

Glass in Buildings: Design and Application
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Lecture - 01
Introduction

Today's session we will take you through how to achieve or how to understand acoustics when use glass as a barrier, because glass been widely used both for interior application and exterior application. So, it is very imported to understand the basic acoustics, the definition of acoustics and noise.

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Let us clear some myths...

- 1 dB does not make a difference !
- 0 db mean silence!
- Same Combinations of glass improves acoustic...?
- One solution for all acoustic problem!
- Glass alone can reduce the Noise?
- Sum of glass = sum of reduction

The slide features the NPTEL logo and the Glass Academy logo in the top right corner. A presenter, Prof. Murali, is shown in a white shirt on the right side of the slide. The bottom of the slide has a decorative blue bar with white icons representing various building and engineering concepts.

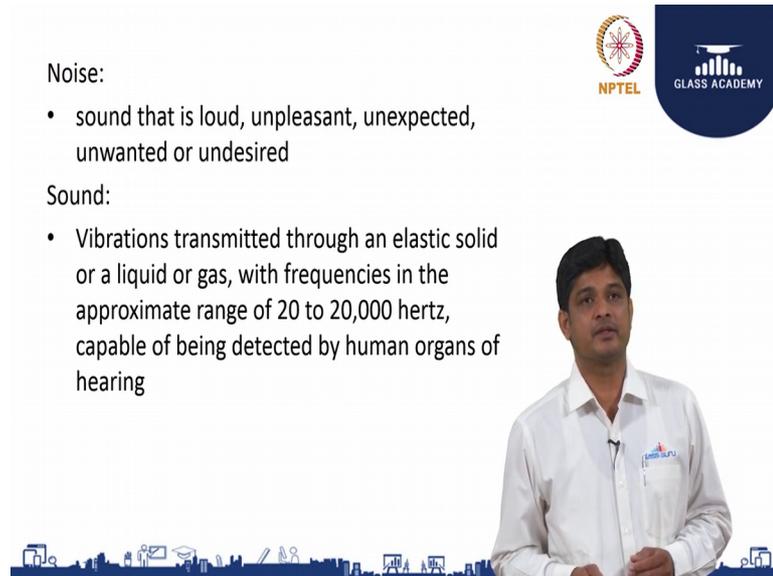
Before getting into generally moment we enter into glass and it acoustics, we always have myths. I would say few myths are listed here.

We believe that there is a reduction of 1 dB does not make any difference, and we always believe that only 0 means its silence. And if I use a same combination of glasses we believe it improves better acoustics or if improves performance. And always we believe one based on one particular combination and we achieve a particular value that cannot be used in any other location, because of the source values different. It means the one solution cannot be constant for any acoustic problem, because its source can be different

And in a glass, you have a glass and framing material. So, glass alone cannot achieve

any acoustics, whatever the overall acoustic we need to achieve it has to be through the glass and the system. Sum of glass means multilayer of same thickness of glass, it does not mean the reduction that possible by one individual glass versus sum of the same thickness of glass is going to be in the same ratio of sum of.

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The slide features a white background with a blue decorative border at the bottom. In the top right corner, there are two logos: the NPTEL logo (a circular emblem with a gear and a book) and the GLASS ACADEMY logo (a blue shield with a white building icon). The text on the slide is as follows:

Noise:

- sound that is loud, unpleasant, unexpected, unwanted or undesired

Sound:

- Vibrations transmitted through an elastic solid or a liquid or gas, with frequencies in the approximate range of 20 to 20,000 hertz, capable of being detected by human organs of hearing

A male speaker in a white shirt is positioned on the right side of the slide, partially overlapping the text area.

What is noise? Sound that is loud, unpleasant, unexpected, unwanted or undesired that is called noise. What is called sound? Vibrations those are transmitted through an elastic solid or a liquid or a gas with a frequency of approximate range 20 to 20000 hertz, and capable of being detected by human organs of hearing.

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deciBel

- deciBel is the logarithm of a ratio.
 - Threshold of hearing – $20 \mu\text{Pa}$
 - Threshold of Pain – 20 Pa
- A ratio of
 - Power
 - Sound Pressure
 - Voltage
 - Intensity...



So why decibel? It is a very important question to be understood, because our human ear is extremely and it is an amazing system it has. Because, human ear can understand the threshold of hearing for an human ear is about 20 micro Pascal, whereas the threshold of pain it is 20 Pascal; if you converted to frequency 20 Pascal it approximately at 1000 hertz frequency.

What is called decibel? It is a combination or it is a ratio of power the frequency that is going to hit, the pressure, the intensity, and the voltage. The combination of all or the ratio of all it is been measured call and by an individual number called decibel.

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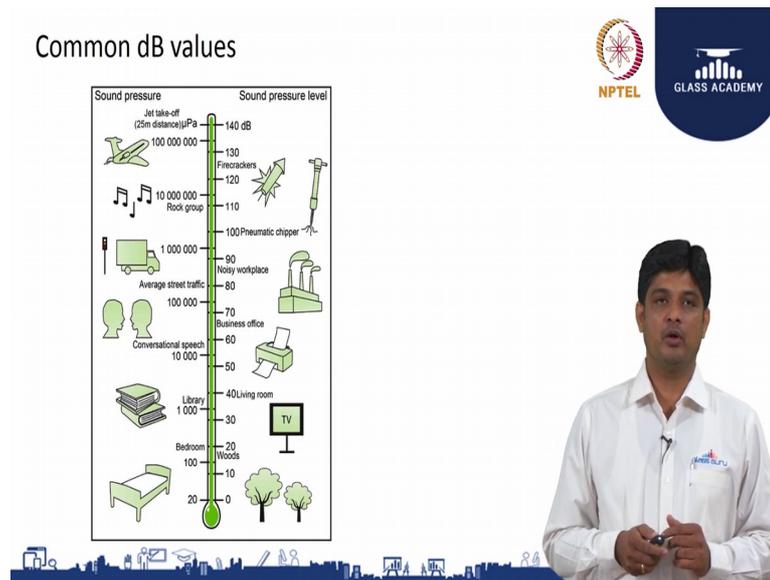
Sound intensity: Decibels (dB)

The image shows two side-by-side graphs of sound pressure (Pa) versus time (s). The left graph, labeled 'Silent', shows a small-amplitude wave. The right graph, labeled 'Noisy', shows a large-amplitude wave. In the top right corner, there are logos for NPTEL and GLASS ACADEMY. A presenter is visible on the right side of the slide.

So, when you have a source: source, you have a huge range of intensity which is the loudness, and there is a medium it going to transfer, and then there is a pitch it is called the frequency pitch; there is a low frequency and there is a high frequency pitches which is going to reach you. So, the 3 combination is going to decide whether it is going to be a pleasant, noise, or it going to be a disturbance.

So, the same I said. So, there is a frequency difference, when you see the silent versus noisy. The way it going to reach you with intensity it is going to be an impact on your ears.

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Commonly what you can, how you can able to withstand, or where you can have what kind of level of noises. Anywhere in an living space you can be at less than 40 dB, it includes your living and sleeping. So, sleeping usually suggested to be less than 35 dB. Where an working station or a business officers it can be even up to 60 to 65 dB. Anything more than 80 dB you call it as an noisy environment and anything more than 100 plus it will be a really a disturbance and more than 120 it became a unbearable.

That is where if you connected to my myth even a 1 dB reduction at this scale it is going to be huge reduction, because a impact of a noise after 40 to 45 dB the impact of noise at every 1 dB the impact will be double, so which you cannot bear. So, the level what you can be bearable versus not bearable is hardly 1 dB difference.

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Sound Interaction






So, how sound interacts? The sound interacts when there is an source going to hit an element or an object or an layer. So, there is a part it is going to get transferred, part it is going to be reflected, part it going to get diffuse which is because of the surface of your the medium it going to hit. And there can be, this all can happen based on the mass of your material, because mass again it relates to the frequency filtration process.

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TL Factors

Sound Transmission loss is given by two factors – R_w and STC

Description	ASTM E-413 (1994)	ISO 717-1 (1996)
Transmission Loss Factor	Sound Transmission Class (STC)	Weighted Sound Reduction Index (R_w)
Method	Contour fitting	Contour fitting
Band used	1/3 rd of Octave bands	1/3 rd of Octave bands
Frequency Range (in Hz)	100-3150	125-4000






So, when you come to glass and acoustics you have to be very clearer to important factors which is called your R_w and STC . STC is called Sound Transmission Class,

whereas R_w is called Weighted Sound Reduction Index. In both when you want to measure when you want to plot both has very similar methodology. Only the basic differences the frequency range and the contour standard contour graph which we going to plot there is a difference be in that. Whereas, when you measure STC you measure as per ASTM E-413, when you go to R_w you measure as per ISO 717. Plus, when the frequency ranges for STC is at 100 to 3150, whereas for R_w it is about 125 to 4000 hertz.

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Rw

- ◀ The 'weighted sound reduction'
- ◀ Single value index
- ◀ Measured in decibels (dB)

Rw + C	fast traffic (highway), railroad, airplane nearby, human activities
Rw + Ctr	slow traffic, urban traffic, disco music, airplane

What is called R_w ? It is an weighted sound reduction, it is a simple and single value index which is measured in decibel. As we understood whatever we receive on from the source to the observer side, we measure it with the single value index called decibel.

In case of specific to a building when you have a when you have a value whether it is R_w or even an STC, specifically in case of an R_w we need to be very careful based on the type of a source; based on the type of the source you have to understand or you have to have an adjustment factors which is nothing but $R_w + C$ or $R_w + Ctr$. C which is it is a adjustment factor, which relates to very fast high traffic railways or aeroplane where the pitch is very high. And then whereas, increase our traffic which is a slow traffic the vehicle moment general public disturbances or different musics which comes under Ctr .

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What Value to Use Where?
International Standard ISO 717-1



Source	R_a	$R_{a,tr}$
Children playing	X	
Domestic activities	X	
Disco music		X
Rapid road traffic (>80 km/h)	X	
Slow road traffic		X
Medium to high speed railroad traffic	X	
Slow railroad traffic		X
Air traffic short distance	X	
Air traffic long distance		X
Air traffic with propellers		X
Industry: medium and high frequencies	X	
Industry: medium and low frequencies.		X



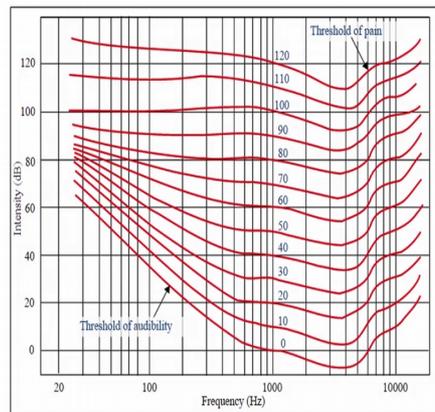
To make it clear say for example: if you take ISO 717 it clearly gives a table. What adjustment factor you have to used to achieve your R_w inside a building based on the type of the source?

Say for example, if a children is playing outside; you have to take your R_w value and you have to apply your $R_{a,tr}$ adjustment factor to it. So, that will be your final achievable or possible noise inside your building which going to come from the source. So, based on the different sources, whether it is from children, domestic, whether its disco music or a different types of road traffic, whether it is slow or high or again it is road or airways or again an industry; what kind of disturbance that comes from an industry.

So, there is very important understand that is something called R_w , and there is adjustment factor called R_a and $R_{a,tr}$ which is very specific to [apli/application]-internal application.

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What is this frequency range?



So, this is to show you how the frequency ranges based on different STCs. When from 0 to 120 whether it is STC or R w, this is how your frequency bandwidth will be there. To understand more if you take the lower STC ranges say less than 30. Your frequency that lower frequency the intensities are high the intensities are very high in, the range of 50 to 60, whereas a frequency is low so that the disturbance the noise which is going to enter or which is going to be affecting you as an individual will be very less; the impact is very less.

Moment you go above 70 and 80 you can see the intensity and the frequency impact are more or less same and which is going to really hit you in your psychological impact.

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What are Octave bands?

- In music, an octave band is a frequency band where the **highest frequency is twice the lowest frequency...**

1/3 rd band name	Frequency
1	100
1	125
2	160
3	200
4	250
5	315
6	400
7	500
8	630
9	800




To derive this graph first we need to understand what is called octave bands. Octave bands is nothing but we need to understand the one-third values, you have to plot your graph or you have to measure your impact of any barrier and you have to plot it in this octave bandwidth, which is nothing but the highest frequency is twice of the lowest frequency. So, this is given in an ISO. So, based on it whenever you measure any material you have to plot your graphs as per your one-third band bandwidth.

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STC Calculation Procedure

STC Reference Contour								
1/3-Octave Band [Hz]	125	160	200	250	315	400	500	630
Reference Contour [dB]	-16	-13	-10	-7	-4	-1	+0	+1
STC Reference Contour (continued)								
1/3-Octave Band [Hz]	800	1000	1250	1600	2000	2500	3150	4000
Reference Contour [dB]	+2	+3	+4	+4	+4	+4	+4	+4

- All contours are defined in the frequency range 125hz to 4kHz
 - 20 – 20000 Hz – human hearing range
 - 500 – 8000 Hz – most sensitive range
- Standards applicable:
 - ASTM E-90-99 Laboratory Measurement of Airborne Sound Transmission of Building Partitions and Elements
 - ASTM E-413-87 Classification for Rating Sound Insulation
- Reference contour is one which has STC Zero
- Methodology
 - Source - Orfield Laboratories Test Result




Then you align it to your standard contour graph so that to understand your STC or R w.

I will take you through how to calculate after you measured something, because measurement usually it cannot be done at has at regular standard locations. You need a laboratory setup condition or you need a very specific setup to measure acoustics based on from different frequency say from 100 or from 125 to 4000, then you have to plot completely the graph and then you have to assign it to a contour.

So, when you plot a graph, it is very important that the measurements values are very important. Because your human ear ranging frequency starts from 20 to 20000 hertz, but whereas very it is very it is became very critical when it is became 500 to 8000 hertz. Usually that is why STC values or R_w values are calculated at the frequency bandwidth of 500.

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TEST RESULTS

Manufacturer: Audio Alloy, L.L.C.
 Specimen: Interior wall assembly
 Date Tested: April 14, 2005
 Method: ASTM E 90, ASTM E 413
 Test Number: 05-0416

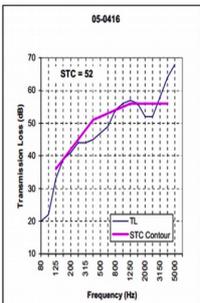
Methodology

- Measure TL
- Select trial contour (curve fitting)
- Identify deficiencies
- Increase trial contour no. in 1dB interval such that,
 - Δ deficiencies < 32dB
 - Max deficiency < 8dB
- Value @ 500Hz is STC

Courtesy - Orfield Laboratories Test Result (On the left)







So, this is a standard graph you can plotter graph you can see. For a particular STC say 52 you have an STC contour line which is drawn and there is an measurement line which is called the TL- the transmission line which is drawn. So, the methodology to do this is: first I have to measure the transmission loss. So, I have a source and have a receiver, there is a different frequency been emitted, there is an barrier, and there is an receiver. So, based on the different frequency been measured inside the transmission loss curve been plotted from say 125 to 3150 and even up to 4000 hertz. Once the transmission [la/loss] loss graph has been drawn then I have to find my trail contour line, I have to fit that contour line into the graph. How to fit I have some basic methodology to be

followed.

Usually I have to start fitting the contour mapping at 500 considering at 500 into 0. So, when I plotted the because of the shape of the contour mapping, because of your transmission losses graph based on your different frequency and pitches, there will be ups and downs. So, there is a particular condition I have to achieve that. The maximum deficiency or the distance between the transmission loss curve and your contour graph contour line cannot be go beyond 8 dB.

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Methodology



Frequency (Hz)	STC Contour Adjustment	Transmission Loss	Transmission Loss - Adjusted ^a	STC you wish to test	Deficiencies ^a
125	+16	35	51	55	4
160	+13	41	54	55	1
200	+10	42	52	55	3
250	+7	45	52	55	3
315	+4	47	51	55	4
400	+1	50	51	55	4
500	0	53	53	55	2
630	-1	56	55	55	0
800	-2	59	57	55	0
1000	-3	60	57	55	0
1250	-4	59	55	55	0
1600	-4	61	57	55	0
2000	-4	61	57	55	0
2500	-4	62	58	55	0
3150	-4	67	63	55	0
4000	-4	70	66	55	0
Total deficiencies					21

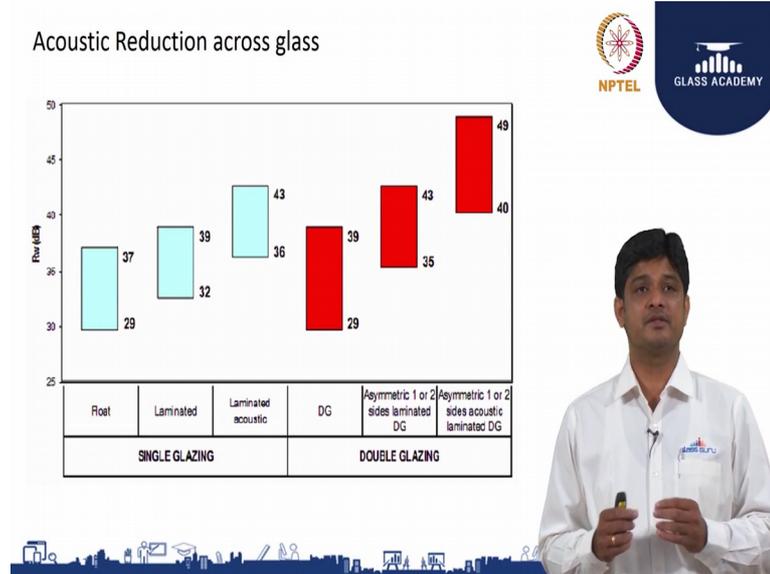
^a To calculate adjusted transmission loss, add the STC contour adjustment to the transmission loss attained from the lab



So, when I plot this at 50, when I assume that it is 0 then I have both the positive and negative which I have to sum it up. In these two important parameters to be considered as: the total deficiency cannot be greater than 32. Even in this case if you see there is a plus 16. So, this contour line has to be further adjusted so that the maximum gap has to be 8 dB.

When I plot that considering these two criteria then I will be able to achieve the contour and my TL. Then whatever it is at 500 is my STC value which is the whatever value in my contour line at 500 hertz will be my STC or R w value.

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So, to understand how it respect to the glass and normal float glass based on different thicknesses, whether it can be from 4 mm to 12 mm. When it is a single unit the ranges will be from 29 to 37 dB, because for 4 mm, so every next glass thicknesses there will be improvement in your performance. Moment I laminated, moment I laminate means I am going to sandwiching two glasses with a material called PVB or it can with sentry based on the number of layers and type of bonding element I use; the ranges can be from 32 to 39 dB. The same combination for lamination, I can even use an acoustic at material which is used which can be which can further improve the efficiency or which can further reduce the noise transferring; so, which can improve from 32 to 36. So it can reach up to your 43 dB.

To further achieve, if I have to further reduce my noise level coming into my building from my source then, the next option available for me is to make a double glazing unit. In the double glazing unit I can go for symmetric glass asymmetric glasses, where based on the kind of thickness of glass combination I used that can be reduction varied, or I can use a laminated glass in a double glazing format which can further increase my acoustic performance.

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Acoustic Performance of Glass



- Why is laminated glass better in TL than a float glass of equivalent thickness?
 - Damping by PVB
 - Coincidental effect of glass is reduced.
- Why is sentry interlayer good in acoustic performance?
 - Due to its stiffness
 - But limited to low frequencies and very high frequencies



How the acoustic glass is going to perform? It going to perform on basically based on two important parameters: one is the thickness of the glass which is going to be a major factor, second one is the PVB which is actually behaving like a dampening material. Whereas, there is another option called sentry interlayer which can further improve the acoustic performance, because it is the stiffness of the material, the dampening property of the material is further enhanced which can have a better impact on the overall acoustic.

So, to recap it: so we have gone through what is called the basics of acoustics mean it has to be measured in a decibel which is a single unit for number. It varies based on the type you do or the kind of standard you refer to, whether it is as per ISO or as per year. So, there is two parameters called R_w and STC . When you go very deep into it the STC R_w the range will be within a deviation of 1 to 2 dB you can derive it its only a matter of the standard and the frequency you take through.

So, based on the source again you have to use an adjustment factors which is called R_a and $R_{a,tr}$. Moment you are able to understand the basic terminology then you should be able to understand how to plot it. So, to plot it we need to plot first the transmission loss graph, then I have to plot a contour, the maximum difference between the contour and my transmission loss is has to be 8 dB. After plotting it I have to calculate the overall deficiency which cannot go more than 30. So, once it is done at 500 whatever is the

contour that will become my at STC value.

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Single glazing:

- ◆The thicker the better!!!!
- ◆Thicker = heavier = less tendency to vibrate
- ◆Drop in performance occurs at resonant frequency
- ◆Maximum possible to achieve 36 db (12mm thick)

Laminated

- ◆The thicker the better!!!!
- ◆PVB interlayer provides a sound absorptive barrier
- ◆'De-couples' the individual glasses
- ◆Reduces resonant frequency problem
- ◆Maximum possible to achieve (37-42db)
- ◆Laminated DGU – to achieve the beyond 42db till 46db
- ◆Laminated DGU with both lite as laminated glass – STC range from 47-55db.

So, specific to glass more thicker is better, because it is heavy; so the if there is a less tendency to vibrate or to resonants. So, but in a single glazing maximum available his will be a 12 mm thick in a single glaze, you can use it in an architectural application. So, maximum you can achieve is about 36 dB to 37 dB.

So further if you want to improve, you have to go in to a lamination format. Again in lamination as always thicker is better but here, because of the benefit of the PVB or your sentry which behaves like an acoustic barrier which helps you to decouples your individual glasses. So, there is two layer of glass and there is an PVB. So, there is and suggested to always go with an asymmetric glasses, because every thickness of the glass because sound travels with the mass. So, every different mass behaves like different filters. So, when you use asymmetric glasses the frequency the frequency capacity to pass through will be varying

So, when you use an asymmetric glass with a PVB. So, the glass one able to block particular frequency and the PVB and then the glass two will be able to block a particular frequency or different frequencies. So, when it is sum of this all there will be a positive or there will be a better reduction. Whereas, when you do simple lamination you can achieve maximum this about 37 to 42 dB.

When the really the source level is about 80 dB outside your building and you wanted to achieve something less than 40 dB or even 35 dB where it is in case of an hotel, where you wanted to have a complete silence I mean complete silence here means anything less than 25 dB; it is very tough to understand I can take an one classic example is the normal air conditioning noise what you were use to it which is in the range of 35 to 37 (()).

So, in hotel which where you have to achieve less than 35 dB from a source of 80. so, you have to reduce more than 45 db. So, 45 dB cannot be achieved only through glass; so glass and a system. So, when you select a glass, it better to suggest or better to take 2 or 3 dB like higher R w or STC, so that even there is a possibility of loss through your system or leakages still you will be able to achieve the 45 dB.

So, to achieve anything more than 40 to 40 3, you have to go for a double glazing unit, where you have to outer light laminated or if you wanted to achieve anything more than 45-46 dB it suggested to have even more the lights laminated. Again to achieve a particular STC range you have to find that different glass thicknesses have very huge impact on your different frequency. So, again it is coming back to what is the purpose and for what source we are going to reduce it. That is where your TL graph is very important to understand, based on your source you have to plot your graph and based on your source, you have to understand your contour and then derive your STC considering your source and your adjustment factors. Once you are able to understand these 3 important parameters: your R w, your adjustment factors, and your source which is very important so that you can play well with an acoustics.

Thank you. I hope this session will help you understanding very basics about acoustics, terminologies an acoustics, and how to understand glass and how to take it positive how to [ink/reduce]- reduce the noise transferring into your building.

Thank you.