Architectural Acoustics
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Lecture – 18
Acoustical Criteria and Space Design (Contd.)

So, we will be continuing with lecture 18, in lecture 16 and 17 we have tried to understand, what are the acoustical criteria's, while we were we are considering spaces for design, particularly rooms and we started with classrooms. And then we moved to open offices, restaurants and we also discussed about the cocktail effect which one experiences, when they move in to a party. And I had shown you a small clipping from a grand viva, where all the professors were asking the students questions and that led to a cocktail effect.

So, in the situations different different requirements are to be understood, what is the source, where are the sources. If there are multiple sources and who are the audience, whether it is one to one correspondence one to a group correspondence, whether individuals from group can interact. So, we will we are trying to build up these understanding of the architectural acoustics through these examples. So, we had understood classrooms, we had understood open office design, where privacy was very important and how that was to be a obtained. Now, we will try to look in to conference rooms.

So, this lecture will be mostly dedicated to conference rooms and, we will try to show examples from the our institute how these are actually planned for. So, coming to the content today's objective is mostly room for speech and, highlighting on the conference rooms and also boardrooms which are bigger in sizes.

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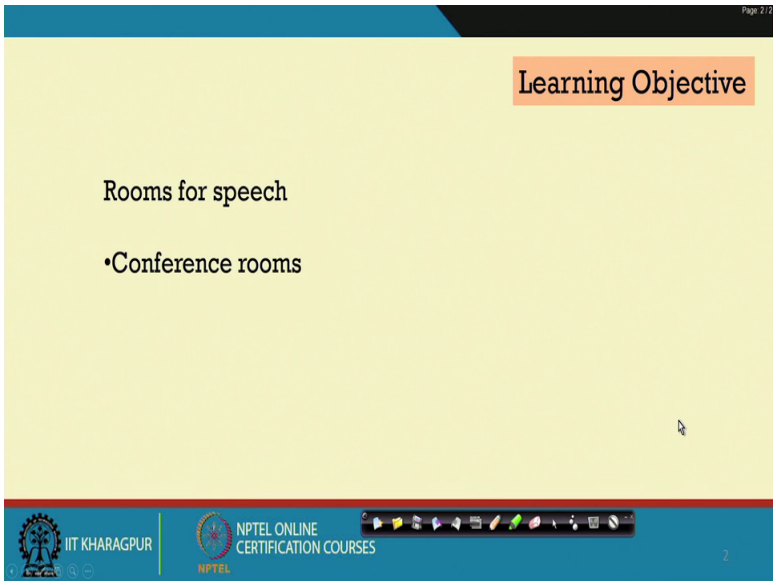

So, we will try to see whether, there is much of difference, or what is the concept, or what is the principle. By now I have already exposed you to the principles.

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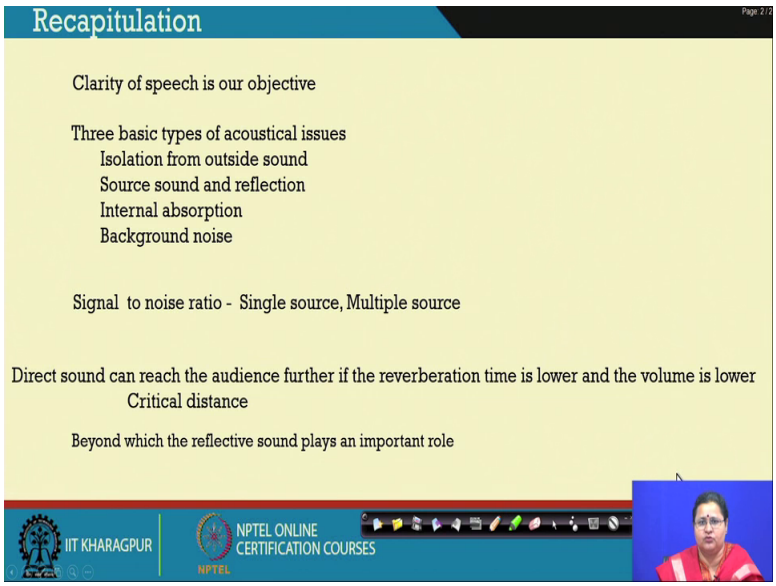

So, let us have a recapitulation, clarity of the speech is our objective and in particularly for conference rooms you have multiple talkers and multiple receivers. So, it is a kind of discussion room, where people exchange their thoughts and come up with solutions. So, must be you have planned by now conference rooms and, we will try to see through plans and, how the acoustical treatments are done in the same plans.

So, we had already discussed about the three basic types of acoustical issues that were the isolation from the out outside sound which will which will be dealt in another totally in another chapter. But however, source sound and reflection, we have we have to know the source sound and how it is reflecting within the space. We have to know the internal absorption, that will determine the reverberation time and, also we have to take care of the background noise because, that effects intelligibility.

So, when we want speech clear speech we have to keep in mind what is the background noise also. So, we have to keep in stopping all those all those issues, but if we have it we have to cover it. So, we had also learnt masking of sound etcetera. So, signal to noise ratio also we understood with single source and, we also understood with multiple sources.

And we also understood critical distill distance, where which until which the direct sound can reach the audience. And after that actually the reflected sound takes care of reaching the sound from the source to the audience. So, there is a drastic fall from the critical distance of the source sound.

So, that also we had in earlier lecture and, we see that the direct sound can reach the audience further, if the reverberator reverberation time is low and also the volume is also volume is low, beyond the critical distance actually the reflected sound plays the important role.

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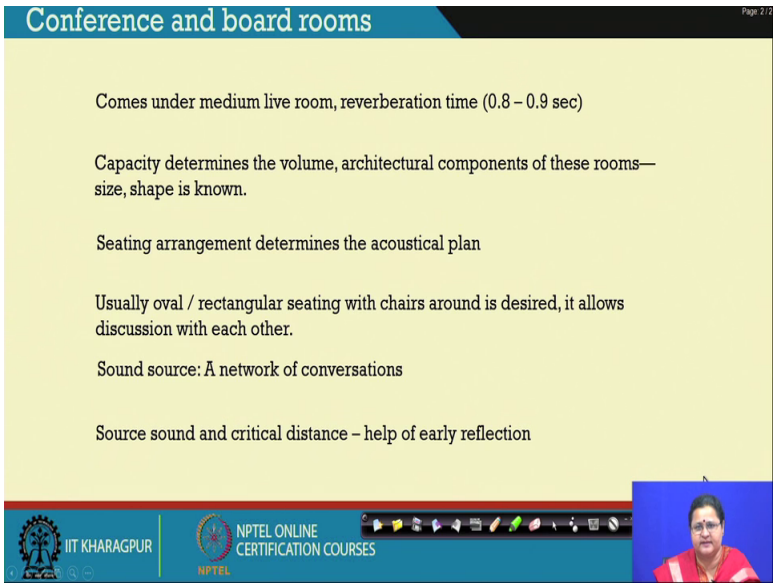

So, we come to the conference and board rooms design, architect acoustical design. So, first we will see the architectural aspects because we cannot plan something and then think of the acoustics. So, we are trying to give you this knowledge. So, that you can plan the structural form, considering the acoustical requirement integrated. So, these comes under medium live rooms, which I had discussed earlier and the reverberation time is around 0.8 to 0.9 seconds depending on the size.

And capacity is deter determined by the volume, I have already told volume of 110 cubic meter per person is the right proportion as Doelle told in 1972, architectural components of the room that is the shape size is also to be known. So, size for size you have to follow the standard area because, here also there are chances of room modes, or standing waves. So, for size you are not supposed to take your multiples of each other.

Seating arrangement will now determine in the acoustical and particularly in this case and, in conference rooms we prefer a oval or a rectangular seating with chairs all around. So, it desire that is desirable because, it allows face to face discussion and people can interact at a distance with one another while, they are having difference in opinion, or they can carry forward the discussion taking opinions from all the participants in the conference.

So, it is a network of conversation. So, it is not always one source there are multiple sources and multiple audience. So, when one person is talking it is expected that the sound should reach all other audience inside the space. So, some persons will be within the critical distance. So, some persons will be receiving the direct sound, who are just sitting adjacent to them adjacent to the speaker and rest will require reflected sound.

So, here it is also very important though there is a eye to eye contact with each other, who is speaking is also very important because, there may be readers who are looking down their head and reading and is difficult to understand who is talking. So, source should be identifiable. So, we have to keep these points in mind and take help of the early reflections. So, that sound can be carried from one into the other between the talkers between the persons who are discussing.

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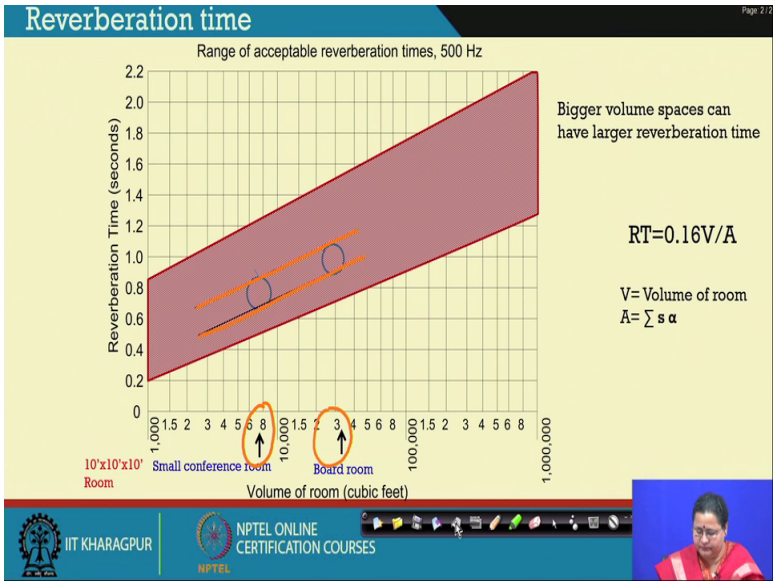

So, here is the reverberation time graph which was discussed earlier and, here you see the black lines where actually which is the zone of which is the zone of medium reverberation time, where our volume lies say some 8000 to some 30000 cubic feet.

So, for small conference rooms, we have around 0.7, 0.75, 0.8 we target reverberation seconds as reverberation time whereas, for board rooms we can go up to 0.9 seconds.

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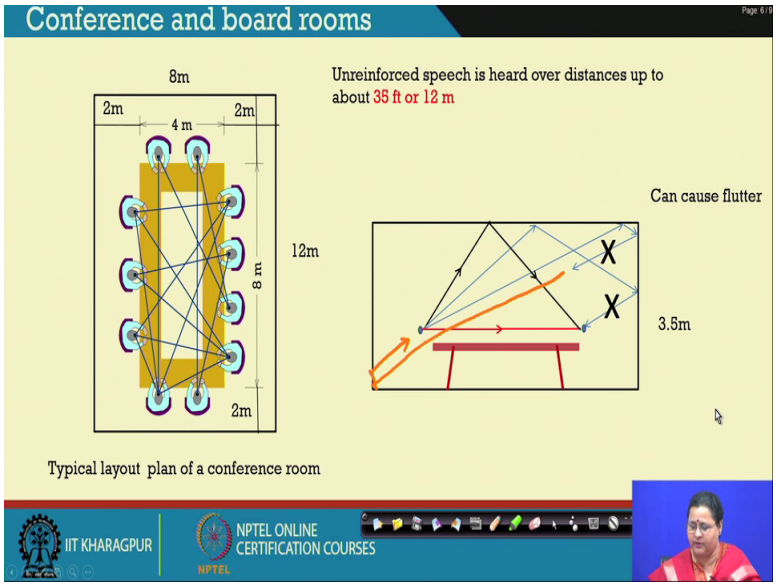

Now, we come here with the typical plan, what we see here, it is a 8 meter by 12 meter room, where we see there is a rectangular table. And what I was discussing in words has

been translated to a plan, which is easier for us to understand and which is very easy to handle for geometrical acoustics. So, ray diagrams can be easily drawn. So, you can see a network of lines that is a network of conversation, that might happen between the individual talkers and, that has to be reached to all others say person who is talking here, can person who is talking here his sound must be reaching the farthest point.

So, that is it must travel around more than 8 meters. So, that is the maximum and this is the shortage where it should be more than around 4.5 meters. So, we have to keep in mind that multiple reflections from walls, may create a problem or reverberation time in can increase the reverberation time and we have to check that by means of absorbers. So, our objective is to sent the sound amongst these people to as much clear as possible.

So, let us see how this direct sound moves. So, once we have the direct sound moving parallely it is the reflect sound, which is also moving to the person. So, if we have a height of say 3.5 meters. So, these sound will travel above the talking level to the ceiling and again reflect back and come to the audience, come to the other end of the table, but parallely there will be some more reflected sound. If we are not taking much care of these reflections, hope you can understand the understand this line, which understand this line which is going to cause a flutter after coming to this end and again going back.

So, we need not encourage such kind of situations, neither we have to encourage these kind of sounds because, this will continuously be created when different talkers are talking in the table. So, what is necessary, we have to check this flutters hence we do not need to reflect back this sound. So, if it is the entire structural ceiling, which we leave bared, then we might be doing leading to some errors, or bad sound inside the room.

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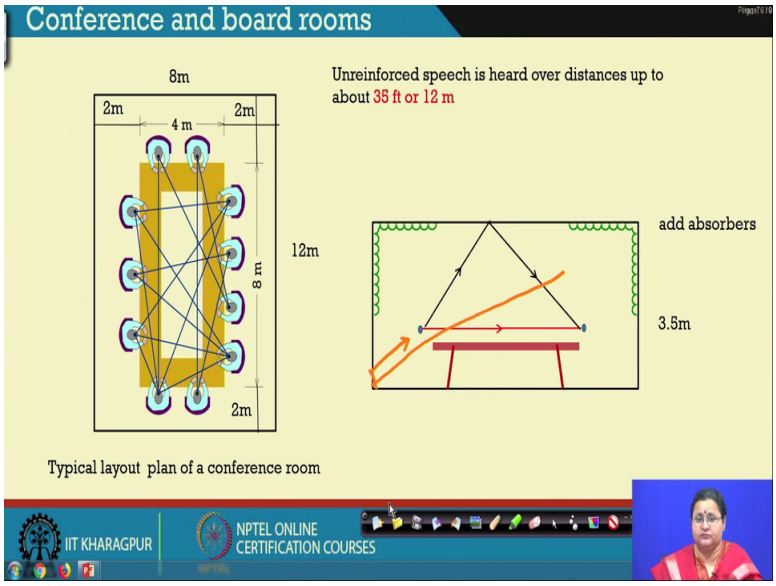

So, we need to add absorbers now, you see you need to absorb add absorbers, but the central part is left for reflection because, that is actually carrying helping in carrying the actual sound to the other end of the table from this particular end. So, we cannot we have to encourage this kind of reflection between talkers.

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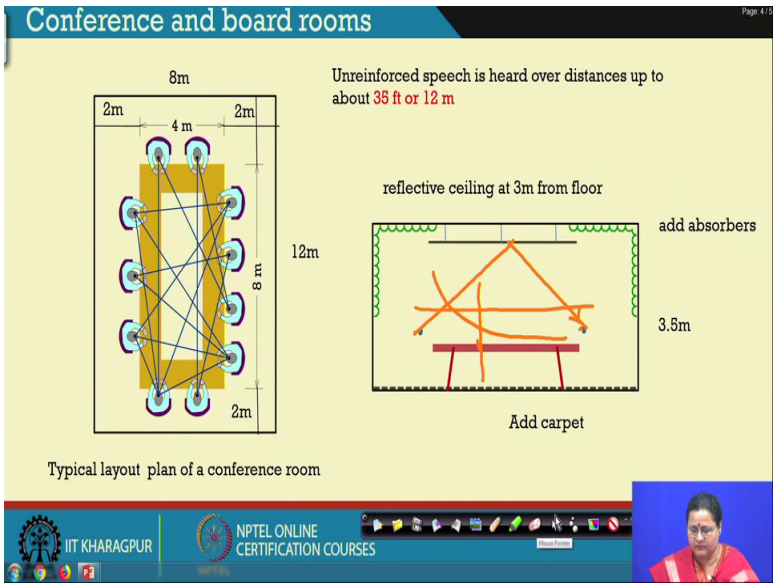

So, that it reinforces the sound, because their critical distances from this person, the critical distance from this person, may not be may not critical distance from this person would be something here, something limited to this particular location and beyond it you

require the direct sound decays. The direct sound the direct sound from this person decays and, here actually the reflected sound will reach. So, we have to think of reflections for a better hearing to this end.

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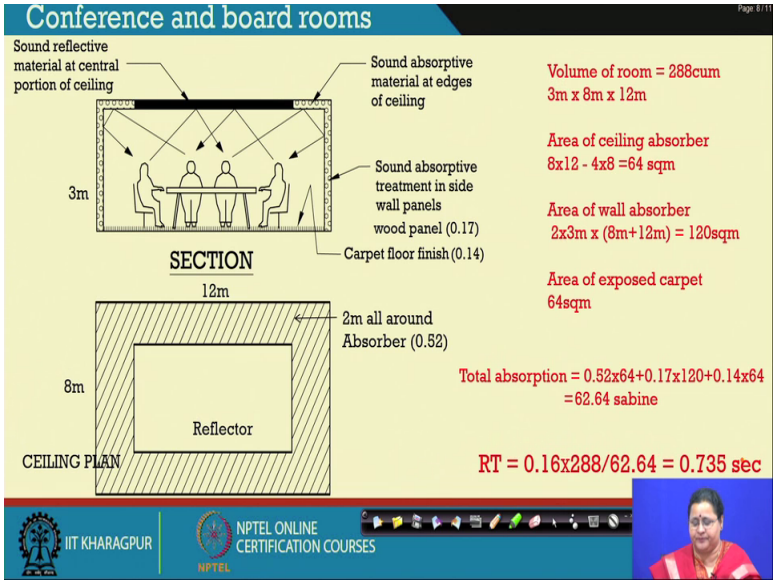

So, we see that reflective ceilings at 3 meters from the floor is encouraged and even a lower reflective ceiling is encouraged and, beyond that we prefer absorbers. We need carpets at the bottoms of the conference hall that is on the floor of the conference hall. So, that we do not encourage the sound that will be pro produced by the foot. So, foot sound can be controlled by putting carpet; however, that does not make much of difference to the reverberation time. [FL]

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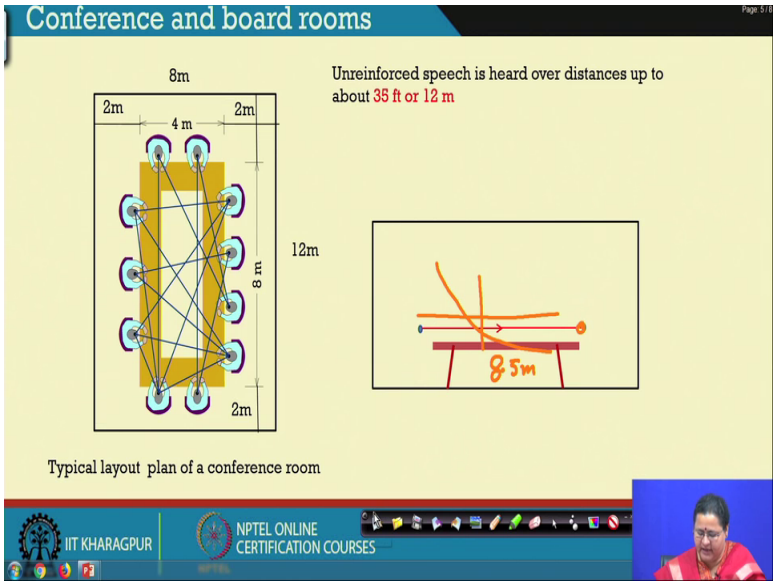

So, we see here typical plan of a conference room, or a board room in board rooms the scale is larger. So, number of chairs or number of or the number of speakers will be more number of speakers, as well as listeners will be more and the size or dimension of the room will be bigger, but for a typical conference room this is the setting. The table may be oval in shape and, here I have taken rectangular wall.

It is a 8 crossed 12 meter room, which is 3.5 meter height and the farthest distance between the talkers you can see it is around 8 plus some plus minus 500, that is 8.5 meters and the smallest distance is 4.5 meters. So, you have a network of conversations that is expected to be happening, in this particular classroom, in this particular conference room and, it is expected that the sound produced that is the source sound should be reaching to the farthest point.

So, in this case we see the farthest point has between this and this talker and, it is around 8.5 meters. So, it may not be possible that the direct sound is reaching. So, we need reflected sound because, beyond critical distance the source sound decays. So, in that

case to reach the sound from to the farthest point, we will need the help of reflectors. Let us see in the elevation in the section, how that is taken care of.

So, you have this as the direct sound moving from the farthest source to farthest receiver and, here the distance between them is around 8.5 meters. And it is expected that the critical distance would be somewhere here, where the actually the source sound will decay after that and, it is the reflected sound which will actually add with the source sound and reach this person.

So, we are expecting that the reflected sound will play an important role in reaching the sound and, this is particularly important when the sizes of the conference rooms are larger than what I have drawn for drawn here as an example. So, you have to see how much is the reflected path and, what is the direct path. And we will come to that little later, as you know it has been already discussed that there is a relationship between the reflected path and, the direct path and that should not inc include that should not be more than 25 milliseconds, in case of clear listening, or speech intelligibility.

So, but what happens to the sound, if we leave the entire ceiling reflective, you can see sound is rebounding from the back wall to the listener. At the same time till the farthest point if you consider, it is trying to create a flutter, which you can see that can that if continued will go to this end and, then move there and then will actually move to the move back and forth inside the room creating a flutter. So, what is our objective? We are not going to encourage this flutter, neither the reflection from the back wall and we propose to put some absorber.

So, the principle is we are trying to take care of the unwanted reflections. In case the reflected ceiling is ref the original ceiling or the structural ceiling is high, we need to bring down the ceiling level, or the reflective ceiling level and, it is preferred it should be it should be 3 meters of or less. So, that we can keep our sound within 25 milliseconds between top between the source and the farthest receiver, we can add the layer of carpet to keep of the sound from the sound from the foot falls; however, carpet is associated with the floor together and, there is no air gap hence it may not act as a very good absorber.

So, now we come to the section and see to through some calculation, how this has to be done. So, we see here a reflected ceiling, we see the talkers the discord the persons who

will who are in the discussion or seating and, we see the same plan here, where the middle part or the table dimension is covered with reflectors. The volume of the room is 3 cross, 8 cross, 12 meters when the height is 3 meters, which is 288 cubic meter area of the ceiling absorber.

So, if we plan reflect if we plan absorbers beyond the reflector, that is 2 meters all around the 2 meters all around it is reflector and, it is absorption coefficient is 0.25, then the area of the ceiling absorber, we can calculate it out. It is the bigger rectangle area minus the reflected area reflected area. So, it is around 64 square meter area of the wall absorber.

It is if it is entirely covered with absorber, we get entirely covered with absorber, we get 120 square meters as the wall absorbers and, area of carpet which has a absorption coefficient 0.14 is which is the exposed area, which is as good as the area of the reflected ceiling plan, what is the absorber in the ceiling plan, which is 64 square meter. So, we have the absorption coefficients here, we have the volume here and we have our formula for calculating, that is reverberation time is equal to 0.16 V by total absorption.

So, we have total absorption as 0.52 in to 64 that is the area of ceiling absorber plus 0.17 into 120 that is area of wall as absorber and, 0.17 as the alpha value or the coefficient at 500 hertz frequency 0.14 in to 64, which is that of the carpet absorption by carpet. So, we have poi we have is equal to total absorption is equal to 62.64 Sabine's. So, when we put in the equation we get reverberation time as 0.16 into 288 cubic meter divided by 62.64 Sabine's that is total alpha A.

And it comes out to be 0.735 seconds. So, it is understood that by putting absorbers on the walls and, partially on the ceiling partially considering the carpet as an absorber, we can reach to the reverberation time of 0.735 seconds for this particular case. So, not merely satisfying the reverberation time, but how you are arranging the absorber is very much important and that is what was demonstrated.

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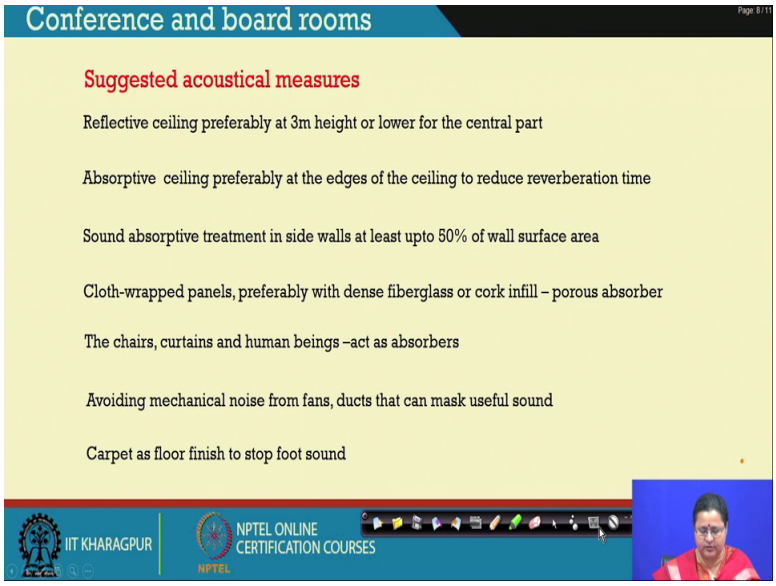

So, suggested acoustical measures are reflective ceiling, preferably at 3 meters height or lower for the central part. So, that the so that the speech is actually clear, speech is actually clear, absorbing absorptive ceiling preferable at the edges of the ceiling to reduce reverberation time, sound absorptive treatment in side walls, at least up to 50 percent of the walls surface area from the top.

That will help in trapping in unwanted reflected sound, or long delayed reflections cloth wrapped panels preferably with dense fiberglass, or cork infill are suggested as porous absorbers, because porous absorbers are the best for absorbing at 500 hertz frequency, which is considered as most part of the speech.

Frequency level of the speech, chairs and curtains and human beings also act as absorber, though it was not considered in the calculation which was done previously. Avoiding mechanical noise, from fans ducts can that can mask useful sound should be taken care of. And carpets has floor finished can missed can be stopped can be used to stop foot sound.

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So, now let us come to some visuals actually whether it is done or not, whatever I have told was theoretical. But let us see some photographs of within a taken within IIT Kharagpur of some conference rooms, see here you can see there reflective ceiling and the wall paneling all around. So, the reflective ceiling is confined just above the table, beyond that you can see these are the absorbers. And this is the reflective ceiling.

Now, here you see in this picture, as you see it is a wood lining in the previous picture, you may be thinking those are all fixed to the wall. See here is the cavity between the see here, the cavity which is pointed out with cursor, you see here the cavity I could manage this photograph for you, though you can you can also sense that it is set inside the electrical line. So, that also make the feeling that it is set inside, but here I could take a snap because that was bare and, that is proof in that there is a cavity inside, which is around 50 millimeter here, you see the flooring.

It is also the wooden finish and there is no space and, you may neglect the absorption by this kind of floor finish. And here you see the absorptive edge in the ceiling, which I was talking of kind of alpha as 0.52 and, you see the wall paneling which is of having alpha of 0.17, which is 3 4th which is which is 1 4th of the ply board fixed onto 2 inches of gap or cavity.

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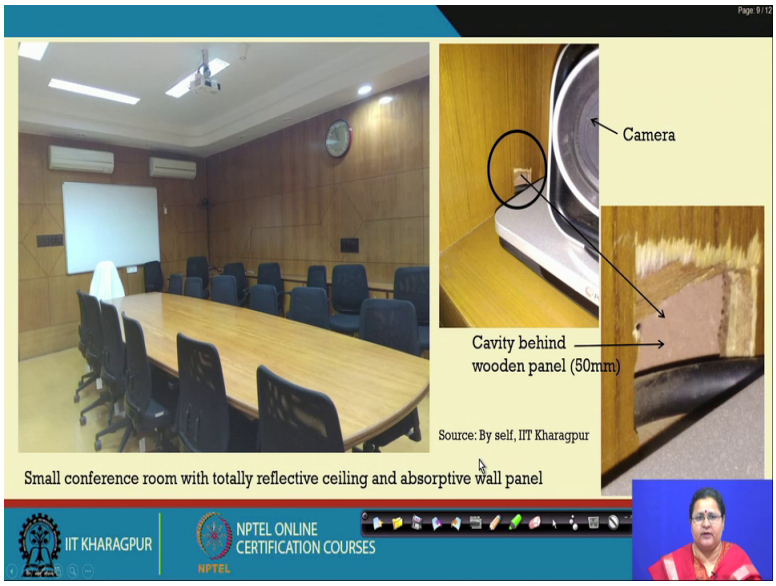

We see we enter into another conference room here, you see the entire ceiling is reflective, here there is not much of absorption in the ceiling, this is the smaller in size you can see around twelve people to sit 12 to 12 13 people to sit, here on the other end there is a there is a projection system and, people who are accumulating here can also have some projections while their discussion continues. You can see wall paneling all around and, those are also acting as absorber.

So, I could find out one picture so, here you have see the camera is there for some Skype's, Skype interviews etcetera and, here from here the cable has been done, which is an afterthought, which I suppose and see here you can see the wooden panels are set behind a cavity of 50 millimeter. So, here it is totally reflective ceiling and absorptive wall panels.

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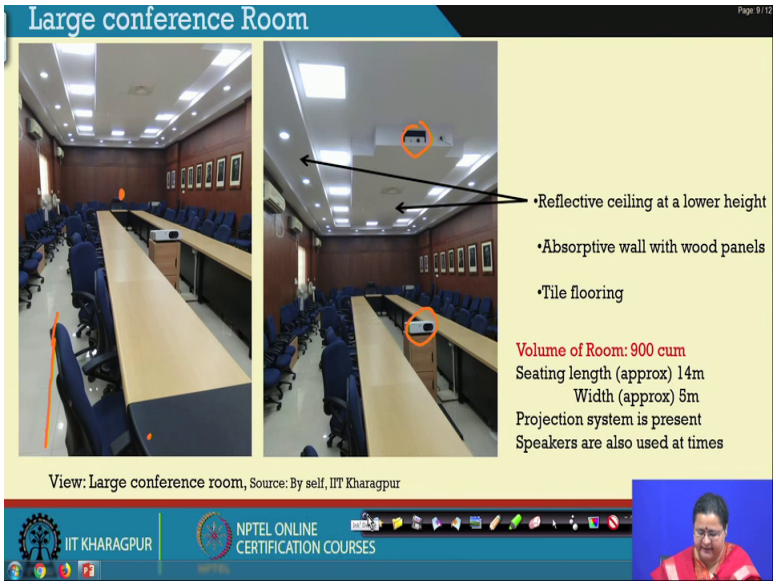

Let us move into a large conference room, which I was referring to as a board room see here, there chairs have increased the length have increased between this end point from this point to this end, there were it is around 40 feet. So, there were around 21 tiles, which I counted to make the distance make sure of the distance. And you see the ceiling over here, this room also has some amplification system, some projection systems, which you can see which are hidden here, present here.

And this in this also in this room also, you can see it is wood lining, which is completely covering the walls, which are side walls and the ceiling is left entirely reflective, here at least more than 50 people can come and sit. The volume of the room is somewhat like 900 cubic meter, seating length is approximately 14 meter which I told, width is approximately 5 meters of the between the table from one end of the table to the other and, we see the tiles are floor the floor is having floor tiles.

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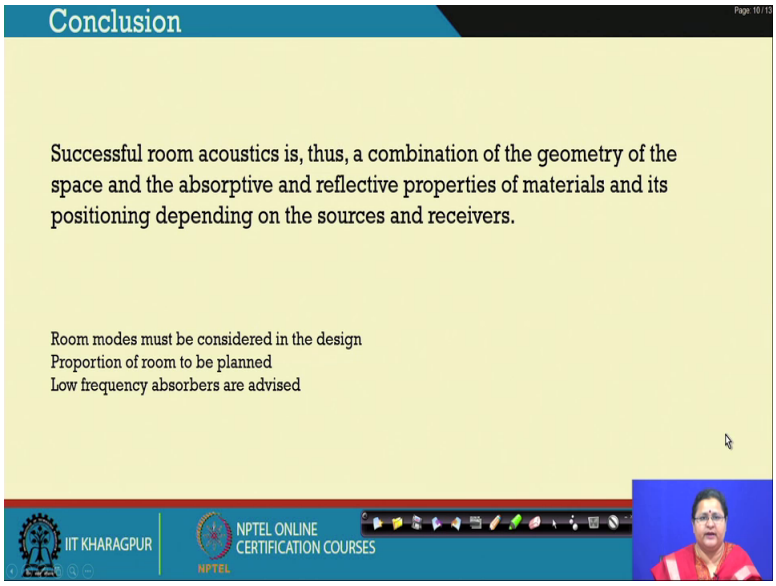

So, what we can conclude successful room acoustics is thus, a combination of geometry of the space and the absorptive and reflective properties of the materials and, it is positioning, then depending on the sources and the receivers.

So, in case of any kind of rooms, you have to be very much concerned with who what is the purpose of the room and, based on that what is the layout and, how you are to position your reflective surface, or their absorptive surface, or the diffusive surface. Though diffusive surfaces are not coming in this picture because, we do not want much of diffusive sound. We are more interested in direct reflective sound and that too mostly from the ceiling or from the walls, which helps in better understanding, or better intelligibility.

Room modes must be considered while we are designing and, proportion of the room has to be planned accordingly. Low frequency absorbers are advised to take care of fan sound from fans, HVACs ducts because those create low frequency sound. Thus, that humming sound can be taken care if low frequency absorbers are added.

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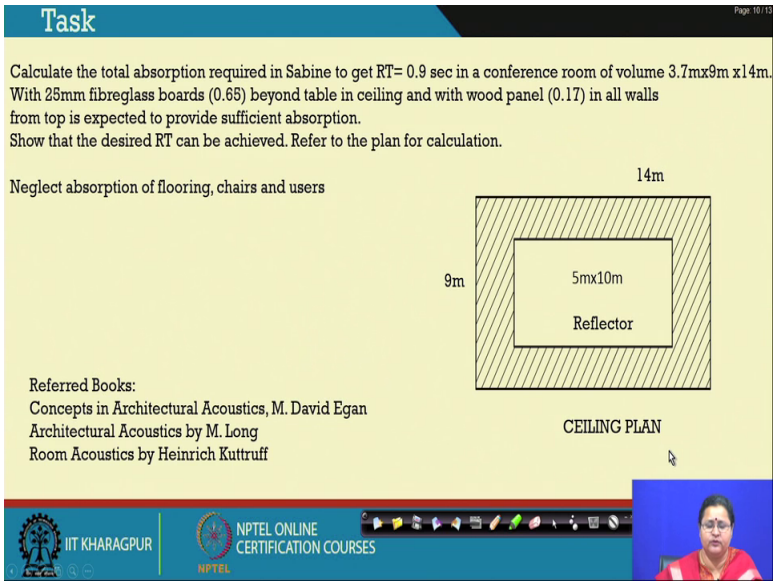

I leave you a small task to calculate the total absorption required in Sabine to get an RT of reverberation time of 0.9 seconds. The details are given here and, you check that whether in this particular problem, you are achieving that reverberation time of 0.9 seconds or not.

So, here the fiberglass boards are used in the ceiling, which has a different alpha value of 0.65 whereas, wood panels are having 0.17 as their alpha value and, you need to check whether it is really receiving a reverberation time, it is getting a reverberation time of 0.9 seconds or not. You neglect you may neglect absorption for flooring chairs and users.

And this much is for today and we will move to other bigger spaces, where we actually also need to know, how to plan for the acoustical plan for the acoustics for lecture halls.

So, next lecture is on lecture halls small and big in dimension and, we will try to move to the auditorium design later, after we finish studios or recording studios in particular; which is also of very much importance in case of architects, in case of architects as profession, architecture as our profession and, we will move to the next lecture now.