IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 19, Issue 5 Ser. II (Sep. – Oct. 2022), PP 24-31
www.iosrjournals.org

An Experimental Study on Double and Triple Glazed Windows Combinations for Noise Reduction

Abishek Uma Shankar
Postgraduate student,
Infrastructure Construction and Management
RASTA-Center for road technology
Bangalore,Karnataka,India.

Aravind Sagar B
Assistant Professor,
InfrastructureConstruction and Management
RASTA-Center for road technology
Bangalore,Karnataka,India.

Abstract
In the new world, nations developing rapidly for economic stability due to which higher growth is seen in urbanization, because of which noise pollution is increasing day by day causing one of a kind of stress to humans who are exposed to those areas. If these stresses are unattended or minimized the human mental health will get deteriorated due to which the productivity of humans in a given environment will affect. Noise control and its principle play a keen role in creating an acoustically pleasing environment. This is achieved by bringing down the sound pressure level which is not harmful to humans. In the experimental study the reduction of SPLs is seen in the presence of noise controlling/noise absorbing barrierGlass. Various test on single, double, triple and composite arrangements with polycarbonate sheet is carried out in which some of the combinations give reduction levels up to 40%. An average good reduction range of 25% to 35% is seen in the study. The testing points were 150 Hz, 3500 Hz, 5000 Hz and ringing bell sound.
Keywords:
Double glass combinations, triple glass combinations, Frequency, Decibels,Sound, Noise, Sound Absorption, Noise reduction, Acoustics, Insulations.

Date of Submission: 10-10-2022 Date of Acceptance: 23-10-2022

I. Introduction

Music is one such field that has been developing in the recent few decades. The busy hectic day and stressed mind can get stress-free when pleasant music is heard. Music has a lot of benefits in stabilizing the mind. With the developed technology and budding infrastructure, there is a great advantage of having entertainment at home. With proper ideas and implementation, this work could be like the icing on the cake, but the smallest human errors can make a huge difference like adding salt instead of sugar to the batter of the cake. This makes the cake inedible, the same would imply here making the enjoyable experience an annoying and irritable one. The experience is because of music which is nothing but sound.

The main focus of the thesis paper is understanding how glass and sound/noise have a relationship which helps in acoustical glass solution ideas. It is understood that glass has a reduction effect when it is used as a barrier and to how far is this true. Most urbanized cities do not want to compromise on the aesthetics of the structure hence is it possible to bring down sound pressure levels without disturbing the aesthetics. If so, then to what extent?

This is to achieve the reduction in noise which is a great concern today. It is understood that this can be achieved by understanding the property and how the material behaves when it is in contact with sound waves and how it interacts with the sound.

Sound wave transfers energy which results in the damping effect of the sound. If this is understood, a correct and scientifically feasible solution is given, which is a great relief as control of energy in buildings is an issue of great importance in concern of the greenhouse and global warming.

The noise levels from different sources are seen to be growing day by day in urban and suburban areas. Protection from noise is a top priority that ensures acoustical comfort for humanity. It is understood that externally produced sounds cannot be controlled but internally produced sounds can be controlled and nullified to an extent. The reduction of the internal noises can be attained by choosing the appropriate material with good sound insulating properties.

II. Research Methodology

2.1 Experimental Set-up

The experiment was carried out in a room showing low decibel and noise levels with moderate lighting conditions. The experimental set-up consists of the box, speaker and decibel meter. The speaker was placed at a height of 1ft from the ground level and was positioned at the center of the experimental box. The glasses were placed at a distance of 1ft from the source that is the speaker. Apart from the speaker and its stand, no other material was kept in the experimental box. After setting up the speaker and connecting it to the mobile the top of the box was closed. Now in the frame section, the top was opened and the glass was placed here. The glasses were kept in different combinations and a series of experimental analyses were carried out. Here the plain, toughened, combinations of plain and toughened, a combination of plain, toughened and poly carbonated are placed.

Outside the box at a distance of 3 ft from the source, the decibel meter was placed. The height of the decibel meter was 1ft. Every time the experiment was conducted constraints such as humidity and temperature were recorded. The experiment was conducted usually when the lab was mostly unfunctional as no other outer sound was required as it would be some kind of disturbance. For every trail, 3 readings were taken. Tests were carried out for both the frequencies and a particular sound that is the ringing bell sound. The different frequencies that were considered are 150 Hz, 3500 Hz, and 5000 Hz.

The above frequencies were considered from the previous paper as these frequencies behaved differently. The 150 Hz is a relatively low frequency and 5000 Hz is a high frequency, beyond 5000 Hz there is no major difference in the noise reduction level this frequency could be considered as the benchmark for the above. The 3500 Hz was considered as it was the relative loudest among all the frequencies in the range of 20 Hz to 20,000 Hz for the selected speaker having a power of 3 watts. The 3500 Hz created some sort of irritation on continuous exposure; hence these are major points of analysis. A sound producing app was used to control the output frequency.

At the time of the experiment, it was seen that all the fans were switched off and all doors and windows were shut. This was to bring the SPL of the room to 40 dB or below. The fan turned on also was a disturbing factor at the time of the conduction of the experiment. It was seen that at the time of conduction there was no source of external noise.

The experimental procedure also considers taking note of the temperature and humidity at all times of conducting the experimental study.

2.2 Safety in Experimental Process

The noise-reducing material in this study is glass. Glass commonly is a heated form of sand, but chemically it is a combination of 75 % of silica, 10 % of lime and 15 % of soda. It is known that glass is a fragile material and may break when exposed to sudden force.

Sound is also a form of energy that causes distress in humans when exposed for long periods of time hence, some precautions are needed.

The glasses were neatly packed and kept in cushioning material.

At times of the conduction hand gloves had to be worn.

- Eye gears
- Hand gloves
- Ear plugs

III. Experimental Process

3.1 Combination of Two Glasses and Three Glasses– Composite Arrangement

The glasses were arranged in double glass combinations and triple glass combination respectively with spaces in between. The space in between was a constant gap that was maintained by the spacers. The purpose of the study was to identify how the interaction would be in the glass arrangement with spaces. The space of half-inch was constant at this part of the study. The sound would come in contact with the glass and move through a medium of air and again propagate through the glass. Later the SPLs are noted and further analysis is carried out to find the best combination of doubly arranged glasses.

A series of tests were carried out for 150 Hz, 3500 Hz and 5000 Hz.

A total of 56 arrangements were found for the 8 types of glasses that are available for the double glass arrangement and 336 combinations for the triple glass arrangement but only the feasible combinations were adapted for the triple glass combinations. All steps of the experimental setup were followed to maintain the purity in the conduction of the experiment.

Table 3.3.1: SPLs of double glass arrangement

SL. No.	Double Glass Arrangement	150 Hz (dB)	3500 Hz (dB)	5000 Hz (dB)
	Humidity	83%		
	Temperature	30.2^{o}c		
1	EMPTY ROOM	39.7	39.7	39.7
2	SPEAKER ON, NO GLASS	62.1	96.5	97.8
3	8T 6T	46.5	71.2	77.1
4	8T 5T	49.7	75.7	67.5
5	8T 4T	49.1	72.1	77.1
6	8T 8P	46.1	74.7	71.8
7	8T 6P	47.8	71.3	77
8	8T 5P	48.8	69.3	72.6
9	8T 4P	46.2	71.5	74.9
10	6T 8T	45.9	63.3	70.4
11	6T 5T	47	76.3	75.2
12	6T 4T	46.9	79.4	73
13	6T 8P	44.8	64	64.2
14	6T 6P	44.4	70.4	76.8
15	6T 5P	46.8	74.6	70.6
16	6T 4P	46.6	74.4	73.6
17	5T 8T	45.4	68.2	71.8
18	5T 6T	45.5	70	69.7
19	5T 4T	47.4	71.2	64.4
20	5T 8P	45.8	67.4	67.4
21	5T 6P	44.4	72.7	74.9
22	5T 5P	48.3	79.5	73.5
23	5T 4P	46.2	76.7	72.9
24	4T 8T	46.7	79.9	74.1
25	4T 6T	47.4	65.5	68.9
26	4T 5T	45.7	69.1	63.3
27	4T 8P	46.4	69.1	72.9
28	4T 6P	47.7	68.4	70.8
29	4T 5P	47.1	72.1	74.3
30	4T 4P	46.9	70.1	65.8
31	8P 8T	46.8	79.2	74.6
32	8P 6T	46.4	66.3	80.1
33	8P 5T	47.6	67.1	66.9
34	8P 4T	47.6	69.9	79.9
35	8P 6P	47.8	70.3	75.9
36	8T 5P	47.7	69.4	72.8
37	8T 4P	48.3	70.3	76.3
38	6P 8T	48.9	71.5	75.8
39	6P 6T	44.2	64.4	63.2
40	6P 5T	49.7	66.8	67.9

41	6P 4T	46.8	64.6	70.6
42	6P 8P	49.8	70.2	63.4
43	6P 5P	51.5	62.5	69.5
44	6P 4P	47.4	74.5	73.7
45	5P 8T	47.8	67.5	73.3
46	5P 6T	48.2	79.6	67.1
47	5P 5T	46.6	70.4	76.2
48	5P 4T	45.4	63.7	62.5
49	5T 8P	47.7	66.9	78.2
50	5P 6P	47.6	72.7	72.3
51	5P 4P	49.9	67.7	72.9
52	4P 8T	47.4	68.1	66.4
53	4P 6T	48.3	68.1	64.4
54	4P 5T	48.2	67.6	61.5
55	4P 4T	47.1	73.5	74.2
56	4P 8P	47.3	72.8	71.9
57	4P 6P	47.2	63.7	66.4
58	4P 5P	47.8	68	71.8

Table 3.1.2: SPLs of triple glass combination

SL. No.	Particulars	150 Hz (dB)	3500 Hz (dB)	5000 Hz (dB)
	Humidity		79%	
	Temperature		28.2	
1	Speaker OFF	40.1	40.1	40.1
2	Speaker ON, no glass	60.8	92.6	95.4
3	6T 4T 5T	47.3	63.8	64.7
4	5T 6T 4T	45.6	65.6	68.9
5	4T 5T 6T	52.2	68.3	69.6
6	6T 5T 6P	42.1	52.3	52.6
7	6T 5P 5T	44.8	65.3	68.2
8	6P 4T 6T	43.1	54.2	56.7
9	8P 6T 8T	49.8	66.1	67.9
10	6T 4T 8T	48.1	63.2	66.7
11	6P 8P 6T	44.2	63.4	69.7
12	6T 8T 4T	47.9	67.5	67.1

IV. Results and Analysis.

4.1 Combination of Two Glasses

Table 4.1.1: SPLs and % reductions for double glass arrangement

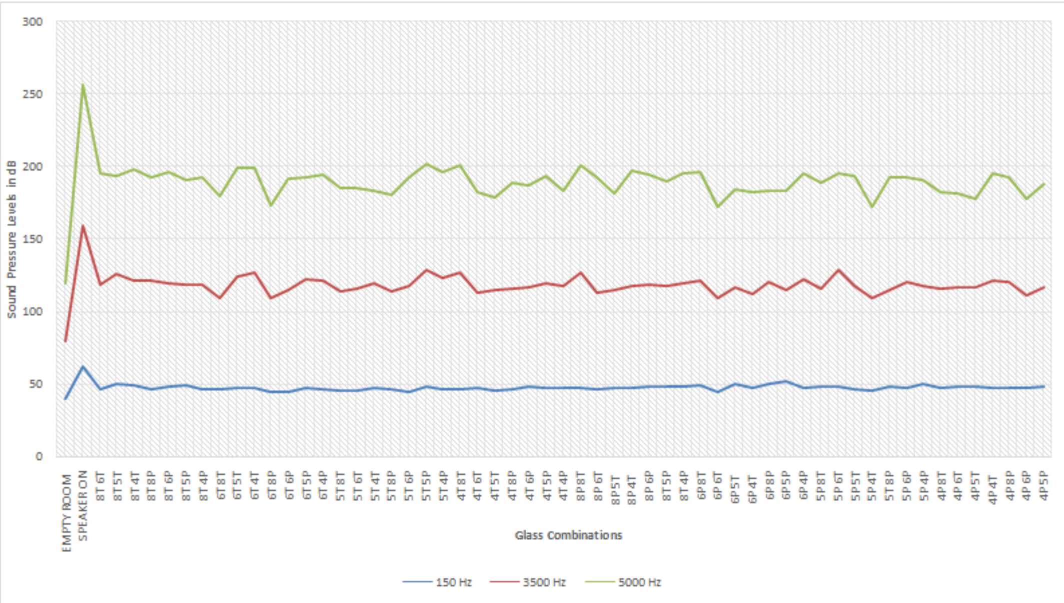
SL. No.	Particulars	150 Hz (dB)	3500 Hz (dB)	5000 Hz (dB)	% Reduction at 150 Hz (%)	% Reduction at 3500 Hz (%)	% Reduction at 5000 Hz (%)
1	EMPTY ROOM	39.7	39.7	39.7	N/A	N/A	N/A
2	SPEAKER ON, NO GLASS	62.1	96.5	97.8	N/A	N/A	N/A
3	8T 6T	46.5	71.2	77.1	25.1	26.2	21.2
4	8T 5T	49.7	75.7	67.5	20.0	21.6	31.0
5	8T 4T	49.1	72.1	77.1	20.9	25.3	21.2
6	8T 8P	46.1	74.7	71.8	25.8	22.6	26.6
7	8T 6P	47.8	71.3	77	23.0	26.1	21.3
8	8T 5P	48.8	69.3	72.6	21.4	28.2	25.8
9	8T 4P	46.2	71.5	74.9	25.6	25.9	23.4
10	6T 8T	45.9	63.3	70.4	26.1	34.4	28.0

11	6T 5T	47	76.3	75.2	24.3	20.9	23.1
12	6T 4T	46.9	79.4	73	24.5	17.7	25.4
13	6T 8P	44.8	64	64.2	27.9	33.7	34.4
14	6T 6P	44.4	70.4	76.8	28.5	27.0	21.5
15	6T 5P	46.8	74.6	70.6	24.6	22.7	27.8
16	6T 4P	46.6	74.4	73.6	25.0	22.9	24.7
17	5T 8T	45.4	68.2	71.8	26.9	29.3	26.6
18	5T 6T	45.5	70	69.7	26.7	27.5	28.7
19	5T 4T	47.4	71.2	64.4	23.7	26.2	34.2
20	5T 8P	45.8	67.4	67.4	26.2	30.2	31.1
21	5T 6P	44.4	72.7	74.9	28.5	24.7	23.4
22	5T 5P	48.3	79.5	73.5	22.2	17.6	24.8
23	5T 4P	46.2	76.7	72.9	25.6	20.5	25.5
24	4T 8T	46.7	79.9	74.1	24.8	17.2	24.2
25	4T 6T	47.4	65.5	68.9	23.7	32.1	29.6
26	4T 5T	45.7	69.1	63.3	26.4	28.4	35.3
27	4T 8P	46.4	69.1	72.9	25.3	28.4	25.5
28	4T 6P	47.7	68.4	70.8	23.2	29.1	27.6
29	4T 5P	47.1	72.1	74.3	24.2	25.3	24.0
30	4T 4P	46.9	70.1	65.8	24.5	27.4	32.7
31	8P 8T	46.8	79.2	74.6	24.6	17.9	23.7
32	8P 6T	46.4	66.3	80.1	25.3	31.3	18.1
33	8P 5T	47.6	67.1	66.9	23.3	30.5	31.6
34	8P 4T	47.6	69.9	79.9	23.3	27.6	18.3
35	8P 6P	47.8	70.3	75.9	23.0	27.2	22.4
36	8T 5P	47.7	69.4	72.8	23.2	28.1	25.6
37	8T 4P	48.3	70.3	76.3	22.2	27.2	22.0
38	6P 8T	48.9	71.5	75.8	21.3	25.9	22.5
39	6P 6T	44.2	64.4	63.2	28.8	33.3	35.4
40	6P 5T	49.7	66.8	67.9	20.0	30.8	30.6
41	6P 4T	46.8	64.6	70.6	24.6	33.1	27.8
42	6P 8P	49.8	70.2	63.4	19.8	27.3	35.2
43	6P 5P	51.5	62.5	69.5	17.1	35.2	28.9
44	6P 4P	47.4	74.5	73.7	23.7	22.8	24.6
45	5P 8T	47.8	67.5	73.3	23.0	30.1	25.1
46	5P 6T	48.2	79.6	67.1	22.4	17.5	31.4
47	5P 5T	46.6	70.4	76.2	25.0	27.0	22.1
48	5P 4T	45.4	63.7	62.5	26.9	34.0	36.1
49	5T 8P	47.7	66.9	78.2	23.2	30.7	20.0
50	5P 6P	47.6	72.7	72.3	23.3	24.7	26.1
51	5P 4P	49.9	67.7	72.9	19.6	29.8	25.5
52	4P 8T	47.4	68.1	66.4	23.7	29.4	32.1
53	4P 6T	48.3	68.1	64.4	22.2	29.4	34.2
54	4P 5T	48.2	67.6	61.5	22.4	29.9	37.1
55	4P 4T	47.1	73.5	74.2	24.2	23.8	24.1
56	4P 8P	47.3	72.8	71.9	23.8	24.6	26.5

57	4P 6P	47.2	63.7	66.4	24.0	34.0	32.1
58	4P 5P	47.8	68	71.8	23.0	29.5	26.6

From the graph, it can be seen that for 150 Hz the double glass combination has no major reduction effect. In the 3500 Hz the slight variations through the combinational arrangements. But when the same is seen in the 5000 Hz there are major differences in the reductions. The best combination from the table is found to be 37 %. The combinations that are making the reduction SPLs are having 6mm plain or toughened glass. It is even seen that the combination of 5mm and 4mm also have great reducing factors. There are some combinations along that have very low reducing SPLs. The lowest possible reduction in the combination was 17%.

Graph 4.1.1: Graph of SPLs double glass combinations



4.2 Combinations of Three Glass.

Table 4.2.1: SPLs and reductions for triple glass

SL. No.	Particulars	150 Hz (dB)	3500 Hz (dB)	5000 Hz (dB)	% Reduction at 150 Hz (%)	% Reduction at 3500 Hz (%)	% Reduction at 5000 Hz (%)
1	Speaker OFF	40.1	40.1	40.1	N/A	N/A	N/A
2	Speaker ON	60.8	92.6	95.4	N/A	N/A	N/A
3	6T 4T 5T	47.3	63.8	64.7	22.2	31.1	32.2
4	5T 6T 4T	45.6	65.6	68.9	25.0	29.2	27.8
5	4T 5T 6T	52.2	68.3	69.6	14.1	26.2	27.0
6	6P 5T 6T	42.1	52.3	52.6	30.8	43.5	44.9
7	6T 5P 5T	44.8	65.3	68.2	26.3	29.5	28.5
8	6P 4T 6T	43.1	54.2	56.7	29.1	41.5	40.6
9	8P 6T 8T	49.8	66.1	67.9	18.1	28.6	28.8
10	6T 4T 8T	48.1	63.2	66.7	20.9	31.7	30.1
11	6P 8P 6T	44.2	63.4	69.7	27.3	31.5	26.9
12	6T 8T 4T	47.9	67.5	67.1	21.2	27.1	29.7

From the above table and comparing the same with the graph below it can be said that the three glass combinations were the most effective combination as they represent the highest level of reduction in the entire study, a reduction level of more than 44 % is seen that is nearly reducing 43 decibels. The best combination was found to be with 6mm and 5mm, but not with 8mm. This clears the fact that densities do have a reducing point but the reduction in SPLs is not only dependent on the densities. All glasses purely with the toughened combinations also do not give desiring results. From the graph for combination 6P 5T 6T which is the best combination in the trials conducted for the 3 glasses combination, we can see that at this point the graph touches the lowest levels. This is the best combination of the methodology adopted in this study.

Out of the desired and selected combinations, some combinations have been found to be failing too, that is they do not produce satisfactory results. The reduction in SPLs are more than 40 decibels, for three glass combinations.

Graph 4.2.1: Graphs of SPLs of triple Glass Combinations

V. Concluding Remarks

Based on the studies on noise reduction using glass as a barrier material, the following concluding remarks are in accordance with the experimental study conducted.

- The 6mm plain glass and 6mm toughened glass arrangement in double glass arrangement showcase high noise-reducing levels. A reduction of 35% in decibels is observed.
- A combination of 6mm plain glass and 5 mm plain glass also displayed good results.
- In the 3-glass arrangement, 6mm toughened glass 5mm plain glass and 6mm plain glass show excellent reductions in SPLs, up to 44% is noted.

References

[1]. J.D. Quirt, "Sound transmission through windows," February 1988.

[2]. Phillip S Davies, "Energy efficient laminated glass constructions," Glass Processing Days, September 1997.

[3]. Terrence A. Dear, "Acoustics for glass and laminates," Glass Processing Days, September 1997.

[4]. Ray V. Foss, Terrence A. Dear, Mohamed Ali Hamdi and Samir Assaf, "Façade noise control with glass and laminates," Glass Processing Days, June 1999.

[5]. Scotty John Wertel, "Experimental analysis of noise reduction properties of sound absorbing foam," The Graduate College university of Wisconsin-Stout, May 2000.

[6]. Antonio J.B. Tadeu, Diogo M. R. Mateus, "Sound transmission through single, double and triple glazing. Experimental evaluation," Applied Acoustics 62, 2001.

[7]. Dr. Uwe Keller, "Improved sound reduction with laminated glass," glass Processing Days, 18-21 June 2001.

[8]. Hoda S. Seddeq, "Factors influencing acoustic performance of sound absorptive materials," Australian Journal of Basic and Applied sciences 2009.

[9]. Xiaodong Zhu, Birm-June Kim, Qingwen Wang and Qinglin Wu, "Recent advances in the sound insulation properties of Bio-Materials," bioresources.com, 2014.

[10]. Kestutsis Miskinis, Vidmantas Dikavicius, Raimondas Bliudzius and Karolis Banionis, "Comparison of sound insulation of windows with double glass units," Applied Acoustics 92, 2015.

[11]. M S Kanteyan, S Utami, I Prasetiyo and R J Yanti, "Sound insulation design improvement for reducing noise of paper factory office," journal of physics: Conference Series 1075 (2018) 012060.

[12]. Ajitanshu Vedrtnam, "Experimental and simulation studies on acoustical characterization of laminated glass," Glass Technology: European Journal of Glass Science and Technology, April 2018.

[13]. Wei Chen, Sheng Hu, Hao Cao, Tao Huang, Xiaowen Wu, Ling Lu and Jiwen Peng, "Review on research process of sound reductio Materials," Material Science and Engineering 612, 2019.

[14]. Walid Labri, Chaima Soussi, Jean- Francois Deu and Rubens Sampaio, "sound transmission loss through double glazing windows in low frequency range," XV International Symposium on Dynamic Problems of Mechanics, March 2019.
[15]. Chaima Soussi, Mathieu Aucejo, Walid Labri, and Jean- Francois Deu, "Sound transmission through double glazed window: numerical and experimental analyses" 23rd International Congress on Acoustics, September 2019.

Abishek Uma Shankar, et. al. "An Experimental Study on Double and Triple Glazed Windows Combinations for Noise Reduction". *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 19(5), 2022, pp. 24-31.