Audio System Engineering
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Lecture – 18
Auditorium Acoustics

So, let us start. So, last class, we have discussed about that different acoustics parameters of the room livingness, clarity, (Refer Time: 00:29) all those things we have discussed. Then we have discussed the how to calculate the reverberation time, mean free path. What is initial time gap, initial signal delay and what should be the value then percentage ALCON all those things we are defined.

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Now, we go for a practical implementation, which is auditorium acoustics. Suppose, you want to design an auditorium or you want to design a lecture hall that who are doing that architectural business the design that lecture hall how should we design that lecture hall, so that acoustic is take and care. What is the parameter who should look for in case of acoustic treatment? So, there are two kinds of thing; one is that the realism architectural parameter for which we have to said that if I want a good acoustic those architectural parameter should be like this. And then we have to provide a wide range of solution or you have to provide a solution for acoustic treatment of the auditorium for better sound arrangement.

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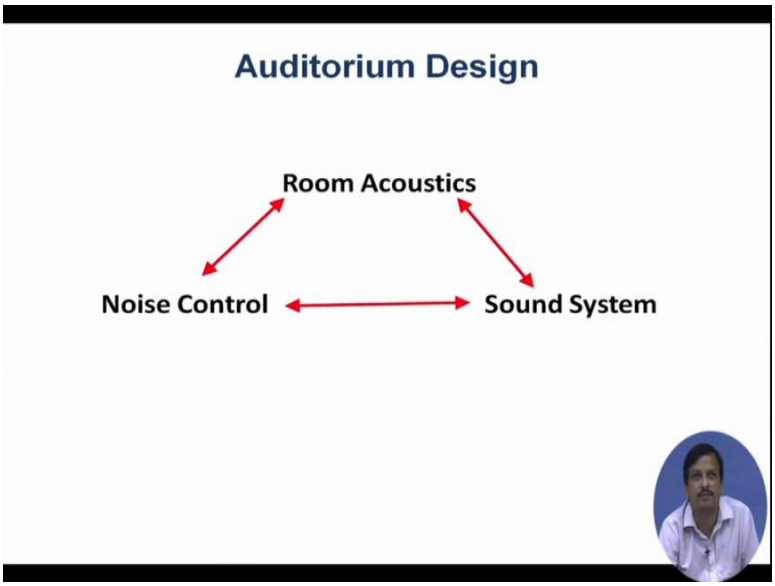

So, now we discuss one-by-one. Let us auditorium it is called auditorium acoustics. So, auditorium design has three part; one is the room acoustics how do you the treat the acoustics of the inside auditorium, sound system what kind of sound system I should use auditorium, so that ultimately aim is that in the auditorium every seat of the auditorium should receive that equal amount of sound that is the my ultimate objective. So how to design that what kind of sound system I should use, how it should placed all those things.

And then noise control, how it is my auditorium is free from external noise; if the external noise is entered in the auditorium, it hampered that auditorium acoustics, because environmental noise of the auditorium will be increased. So, which is distracting that sound system was the auditorium. So, we have to pre prompted that external sound source, so that is called noise control. We have to control the noise of the auditorium, so that by external noise should not enter in the auditorium. So, one-by-one we discuss all that issue and at the end we will go for a design class.

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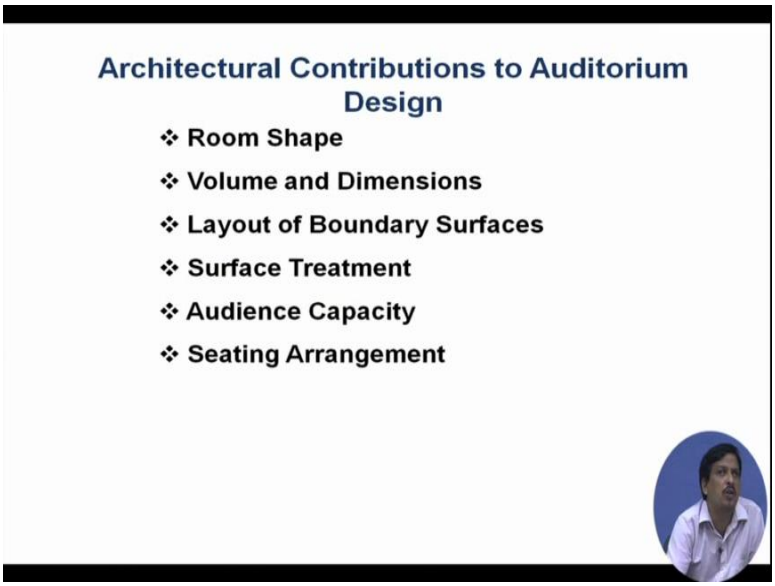

Then architectural contributions to auditorium design. What architectural do, room shape is defined by the architecture; volume and dimensions is defined by the architecture; layout of boundary surfaces is also defined by the architecture; surface treatment, audience capacity, seating arrangement all at the civil design parameter when the auditorium is designed initially they are consider those of the parameters. Now, as an acoustic engineer what kind of feedback you should provide to those architectural engineer that yes, design an auditorium due to the acoustics point of view room shape, volume of the room, this should be look like this. So, those guideline is called the acoustical guideline to the architectural design.

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So, let us one by one discuss. Room shape, so what is the acoustical requirement, before come to room the shape let us start what is the acoustical requirement in auditorium design. There should be adequate loudness in every part of the auditorium, particularly the remote seats. So, what is my requirement is that at the end seat if some audience is sitting, his loudness of that sound on that seat should be same as the loudness of the sound at the front seat. So, then the design will be very good. So, I want there should be adequate loudness is that the last seat cannot heard if the sound level is reduce that should not be happen. So, adequate loudness should be providing at in the last seat also, so that last seat people can also heard that sound.

So, and the goal is that we should not waste the sound energy. So, reducing sound energy loss, how can we analyse the sound or how can we distributed in the sound inside the whole auditorium is our goal. So, the auditorium should be shaped, so that the audience is as close to the sound source as possible as thereby the reducing the distance from so[und] the distance the sound must travel. What is the meaning is that I want to design an auditorium, so that everybody has a feeling that he is seating close to the stage, because performance is happening on the stage. So, everybody should have a feeling that yes I am close to the stage. What is the acoustical effect, suppose the there is only loud speaker is placed in the front of the stage then the setting on the large distance the direct sound will be less, setting in the front seat direct sound will be high. So, I have to

minimize detect sound travel time to the last seat that means, I have to minimize the distance of the stage to the each of the seat how do I minimize it.

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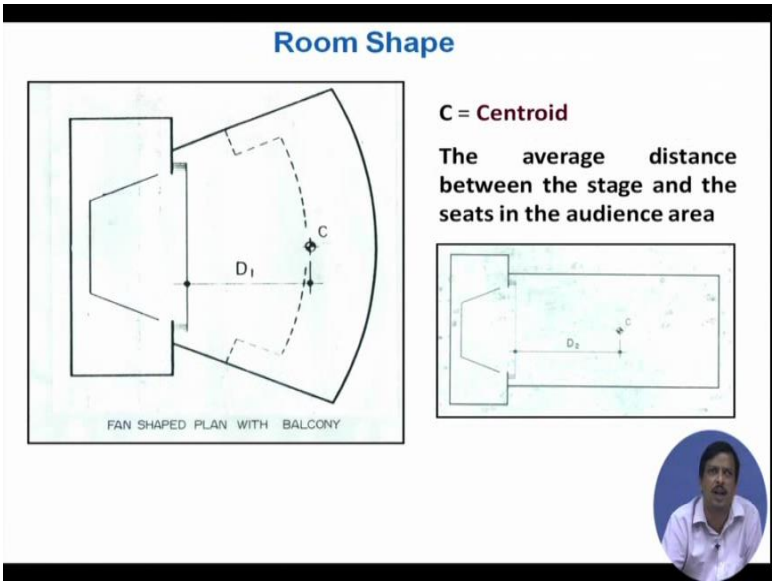

Suppose if the design auditorium room that the room shape, if that is if the design auditorium that is the second case in this region. So, the centroid the average distance between the stage and the seat, let us calculated is this. So, D 2 is the centroid is D 2 is the last compact of D 1. If I place the audience like this way because that if the wide angle, that the distance from the stage to the person is less. So, average distance will reduce. So, everybody has a feeling that yes I am close to the stage. Now, if you required large capacity let us you want to require a design length is very coming is very high then use the balcony to reduce the length use, the balcony to reduce the distance from the stage. So, there is some guideline is there.

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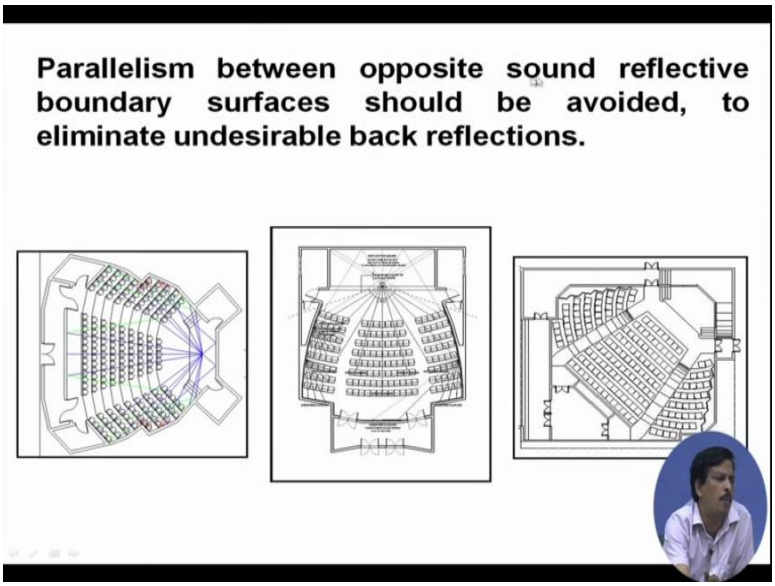

Then another one is that parallelism between the opposite sound reflective boundary surfaces should be avoided, to eliminate that means, it said that any auditorium must be have any parallel reflector. Suppose, I make this auditorium or make this auditorium without this curved surface inside there is a seat the inside this curved surface if the curved surface is not there and this wall and this wall is parallel, which effect the sound quality which undesirable reflection will come and standing wave will be generated. So, it to reduce that what I do, yes, this is the concrete wall no problem, but I should make a inside arrangements such as the surface is curve see that inside surface is curve to avoid the parallelism between the two reflecting surface. Similarly, I can do like this change that change the shape parallelism is avoided or I can do like this way design the auditorium like this way. Here see that the no parallel wall or if it is rectangular then inside the auditorium keep the wall such that it create the curve surface which is required.

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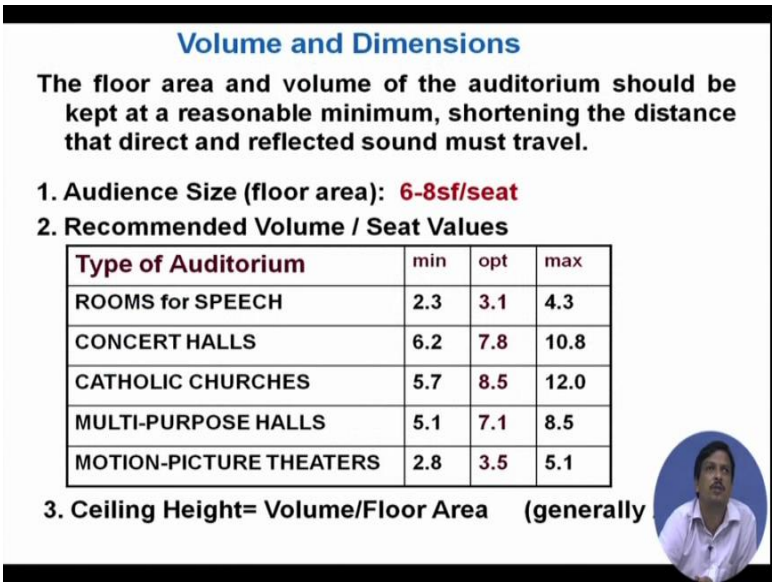

Then what should be the shape of the auditorium volume and dimension of the auditorium. So, shape of the auditorium is discussed. The shape of their, should two parallel wall parallel reflecting surface and the distance between the audience and stage must be minimize. So, to do that what kind of arrangement is required, we have to derive. Mostly this fan shape is use to with balcony if have to design a large capacity auditorium. Now, volume and dimension the floor area and the volume of the auditorium should be kept at as reasonable, reasonably minimum because unnecessary creating volume is not required it is architectural it is civil construction cost also reduce the sound energy.

So, I have to minimize and the volume starting the distance, starting the distance stage and people, so that distance should be minimize. So, two parameter optimum volume and optimum distance from the stage to the person is required; for that I have to design the shape and then I have to design the volume and dimension of the auditorium what is the length, width, breathe all kind of things. So, it some rule is that in audience size floor area should be 6 to 8 square feet per seat. If the 100 seat then 600 square feet to 800 square feet the floor area.

Then recommended volume per seat, it dependence on the type of the auditorium, it is for speech there it is said minimum like the lecture theatre, it is 2.3, maximum 3.1, maximum 4.3 square feet per seat. Then 6.2, 7.8, 10.8 square feet per seat for the concert

hall; for the picture theatre like cinema hall, it is 2.8, 3.5 is optimum, minimum is 2.8 and maximum is 5.1 is sufficient; for the picture theatre means cinema hall. So, you know the volume and also the volume come from the large room acoustics the volume must be support the large room acoustics. Suppose you can say I am to design the room for 10 people then the volume may be very small, so that connect support the large room acoustics then it I cannot design that large room acoustics design which is followed by the auditorium design for that kind of room. Then we have to go for the small room acoustics design.

So, this is minimum volume per seat that thumb rule is that that volume should support the large room acoustics. Then ceiling height volume by floor area; generally, it is 20 into multiplication of the reverberation time. So, it is volume, once I get the volume then divided by the floor area. So, floor area I get per seat, I get the volume per seat, I calculate the volume and floor area then I get the ceiling height.

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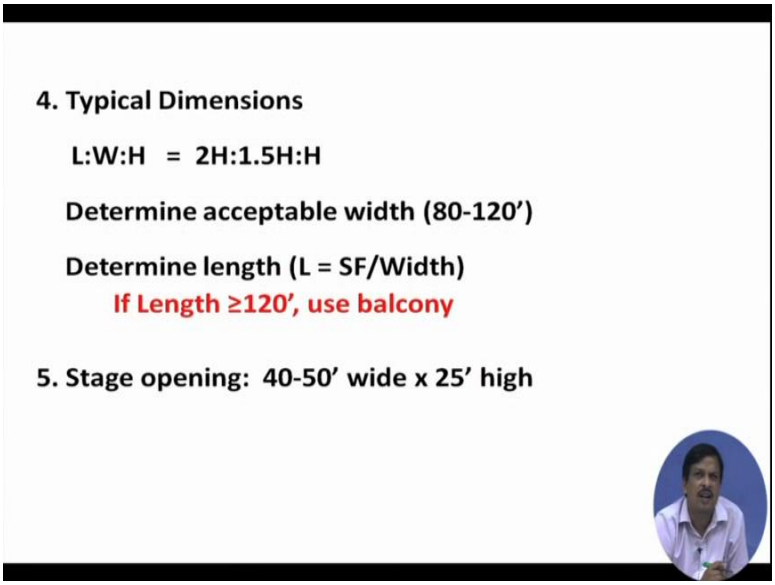

Then typically the dimension will come in the L – length, width and height is 2 H length should be twice then the height; width should be 1.5 times of the height and height in edge. So, if the height is 10 feet let us 10 feet then it should be 20 feet and 2 times 1.5 times that means, 15 feet and 10 feet, but the volume should support the large room acoustics. So, it may not be support the large room acoustics, so it cannot be large room

acoustics auditorium. So, minimum volume we have to say I have to design for 200 plus I have to design for 200 capacity auditorium.

So, 200 people if I say the picture hall; that means, cinema hall then let us optimum values 3.5. So, into 3.5 is the volume minimum volume is required which is nothing, but a seven into 10 to the power. So, 700 square feet square feet cube or meter cube whatever is required. So, this the minimum feet square is required meter is not meter q. So, this is the minimum volume is required. So, you know that then how to design that then I get the ceiling height. Once I get the height I have to design the floor area that will come in this almost come.

Now suppose in this formula if you learn this very long, suppose length is come 120 getter than 120 feet then what will happen it is it is increasing the direct sound distance. So, I have to reduce it how can I reduce it use, the balcony. If I use balcony the length will be reduce. So, I can use the balcony as stage opening should be this side. So, those of the basic parameter, which is available from the literature and I have given you.

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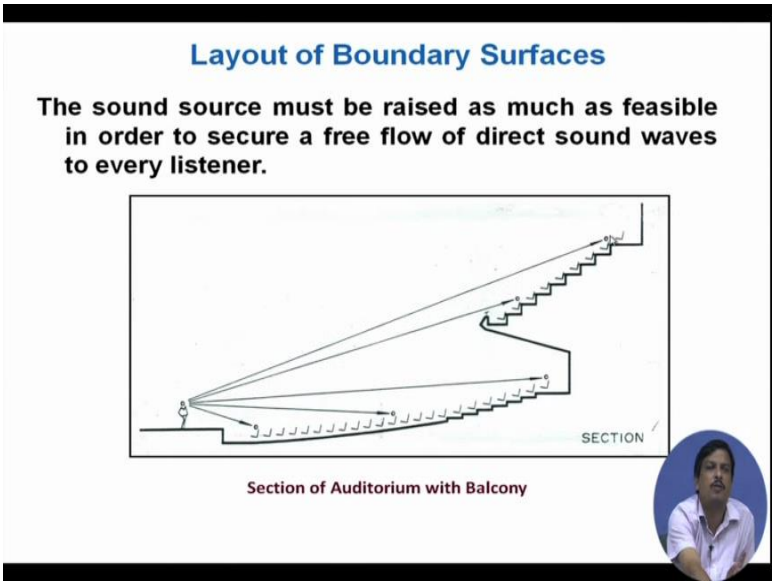

Then layout of the surface, how we are designs the surface. This is see that there is no parallel curve and there is a ramping here and balcony also ramped. So, why the ramp is required the sound source must be raised as much as feasible in order to secure the free flow of the direct sound. So, this is the one criteria that if I want to put a loudspeaker in here you should not be put in below the stage it should be as raise as possible, so that the

direct sound has a direct link with that last seat of the balcony. I have to see that if I put the box in here let us I design an auditorium like this and this is the balcony, and I put the sound loudspeaker in here. What will happen there is no direct sound to this seat. So, this will effect. So, raise the loudspeaker in here, so that sound is come here and here also as much as possible. So, the direct sound reaches the last seat of the balcony.

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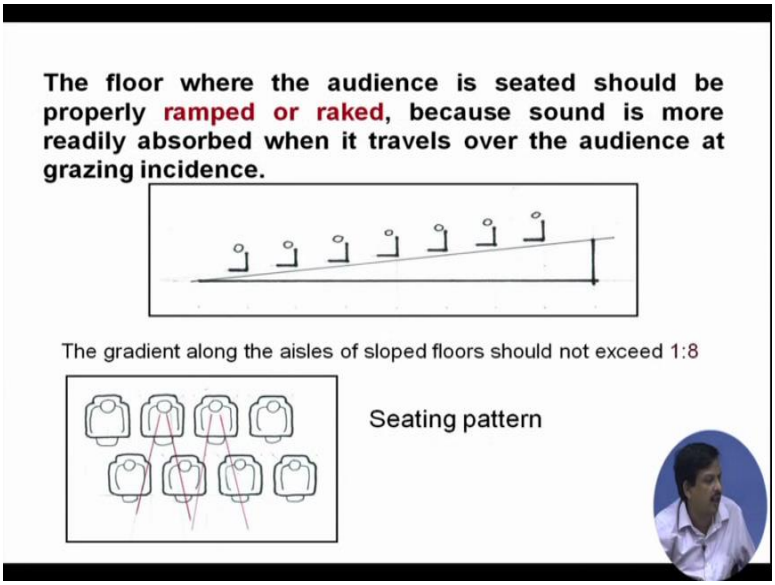

Then another criterion if I place that all seat in flat. So, human being is a observe observer of the sound. So, this man may foul to the direct sound to the next man. So, direct sound cannot reach there. So, there is a ramping is required this is also required for a hearing in viewing side also. So, there is a ramping is required, but this ramping has a limitation I cannot ramped would not like this. So, I ramp it 1 is to 8 in ratio. So, if the length is eight feet then the ramp last seat ramp should be one feet in length is hundred feet one is to eight ratio I have to ramp it. So, I ramp it then how do arranging the seating, seating pattern, how do you arrange the seat. If I arrange the seat, suppose I put a seat in here and next seat in here then what will happen the direct this man foul the direct sound to the next man.

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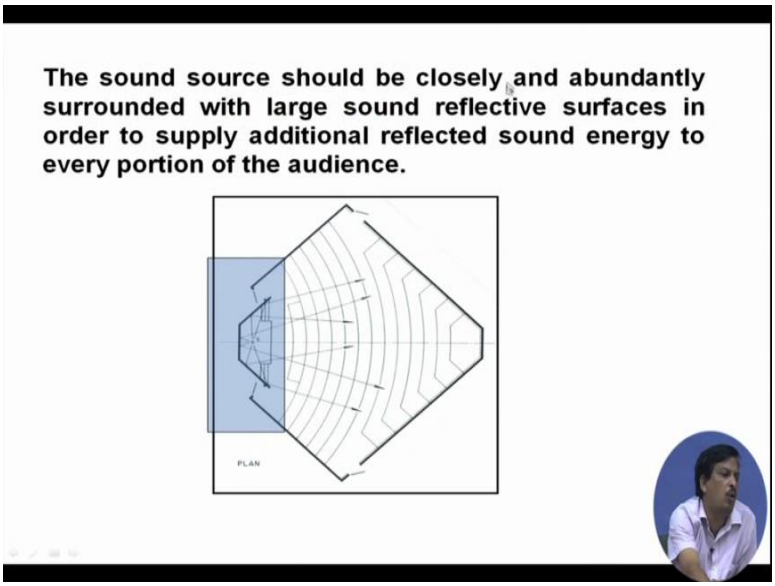

So, instead of doing that, you can make the seat arrangement like this picture; the man setting in the gap between these two seats. So, there is a possibility the direct sound will be go there. So, this kind of seating pattern must be maintain maintained then the sound source should be closely and up close. So, let this one do not want, I do not want read the slide. What is say that suppose I put extra sound source in the wall or in the stage wherever I put the sound source it should be covered by a reflector or it sound source should be put in such area square the sound is reflecting. So, that it reinforce the sound reflection sound in the room. So, if I put a acoustics blanket in backside and then put a sound source, what will happen the if I put an acoustics blanket in here, so let us 100 percent absorbed if I put a sound source here.

So, the source sound which suppose to come this side and reflected back to this side to increase the directivity will be absorb. So, directivity cannot be two, it come one because the backside sound is absorb instead of reflected into the front side, so that it reflected sound can travel to the audience it is absorb. So, if I put a loudspeaker in backside, if I required then loudspeaker should be surrounded by a sound reflector, so that the reflection of the sound should reach to the audience.

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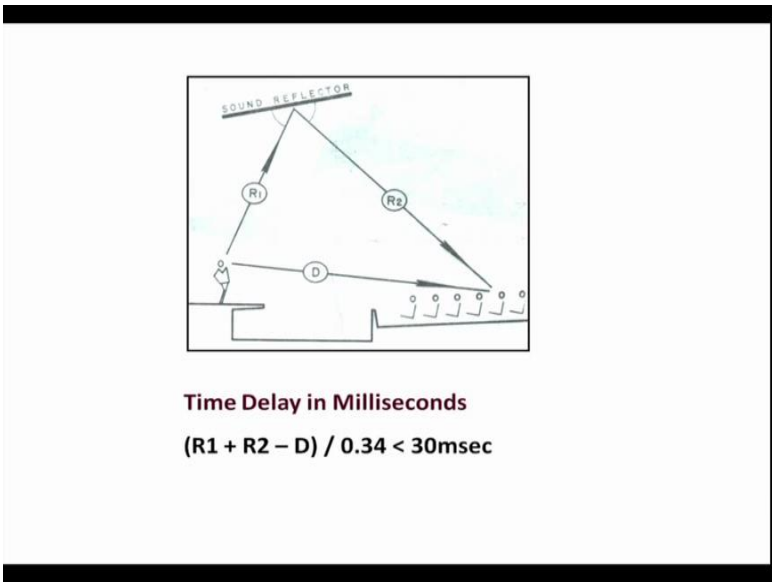

Next, time delay, this is very important. We have to think about those at least initial reflections with the audience should we reach within the thirty milliseconds which is nothing, but direct sound is d distance then r sound is reflected sound is the R 1 plus R 2. So, R 1 plus R 2 minus D divided by 0.35. So, this that distance time gap between the direct sound and positive reflection it should be within the 30 milliseconds. So, how they are do it. So, the surface of the auditorium if I say that or the top of the auditorium the top surface of the auditorium must be not like a just plain ceiling.

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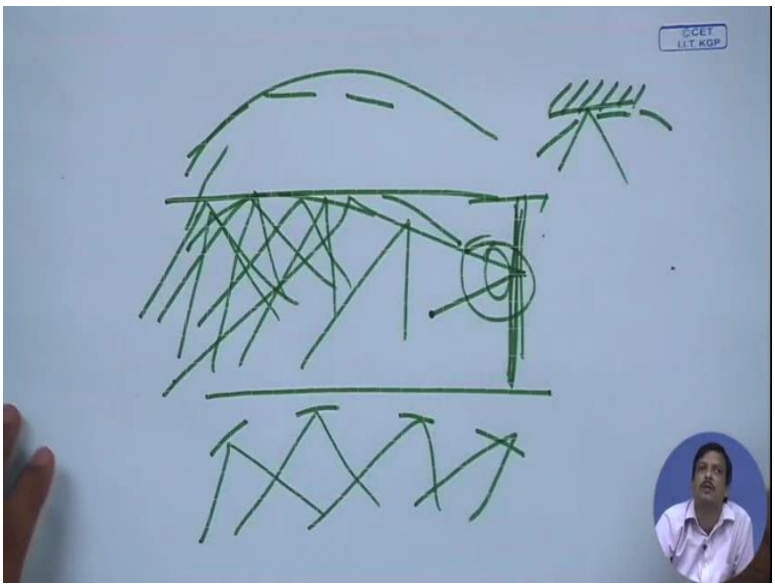

If I put a plain ceiling, what will happen? If I in top of the auditorium is just plain ceiling, then it is not it will not create that equal reflection in the all part of the auditorium instead of top ceiling. If I make a curve ceiling, I put a reflector in curve surface; or suppose my ceiling is flat, but I can put a reflector to make a curve, so that the reflection can happen in everywhere. So, unless what will happen this reflection does not have a meaning because if I want that that is again reflected by the back surface and come to here it may hear as echo. So, this reflection because backside will be treated as a acoustics blanket. So, this will not reinforce the sound system.

So, what I will do, I will make a curve reflector in the top ceiling. So, that it reflects the sound unless the ceiling height is very high always put reflector in the ceiling. If the ceiling height is very high then what will happen from the ceiling reflection may create an echo. So, to avoid that echo in that case I required a treatment of the light wave total absorptive surface in the ceiling, so that there is no reflection come from the ceiling if it is too high. If it is not that high like that it, there is possibility to the harden echo I can put a sound reflector there, so that it reinforce the reverence sound, so that kind of treatment I have to make.

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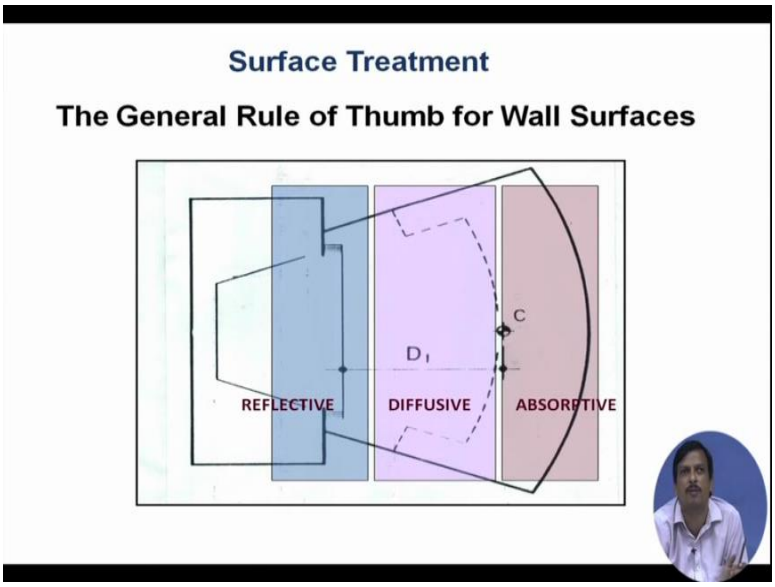

Now, there is a thumb rule of the surface treatment of the auditorium. So, near the stage it should be reflecting. So, that maximum energy channelize to the audience. So, stage should be reflective or near the stage and stage should be reflective next is middle

portion should be diffusing means there should be irregular res reflection from the surface not regular reflection. If it is regular reflection, then what kind what will happen the some area will be focused and some area will be defocused. So, I want diffusive treatment after the stage after the front part of the stage; let us that up to may be few and few fit that there will be a reflective surface.

Then next portion is diffusive surface. And last portion should be absorptive. Why, because if the length is long enough then I there may be a chance that I can harden eco to avoid that the last portion of the auditorium must be as much as absorptive. So, that the reflection sound intensity is very low, so that the eco is avoided. So, why know we design an auditorium the acoustics treatment of the auditorium is reflective in the stage and front part of the auditorium. Middle part of the auditorium will be diffusive and rear part of the auditorium or the last part rear part of the auditorium should be as possible as absorptive, so that no sound should be reflected from that area so that is the thumb rule for acoustic treatment in any auditorium.

If you visited any good auditorium, you found that front stage is stage front part of the stage or made up a polish wood and some channel. So, the channel create a diffusive reflection and it is a reflective glace. So, glace means reflection co efficient is very high there is no acoustics tiles is placed on the front part of the stage or after stage there is a few metres or look in a one or three metres there will be in all reflective surface.

Then next part is diffusive. So, there is a acoustic diffuser is placed as you discuss in the last class the acoustic diffuser, how do know that you know that acoustics diffuser is a irregular surface. And you know what kind of acoustic diffuser is available in the market you can go to the market and see that what kind of acoustic diffuser. So, that diffusing surfaces not the regular surface. If I make a wall of the auditorium painted glace painted in the surface then what will happen it create a regular reflection, so that is why auditorium inside the auditorium you do not find that except stage part that there is a glace surface which can produce a regular reflection. There is a reflector, but it is diffuse reflector, that means it creates an irregular reflection. So, instead of plain painted wall we use a rough wall kind of things to provide a diffuse reflection.

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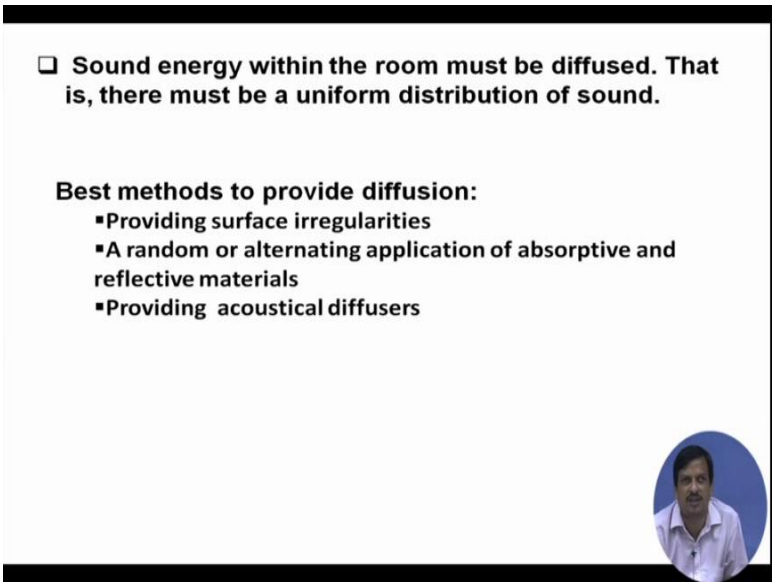

So, there is a material provide a surface irregularities, random, alternative. So, I can see there is some moral. If you see digital auditorium, sometime is the front part of the stage there is some moral. Since, moral has an ordinary surface it can access diffuse reflection and moral is painted then the absolutely of the moral is very less. So, front part of the stage is reflective. So, I can do some moral or wooden work in the front part of the stage. If you visit in our Kalidas auditorium you see the front part is made painted wooden design. So, it is irregular diffuse design, but its reflection coefficient is much higher. So, that it reflect the maximum energy, but after that we put some acoustics tiles which is a acoustic diffuser, so that it create a diffuse reflection. But in the rear part of the auditorium, we should did total absorptive that means, the material is its absorption coefficient is very high should be put in the rear part of the auditorium.

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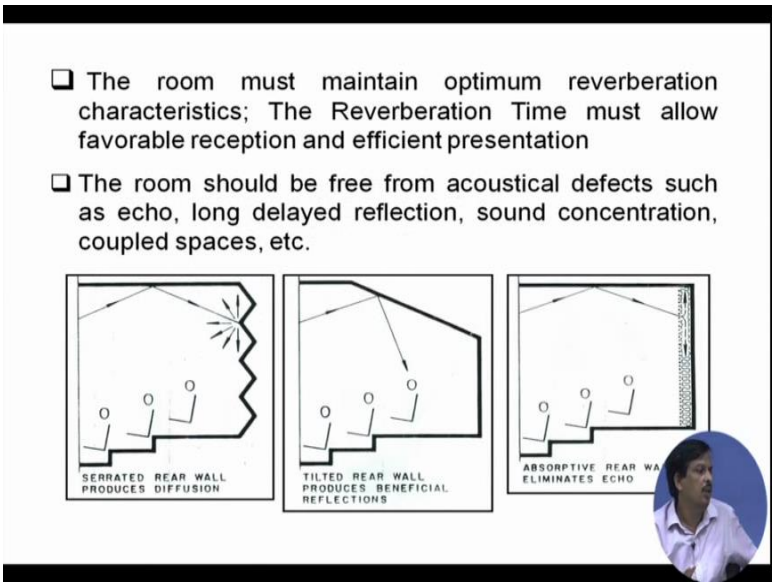

Now, the room must maintain optimum reverberation characteristics, the reverberation time must allow favourable reception and efficient presentation. So, I cannot say that I make auditorium whose reverberation time is very less, and whose reverberation time is very high both are problematic. So, I have already said you give you slides where I say that different kind of purpose of the auditorium. If this purpose is peace theatre, if it is purpose is concert hall, what should be the optimum reverberation side time that there is a chart available from the architectural design side?

Then the room should be free from acoustical defects such an echo, long delayed reflection, sound concentration and coupled space; that means, what is the meaning. When I get an echo, if the delay between the direct sound and reverberation sound is much high then there is a possibility that I heard an echo. So, suppose my room has a long distance long end room if the end reflection comes to me, then I am a heard is an echo. Then what I do at the end part of the auditorium I must put absorptive material, so that the maximum sound energy is observed by the surface. So, the reflection sound intensity is very low then I can avoid that echo, the echo will be not there.

Or I can change the shape if you see the shape of the rear part if I design auditorium ceiling such that there no sound energy can receive here and or the minimum sound energy will be reach in the last portion of the auditorium then I can tape that second part. So, the volume of the rear part is reducing, to reduce the number of reflection. Then I can

make a rear wall acoustic blanket kind of arrangement, so that even if a reflection is come totally absorbed every direct sound is fall on that wall is totally absorbed.

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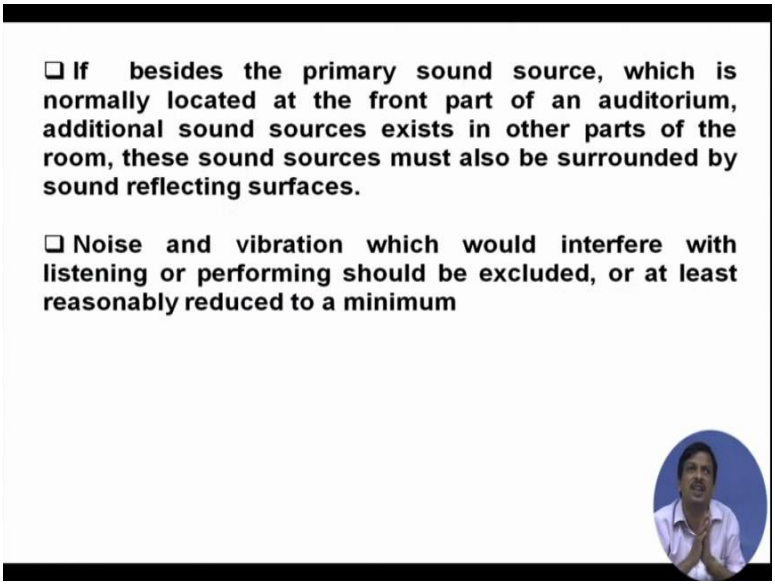

So, if you visit any auditorium you should see the end wall or the rear wall of the auditorium will be treated with an acoustic blanket or a material which has high absorptive if the primary sound source which is normally located at the front part of the audit. So, suppose I want to put you can read the slide I not reading the slide. So, suppose you want to put an extra loudspeaker in the in the auditorium. So, as I mentioned, while I put the extra loudspeaker, I should put with the reflective surface. So, that the sound energy of the loudspeaker is reflected back to the auditorium. So, I put a reflective surface.

Noise, external noise is very important. Suppose, we are creating ac dock in the auditorium, you should very causes that acoustic with through the acoustic dock external sound should not enter in the auditorium. So, there is within the dock also, you required an acoustic treatment, so that external noise is avoided to the ac dock also. And also we have to see suppose I have build an auditorium beside a highway what will happen the sound highway sound will be there is a vibration conduct sound will be there. Conduct sound means say let us you put that wall thick, so that the external sound not entered in the auditorium then you put a acoustic blanket after the then you put the acoustic reflector. So, the inside sound is reflected back, but outside sound cannot be enter

because there is a acoustic blanket and there is a brick wall you have hard ever the intensity transmitted intensity is inversely proportional to the l square. So, if the length of that wall is increases then the rare sound intensity will be entering in the auditorium. So, I can say that yes I can make that arrangement, so that highway noise is not entered.

But if it is totally concrete to the highway what will happen, the vibration conduct vibration conduct conduction will come out. So, to avoid that I should make an arrangement, so that the auditorium is separated from that conduction, I can make a channel outside the auditorium, I put a stand there. So, it actual absorption and direct sound will not come. Similarly, in the floor how to treat a floor of the auditorium, you found the generally the auditorium floor is carpet, why because we want that there is two kind of things if it is not glace surface there will be a reflection from the surface, so that audience also create a noise that noise also reflected.

So, I want the auditorium that diffuse see I required diffuse diffuser in the middle portion. So, instead of providing a middle portion only blanket, I whole auditorium is a stop acoustic carpet. So, that that reflection sound does not come, but the stage I required a reflective surface. So, I can make a concrete stage with the high reflection high reflection coefficient or the front of the stage also I can make a high reflection coefficient. So, I can make a concrete on that that area which is high reflective coefficient. But in the rear part in the floor also has to be treated as a either diffusive and the sorry in the rear part the I have to treat that floor also whose absorption two percent is very high, so that is nothing but carpet.

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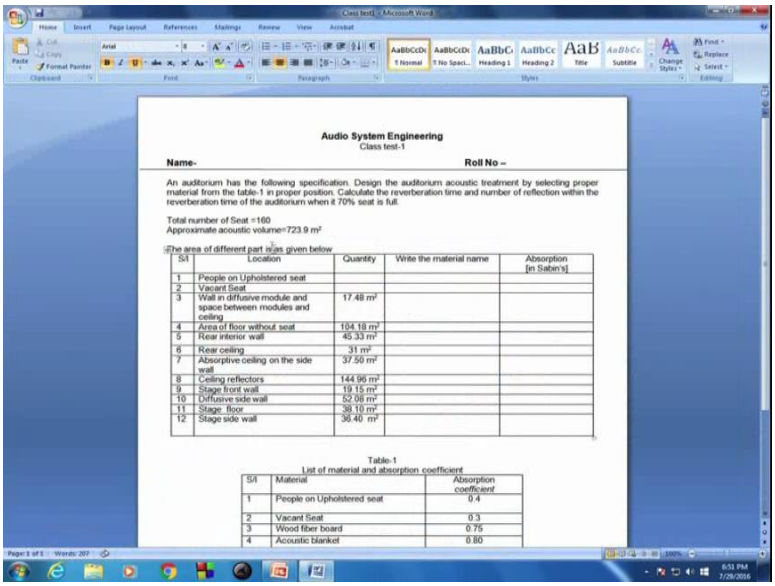

Audio System Engineering
Class test-1

Name- Roll No –

An auditorium has the following specification. Design the auditorium acoustic treatment by selecting proper material from the table-1 in proper position. Calculate the reverberation time and number of reflection within the reverberation time of the auditorium when it 70% seat is full.

Total number of Seat =160
Approximate acoustic volume=723.9 m³

The area of different part is as given below

Sl/I	Location	Quantity	Write the material name	Absorption [in Sabin's]
1	People on Upholstered seat			
2	Vacant Seat			
3	Wall in diffusive module and space between modules and ceiling	17.48 m²		
4	Area of floor without seat	104.18 m²		
5	Rear interior wall	45.33 m²		
6	Rear ceiling	31 m²		
7	Absorptive ceiling on the side wall	37.50 m²		
8	Ceiling reflectors	144.96 m²		
9	Stage front wall	19.15 m²		
10	Diffusive side wall	52.08 m²		
11	Stage floor	38.10 m²		
12	Stage side wall	36.40 m²		

Table-1
List of material and absorption coefficient

Sl/I	Material	Absorption coefficient
1	People on Upholstered seat	0.4
2	Vacant Seat	0.3
3	Wood fiber board	0.75
4	Acoustic blanket	0.80

So, there is an example forgot about that there is an example, I have given in here. Say that I think it is not visible. So, let us I make it large. What I said that an auditorium has on the following specification design the acoustic treatment what is that I given a table people on upholstered quantity, I have done vacant seat. So, there is all acoustic coefficient is given in table one absorption coefficient vacant seat and absorption coefficient vacant seat is 0.3. And if it is people will occupy 0.4 then wall in diffusive module and space between the modules and ceiling the surface area is given area floor without seat, rear interior wall, rear ceiling, surface area is given absorptive ceiling on side wall, ceiling reflector, stage front wall, diffusive side wall, stage floor, stage side wall. Then I said write the material name which kind of material you should acoustic material you should use to treat this area.

So, what I say thumb rule is that stage area must be reflective. So, when I said the stage front wall I should use the material which absorption coefficient as low as possible. Suppose, absorption said those of the material I want to use in that auditorium. So, I can say that see that fibre cement board absorption coefficient is very low. So, I can use that in stage front wall. Stage floor is there anything floor, hardwood I can use in stage floor. Painted concrete I can use in the stage side wall. So, all those things, so reflective part I design.

Then if you see the rear ceiling and rear interior wall rear part of the auditorium must be as much as possible absorptive. So, I have to see which material has a large material absorption coefficient, acoustic blanket, wood fibre board. So, I can say acoustic blanket I can use in the rear interior wall and rear ceiling I can use wood fibre board. So, depending on the choice aesthetic I can choose the material from the market and treat that area, but thumb rule is that stage area must be as reflective as possible; middle area must be as diffusive as possible; and rear part must be as depth of absorptive as possible. So, you put that material name in here then you know that absorption coefficient multiply with the quant surface area you get the absorption in Sabin then add them to get the total Sabin then you can calculate the reverberation time if the volume is given number of seat is given. So, acoustic volume, so it is not meter square. So, it is meter cube sorry, it is a meter cube not square.

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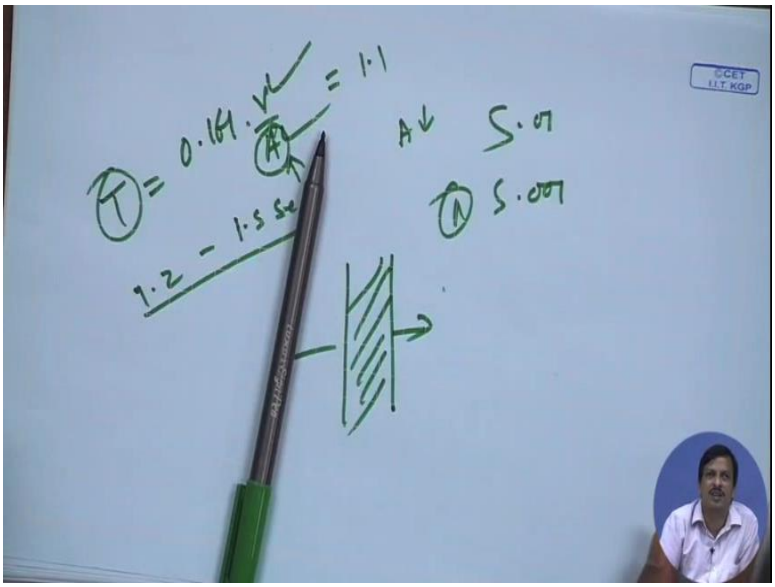

So, volume is given a is given. So, reverberation time is equal to 1.161 into V by A; V known, A known then I estimated reverberation time. Suppose, the user says that and my auditorium should be reverberation time should be 1.2 to next 1.5 second then after calculation I found it is coming 1.1. So, I have to realist the material and decrease A, so that reverberation time is increase. So, front wall part front part of the stage I can use other material which has absorption coefficient is much lower if it is much lower than a will be suppose 0.001 s into 0.1 s into 0.01, then A will be less in here. So, much reflective surface I will be used.

So, then I just changing the A, I find out the desired t, then my design is dock. So, why know you do a design of an auditorium two things one is that concentrate is give a consultant to the acoustic architectural engineer that I required this kind of shape because if it shape is not describe then I cannot auditorium acoustics will not good. So, I required this kind of seat arrangement I required this kind of ceiling volume this minimum volume should be this I required this kind of ceiling arrangement, this kind of ramping and this kind of seat arrangement, all things you can con give that suggestion. These are the desired for a good acoustics then design is done.

Then you know the surface area then the design then the user said I required reverberation time 1.2 to 1.5, then you to choose the material which portion you want to treat by which kind of material acoustic material. So, there is the thumb rule is that reflective, diffusive, and absorptive. So, that is thumb rule it cannot put a glace style on the rear wall because then the echo will heard in the auditorium. So, rear side has to be absorptive now you adjust the material depending on the aesthetic, aesthetic part is also very important. So, depending on the aesthetic and reverberation time, you adjust the material and design the auditorium.

And also there is another one work is there you should also give an advice that what kind of sound isolation is required inside the auditorium; outside noise sound should not enter in the auditorium. So, there should be suppose I make an auditorium in a glass window. Can it be possible? No, if it is the glass window then outside noise should come enter in the auditorium I cannot avoid that ambient noise. So, ambient noise will be increases, so that is avoided.

Now once want to design a door, I just simple use a glass door; if the door is glass door then outside noise is come inside. So, I have treated the door also in acoustic treatment, so that the outside noise should not enter when the door is closed. So, I have to design the door also. I have to choose the material, where I have to design the door such that that outside intensity sound intensity should not enter in the room. You know that how the sound intensity is travel through the through the material, if the two boundary then you know that it depends on the l, thickness.

Suppose, there is no thickness, thickness separation is not possible I cannot make the door so thick. So, what I will do I make the air gap inside the door or I make I put a

acoustic blanket in middle, middle of the door. I make a two kind of wooden plate and then make a acoustic blanket here then the sound transmission will be reduce, so that kind of consultancy you have to provide to the engineer. So, this is the auditorium design. Let us try a design of this kind of auditorium kind of things real part, then if you have any query then you ask me then if I know I will answer it.

Thank you.