Architectural Acoustics
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Lecture – 01
Introduction to Historical Overview

Welcome to all of you those who have registered for this particular course on Architectural Acoustics. I believe that most of you are students and some of you must be from the academics who have registered, some maybe in the profession. For those who are students, I would say that this would help you in building up the knowledge so, that you can take help of these lectures or this particular course and make quality improvement in your designs.

At least you will consider that yes sound is also to be considered or accounted while we enter into the process of design. We architects always look into spaces, we create spaces, we innovate and think of different forms, we think of different how to assemble different functions in a logical fashion so, that we actually can satisfy our users; now who are the users? Users come for a purpose, users maybe you and me who will try to seek comfort in the space you have designed.

We are taught with different lessons or theoretical classes on climate; on climatic conditions where you account for all the sun path diagrams, the wind direction, the climate of that particular area, the weather conditions and then you think of how to start your design, what will be the openings, what will be the orientation, how you can help the; take help of the passive measures within your building to give the comfort condition to the inmates or the people who are the users.

Similarly, sound is also a factor which has to be accounted for many of the spaces which we sometimes neglect or forget or end up by using active measures to get rid of some unwanted sound or unwanted sound which is known as noise in the system say if you just start thinking of a hospital in a site; obviously, it is along a road. And if you do not think of taking the sound or the noise which is coming from the road, your design would be very good, but the patients will be staying there will be hit by the sound every time from the road.

You may put signages that no honking, no haunts, but if you just move your building at least some distance from this; from the road you can get a better feeling. So, you have to look into or account for sound whenever you are starting your design, but this is not the end. When you are within a system say in a classroom, I am considering that there is no outside noise, but within the classroom the sound needs to move till the last person or the last child who is sitting in the classroom and the correct pronunciation of the teacher must reach the primary section students particularly.

So, how well you are designing the classroom inside is also very important; there may be 3 fans moving in a classroom, there may be 5 fans in a fans moving in a classroom or maybe the air conditioner that is creating some noise. So, you have to think of all those unwanted sound which can actually reduce the quality of the sound being produced.

I am sitting here in an environment where my sound is being recorded. So, that it reaches you to the perfect way which is which is told here. So, every particular area may have some special acoustical requirements other than auditorium or some concert hall. So, for every small area or to a big area which is an auditorium or say which is the special design, we will try to show you the basic principles how sound has to be tamed within a system so, that it can give the best quality towards the audience.

When you are buying a ticket what say rupees 500, 300, 200 to enter into an auditorium you are having an expectation. The expectation is you will hear the performer the best, it may be a speech, it may be a lecture, it may be a performance, it may be a theatre, it may have mixture of all. So, the hall should respond to that kind of sound and that can that should give you the best feeling and the worth of paying the money for that particular seat or for that particular performance. So, the space where I am seating is not one with solid concrete wall.

We will come to those particular lectures where we will show you how the entire room environment is where I am actually sitting.

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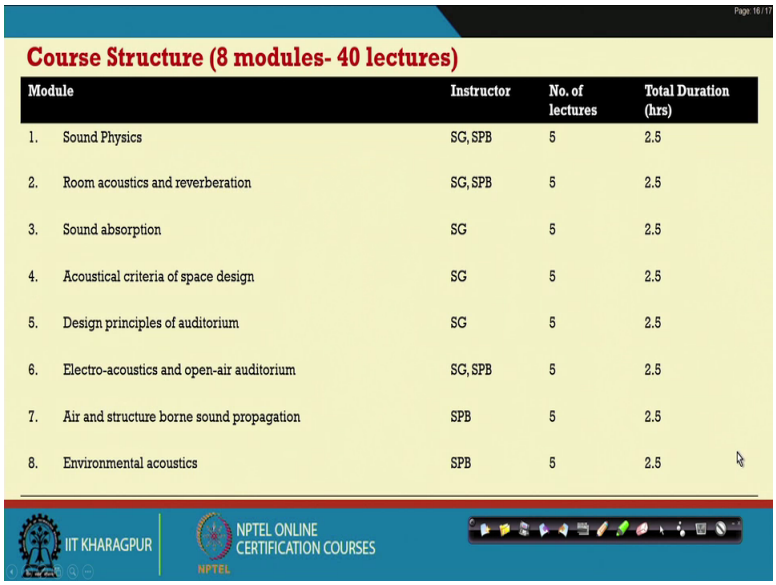

So, this is a 8 module 40 lecture course which has been segmented into its 8 module like sound physics, room acoustics and reverberation, sound absorption, acoustical criteria of space design, design principles of auditorium, electro acoustics and open air auditorium, air and structure bond sound propagation and environmental acoustics.

So, we will try to give you a total comprehensive understanding of how to take care of sound while we are and we are considering different kinds of design. Myself Dr. Suman Gupta and Dr. Shankha Pratim Bhattacharya we both have shared the course 20 lectures each and we will be giving you these lessons over the time of 8 weeks.

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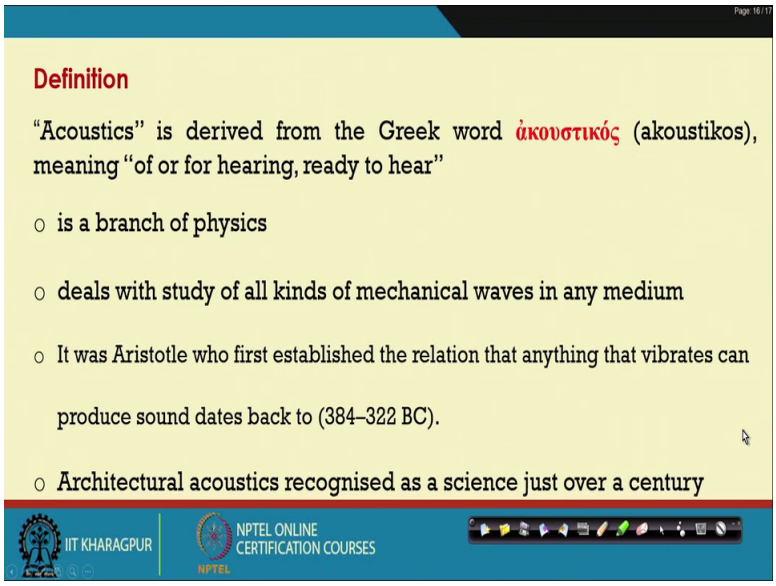

So, coming to the basics what is acoustics? It is derived from the Greek word meaning of or for hearing or ready to hear. So, the Greeks and the Romans were actually the pioneers of this particular subject and it is a branch of physics which deals with lot of calculations, but we will really keep we will really enter into calculations, but not deep into those, but deep into the understanding of architectural acoustics.

I will come to that; it deals with all kinds of mechanical waves in any medium and Aristotle was the first to establish that anything that vibrates can produce sound and it takes back to the BCs. And architectural acoustics, if you consider is a science just over a century and lots of experiments are being considered till today.

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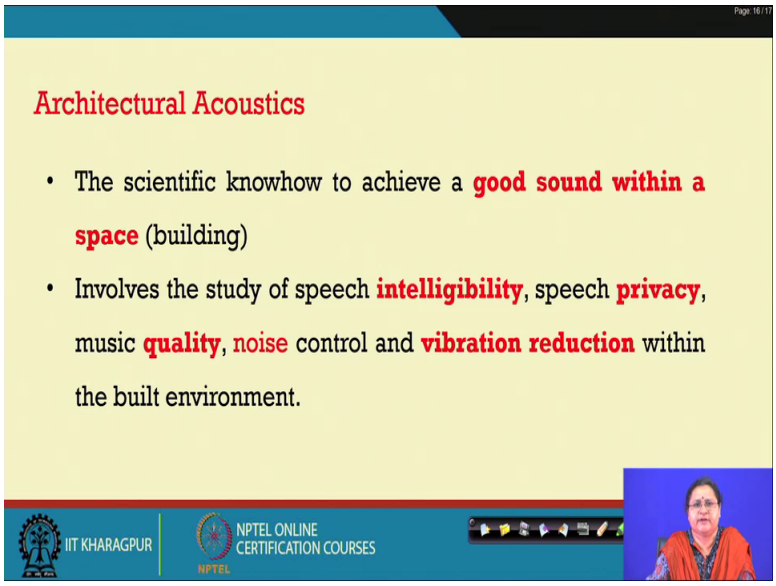

Coming to architectural acoustics in specific, it is the scientific know how to achieve a good sound within a space or a building and also outdoor. It involves the study of speech intelligibility that is clarity of the speech, speech privacy; if you require a privacy of speech within an office space. And even when you need to talk or say within a restaurant area when you need to talk with the people with the friends with you have come and it does not disturb the other people.

It also involves music quality, noise control and vibration reduction within the built environment. So, all these are coming under the topic or subject architectural acoustics.

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So, we need to look back to history how people started thinking or what was the notion on acoustics in earlier days?

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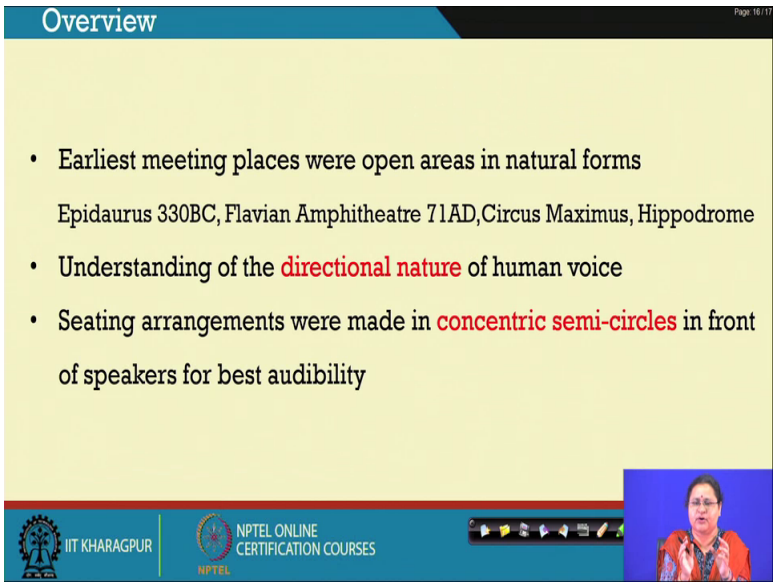

So, we always see that the earliest meeting places where the concept of sound was being experienced where open airs; open areas in the midst of natural forms. So, people started together for some political discussions, for some military purposes for or for some performances and that started to the requirement of such spacem where acoustics was felt as important.

So, in the Hellenistic great Hellenistic theatre Epidaurus of 330 BC is the oldest we have the hippodromes where the horse used to race or the courses horse used to race in the courses; those were mostly for visual communication. The Circus Maximus, the Flavian Amphitheatre which is the Colosseum all are examples from the Greek and the Roman time. And those which were and those were following certain principles while they were designing so.

Understanding of the directional nature of human voice was being felt while studies on these particular buildings were carried out in later times. Seating arrangement was also one of the important characteristics that was seen that everything was kind of concentric semicircles in front of speaker for best audibility. Actually the ones they started gathering, it was saying to get the best audibility the people tried to converge towards more towards the speaker and they tried to spread out in a fan shaped pattern for best audibility.

So, the requirement or the need actually led to this concentric semicircular form which was seen in the Epidaurus in the Greek Hellenistic theatre of Epidaurus which was unearthed in 1870, 1871.

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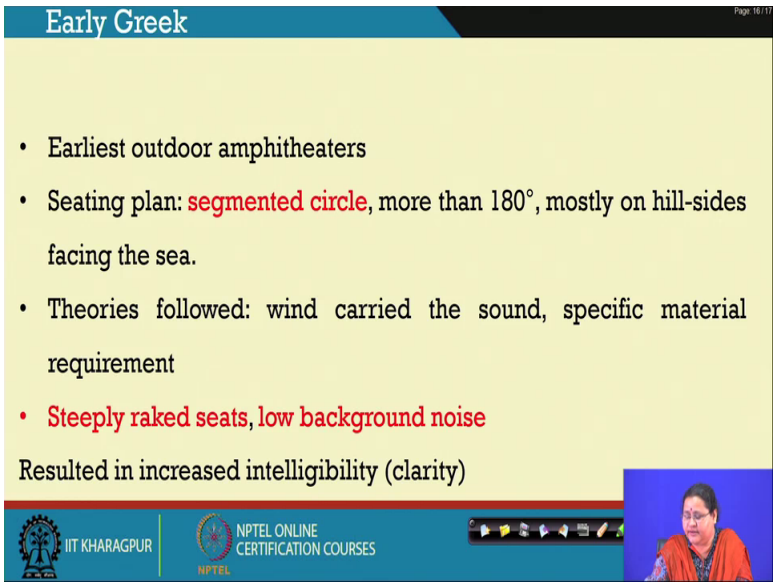

So, let us see the earliest outdoor amphitheatres which had segmented circular plan which were more than 180 degree during the Greeks and they preferred the hillsides facing the seas which were very chosen location for the Greeks.

They had experimented in several spaces, but they came out that hillsides along the sea where the best locations for getting better audibility; it could be because facing the sea could be because of the wind direction. The wind carried the sound and the specific material requirement was also seen when later the studies by Georgia Tech University revealed that limestone as a material was chosen maybe because of helping sound in reflections.

Steeply raked seats with low background noise where preferred. So, the angle against which the Greeks plant or the hill slopes had a very steep slope which were chosen as preferred locations. These all resulted in the clarity of sound which was being produced by the speaker because that time no amplification system was there. And you will be astonished to know that these plants where as big as having the radius of as big as 60 meters or 180 feet.

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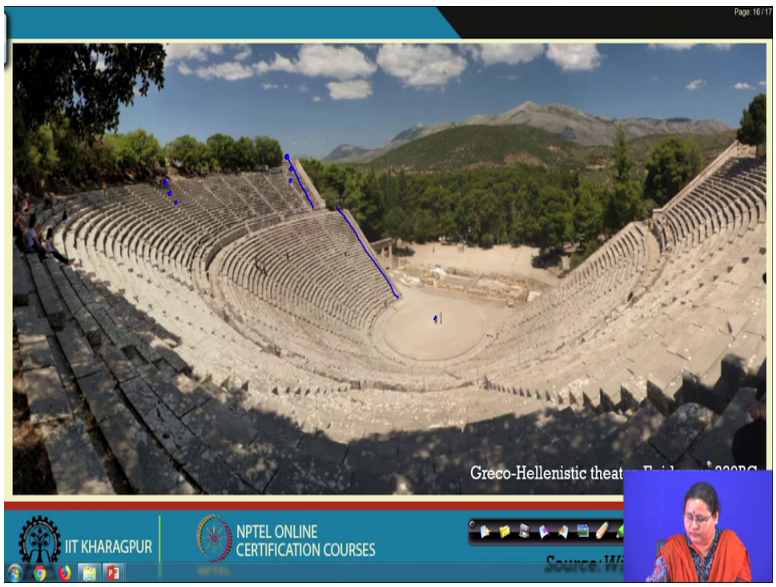

So, this is the Greco Hellenistic theatre of Epidaurus which was unearthed and you see the first part these had 34 seats, 34 rows and later there were 21 rows which made the 55 rows and the radius of radius from this particular speaking point this was 180 feet or 60 meters.

And sound particularly at all these locations was all heard; later researches were also carried out, we will talk on that later. Here you can see the steep slope and the seating area how this has been made with stones.

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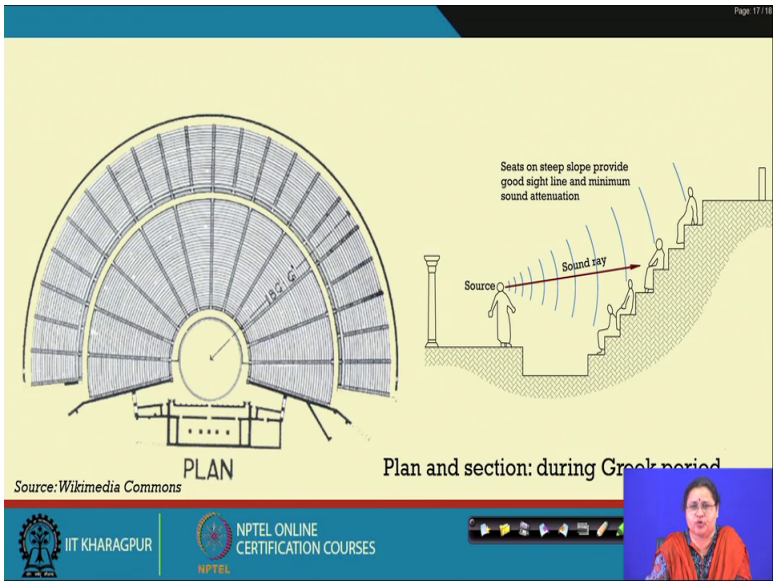

This is the typical plan, this is the section where you see that the sound is moving till the top and the slope is almost 2 is to 1, this where the plants during the Greek period and mostly those were along the hill slopes, but later in the Roman period those where who were better engineers they actually discovered the walls and the arches.

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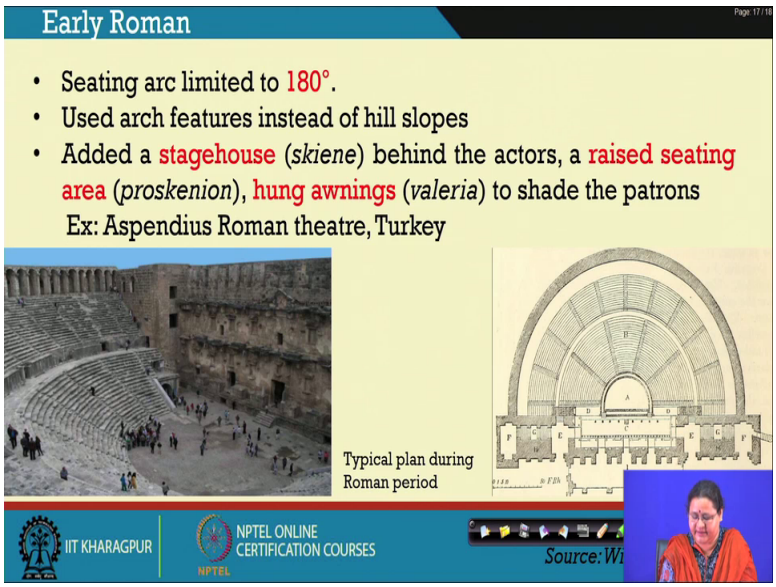

So, they never confined themselves to the hillside slopes and neither to neither had restricted to the natural forms.

But they followed almost the seating arc of 180 degree. So, that they get a straight back and used the arc features to create their support or the backdrop of the entire seating. So, they also added a stage they created a raised seating area and added some shading devices for the patrons. So, as because the sun was not facing the audience maybe the patrons or the performers were facing the sun.

So, in that case the huge awnings were supporting were shading the performers and knowingly or unknowingly they helped in the reflection of sound within that small within that system. So, the Aspendos of Rome in Turkey Aspendius Roman theatre of Turkey is one of the examples, you can see here you see the backdrop with the arched openings the height was around 85 meters.

This is the stateside, this is the typical plan. So, the stage is here in this A; the backstage and it had the raised stage and the awnings. So, the back wall here also might have helped in reflecting sound.

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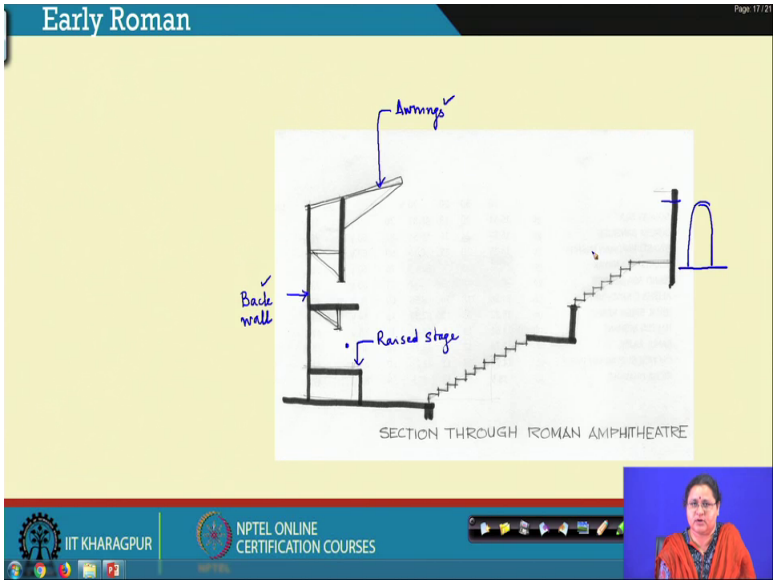

So, here you can see this is the raised stage; so, these are this is the arched; this area this is the arched wall which had which had shown you in the previous picture and this is the back wall. So, it is believed that these features the awnings, the back wall helped the sound to move better in this particular closed designs.

Here you also see the raised stage which actually elevates the source and helps more amount of sound moving towards the audience.

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So, this is the Flavian amphitheatre or the Colosseum Rome, this is the inner picture on the right is the inner side picture on the left is the outside picture. So, you can see the series of column series of arches and inside the picture is presently like this the capacity of the Colosseum was around 40000.

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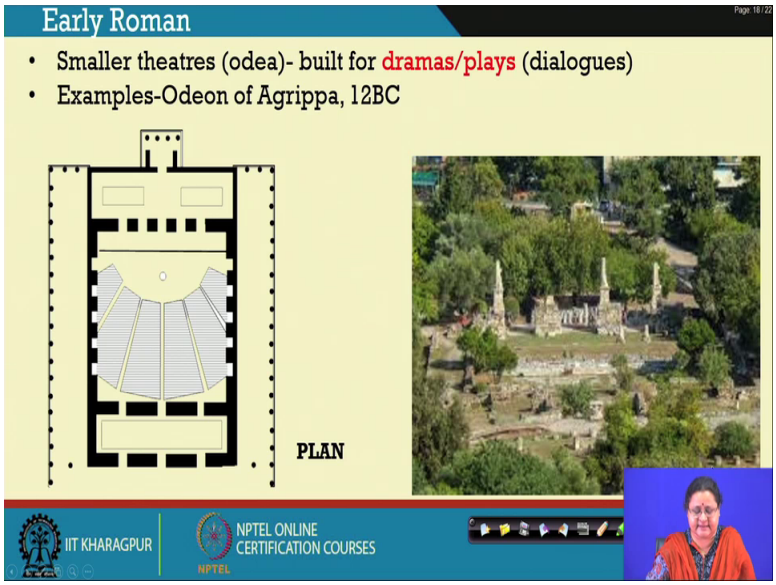

Later the Romans also created small theatres which were closed structures for dramas and place or dialogue exchanges and Odeon of Agrippa which had span of 25 meters; in those days made of wooden structure is also seen. Inside the stage you see the similar type of seating has been adapted that is semi circular seating plan.

But it was ruined later on can you see the remains as it presently is seen as like this.

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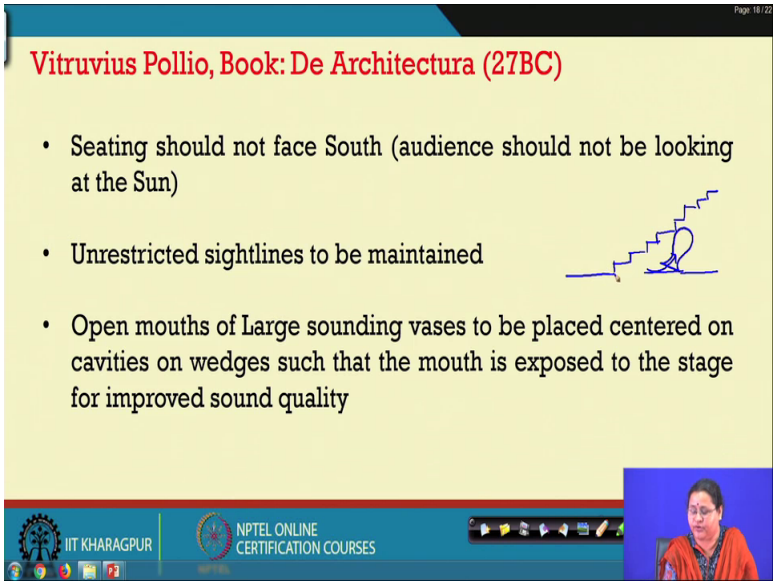

Vitruvius Pollio in his book De Architectura of the 27th BC mentioned that seating should not face the sun, it should not face the south also and that would help in getting that getting that they are not looking into the sun. Unrestricted sightline has to be maintained was also meant mentioned in Vitruvius in Vitruvius Pollio's book. Vitruvius Pollio also mentioned of open mouthed large sounding vessels to be placed below the seating area that would help in improving sound quality.

It is kind of below the seating area, he suggested that there should be pictures like structures that should be placed below the seating so, that they can absorb sound.

The reason is not mentioned, but the book mentions the application of search items in below the seating area. And with modern studies researches it is felt that they had a good understanding of those of the movement of sound or the theories of sound.

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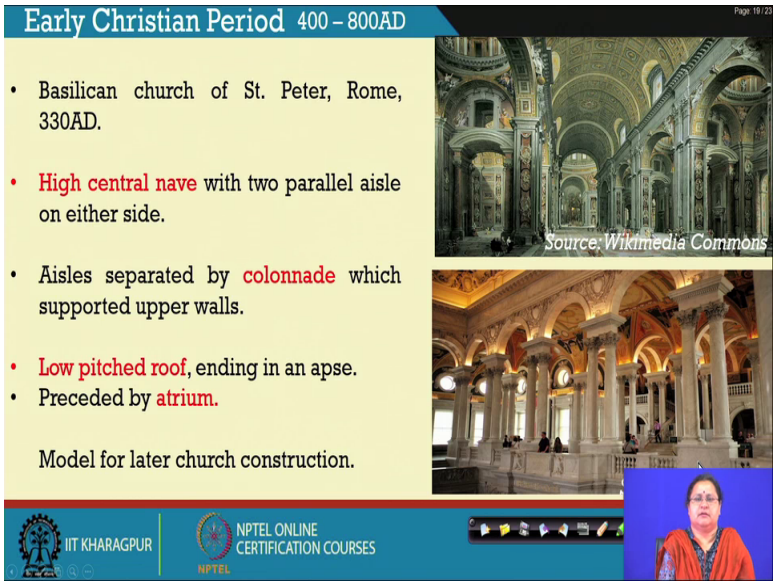

If you look back, if you look back to the early Christian periods when religious came into existence and the people started congregating in closed structures; we see the first examples of St. Peters Rome of the 330 AD. So, when the Greeks and Romans where concentrating in the open air areas with this early Christian period, they started thinking of religious structures like the Basilican churches. These are characterized by the high central nave which you have already covered in your history of architecture.

The aisles separated by the colonnades which were supported by which supported the upper walls; the aisle sides had low pitched roofs ending in the apse and these kind of halls had an atrium at the front. This became the model of latch later church construction, but how these areas within this areas sound was accepted?

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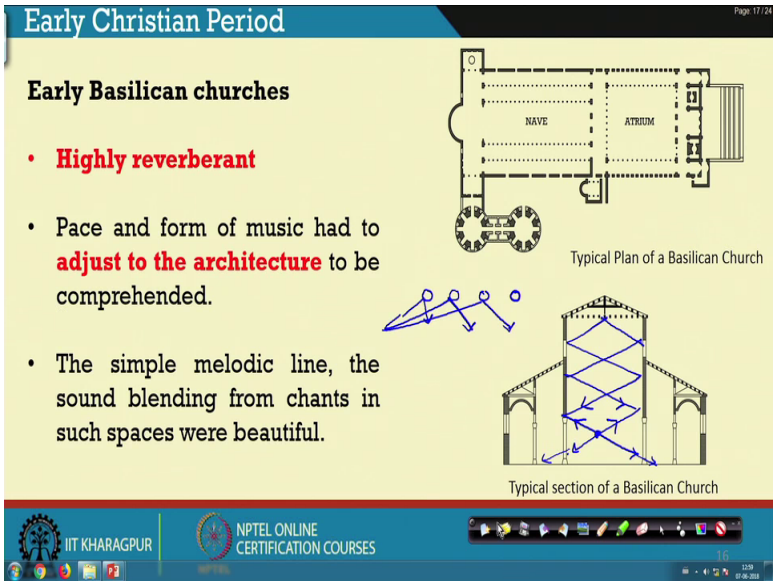

These halls were highly reverberant, even the Georgian music's, the enchantment were designed considering the hall, considering the church where it will be played. So, the simple melodic lines the sound blendings from the chants in such spaces were felt as beautiful.

If you look into researches present researches you will see that each and every element of say around 40 churches of different volumes were studied. And it was seeing that each of the features within this churches played an important role in the acrostics. The pace and form of the music had been adjusted considering the internal architecture of each of the churches.

You see a series of colonnades here, it is believed that these columns which had additional surface area of 25 percent of whatever wall surface areas where there; they actually helped in reflecting sound towards the audience. Each and every column participated in this and the huge amount of area additional area produced helped in the sound being reflected back and forth with in this area having this high reverberation time.

We will get into the details of each of these aspects later on; the section which you see here, the sound you sound travels till the top and again rebounds back to the floor. So, the source sound moves and again comes back to the floor for the audience and these sound also reaches to the areas in the aisle.

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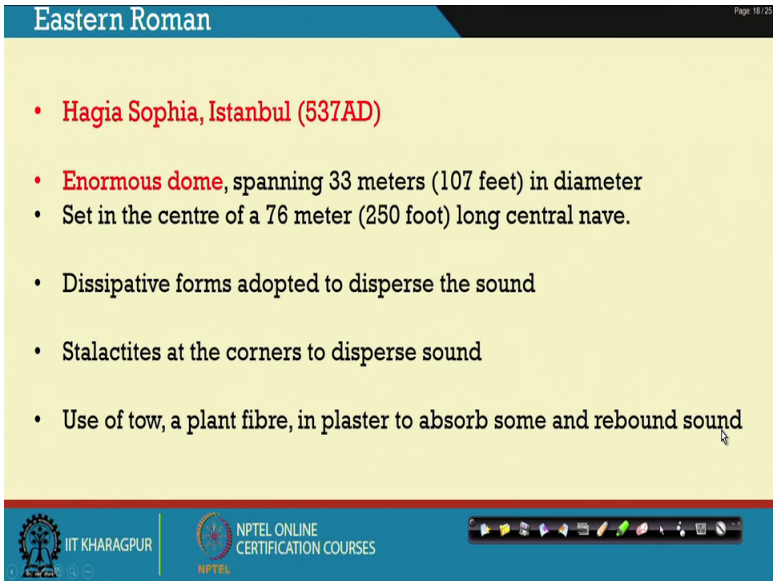

So, if you move to the eastern Roman we have the Hagia Sophia in Istanbul which has the enormous dome which is different in structure, which spans 33 meters and sets in the centre of a 76 meter central nave.

Here the dissipative forms where adapted to disperse the sound that is believed. Stalactites at the corners helped in dispersing the sound, even use of tow which is a plant fiber in the plaster to absorb and also rebound sound has been researched out.

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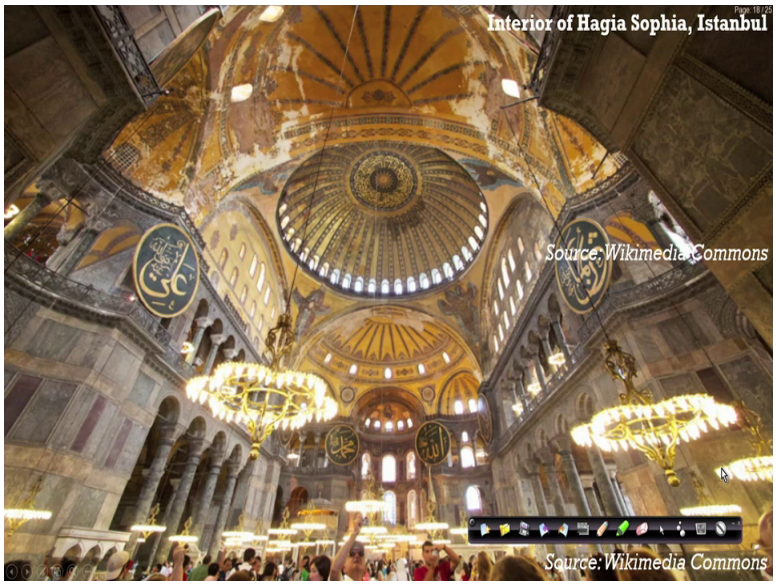

So, you see this is the enormous dome where sound was absolutely heard in its best form.

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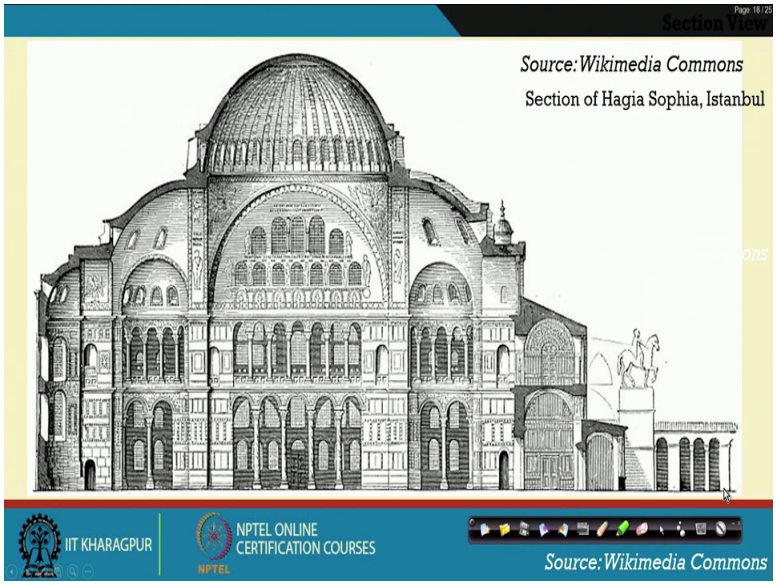

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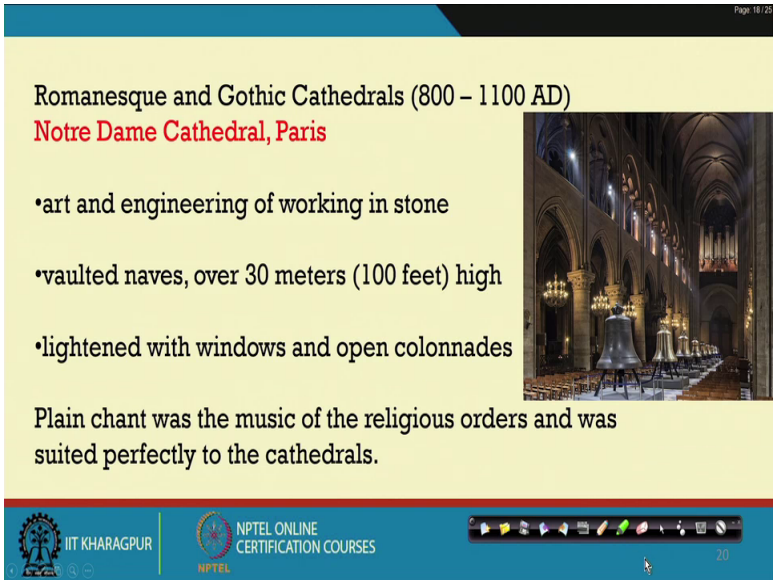

Coming to the Romanesque and the Gothic Cathedrals, you see it is between 800 to 1100 AD, the Notre Dame Cathedral of Paris is one of the notable. During this time the stone was in use and the vaulted naves were around 30 meters high; lightened with windows and open colonnades and it is believe that this glass windows, the rose windows also helped in observing low frequency sound.

So, the plane chants was the music of the religious order and was suited perfectly for these cathedrals; so the enchantments were created considering the entire internal environment, the volume, the capacity of these halls.

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You see these are some of the pictures from the gothic cathedral, you can see the rose windows here and maybe some more pictures of the rose glass window in front of you.

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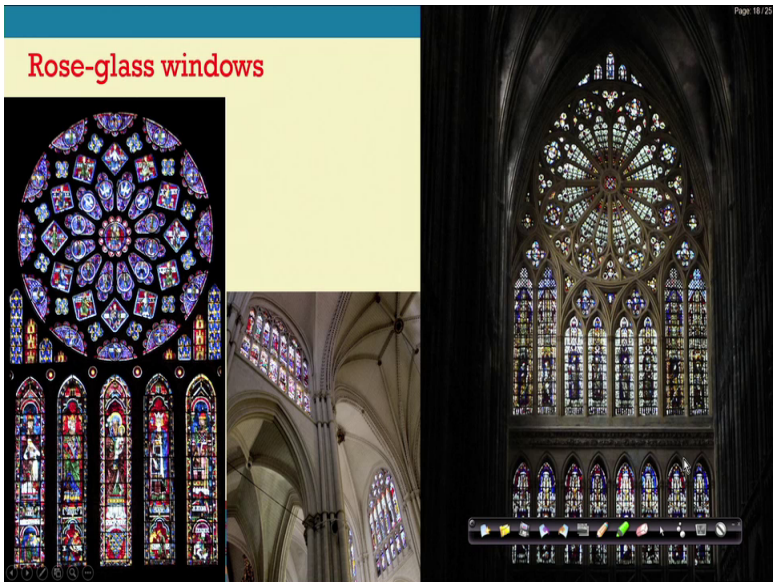

The high walls are also, the high walls are also seen in the pictures.

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It would be incomplete if I do not mention The Suleymaniye Mosque of Istanbul which was built in the 1850s and the series of openings in the dome present for sound absorption. Here you see the overall picture and next you see the circlesm here are actually seen in this parts these where you can see the entire row is having these circle which are hollows which are believed to be used as resonators, they used to trap in sound

So, Sinan the architect avoided using regular forms like perfect squares or cubes and used niches and corners, buttresses, galleries to break this kind of regular features. You see here the column capital, it has lots of niches, curves inside it; so, that they can actually spread the sound in a very uniform manner within the space so, huge.

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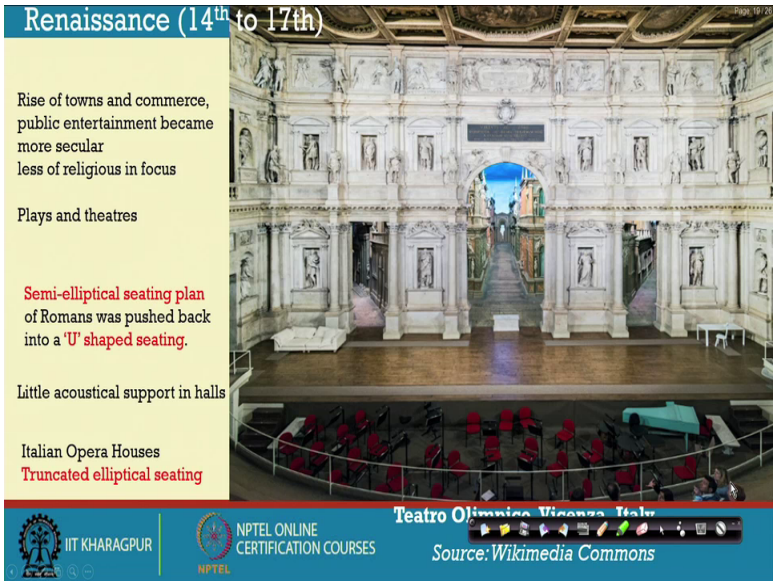

Gradually, the renaissance period had witnessed a different kind of requirement; people moved from religious has focus to plays and theatres, more social gatherings being happening. Plays and theatres started and semi elliptical seating plan was preferred instead of the regular semi; regular semicircular plan.

So, the 'U' shaped seating was observed during the during the renaissance period and little acoustical support in the halls where seen. But there were lot of sculptures additions inside the halls or the performance areas which is believed to have helped in some; achieving some sound quality, but there was really no understanding during the renaissance period for sound are only the changes or experiments where thought of in the way of seating arrangements.

The Italian opera house had truncated seating plan in an elliptical fashion.

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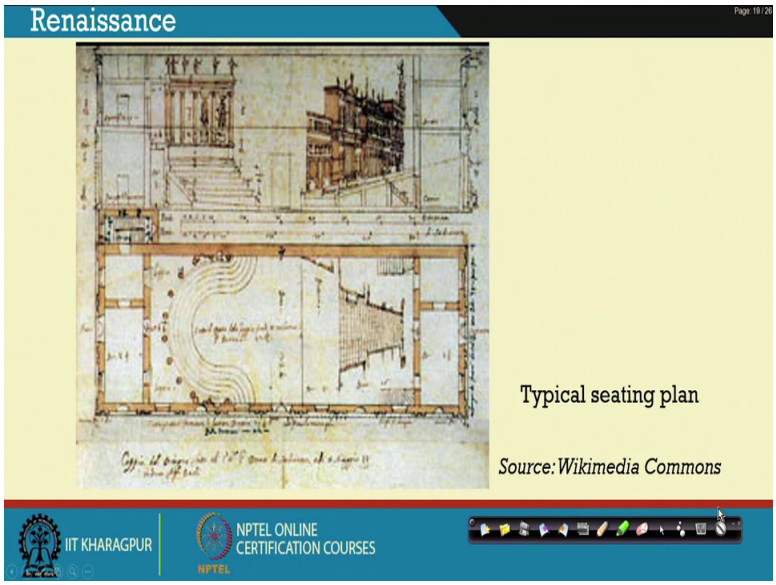

So, you can see the plans which were adopted during the renaissance period.

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The baroque period also the theatres, the instrumental music came in and you can see a proper interior planning of the seating which is quite different from the semicircular planning.

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The baroque period had high vaulted charges the; so, the charges those came out during that period also witnessed similar characteristic which is the earlier churches were practicing.

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The classical period actually saw; a revival of the visual and performing arts and music concerts when Haydn, Mozart, Bach, Bethoven; all started their music concerts. Truly to speak they composed their music's seating in the hall; so, it was the other way the hall did not help them, they had to sit and composed their music that would be heard very

nicely. So, the acoustics did not dictate their thing; the hall actually dictated how the composition would be. So, they had sat inside the halls and composed their music's to satisfy the audience.

So, the Shoebox halls came during that time evolved during that time which were very much rectangular with a back with a circular back and high ceilings giving multiple diffusive surfaces and low seating capacity. You can see two pictures in front of you, the Hanover Square, London and the Altes Gewandhaus house in Leipzig, Germany which are considered as the best examples of shoe back halls; shoebox halls, but the capacity is were very low and the seating plan if you observe are very much linear.

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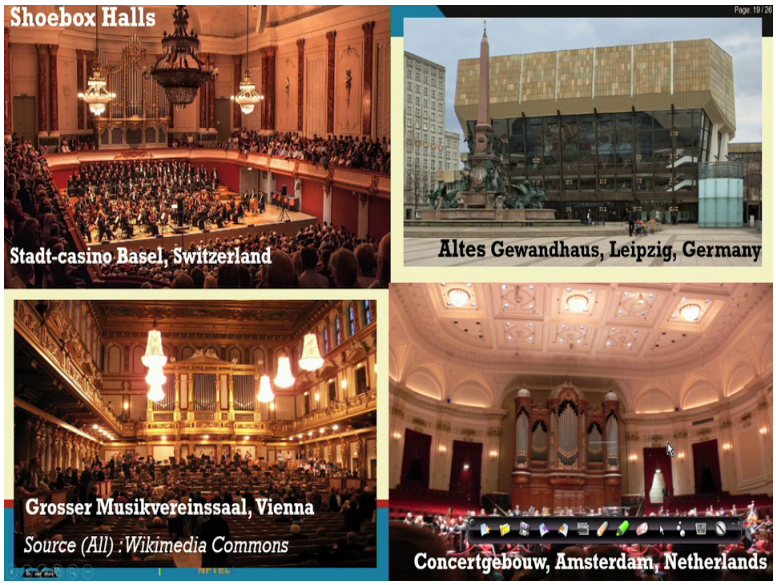

These are some more halls.

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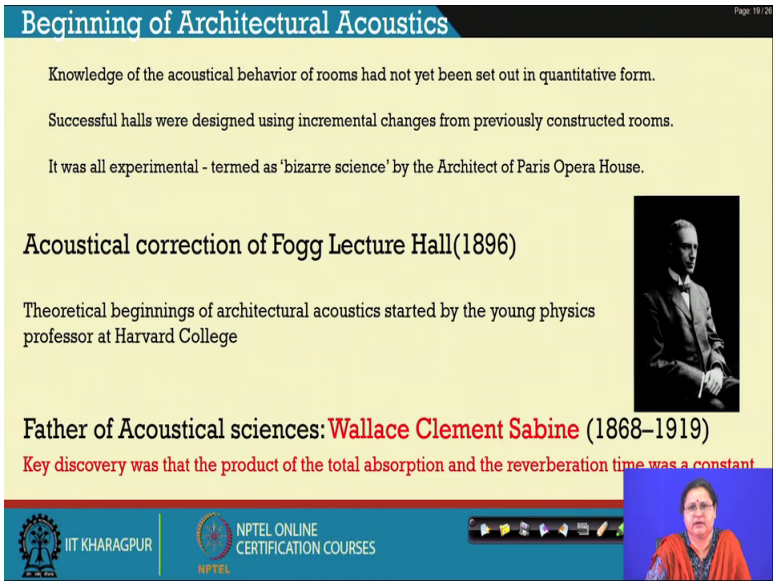

And it is understood that the knowledge of acoustical behavior of rooms had not yet been set out in quantitative terms.

It was quite experimental and incremental changes were made inside the rooms and successful halls where only achieved by adding or adopting certain changes. At some point of time the architect of Paris opera house said that it is bizarre science or a weird science. Later while designing the fog lecture hall in 1986; a young physicist professor of Harvard College was appointed for improving the acoustics of the Fogg lecture hall which had which was really sounding bad.

And it was offered to the scientist or the professor; young professor Wallace Clement Sabine who experimented over sleepless nights with the Sanders hall and the Fogg lecture hall by changing seating's, by changing cushions, by bringing in, adding cushions with a stopwatch and an organ pipe who actually found out that key discovered; found out that the product of the total absorption and the reverberation time was a constant. This laid to the starting of architectural acoustics and he is considered as the father of the acoustical sciences.

So, with this introduction; with the historical background I set the ball rolling and we look forward for many more interesting things of the subject.