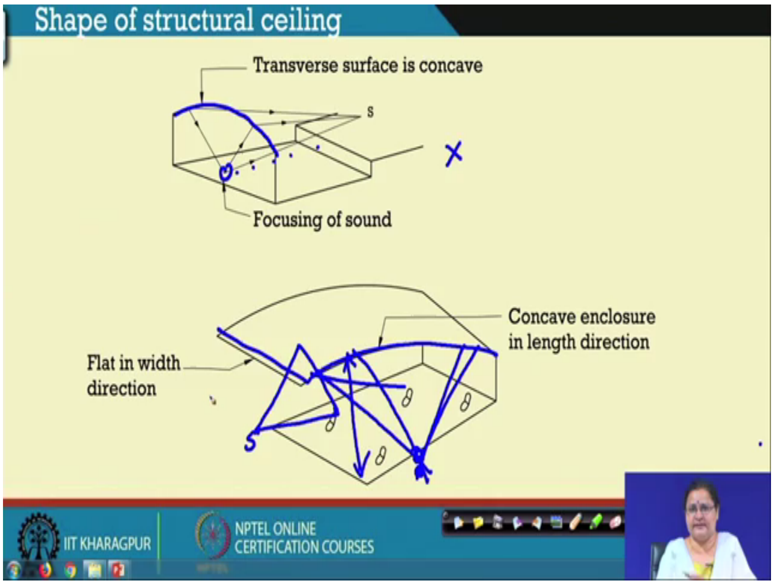

Now, coming to the ceiling, how should be the ceiling like? You see in the first picture, if you cut across you see this is the transverse surface, if it is concave that is you have a concave ceiling. Then, what will happen sound from the source gets focused along the center of the audience, which is really not at all desired.

So, the at any point in the transverse section, the in the transverse section you see this is a straight line and not a curved surface. So, concave enclosure, if it is continuous should be in the direction of the length, in the transverse direction it should never be concave. So, this is another shape another important point, while thinking of the shape of the floor or the audience area.

Yes, this can also lead to focusing of sound, but look at the curvature it is quite flat. So, even if there is sound focusing the focusing will happen below the sitting area. This we had shown earlier, I think we have another slide to show that. This could be at a height, which again, if here is the source the direct distance, we saw we the reflected distance should not follow. So, that echoes can happen. So, all these points are to be accounted when you are thinking of the covering of your audience.

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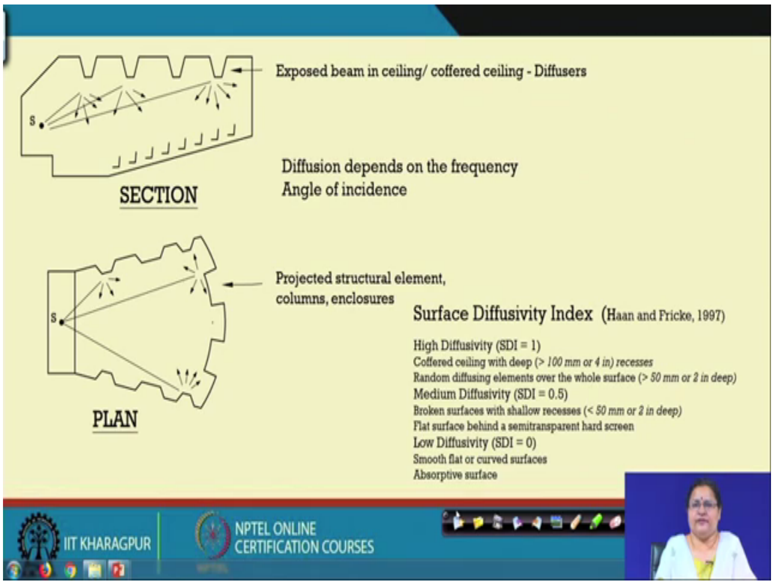

Now, coming to diffused surfaces, while you are doing your auditorium, you cannot forget thus columns the beams. For such column free spaces, you need Crawford slab, you can keep them exposed and help them in diffusion, if the scale is that big. You, see how diffusive surfaces could be of 4 inches or greater beams, which come intermittently interred in the entire ceiling. These are for small sized auditoriums. If, you have broken surfaces with shallow recesses say 2 inches or less deep structural system, those can act as medium diffusive surfaces.

So, surface diffusivity index which is 1 considered by Haan and Fricke in their study in 1997. They told this Crawford ceiling has a high diffusivity of 1, medium diffusivity are 2 inches or lesser surfaces projected surfaces and low diffusivity which are actually absorbers or the reflectors. So, that is 0. So, you can think of your structural system acting as a diffuser, because we need uniform sound in the audience. And, we cannot avoid the ceiling; beams columns, the edge beam can beams columns.

So, if you have projections of this nature. You can actually treat them and really create diffused surfaces on the ceiling as well as the side walls. So, these projected structural elements columns enclosures can actually act as diffusers and help in achieving uniform sound in the system. So, we have talked of the ceiling once it is curved we have talked of the ceiling if it is Crawford.

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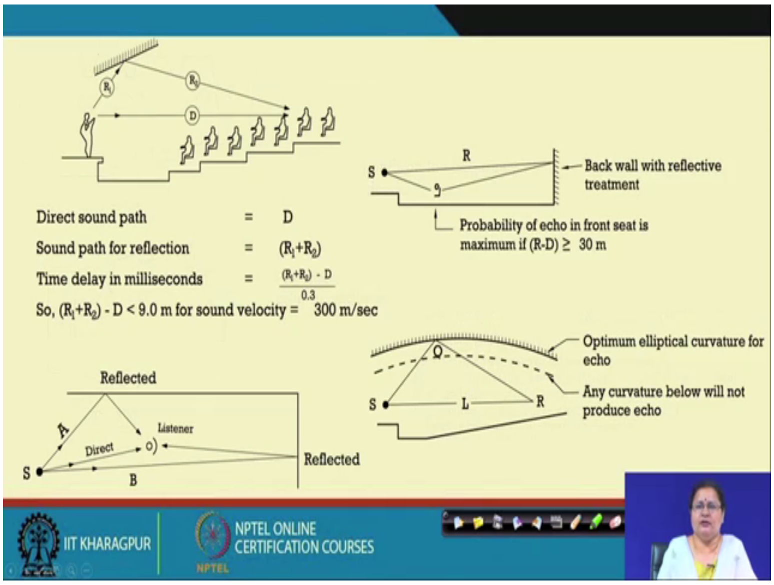

Here again we come to a previously discussed slide, where we see that direct distance and the reflective distance is of still at most importance, because this is a big space. It is not room acoustics that is not in a scale of classroom. Here, the space can lead to eco can lead to concentration of sound and we have to look into this condition of R 1 plus R 2 minus D, that is the difference in the reflected path and the direct path considering 300 millimeter per second speed of sound should be less than 9 meters, earlier it was worked out with 340 meters per second and some 11 meters, who are shown.

So, we have to keep in mind this condition. You see here the reflected ceiling shown here is very flat. The curved ceiling shown here is really very flat. And, below this is the and the height of it that can lead to echo condition is first drawn. So, any curve below it below that particular height will really not lead to any problem caused due to echo. So, if you draw the boundary condition of echo and plan your curvature, if you keep in mind that the radius of curvature does not convert within the floor area, then you can have a shell structure.

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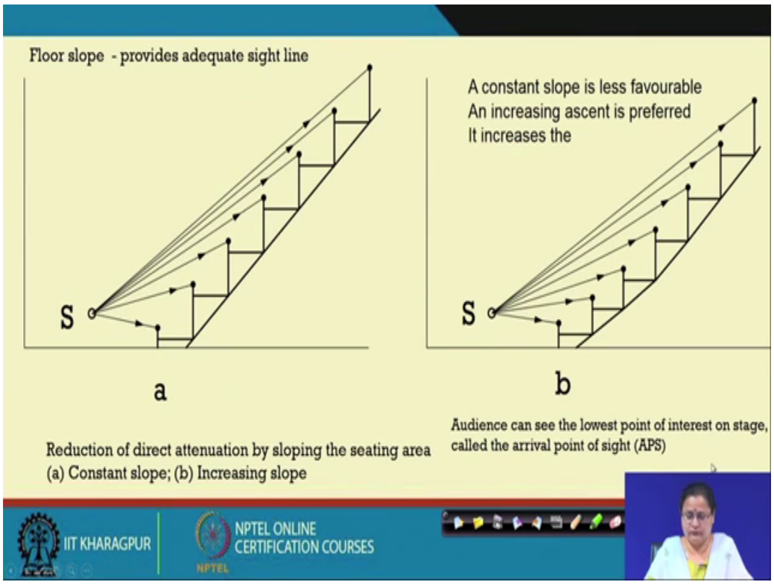

Now, coming to the floor slope we had talked about it while we were talking of stage. Now, if you have regular floor slope the first that is the a which is showing that is a constant slope, you can gradually what is happening till the top you can see the distance is gradually diminishing. Towards the aps or the source, where here it is little raised, but in the second case you see the slope has changed. A constant slope level is less favorable and an increased accent is preferred, because here the heights if you can compare here it is getting closer and closer, but here it is following a regular pattern, but this has another advantage.

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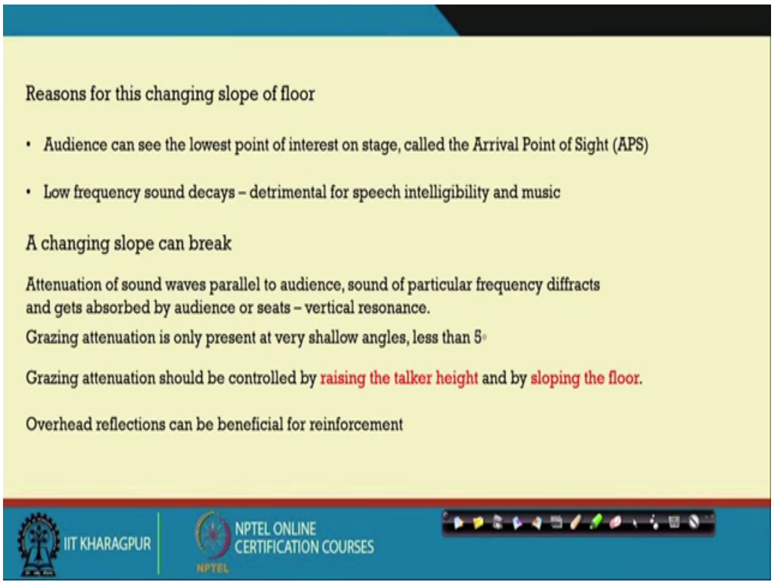

We will see that in a few minutes. So, reasons for changing slope floor slope of the floor is audience can see the lowest point which I had already discussed, which is the point of interest, lowest point of interest that is the aid arrival point of sight. And, low frequency sound decays, as we had discussed while talking grazing attenuation. If your sound level is moving parallel to your seats just changing by within 5 degrees, that is grazing attenuation, then sound gets lost. Sound seed tip effect takes place low frequency sound actually enters as if the seeds are resonators.

We have discussed this earlier. So, grazing attenuation to cut down grazing attenuation to cut down seed tip effect to cut down, low frequency sound getting lost, we need to rake the slope, we need to rake the floor. So, attenuation of sound wave parallel to the audience sound of particular frequency diffracts and gets absorbed by audience or the seeds, which is vertical resonance and which happens in 125 to 200 hertz. If, you remember warmth which was discussed in the first introduction to auditoriums, you will actually lose the low frequency sound that does not give warmth. So, if you raise it, you really cut down all these raising problems or all these defects arising due to grazing attenuation.

So, by raising the talker height and sloping the floor you can check or control grazing attenuation another is overhead reflections are always preferred. So, that it can help in beneficial reflection reinforcement of this low frequency sound in particular, because if the direct sound is lost the reflected sound should actually fill in the gap. So, this changing floor can break this grazing attenuation. Even the raising of the slope raising of the floor can check grazing attenuation. So, apart from viewing acoustically these are the purposes for raking the floor.

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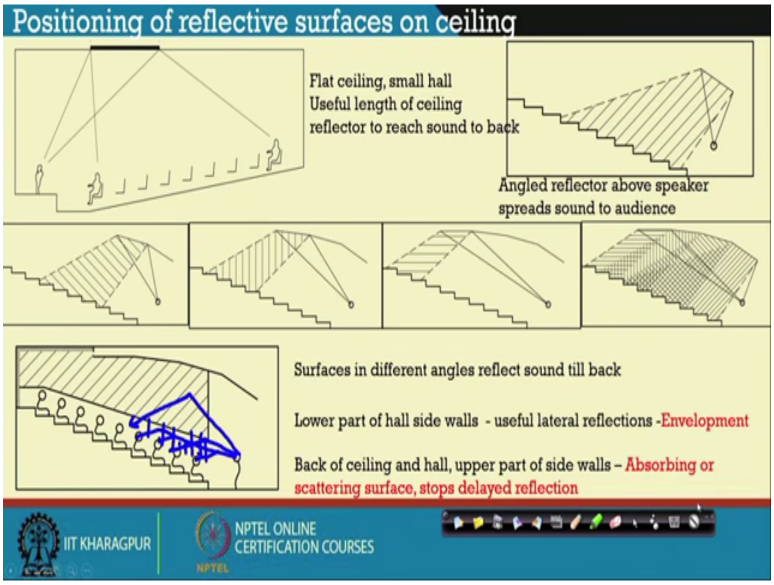

Now, we move to the position of the reflective surfaces on ceiling, if it is a flat surface. The first one third part of the ceiling always helps in reflection, helps in strengthening or reinforcing sound and these are useful reflection, but if it is a bigger size hall we can add or hang reflectors in an angular fashion. So, that it throws the first reflected sound to a further distance to the maximum distance it can pose, it can possibly do.

You see if you can actually keep on adding one by one reflectors then sound from the source directly hitting those reflective pieces or the reflective surfaces can direct sound to the entire hall. So, you see here this picture also shows, how the maximum sound is received at the central part of the auditorium, apart from the side reflections apart from other phenomena. So, this direct sound first reflected can from the ceiling can reach the central part at maximum.

So, if you go back to the seating plan, you can get a justification why the viewing as well as the listening part best is the central part, because ceiling is undisturbed. So, once you have got the entire floor being supported with sound, you need to put absorbing surfaces at the rest of the ceiling, the back of the audience

The lateral reflections do take place from these side walls. So, these lateral reflections can actually happen, can reach this audience from the source and laterally moving, from the source laterally moving. And from the above they are really they may lead to delayed reflections to this audience.

But, yes if there is no more audience at the upper level. If, there are audiences at the upper level they do help in better listening to the balcony locations. So, to create the spatial impression, the useful lateral reflections and the ceiling reflections can create that intimacy and that envelopment of sound, which will make them feel, that they are very close to the source.

So, back and ceiling of the hall requires absorbing or scattering surfaces, they will be they will be checking the delayed reflections, and we are encouraging ceiling reflection. As well as lateral reflection in the first part and ceiling reflection up to a distance which is really required.

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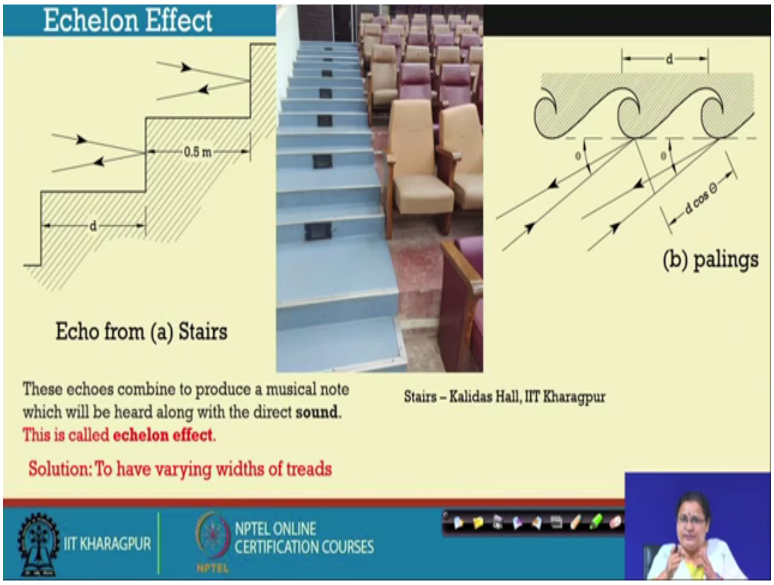

Now, coming to another important effect, which is the echelon effect or the eco effect you can say. So, these when you have this rise or the treads with which you are going up at a very regular way, which we discussed in the if below before last to last slide. Here, you see that this regular hitting and going back of the sound at a very regular interval of time and at a regular interval of distance creates a regular phase difference and echo while the sound is going back. This actually is heard along with the direct sound and this is called echelon effect.

If, you actually have different slopes or different row widths at least broken at some points this echelon effect can be reduced. So, you can have varying widths of the trades or you can have varying heights and varying widths of the trades at varying heights. So, this echelon effect can be cuttled. You see here the picture, where you where they have taken care of the echelon effect you see these are these are wider trades, these are wider, these are wider and later on some are some are of same height and again some are wider.

So, the echelon effect cannot have happened or is taken care in this particular case. Where else can it happen, it can happen in ceiling patterns, that is the palings. Various reflectors or surfaces can be put as you have seen in the last slide, that the ceiling reflectors are put. Various shapes are taken, but if it is a repetitive shape of a particular concave surface or a flats even a flat surface the same effect can happen considering the angle in which it is falling, it will come back and again hit, again come back, again hit and create a additional sound that will actually disturb the basic or the original sound or the desired sound. So, that is called echelon effect and that is how you can take care.

So, no continuous repetitive form is encouraged within the auditorium. And, again of particular wavelength of particular dimension which corresponds to the wavelength which is being performed in that particular space. So, if it is less than lambda or one-fourth lambda for 500 hertz it is 2 fit for 1000 hertz it is 1 fit for 2000 hertz, it is half it is half of it

So, you have to keep those wavelengths in mind, what frequency is being performed? What would be the wavelength? How it could take? How it could affect the sound quality? And, how it could affect or create this f fill echelon effect or not you have to keep this in mind while you are designing?

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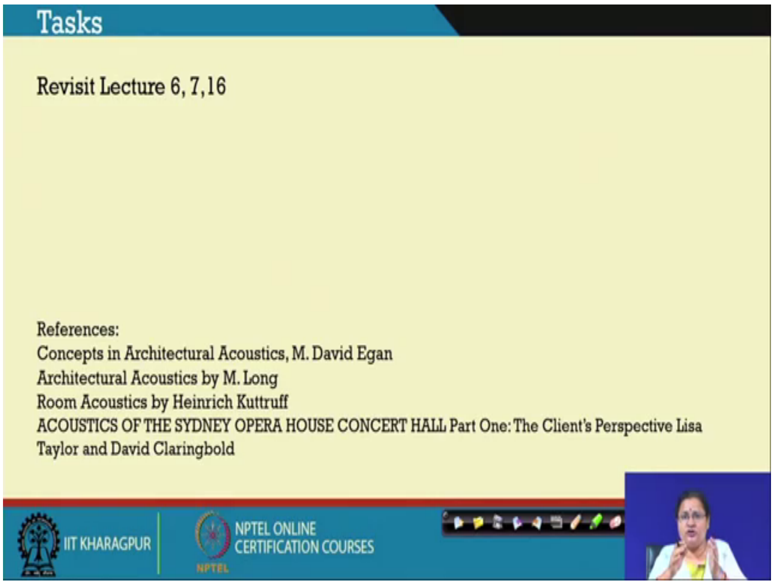

So, with all these I request you again to revisit the earlier slides, where the basic principles were told these dimensions the wavelength, the frequencies, what kind of frequencies do take or do happen when it is speech, what is it is 500? When, it is a performance it is from 125 to 2200 4000?

So, you have to know: what is the range dimension of the wave that is the wave lengths also, and then how to plan it? So, it is not very difficult if you keep this in mind you can single handedly take care of small auditoriums. So, we will move to the balconies which I have not addressed it in the next lecture and hopefully you will get much more interest and will surely take up one such design in your entire architectural program.