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

Lecture – 29
Topography and Sound Propagation Historical Contexts

So, in the previous lecture 28, we had seen that how sound behaves under different meteorological conditions, that is air, when sound passing through air, sound passing through the different temperature, sound moving on the different wind speed conditions, and we also told that it is a combined effect, which should be considered. And, there I already told that we also need to look into the topography the landscape of that particular area. And, we will continue with lecture 29 discussing on the Topography and Sound Propagation and the Historical Context.

So, earlier in the lecture 1 that is the introductory lecture, we had given an overview of the open air theatre which were designed by the Greeks Initially and then by the Romans, which were continued and we found how they had design those. And, now we can see on with this understanding of how sound behaves in open air condition? We will see that yes really during the BC's also the same principles were adapted, which were learned while we are not them we tried to research them out, but yes some concepts of acoustics were also win in their studies.

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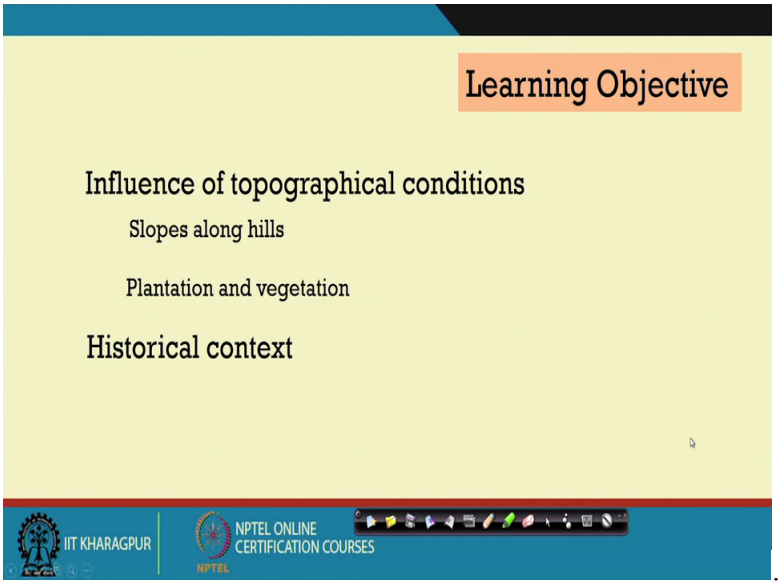

So, in this lecture we will see the influence of topographical condition, particularly the slopes, particularly the undulations and how sound behaves, then the plantations and the vegetation and then we will look back into the historical contexts.

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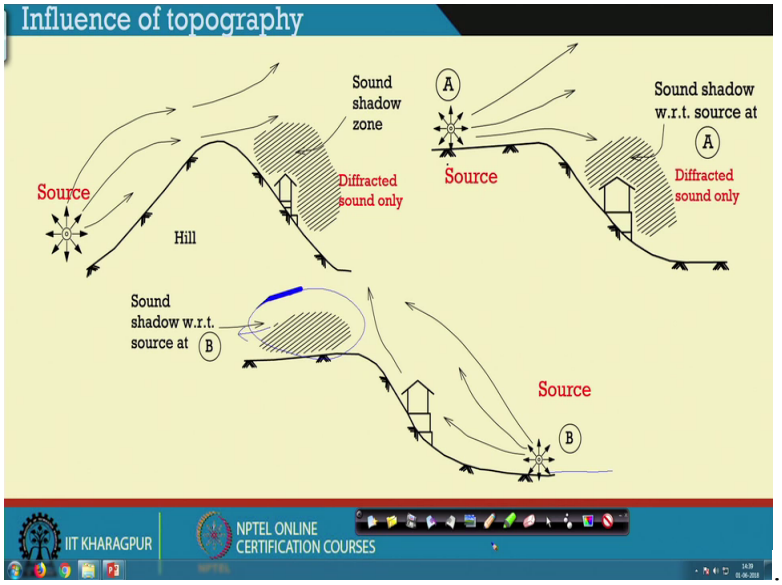

So, if we see the picture in front of you, you see a hillock or a hill which is there and the sound is produced at one end of the hill, which is not at all reaching or very small amount is reaching to the house or the receiver at the other side or the other slope of the hillock.

If, we had a house here on this side sufficient amount of sound would have reached the receivers or the inmates along in this house, but on the other slope no one is receiving sound here. It is only the diffracted sound, which is reaching this particular area. If, you look back into history, into the history amphitheaters, they sorted after locations which were along the hill slopes, which were opposite to the sources of sound.

So, the noise which is created in this particular area does not travel into this area much and this is considered as a quieter area. So, we as architects also need to seek our open air theatre locations in such areas where this kind of hillock or hill could be artificially created or a barrier could be artificially placed or planed so that the noise which is coming or this where we see the source, which is a noise should not affect or does not affect the other side of the slope.

So, this is how we can take advantage of the topography and design start our design. Similarly, we see we may always get a hill side, but even we can think of a plateau, which the second picture shows where source is at point A and we see some diffracted sound may be little more than the previous case is reaching this particular area, which could be further treated by landscape elements.

So, this house again where the receiver is not receiving much amount of sound, which is desired or which he or she must have received if the house would have been located somewhere here. So, this downhill is an appropriate location for areas for seeking areas, where we need to put some acoustical some space, which needs acoustical quality. Here is another case, you may have a source from the downhill and you see the source sound is moving upward and is not getting or not affecting this particular area.

So, this particular area and beyond is also a good location, if the sound sources are at this particular area. So we can take advantage of being at a raised level. So, that sound from roadside, sound from industries, can be (Refer Time: 06:11) and we can plan for an acoustical space at a level elevated. So, through this small examples, we try to impress you up on the fact that change of levels can really change the amount of sound, whether desired or not depending on that you can choose your location and we should not we should keep in mind, that we need not always adopt measures, but taking advantage of the topography we can plan our entire set of buildings or set of requirements that has to be fitted into a given site.

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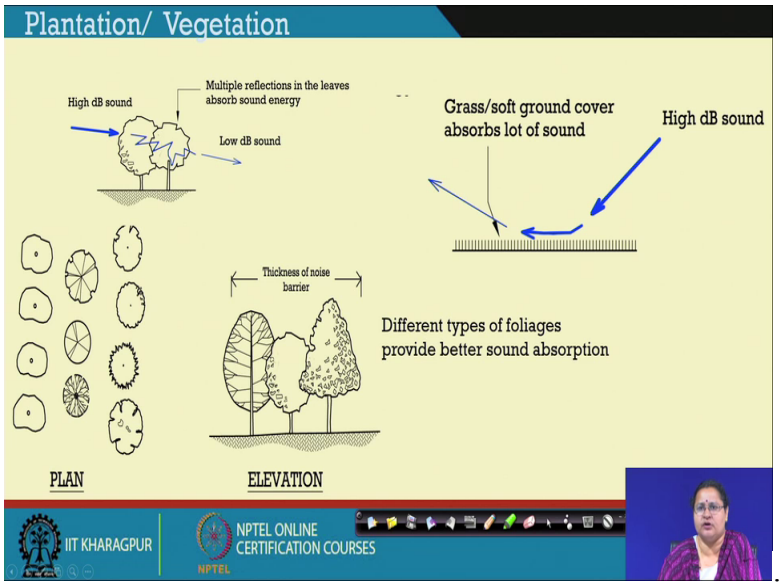

Now, coming to plantations and vegetation, here is a small picture where you see when the sound is coming from the source from this direction, which has high decibels or high sound pressure level, passes through multiple reflections between the leaves, the branches and it comes out on the other end with a low decibel. So that means, plantations and vegetation do also absorb sound. And, hence they can be taken into account for when we are doing some outdoor design, where noise has to be cut down or noise is nothing, but unwanted sound. So, when unwanted sound has to be cut down, we can take help of trees and plantations.

Now, coming to how much? How many? What type? You will see if you can plan for dense amount of plantations with different types of plants, you having different types of foliage's then the amount of absorption is better. So, this has been experimented. So, on this ends some this ends, some noise has been produced on the other end the readings are taken and then depending on the source location they keep on varying, but it has been proved that around 5 to 10 decibels or even more can be absorb by dense foliage of 15 to 30 meters.

So, these are researched way back in 1970s 70s 72 75 and even in 1990 many researchers have worked and come out with different foliage types, different formulas, but we are not specifically giving any formula, but when you make keep this as an understating or a thumb rule like 10 to 15 meters of foliage way allow you to absorb 5 6 decibels of sound.

Now, coming to the grass, there may be areas where plantations are not there, but if the sound falls on to the grass that is the angle of incidence is such that it encounters the grass surface or soft ground covered surface, then high decibel sound good amount of sound gets absorbed. So, grass or over soft ground absorbs lot of sound.

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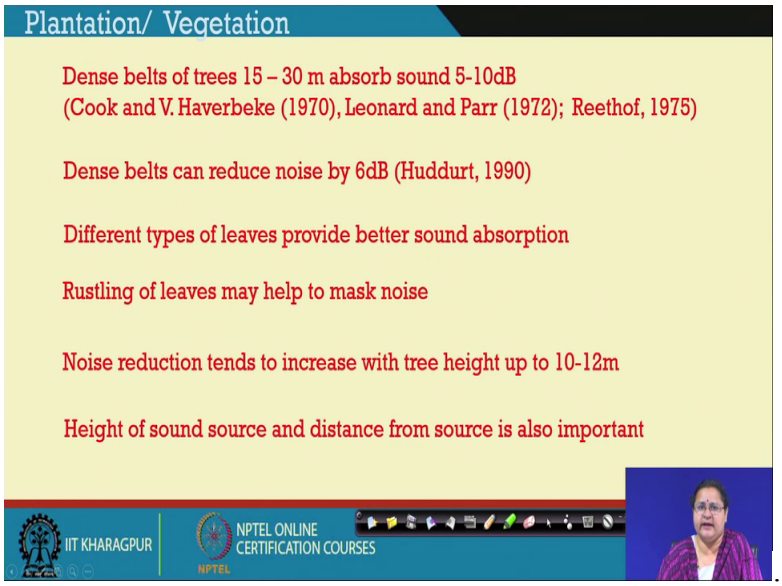

So, coming to the conclusions for plants and vegetation's you see that dense belts of trees of 15 to 30 meters absorb sound of 5 to 10 decibels.

So, up to 10 to 15 meters you can surely get a good absorption of 5 to 6 decibels. Rustling of leaves may help masking of noise, further dense belts, further different types of leaves provide better sound absorption.

So, if you have trees plant that is landscaped with different types of trees having different foliage's like deciduous trees, evergreen trees, even coniferous trees, if you can plant such kind of thing, so, you have to know landscape, how what kind of plantations grow in that particular area? And, you have the area or the provision of putting plantations then you can create a belt of trees to check noise or check unwanted sound, rustling of the leaves help masking the noise.

So, if the noise are of similar frequencies, noise then masking of the sound can be happening because of the rustling of the leaves and the branches. So, noise reduction tends to increase with the height of the tree. And, that has been researched or that has

been experimented and researched that up to 10 to 15 10 to 12 meters, the height of the trees are effective in noise reduction. However, if you have higher canopies, canopies at higher levels they really do not have good effects. And finally, the height of the source of the sound and the distance from the source is also very important.

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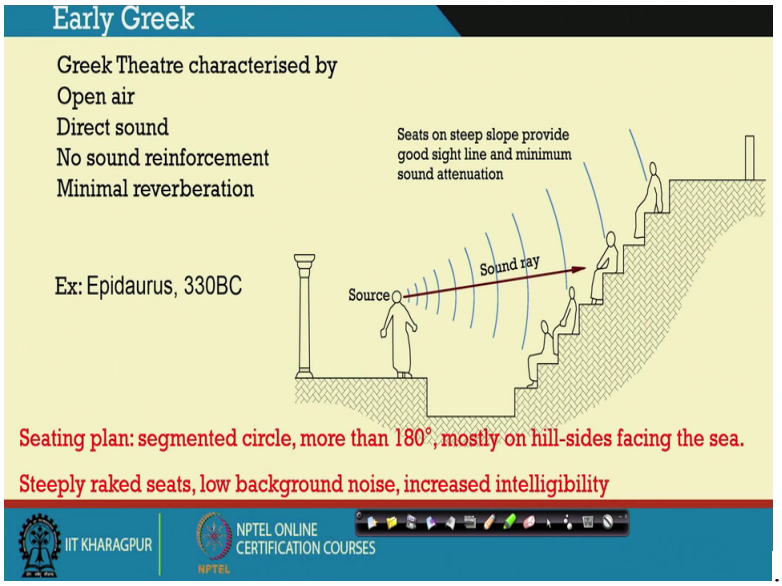

So, with these understanding, the topographical affects, the meteorological effects if we revisit lecture 1, if we go back into the early Greeks and the Romans, how did they plan? We will see that they had planned everything in the open air that took advantage of direct sound reaching to the audience, they did not have anything to reinforce sound and there was no concept of reverberation neither at that time and neither it happens in open air cases. So, there is now reverberation per say if we do not have any enclosure kind of effect. So, if the sound gets enclosed then only the reverberation that is coming back and forth things happen.

So, we have to look into how the early Greeks really whether they knew all these and understood and they planned or really they came up with such solutions through their experiments. So, they had sea ting plants, which were segmented circle more than 180 degrees mostly on hill side facing the sea.

Now, here you say they had an understanding they must have had an understanding, that mostly on hillsides, so, that the noise from the other side of the hill does not reach and facing the sea that also shows the wind direction. So, they accounted the meteorological

condition as well as the topographical condition, way back in the BC's. They had steeply raked seats and obviously, low background sound, because at they were on the other side of the hill. And, these all increased the intelligibility and here you can see the source sound is directly reaching the audience.

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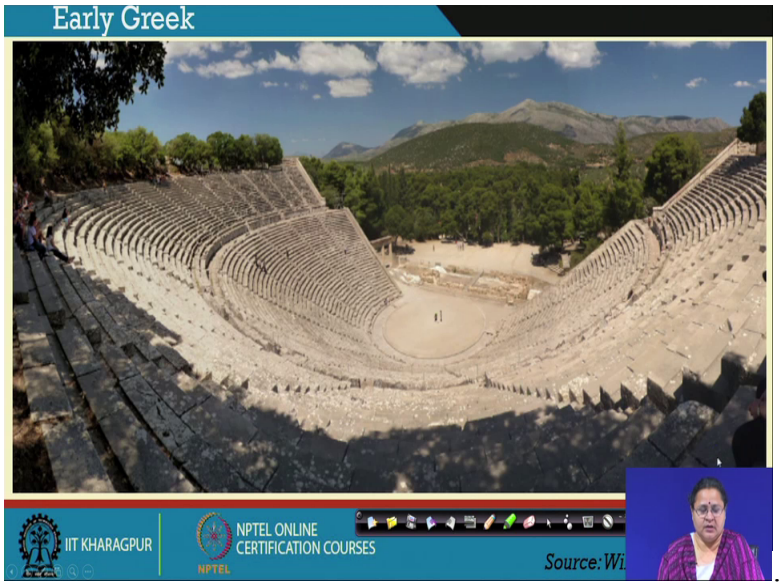

So, this is Epidaurus, which was on earth, it had 34 rows initially where which you see here and later the 21 rows were added and it had a radii of 60 meters or 180 86 feet. And the sound reached at the for this point, which has been explode further by researches of Georgia Institute of Technology in 2007.

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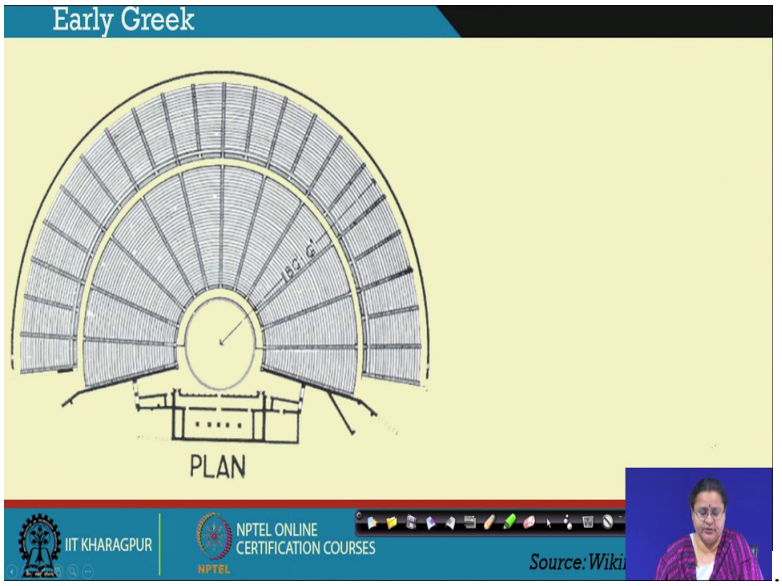

And here you see the Plan.

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And, here you see what the researchers have come out with. So, the researches by the Georgia Institute of Technology finds, that limestone seats filter out the low frequency sounds, which were not desired and they allowed or amplified the high frequency sound from the stage.

Now, these limestone seats are considered as corrugated surfaces, which acted as filters to emphasize certain frequencies. So, these limestone seats are not just vacant seats just added to create the seating the item of seating, but they are people the designers at that time did consider limestone seating and this particular corrugated o r folded structured so, that they get the advantage of cutting down low frequency sound, due to footfalls of the crowd etcetera and amplifying the high frequency sound, which was desired. Prevailing direction of the wind was also considered and that was flowing from the stage towards the audience.

So, that also helped in that also helped in getting better sound quality. And, this steep slope brought the people help the sound to move to the farthest point which was around 60 meters away.

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If, you see this picture, you see dense foliage at the back. This actually did not allow the sound to reflect back, rather those where absorbed within those within the foliage's. So, this is a present view, but yes during it is believed that that time also such kind of foliage's were around and the tree is actually good absorb the unwanted or checked the delayed reflection, that would have disturbed the sound quality in this amphitheater.

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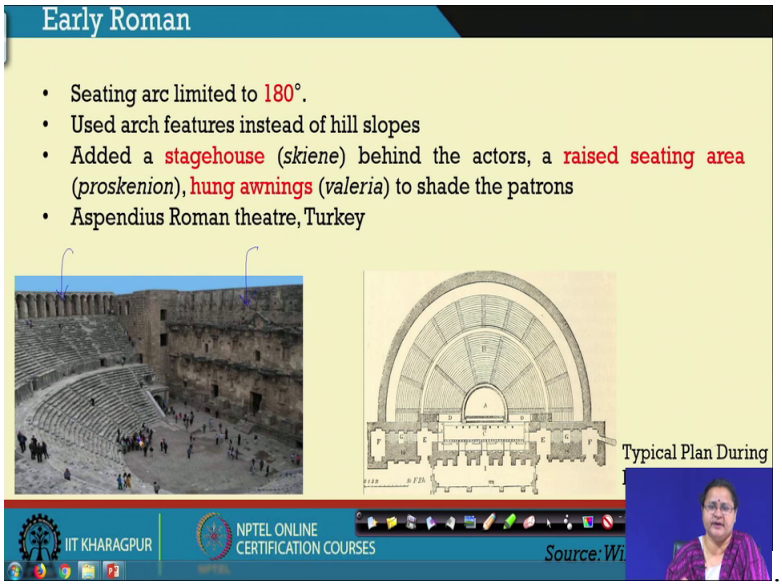

The Romans also followed the seating arc limited to 180 degrees they also used arch features instead of hill slopes.

So, they had high guard wall which actually helped the sound outside to not to enter into the within the amphitheater area. So, which was adopted by the Greeks along the hill slope, the Romans created arch facade to cover or enclose the sound that could disturb the performance the sound from the performance performers.

So, they had high wall at the back to cut down the noise from outside. They also added the stagehouse and the raised seating or raised seating area of the stage and had huge awnings to shade the patrons and these actually helped in early reflections of sound.

So, if you see the Roman theatre of Turkey, you will if you see Coliseum which is here, if you see the Aspendius Roman theatre of Turkey you will see these feature. So, this is the typical plan and this is the view of it. So, you can see the, colonnades at the back which helped in cutting down the noise, you can see at the front on the stage area there was a high wall, which also help to cut down sound and you see similarly the seating area is similarly planned like the Greeks and these all helped in getting better acoustical quality of these spaces and these were not done today.

So, the understanding which you have formed from the meteorological conditions and the topographical conditions, were adopted way back in the BC's.

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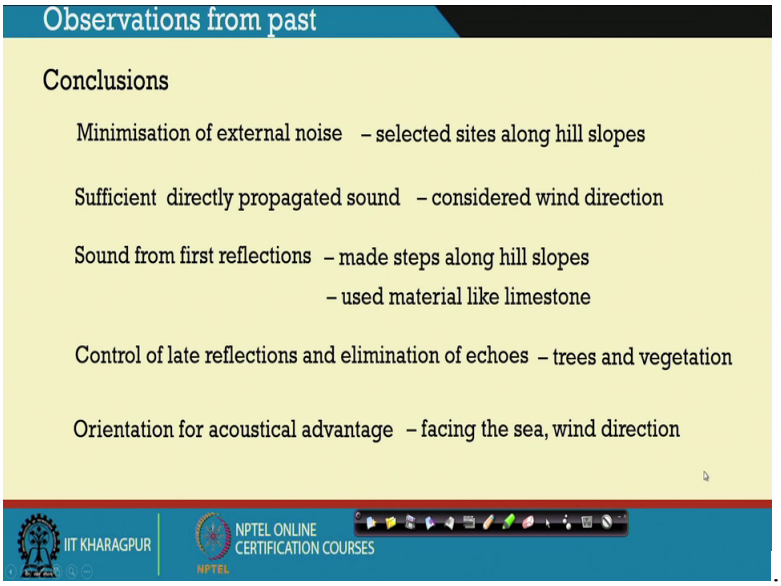

So, we can conclude that minimization of external noise is required, because from here in the next lecture we will go to open air theatre design. So, we can conclude that we need minimization of external noise. And that could be selected sites by selecting sites along hill slopes or selecting sites at a elevated level or shielding the site with barriers or walls which could check the external noise.

Sufficient directly propagated sound has to be encouraged so, that as because there is not much reflection or diffusion or diffraction anything playing a role here in propagating the sound, and it is the direct sound which needs to be moved and for that we can take into account the wind direction.

So, orientation is very much important which should account for the wind direction. Sound from the first reflections as the Romans adopted some canopy over the stage, we can plan when we look into open air design we can plan or keep in mind that first reflections can be taken help of by providing some sort of canopy over the stage so, that the performers can get back the role sound and it can help in sending the sound more towards the audience.

So, moreover the steps along the hills slopes also helped in sound reflection as the limestone steps of the epidurals showed. Use of material like limestone can be used and in the corrugated fashion so, that they can also help in first reflections. Control of late reflections and elimination of echoes by doing proper plantation at the back that can help

in checking late reflections, you can also pre propose or built up a wall at the back so that it can cut down it can allow the sound to move to the towards the trees and vegetation's and it can check the external noise.

Orientation for acoustical advantages, that is orientation towards the wind direction, orientation considering the noise where from the noise is coming all these are to be taken into account when we start or when we think of planning for a open air theatre.

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So, with these with these conclusions, I would request you all to revisit lecture one and find the planning considerations followed in the ancient amphitheaters, which are scientifically proved and which are now scientifically proved and also applicable in today's context.

And, I would also like to say that we have not made much change in open air theatre design if we think of or see what the Greeks and Romans have done. We have actually followed their path and till date similar kind of designs are or principles are followed particularly for open air theatres.