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

Lecture – 17
Acoustical Criteria and Space Design (Contd.)

So, today's lecture we will continue with lecture 17, which we will actually con it is a continuation of lecture 16. And we will continue with the classrooms which we classroom design, which we were discussing in the previous lecture.

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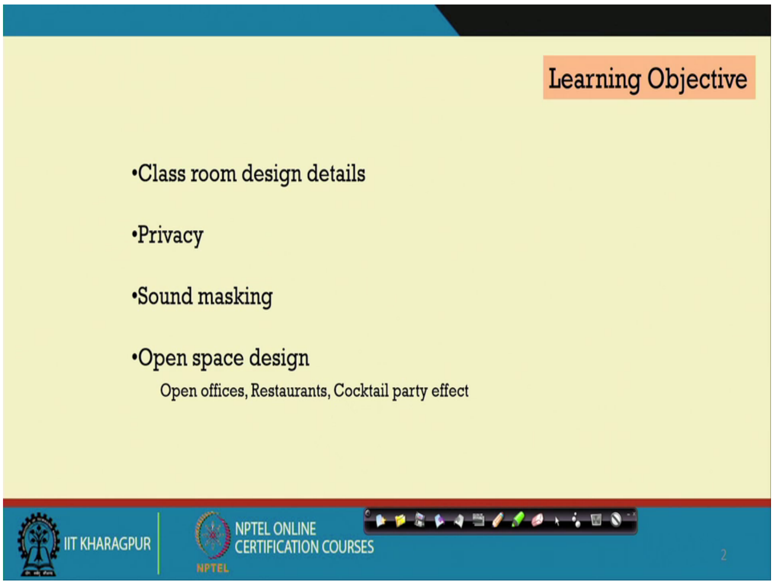

And what we understood there which was signal to noise ratio, the precedence effect and how we take care of all these things how to calculate the signal to noise ratio how to find out, if we know the know the noise level and the signal decibel pressure level and, the noise pressure level. So, we can actually find out and, what is our desired range, where we should fit in to get a better intelligibility.

We had also tried to find out which is the critical distance and, that is important because we found that with increasing reverberation time, the critical distance gradually decreases. So, we have to take help of more of early reflections for that. So, that the sound can reach the audience that is the that was where we stopped.

So, that critical distance the role of critical distance is to find out, where actually we need to take help of the reflected sound, where from we need to take help of the reflected sound.

So, the first part of the hall, or the classroom, which we are designing, the source sound will reach, but after what distance the sound decays and the original source sound decays. And it is the reflected sound which is reaching, though we have though we know the inverse square law and, that sound decreases by 6 dB every doubling of the distance. And this critical distance determines where is the meeting line of the reflected sound and, what is the meeting line of the source sound level and the reflected sound level meets.

So, beyond that it is only the reflected sound, which is which is helping in the listening process. So, we start with that and we will move to the just the opposite part of it that is privacy, when we are talking so much of intelligibility that is people should hear, we also come across spaces, that is particularly open offices where we require privacy.

It is not only offices it is a formal space, everyone understands that a formal space will people will not talk that much people will try to maintain a decorum and, that is where we require privacy and, people are all tuned to that they know. But when a when you move into a recreation space like a restaurant, you do not know who mean how many people will be there, there also you require privacy.

You are sitting beside another table some people are conversing, you are sitting at a point you are conversing with whom, you have gone to the restaurant that is also a place, where it is privacy is desired.

But not at all points we can achieve privacy, but we try to achieve privacy and, with that we will come to understanding of sound masking and, there we will highlight on the particular design criteria for open offices what should be the principle or the rational. Restaurants and we will also discuss around another thing, which is cocktail party effect. So, that is a little informal in the lecture let us carry on.

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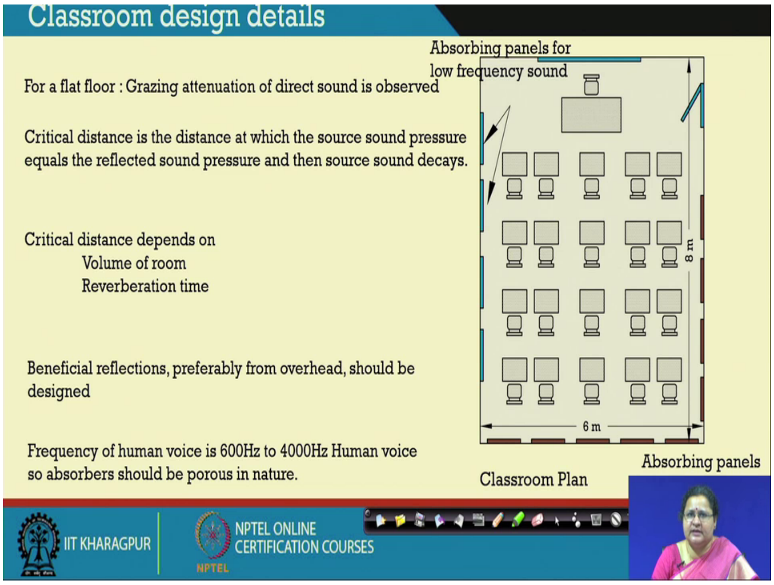

So, if you if we see a typical classroom layout it is a with very small capacity, but you know how to make plans and, we usually have a flat floor and, I have already discussed with you if the chairs are kept in an ordered fashion, they all help in grazing attenuation. I am not repeating this I have already discussed. And the critical distance we have discussed where the distance at where, which the source sound pressure and acquires the reflected sound pressure and then the source sound pressure decays.

So, if we know these two this these phenomena, what is the critical distance, which is a dependent of the how loud the talker is talking and, how what is the reverberation time of that place, what is the capacity or the room, room constant of that space we can know the critical distance. So, the critical distance depends which was which is a dependent on the volume of the room and the reverberation time, that is a tool for you and the flat floor that can lead to grazing attenuation of the direct sound, that also you have to keep in mind.

So, for small classrooms what is whatever is shown here that may not be a problem, but critical distance a beyond the critical distance, you need reflectors good amount of reflectors directed towards the audience that is the receivers, that is the children. And what I told, you require maximum intelligibility possible. So, beneficial reflections can be taken from the overhead because, this is a small room. So, the reflected sound can actually reach from the overhead to the children because, the walls may have panels etcetera, which are apparently absorbers, which are apparently absorbing low frequency sound, low frequency sound in small rooms create resonance, or standing waves and to take care of that you can have absorbers in the wall, in the in the form of absorbing panels, which will absorb the low frequency sound.

So, in case of small classrooms you can take help of the ceiling as a reflector and, those will actually reach the sound to the audience in a very uniform fashion, which was also one of the objectives of (Refer Time: 06:55). And frequency of the human voice is between 600 to 400 hertz. So, human voice whatever is producing beyond that I have talked it is the low frequency sound absorbers, but for 600 to 4000 if you need absorbers, these absorbers should be porous in nature.

So, wherever you need absorbers that is the back of the classroom, what you see here at the back of the classroom, you see the absorbing panels are laid because, you do not want reflected sound much. So, here the sound is absorbed by means of porous absorber, we where which are put in to trap the sound, which are of the which are created by the human voice.

So, porous absorbers are welcome at the back wall the ceiling should be reflective for small classrooms and, which is classrooms which is having flat floor. So, the sound will graze through and grazing attenuation that is loss of sound energy can happen, because of such kind of seating arrangement, though these are this is not as high as what and or what you had seen in case of an auditorium.

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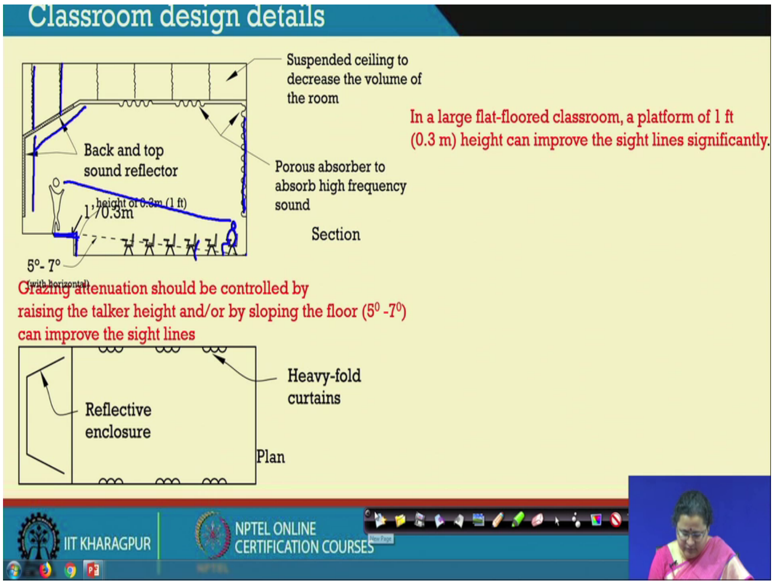

If we look in to the section you will see, you can adjust the ceiling by suspending fall ceilings, which can have porous absorbers if required see the reflecting surface see the reflecting surface, surface in front of the in back of the talker. And see the angle how it has been placed.

So, these are all leading to helpful reflections to the floor and, what you require more is sound should sound should be reflected from this portion actually sound is moving here and, sound is actually moving much to the back where, this reflected sound is most desired. Because, may be here the sound is not much desired because of the it is getting the sound, because of the it has not actually reached the critical distance. Now, here another thing you observe in this picture that the stage has been or the talker is at a elevated position.

So, this is to take care of the grazing attenuation. So, if you have a big hall, big classroom. So, it is say having holding 30, 40, 50 students even more. So, you have a pattern of chairs which will lead to grazing attenuation. So, if the talker that is the teacher is standing at a platform say 1 feet high not much, then the grazing attenuation problem gets solved.

So, people here sitting over here, can get the sound better and grazing attenuation can be avoided. And if you see here is a directive for the angle, the lasts from the end of the classroom, if that raise is by at a 5 to 7 degree angle, then that is the best height for the talker to stand and talk this also improves the sight lines.

So, the person or the child who is sitting at the back here, can have an eye contact with this teacher with his teacher not only listening to the sound, but also having an eye contact if with the teacher is very important. So, this rising of this platform, rising of this teachers area will help to take care of two aspects, one is the grazing attenuation and second is it can improve the sight line from the of the back seat the students at the back seat.

So, this reflective enclosure what you see here, has been suspended from this as of kind of false ceiling what you will see and, that has been treated with reflective materials in the front part. In this front part whereas, absorptive materials absorptive materials on the ceiling part, wherever in wherever it is required, the back part is always of porous absorbers because, you need to trap in the additional sound the late reflections from this from this backward.

So, in large flat roofed flat floored classrooms, this plat form of height of around 1 feet or 0.3 meters can improve the sight line improves the grazing attenuation can take care of the grazing attenuation.

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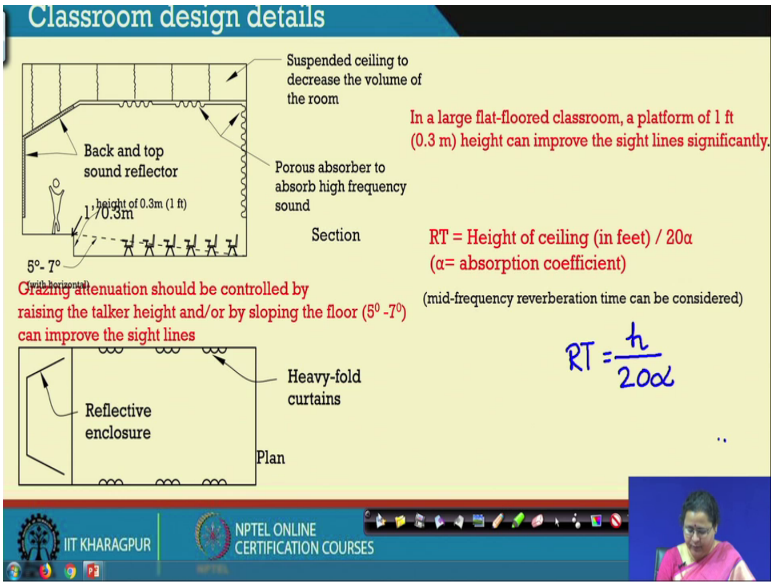

The reverberation time is a function of the height of the room, as I told you the volume is important. So, it is said that RT is equal to RT is equal to h that is height divided by 20 alpha, where alpha is the absorption coefficient, that is height is equal to RT times 20 alpha.

So, if we consider the mid frequency reverberation time, considered like 0.6 second 0.4, 0.4 second 0.8 second. And if we know the alpha value, what you can adapt in this particular room, you can get the height approximate height.

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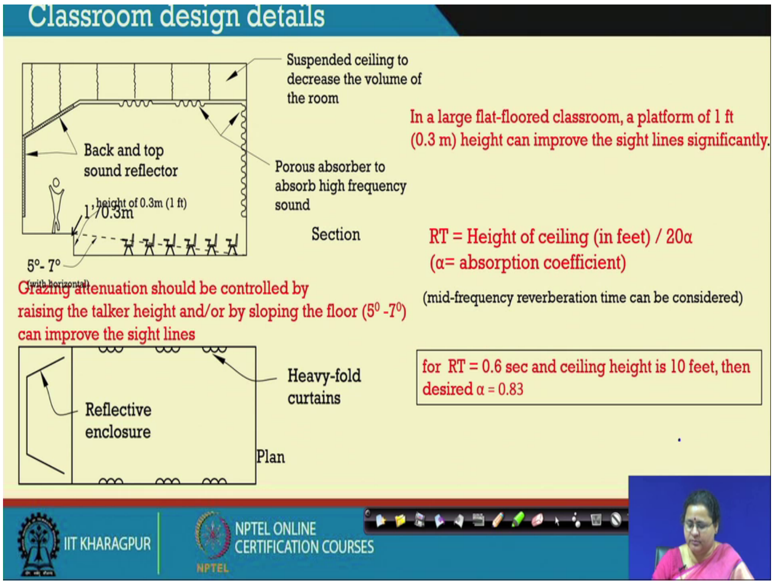

So, if you have so, if you have 0.6 as RT and the ceiling height is say 10 feet, then the absorption coefficient of the material desired is say 0.83. If we go the other way because height you can change by approximately positioning the false ceiling, you can actually achieve the height with a desired RT and with a desired material, which you plan for as absorptive material within the classroom.

So, you can plan the location of the false ceiling to control the v which will that is controlling the RT. So, you can work, you can change with the alpha, you can change the height, you can change the RT and your objective is to keep the RT as low as possible.

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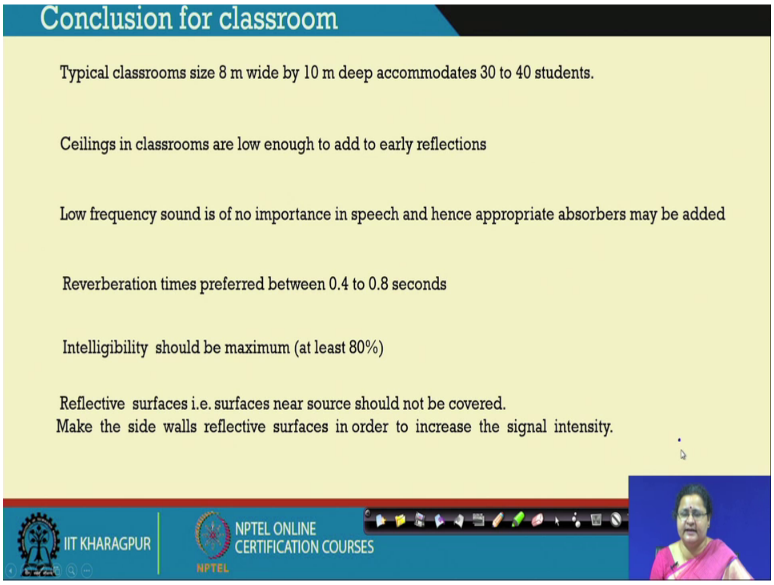

So, the conclusion from the classrooms classroom is typical classroom size 10 meters, 8 meters, 10 meters deep can accommodate 30 to 40 seconds students, which with the thumb rule of the volume you will get all these and, you all know how to plan a classroom. So, you know the chair height chair dimension, you know that table dimension all these things.

So, you will if you actually work out a plan, you will get the sense of the length and the breadth, height is under your control, though there is a structural wall structural level or the structural ceiling. You can always change your height by putting fall ceiling if required, ceilings in classrooms are desired to be as low as possible because, you can take help of the ceiling for early reflections.

And minimum the distance lesser the distance higher is the contribution towards the early reflection, low frequency sound is of no importance in speech. So, if there is sources of low frequency sound, which are actually the noise they can create a humming noise within the room that is the room mode, they can create the cause the room modes or the standing waves.

So, they should be stopped or checked by putting in appropriate resonating resonators that is the absorbers of low frequency sound. We have reverberation time preferred between 0.4 to 0.8 seconds, intelligibility is desired to be the maximum at least 80 percent, then we have the reflective surfaces which should be near the source and, they should not be covered in any case there and make the side walls reflective surfaces in order to increase the signal intensity.

So, we can take help of the ceiling, maximum because ceiling is uninterrupted, but walls what happens either is doors punctures for doors there are pa there are requirements of soft boards, to put in instructions notices within the class.

So, walls are interrupted here and there. So, we have to with windows with curtains. So, we have to tell with blinds curtain. So, we have to take care that ceiling should be uninterrupted reflective in surface, the height of the ceiling adjusted and that is what all the lessons are.

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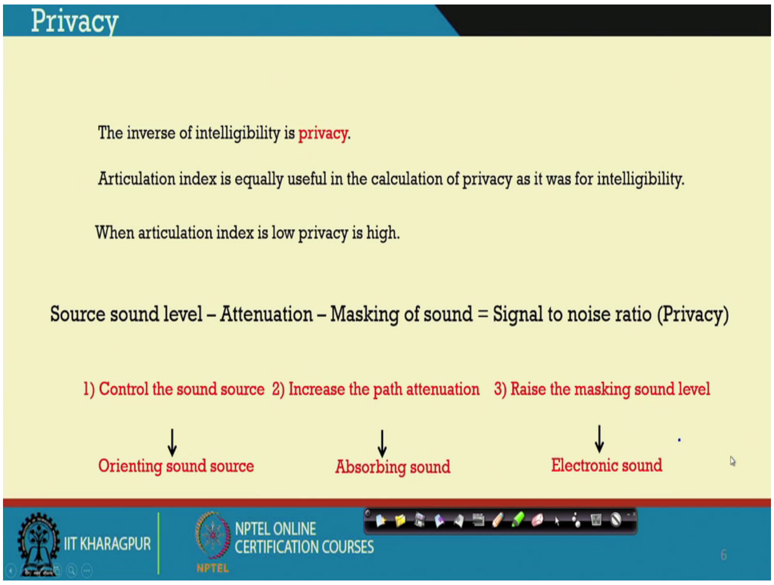

Now, we move to the next phenomena, which is privacy. As we have talked so, much of intelligibility and that we had discussed about articulation index. We have we also need to know what is privacy. So, in privacy we cannot entertain noise. So, here it is the signal and, we have to check the signal to further move.

So, signal is important here, noise is not at all to be entertained, but whatever signal is produced it should remain in the domain where it is to be where it is to be there. And it should not move to other places. So, you have to put materials or you have to think of how to check this and, then only you can get a get higher privacy.

So, we had talked of articulation index, which is equally useful that is also equally use useful in privacy as it was for intelligibility. So, when articulation index is low, it is expected that privacy is high. So, sound source level source the sound source level minus if you can attenuate the sound, or if you can mask the sound that is cover the sound, you all know mask; mask is a covering, you remain behind. So, something is covering the sound, then you can get a privacy.

So, source sound is of importance, if you can trap the sound that is absorb the sound that is you can attenuate it, or you can mask the sound or three of these can be done parallel, then you can achieve privacy. So, you can control the sound source, you can increase the path of attenuation that is maximum absorptive surfaces nearby. And if you can raise the masking sound level, then you can achieve privacy. So, controlling the sound source you can orient the sound source, or you can reduce the sound source.

\So, loudness the voice can be going down we as if privacy, or you can turn that side you can plan that plan the positioning of the people, if you keep because perception of hearing with the direction it changes. So, orientation of sound source can control the first part the sound level produce that can control the first part. The second part by absorbing sound you can achieve the second part, and by electronic sound you can actually take care of the third part. So, you can that is called masking we are coming to that.

So, if you want to achieve privacy, you can control the source sound that is you can control your loudness, that is one part, or else you can orient the sound source, you can turn the head or the producing sound, producing source in a different reduction, you can put absorbing surfaces and, you can take help of electronic sound.

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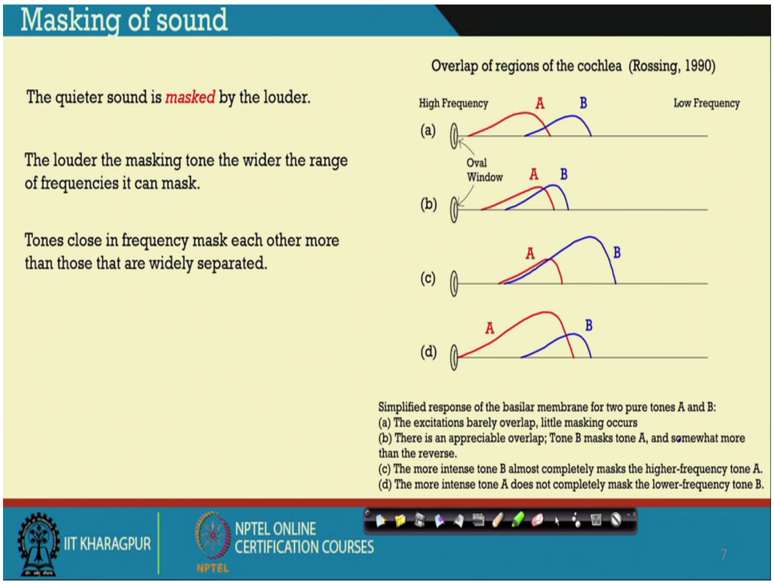

So, we come to the masking of sound, in the cochlea Rossing in 1990 experiment the overlapping regions of the cochlea, which you have which was experimented and here are the graphs, which is the simplified response, which has been represented here. We see that if two tones are entering your oval window that is the first part of the mediar, see the high frequency sound is shown in this part and the low frequency of the sound is shown in this part.

So, if you have very close tones produced in produced in after the oval window is entering, you see this A and this B the two different tones here, you can distinctly understand A and B. But when you see there A is overlapping a part of B, you will see that if there is an appreciable overlap tone B is masking tone A and sometimes and somewhat more than and, even you can see the B is masking sorry B is masking more of A.

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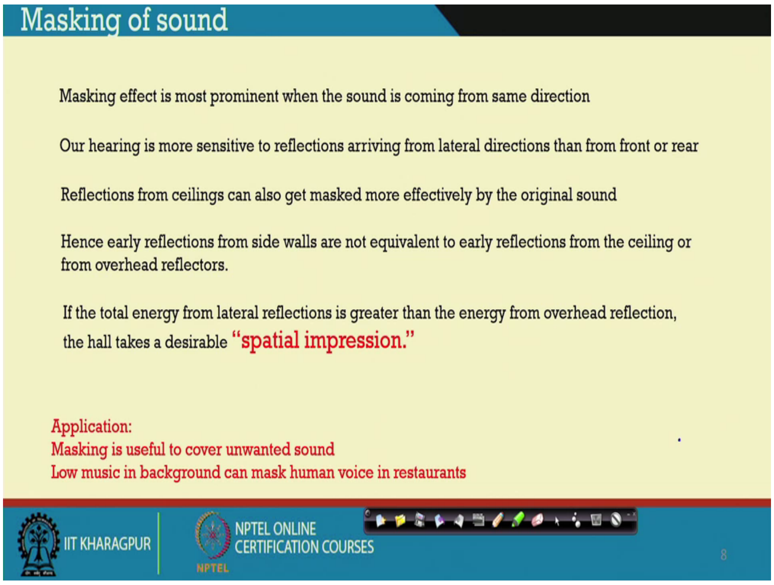

In the third case that is C the more intense the B tone goes, it is masking the entire ray and if the tone A tone A is more intense, the tone B ad it does not completely mask B partially masks B, because B is always moving to the lower frequency end.

So, what do you understand from this picture, that the quieter sound is masked by the louder sound, that is the more intense sound is masked is masking or covering the less intense sound. The louder the masking tone, the wider the range of frequencies it can mask and, tone closing frequency mask each other than when they are widely separated.

So, in the first case what we see that the tones are tones which are widely separated, do not do not mask each other each other. So, you can discretely understand a tone, you can discretely understand B tone, when they are close then in case of the figure B you see B is masking more of A. So, you do not hear the lesser intense that is the lesser intense sound that is the A and B is only heard.

So, in case of C you see B has completely masked A. And in case of 4, where A is even if of a higher intensity, but as because it is of a it is of a lesser frequency, it is of a higher frequency, it is not masking B. So, masking effect is most prominent when sound is coming from the same direction. So, within the ear this thing is happening if the sound is coming from the same direction. So, our hearing is more sensitive to reflections arriving from the lateral direction than from the front or the rear.

So, what we hear or as reflected sound is mostly coming from the side directions, what is happening the reflected sound and the original sound may mask each other. So, the reflections from the ceilings can also get masked more effectively by the original sound whereas, the lateral reflections would not get masked.

Similarly the total if the so, if the total energy from the lateral reflection, that is coming from the side to your ears, than from the ceiling if the total energy is coming more, then the space is take is told to achieve a desired spatial impression. Now, coming to the masking of sound, we take help of this masking to cover up the unwanted sound, in restaurants you will find whenever you enter, there is a background noise going on back background music going on.

So, that actually masks the sound produced by the people, who are actually sitting there and enjoying their time personal time. So, they are actually they are not going to entertain what conversation is going on in the table here and there. The same is happening in the office in some offices light music goes on that actually masks the unwanted sound.

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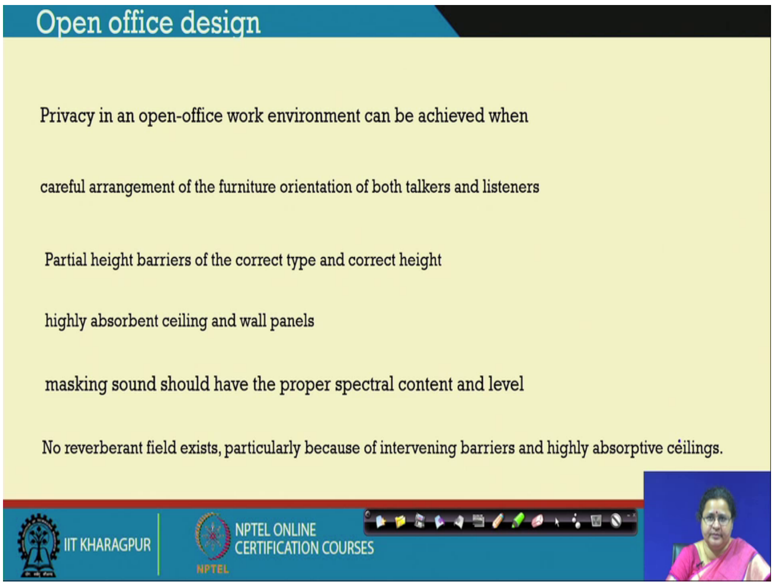

So, if we see an open office design privacy is of at most importance and furniture orientation both of the talker and the listener to be kept in mind. So, if the orientation is kept in mind, then you can achieve a certain amount of privacy, partial height barriers are adapted to absorb sound. So, that you can attenuate the source sound highly absorbent ceilings and wall panels are put in. So, that you can mask and above all the talkers we were talking inside are maintaining a low sound level low loudness. So, that is also one point how they can officers can achieve privacy.

So, masking sound should have proper spectral content level. So, one should understand what kind of sound is being produced that is what tone, which spectral is being is to be masked and, based on that the music has to be selected. And in case of such an office design no reverberation field exists, because it is always interrupted by barriers with highly absorptive ceilings highly absorptive partitions. So, in this case in case of open office design, there is not much role of the reverberation time.

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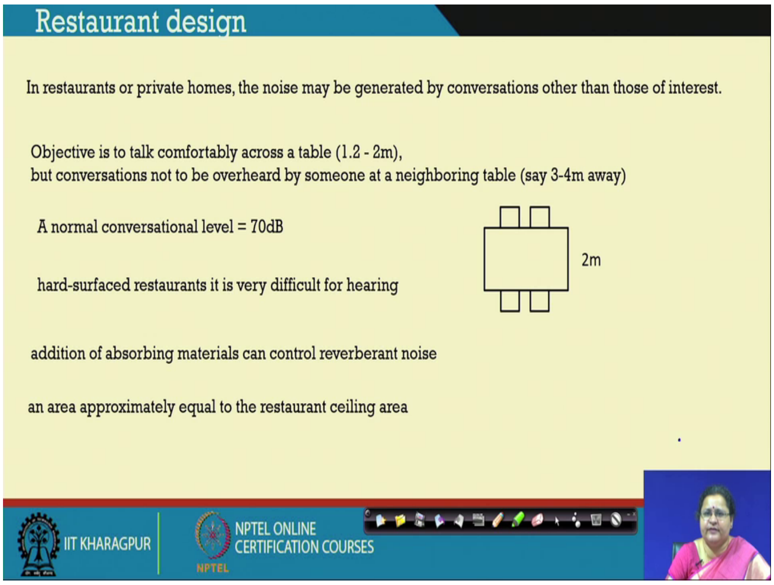

In case of restaurants design the loudness cannot be controlled, yes people try to talk between each other. And usually at table say 1.5 1.2 meters plus that is 4 feet 2 meter maximum with number of good number of seating. And the objective is there to talk comfortably across the table and, they should not be over heard by the tables nearby say within 3 to 4 meters.

So, hard surfaced restaurant is very difficult, we have to put in absorbers we have to put in carpets, additional absorbing materials within the space. So, you can have lot of options like ceiling can be made totally absorbing. And if the entire ceiling is made of absorbing materials carpet is placed on the floor, if it is of such level of restaurant you can put in carpet in place. So, you can achieve a good reverberation, you can achieve a good sound level and above all sound music is used to mask the noise part.

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Here are two interiors shown one of an office layout and one of a restaurant here, you can see the chairs are also having absorptive surfaces. So, chairs itself are absorbing sound at that, but which is created within that particular enclosure. Here the carpets are there, the ceiling if you watch they are all false ceilings, which is embedding the electrical lines also.

But it is above all purposes is also take care of the acoustics. In the office you also see there is absorbing material in the ceiling, the there is carpet at flooring, the chairs are having cushions, which will absorb sound and that is how you have to plan for open office or restaurant.

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Now, we come to a small phenomena which is cocktail party effect. So, here I will expose you to phenomena, which is called cocktail party effect.

So, just listen to this video the background is it is a comprehensive viva going on, where the faculty members are taking viva of individual students and, when it initially starts a 2-3 students start coming in and, then when all faculty members are busy with each of the student, there is a lot of that is to be observed. So, you watch this.

So, what did you find here say in a party, when 2-3 people arrive between 2 persons conversations can go on, when another two join and they keep on starting talking the scenario changes.

That is it adds some noise to the previous two talkers, if another two party joins then some more noise is added to the system and what happens these two persons try to come closer to communicate. Each of them are continuously trying to do that, but after coming close what they try to increase their loudness because, he wants he or she wants to communicate these words to the person who has already come quite close. But even then nothing is whatever is heard, it is above the noise which is produced all around. Actually these can be all calculated out.

And really this is called the cocktail party effect, which you could feel here that each of the professors taking viva of the students are really in a difficult position. You can see me in the picture it is really difficult to listen to the student, who is sitting very close to you even then you are asking him to speak little loudly.

And even the students is all student is all also asking the teacher to speak little loudly, to ask the question please repeat, you could not hear any of those, but we were there in that environment experiencing this. So, that is called cocktail party effect. So, with this I close today's lecture, I close today's lecture, but I leave some but I leave some task for you.

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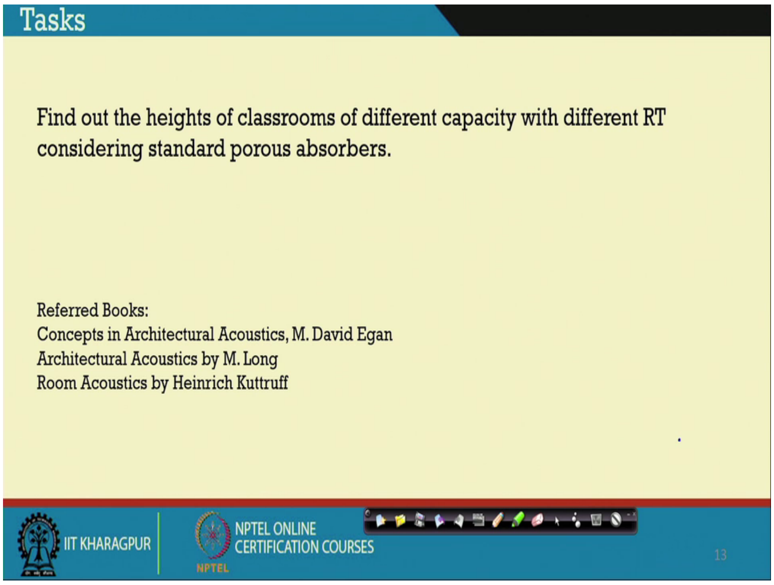

So, you find out the heights of classrooms with different capacities, you keep one particular RT and find out the heights, then you keep on changing the reverberation times say 0.4 to 0.8, you can do 2-3 exercises. And consider some particular absorbers, or from the standards standard list and, then you can find out the height what is the height requirement for the classrooms.

So, if you keep on doing some small exercises that will actually help you to grasp how you can actually take care of acoustics and, whether to increase the height whether to decrease the height, what could what should be the objective of yours.

So, we will carry on with the next lecture. So, I would expect that we will carry on with the next lecture and, I would expect that you will be doing this exercises small exercises or tasks. So, that we it helps you in better understanding because, we will move in to the next little bigger spaces because, we have already covered the small rooms, or the rooms for speech.