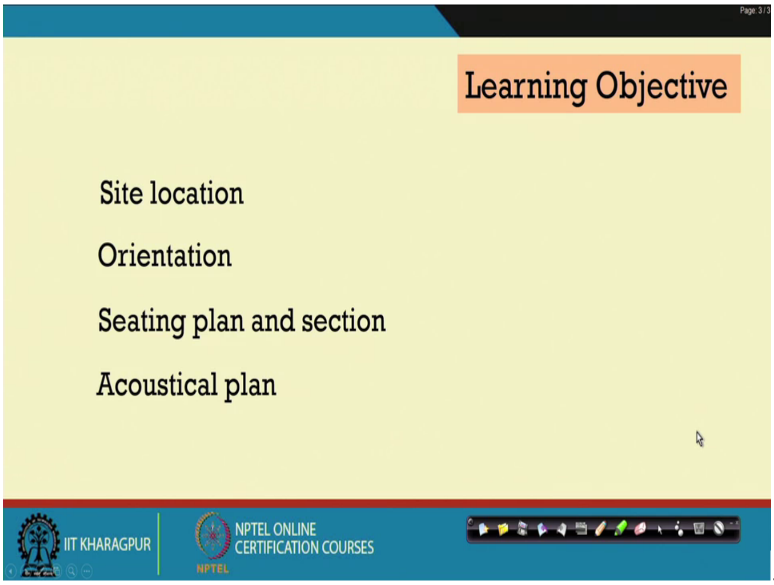
Architectural Acoustics
Prof. Sumana Gupta
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Lecture – 30
Open Air Theatre Design and Acoustics

So, we are at lecture 30, which is the last lecture of this particular module. And, after knowing the meteorological conditions how it influences sound, knowing the topographical conditions and how these were practiced in the earlier times,? T that is during the Greeks and the Rromans. We had discussed many of those criteria's in the last lecture and also in the introductory lecture. We move to the Oopen Aair Ttheatre Ddesign of presenting. Aand, we really cannot most much telling that we have done miraculous difference, then what the Greeks or the rRomans did? Aand we are actually trying to follow them and with some additions alterations to what they had done?.

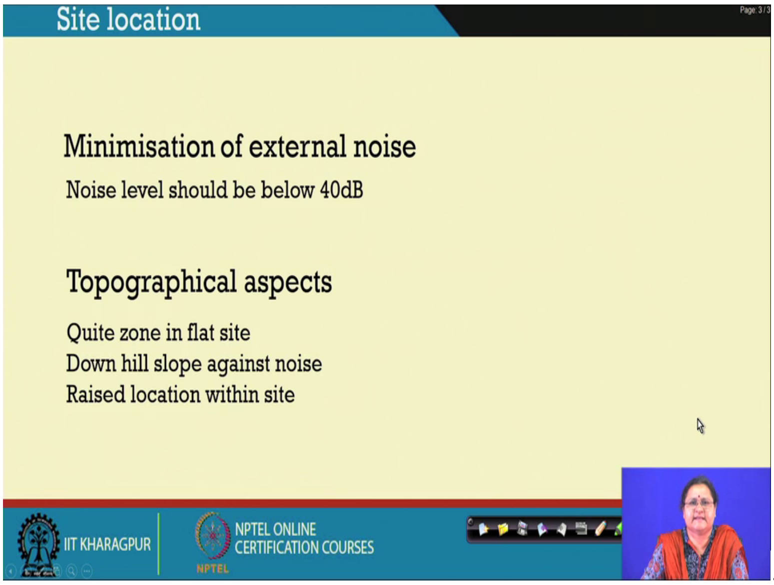
(Refer Slide Time: 01:09)



So, as we had gone through the meteorological conditions and the topographical conditions, we will try to see where to locate and how to locate in site and open air theatre.? Because, we really do not have abundant of land or hill slopes, where we can actually locate, we can locate in the we have to locate in the midst of the city also at times our open air theatre. We also have to look into the orientation as vitreous polio already told that facing the sun for the audience is a difficulty to observe the performances. Then the seating arrangements which were initially started by the Greeks and ~~romans~~Romans so, we need to acknowledge their thoughts and we still follow mostly such principles.

And coming to the acoustical plan, we have added or subtracted certain features which could be which were not available may be during those times, we have certainly added to our sites and we have tried to improve the listening conditions, while we place our open air theatres in cities or urban friends.

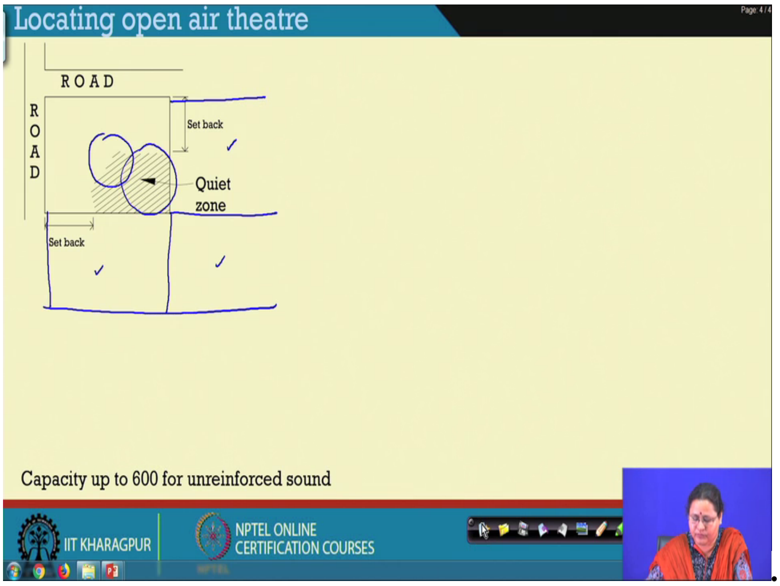
(Refer Slide Time: 02:36)



So, coming to the site location, first objective is to minimize the external noise. Because, if we are in the middle of a city we can expect lot of noise from the roadside or from other buildings which can add to the noise so, to keep away the noise we have to think of buffers, which we had discussed earlier.

The noise level should be below 40 decibels that is mandatory and also we need to know the topographical aspects. We have to find for a quiet zone in a flat site or some site downhill in the slope, if the site has a terrain or raised locations within a site to fall in the sound shadow area considering where the source is. ~~this~~ These w~~h~~ere all discussed in the earlier presentation earlier lecture.

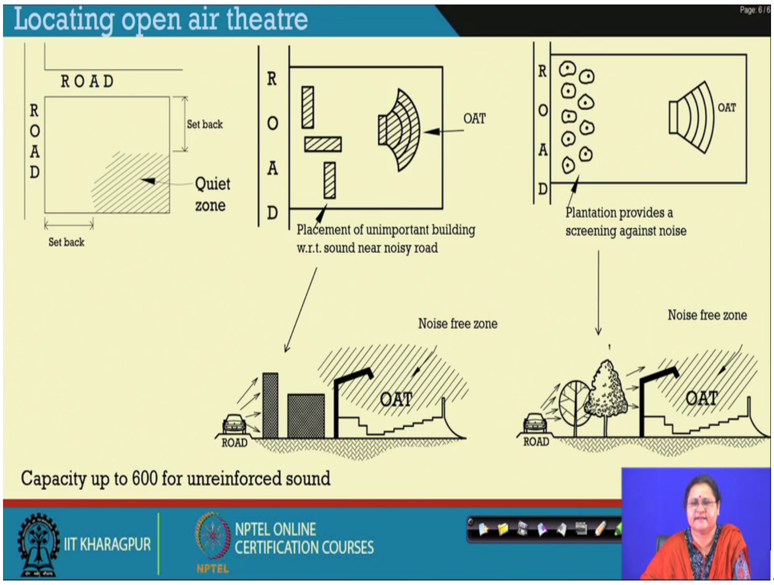
(Refer Slide Time: 03:38)



So, when we think of locating an open air theatre in an urban scape. wWe see that if the site is like this a rectangular plot as seen in the picture and it is having adjoining roads set at its side we can see that the quite area is actually forming at this particular zone, but if you see what are the other activities in the adjoining plots, that is this plot this plots this plot may be you may come up with an understanding that these are also creating some noise. So, just putting a set back from the road can save your site, save your location, from the roadside noise, but you may end up in some more noise from the activities on the adjoining sites.

So, you have to first understand where is your site located what are the adjoining conditions? That may probably have some influence or can add to the external noise to that particular site. So, in that case you can think that the central part of the site maybe more comfortable so, far as noise from outside is concerned. So, this decision has to be taken first before you, before you start designing your open air theatre.

(Refer Slide Time: 05:22)

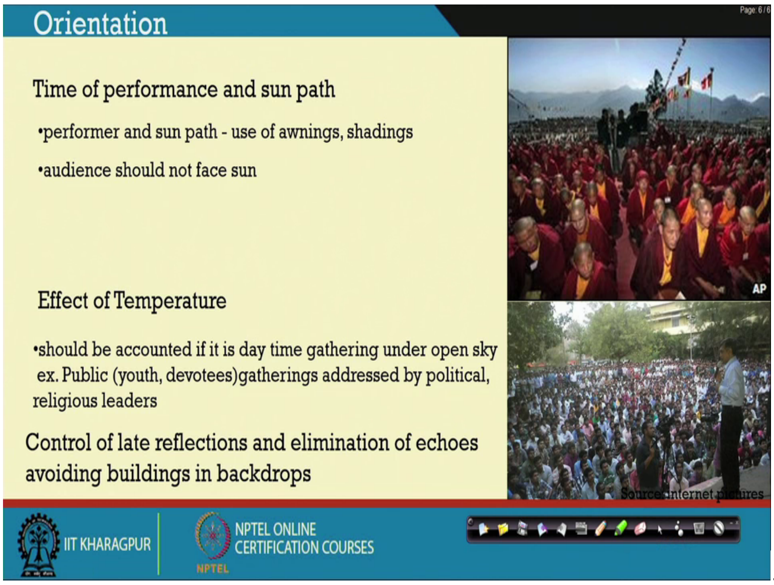


So, if you have road and you have other parameters quiet on the other sites adjoining plots, you can plan to cut down the noise from the road considering a line of buildings, which are not that important so, far as if it if there placed in the along the noisy roade. So, these buildings act as a reflector to the sound which is created by the road and does not allow the sound to enter into the open air theatre area.

Further, you can see that there is an addition of a backstage or a wall behind the stage, which can also protects the sound from entering into this particular area. So, you can create a noise free zone within your site by creating a line of building or a back wall behind your stage so, that you can protect your oat OAT from the external noise.

Similarly, by putting a line of trees few lines of trees of different sizes of foliage's as we have discussed in the plantations and vegetation's, we can plan for that with shabari heights of up to 10 to 12 meters, we can actually protect some amount of amount of noise and allow the way to be in a noise free zone. Usually capacities of upto 600 does not require any amplification of the sound and you can carry on with the performers own voice.

(Refer Slide Time: 07:15)



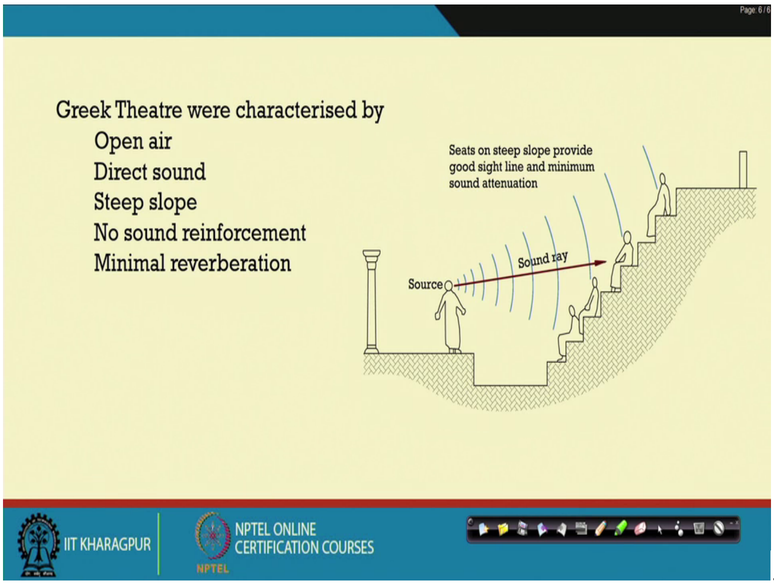
Coming to the orientation; the time of the performance is very much important along with it the study of the sun path. So, performers and the sun path use of awnings and shadings, which the R~~r~~oman had thought way back could be adopted and audience ~~shout~~ should not be facings sun, if the performances at during sun during day time sorry.

So, if you have such gatherings, which you can see in the picture some religious gathering~~.~~ ~~W~~where there is really no open air theatre, but a open field where the level is 0 all along that is the ground level or a youth gathering, which is in a open field you have to take care of the effect of temperature. As, you remember that temperature on the ground side is more and that bends helps bend the sound on the upper side creating sound shadow areas at the back.

So, maybe the youths who are sitting at the backside may not get any sound. Just not because the person on the or the on the state side is not speaking at a high voice or is not amplified, but because of the effect of temperature. We must also consider~~ed~~ late reflections, which are not to be allowed because that those are causes of echoes.

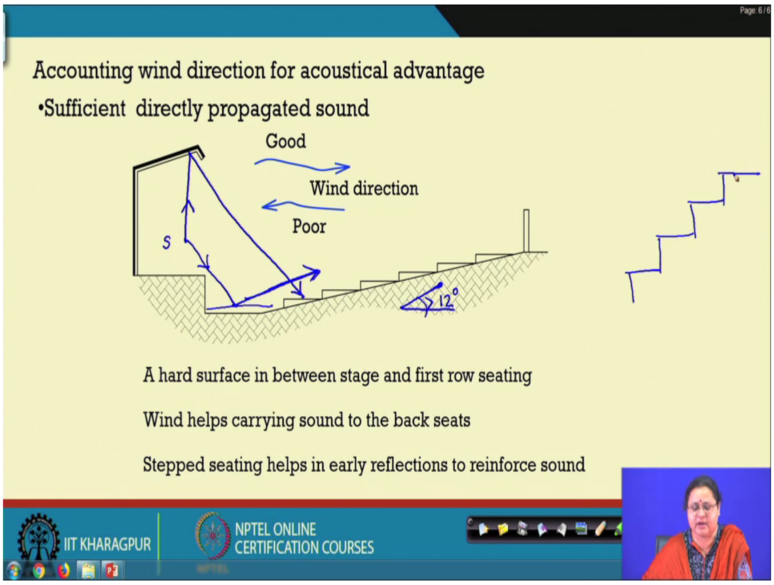
We can avoid buildings at the back drops, that is at the back of the stage, back of the audience at the end there are should not be reflectors like strong buildings or high buildings, which can actually reflect the sound as form helping forming the echoes.

(Refer Slide Time: 09:22)



If, you remember the slide of the very first lecture, the Greek theatres were characterized by open airs direct sound moving to the top of up to 60 meters~~.~~ ~~There~~ they ~~was~~ were steep slopes of 2 is to 1 and there was no sound reinforcement during those time, there was no concept of reverberation, which was very must minimal in those time those kind of structures; the same are adapted in our open air theatre also.

(Refer Slide Time: 10:03)

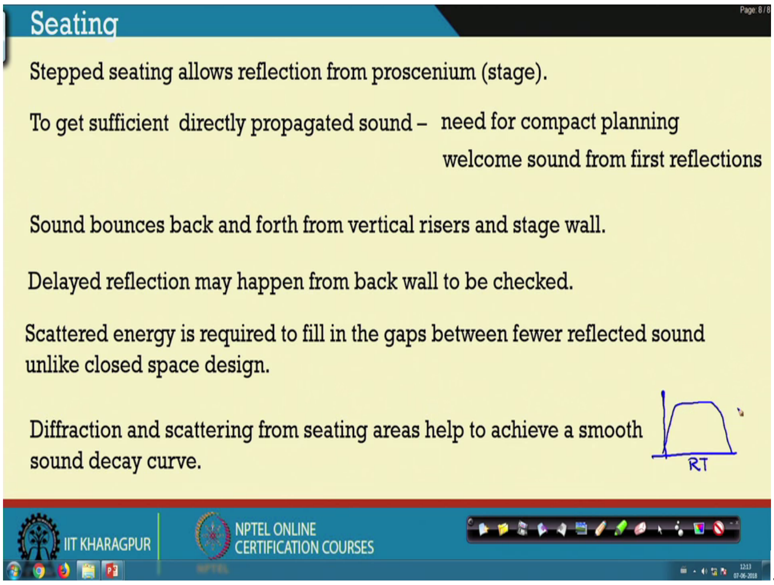


They also accounted wind direction, which we have seen that yes if the speech is along the wind direction it helps the sound to move to the farthest audience.

So, accounting the wind direction for acoustical advantage has to be kept in mind, sufficient directly propagated sound has to be reached and we do not go for a very steep slope, but we prefer slope at least greater than 12 degrees. So, this particular slope should be more than 12 degrees. A hard surface if you have a hard surface here that can help reflected sound to move towards the audience.

If you are sources here your reflected sound from this area can move towards the audience, yes with the wall at the back of the stage some amount of sound also can move towards the floor because in an open air theatre, there are very less chances of early reflections or helpful reflections to reinforce the source sound. As, we had seen in the epidurals in the in epidurals in the studies the limestone steps, which were kind of corrugated or folded forms, which helped in which helped in multiple reflections of the sound we see the adoption of the same thing in our cases.

(Refer Slide Time: 12:06)



So, coming to the seating, stepped seating allows the reflection from the proscenium side or the stage side, we will show in a short while. To get sufficient directly propagated sound, we need compact planning. Welcome sound from first reflections.

So, only the direct sound should not be enough for the last seats, we need the first reflections so, that they can create a better sound quality within the space, sound bounces back and forth from the vertical risers and the stage wall. So, we can take advantage of these as creating first reflections. And, this can actually help in creating a blended sound within the open air theatre. The major problem is this is not room acoustics you are in the open air and chances of reflection from the ceiling or the side walls are no more prevalent.

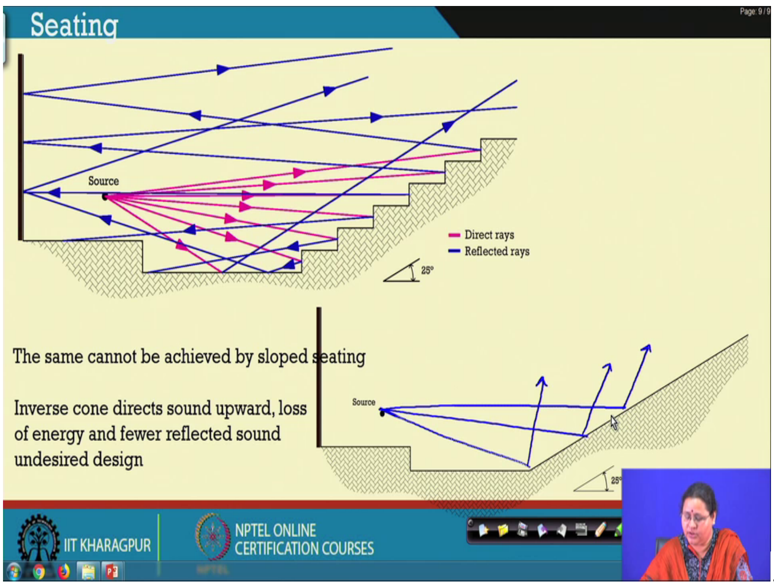
So, we are trying to take advantage of whatever reflecting areas, we can add and take help of the first reflections for the process of better hearing or better blending of the sound. Delayed reflections may happen from the back wall if we plan for a back wall at the end of the weight, then we have to check the delayed reflections or the echoes.

So, the wall should be of that particular height we will show in the next slides. Scattered energy is required to fill in the gaps between the few first reflections happening. And, those can be taken help that such scattered energies can be taken from the reflected sounds from the trades and the risers, which are forming the open air theater seating area.

So, the gaps where there are no audiences really help in accumulating this scattered energy in better hearing or better quality of sound. Diffraction and scattering from seating areas helps achieving the smooth decay curve. If you remember the decay curve and the reverberation time, which was the summation of ~~so, many,~~ so many early reflections this is not actually happening to create a blended sound.

So, these diffracted and scattered sounds add sound to the first reflections to achieve the smooth sound decay curve creating a blended sound, within the audience area.

(Refer Slide Time: 15:34)



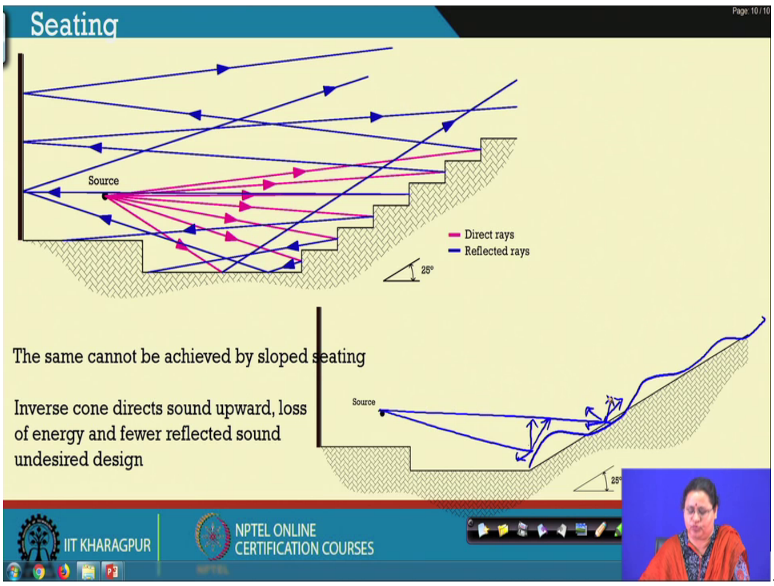
.

So, here you see how the sound is moving. You see the direct lines are shown with the pink colour and the reflected sound is shown with the blue colour. So, taking advantage of the back wall here and taking advantage of these raisers here, some amount of early reflections are happening to reinforce the source sound. And more you can add to these that is this corrugated seats are actually helping more you get blended sound. And better quality of sound.

If, you see a flat slope this kind of multiple reflections are unable to happen, it is like a cone inverted. Whatever sound is falling here, whatever sound is falling here is getting into the open sky.

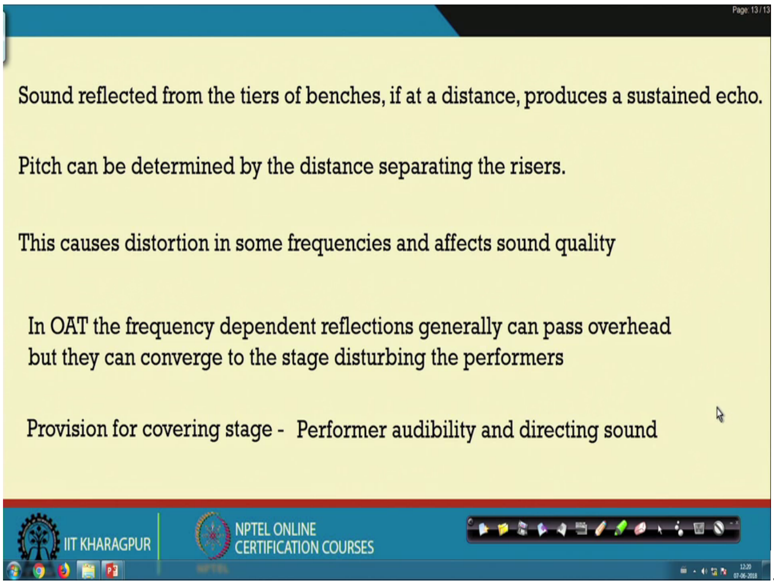
So, if you think of a flat slope, then you would be ending up with a bad quality of sound. So, inverse cone directors the sound upwards loss of energy and fever first reflections or early reflection sound and it is an undesired design. You can plan yes if you end up with a mound keeping it very green, you can plan for you can plan for undulations those will help in scattered sound towards the audience.

(Refer Slide Time: 17:47)



So, if your audience is seating then they might get some scattered sound. So, undulated surfaces are better than flat slopes.

(Refer Slide Time: 18:14)

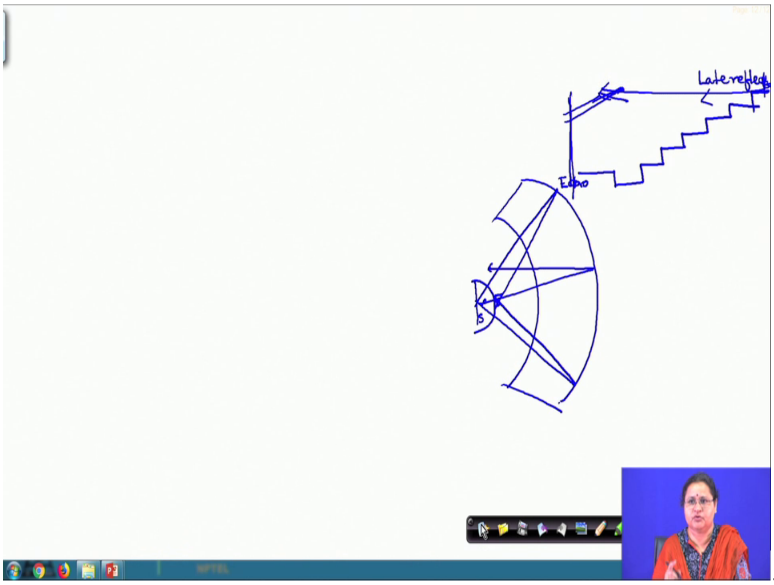


So, what we say that the sound reflected from the tires of benches, if at a distance can produce sustained echoes. So, this early reflections are to be happening in the front part of the open air theatre, we can even determine the pitch that which of those particular frequencies will be echoed as we had learnt in the auditorium design. This causes distortion of sound particular frequencies and may affect sound quality.

The echelon effect of auditorium design can happen for this particular kind of corrugated seating. In OAT the frequency dependent reflections generally can pass over-head, but they can converges to the stage disturbing the performers. You have to remember that yes the as because the seats are circular in nature, they can actually create the concave effect and they can all focus back to the stage and the performers can create have a disturbed sound from the audience side.

So, that could be helpful if the performer side is having covering over the stage. So, that it can cut down from the late reflections, which are coming back from the concave surfaces of the seating area.

(Refer Slide Time: 20:00)

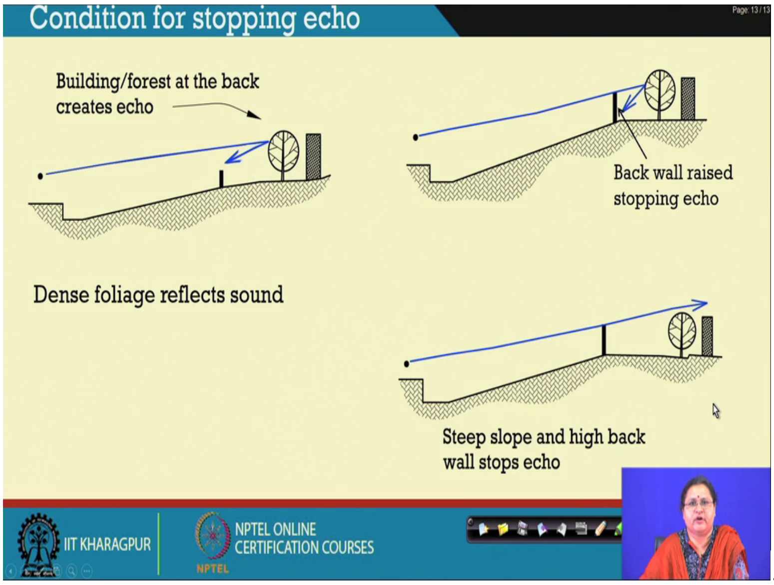


So, if this is the stage area and these are the concentric seating's the sound may get reflected back towards the stage area from the back seats. So, this can create echo condition, that is the source can get back the sound at a later as a late reflection from the backseat curvature.

So, as you are moving to the back your height is gaining. So, if you can create the awning or the support or over the stage and cut down the reflected back sound, towards this towards the stage in a certain high at a certain height. Then you can actually cut down the late reflections late reflections happening from the back of the seating.

So, this convergence of sound towards the stage can be cut down by the help of this awning or the support over the stage. So, these are to be calculated out specific to your site.

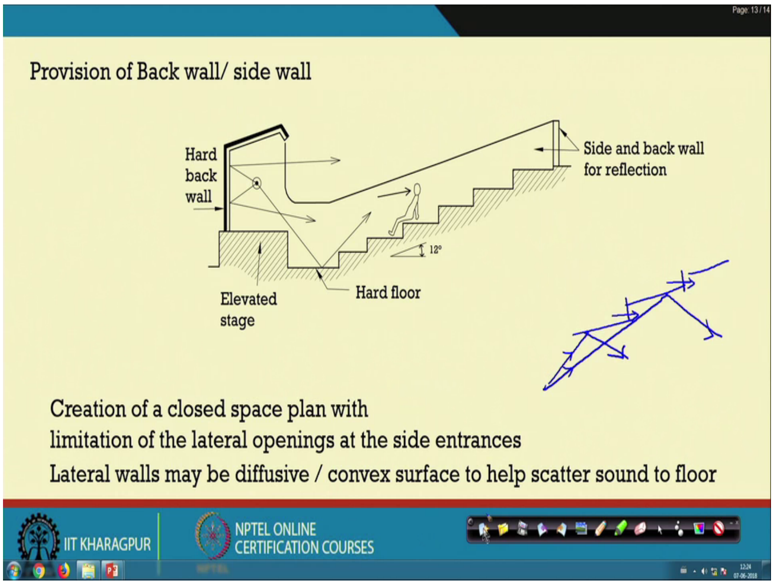
(Refer Slide Time: 21:53)



So, condition for stopping echoes towards the audience, you can see you can create a back wall, but if you are source sound is hitting directly to the features at the back that it may be a building or a tree or a line a foliage's they can echo back partially towards the audience. The building may if made of break or concrete will observe a very small amount and the entire energy will be coming back, in the form of echo and in case of trees, it will absorb a small portion and will reflect back a small portion, depending on the amount of foliage over there.

If, you see this picture, you will see the wall, you will see you will see the wall has been raised and that is stopping the return sound just by guarding creating a guard wall to the at the back end. So, the real end wall is very much important and has to be taken care accordingly. And, if you have a very high back wall it will completely stop echoes. So, the sound that is coming from the source which is going for will just move out from the particular area, that is also not much desired.

(Refer Slide Time: 23:30)



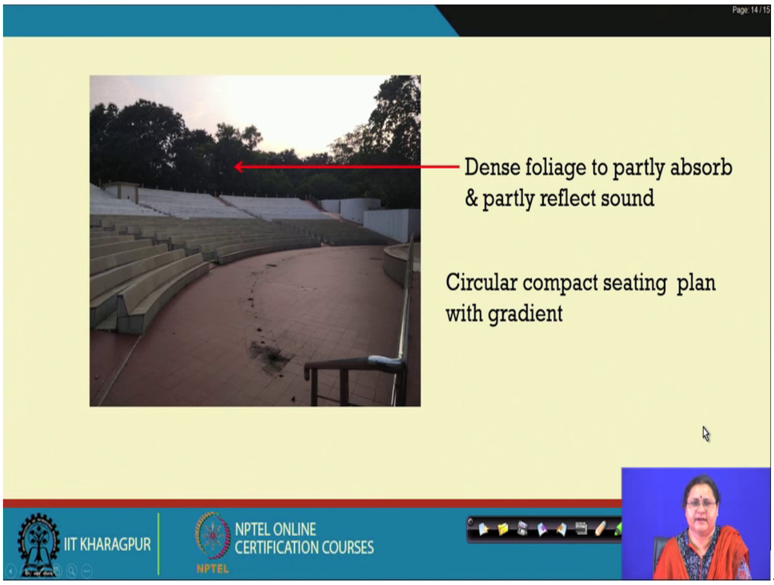
Now, to see how we can increase the lateral reflections for an open air theatre, because on the top we cannot provide anything so, there is no ceiling purse for an open air theatre you see here is a side wall plant. So, these side walls can also help in reflecting sound towards the audience, which are to be accounted as lateral reflections.

So, nowadays this side walls are made~~.~~ s~~S~~o, that sound can be pushed more towards the audience side. ~~a~~A percentage of the sound energy moves back towards the audience helping in early reflections or helping in better blending ~~are~~ of sound. So, this creates a closed space kind of plan. And, you have to keep in mind you have to provide your openings for the people to enter into these places.

So, if you can keep minimal entry through these walls or if you plan for indirect entry so, if you have a sidewall planned in this fashion your entries could be plant from this way, and these walls could be taken help for early reflections towards the audience.

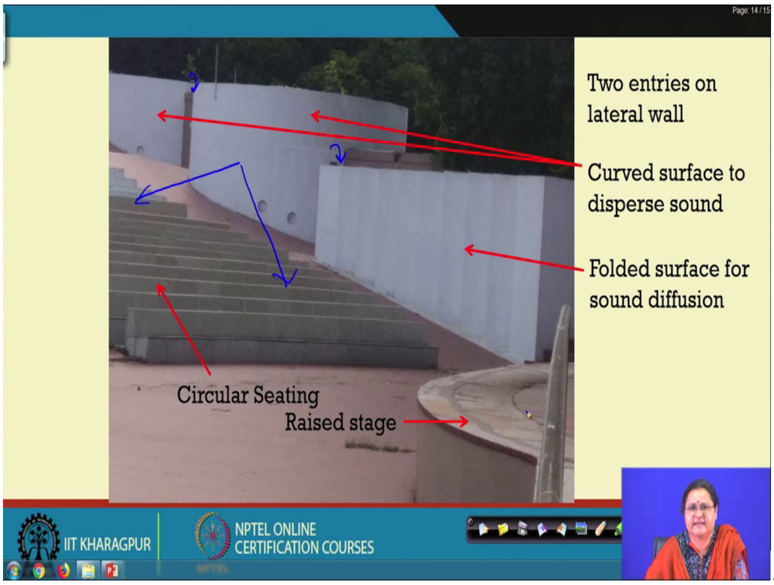
So, entry should be planned accordingly. So, that it does not cut down lateral reflections in the process. You can also plan for convex surfaces or corrugated surfaces along the lateral wall; I will show you an example.

(Refer Slide Time: 25:45)



Here is the open air theatre at IIT Kharagpur. So, you can see trees at the back which helps in absorbing some amount of sound as well as reflecting back some amount of sound. You can see the raised stage here, the circular compact seating plan with a gradient, you can see the stage over here and you can see the lateral walls of different shapes at the side.

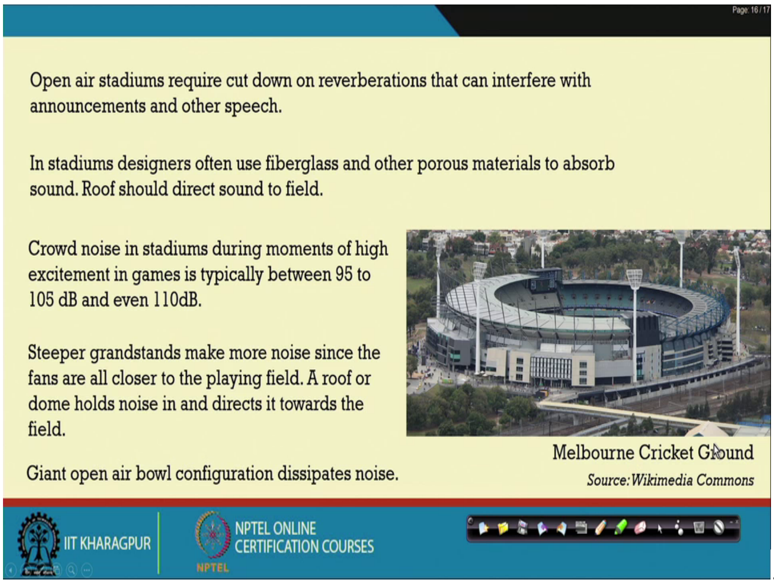
(Refer Slide Time: 26:21)



I bring you are closer picture, you see here this is having the front part is having a folded surface for sound diffusion. This is a curved surface to disperse the sound to the middle part of the hall.

So, you see the sound which is reaching here we will disperse in this fashion this corrugated features will help in diffusing sound towards the audience. And there is another surface here with a different, different radius of curvature and you see the entries are plant at different points here. So, this is how the adaptation of the same principles have been applied in today's open air theatres keeping the basic principles the same.

(Refer Slide Time: 27:28)



Now, I will try to just give you a small example of a stadium open air stadiums. Nowadays are covered with fiberglass E T F E or P T F E sheets. And when the crowds really shout towards the performer's maybe the players who are playing it creates the sound of around 90 to 95 decibels, even up to 100 and 5 and sometimes recodes are 100 and 10 decibels and those all sounds are directed towards the field.

So, if you have curvature or the covering, which will direct the sound towards the field then it is. Otherwise this amount of noise will not allow other spectators to listen to the announcements or the speech, which is being told or being discussed during the game. So, usually these are not for audibility the performance is not for the performance is not for sound, but it is for viewing more, but sound that is produced from the crowd reaches the field.

So, steeper grandstands make more noise since the fans get closer to the play towards the playing field and the roof or dome holds the noise as it directs the sound towards the field. So, this kind of concept of covering these kind of stadiums are to be kept in mind while thinking of open your stadiums being covered. So, with these I finish this particular lecture and these are you have to adopt the principles as and when required in the way you really want to apply it in the particular domain of architectural acoustics.