Volume 216 • 2018
ISSN 1877-7058

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Procedia Engineering

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Building glass OITC in warm temperature

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Abstract

Glass installed for building façade ideally possesses significant level of outdoor indoor transmission class (OITC) so it does not decrease OITC of conventional wall façade significantly. This study is about OITC of glass building in the temperature warmer than the one outlined by ASTM E-90, as it is commonly experienced in a tropical environment. Monolithic, laminated and tempered glass were tested using ASTM E-90 and calculation of OITC was conducted using ASTM E1332-90. Modification of room temperature was made to replicate warmer temperature like the temperature in a tropical environment, whilst other specifications was made based on ASTM E-90. The test showed that at higher frequency of 630 Hz and above, laminated glass performed slightly better insulation compared to monolithic and tempered but the OITC of laminated glass was dropped to 29, caused by a very sharp coincidence dip at frequency of 125 Hz which was 17 dB only. This explains that within temperature approximately 5°C warmer than the one outlined by ASTM E-90, laminated glass used for building façade would not perform noise insulation better; it is different from many earlier studies which concluded laminated glass had better sound insulation compared to monolithic and tempered glass in term of STC and OITC.

Peer-review under responsibility of the organizing committee of ICSDEC 2016

Keywords: monolithic glass, laminated glass, tempered glass, warm temperature, OITC

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Peer-review under responsibility of the organizing committee of ICSDEC 2016
doi:10.1016/j.proeng.2016.04.053

1. Window Glazing

Substitution of conventional masonry walls by glass walls is now widely applied, especially for high-rise buildings. However, glass producers and users are mostly put their outmost concern to solar and thermal control of the glass. A very little attention is put to consider sound transmission aspect. As glazing walls are usually thinner than masonry walls, the sound insulation property decreases accordingly [1,2,3]. In order to provide similar sound insulation like masonry walls, glazing walls should possess significant outdoor-indoor transmission class (OITC) close to that of masonry wall which is 43 to 49 depending on the thickness [4]. Glass manufacturers' manual shares limited information on sound insulation property of their products. When available, it is mostly in terms of sound transmission class (STC). In fact, STC is a method of predicting sound insulation property of vertical building materials which is for indoor usage such as partition wall. The STC calculation does not include low sound frequencies which exist in environmental noise, especially transportation noise. This causes STC of glass may not be directly referred for sound insulation of façade installation. OITC of such vertical building elements is usually lower than the STC caused by lower transmission loss at low frequencies, i.e. 80 Hz and 100 Hz. Coincidence dip that exists in the contour may also decrease insulation property of a material from its STC to its OITC, especially when the dips are at low frequency of 80 Hz and 100 Hz [5].The occurrence of coincidence dip is controlled by material's stiffness and thickness and happens at the point where the sound transmitted through the material equals the natural frequency of the material installed [6,7]. The thicker and stiffer the glass is, the lower the frequency at which the 'dip' occurs is [7,8]. When specific frequencies are targeted for noise reduction, an analysis of where the frequency 'dip' appears for any glass types under consideration is important. When all of 1/3 octave band frequency is in the noise spectrum, OITC single number may be used as reference, with particular consideration to frequency at which the frequency 'dip' appears [9]. This explains STC information provided by glass manufacturers may not be directly used as OITC.

Indoor living spaces are suggested to maintain interior noise levels at 45 to 50 dBA (approx. NC 40 to 45) or lower [10,11]. Thus, replacement of masonry wall to the lighter and thinner glass wall ideally provides interior noise levels close to that of proximity by having high OITC rating with minimum coincidence dips.

2. Glass façade in Indonesia

The use of glass façade in low and high-rise buildings is also a trend in Indonesia, either for operable windows or glass walls. The fact that this thinner material provides lower noise insulation gets worse with minor installation details and improper supporting materials. These issues are very common in Indonesia, due to loose noise regulation and limited knowledge and awareness of Indonesians on noise [12].

Leading glass manufacturers in Indonesia, i.e. Asahimas glass do not provide detailed information on noise insulation capability of glass as building façade. Asahimas provides STC of glass only excluding the OITC [13]. Although currently it is not required by the International Building Code [14] nor by Indonesian Building Regulation [15] and in most cases STC is not sufficient for outdoor usage, information on façade OITC is important, especially due to rapid increment on environmental noise.

Studies on acoustical property of glass have been conducted in cities and countries with different climate to that of Indonesia. Thus, they cannot be fully adopted in Indonesia. Standard for conducting acoustical testing of partitions, including glass partitions was set to comply room temperature in the range of 22 ± 5°C (ASTM [16]), which rarely happens in Indonesia. Even if molecular formation of glass only responds to temperature above 600°C [17,18], a testing condition close to daily temperature in Indonesia is considered important to see whether temperature difference between ASTM and actual daily temperature in Indonesia affects sound transmission within 1/3 octave band frequency assigned. The occurrence of certain coincidence dip which would affect the OITC single number would also be observed.

In the last ten years, many cities in Indonesia have average annual temperature of 28°C as in Jakarta, the capital city [19,20,21]. The maximum temperature might reach up to 33°C [19]. Considering this issue, investigation on glass OITC in warmer daily temperature in Indonesia was carried out. The result is reported in this paper.

3. Methods

Examination of building glass OITC was performed in accordance with the following method:

- Selection of glass types was limited to: monolithic, laminated, and tempered. The selection was based on glass types commonly used for building facades. Double glass was not selected considering seldom usage in Indonesia [22].
- Thickness and dimension were set as fixed variables here. Since earlier studies significantly proved that thickness and dimension play important roles in the decrease or increase of OITC, where thicker glass owns higher OITC than thinner ones and larger glass dimension decreases OITC than smaller ones [7]. Fixed dimension of 10 mm thickness and 110 mm x 100 mm was used for all glass specimens (Fig. 1 and Fig.2). Specimen variables are monolithic, laminated, and tempered. All glass specimens were provided by Asahimas glass Indonesia. The laminated glass is composed as 5-0.375-5, which is 5 mm for pane 1, 0.375 for polyvinyl butyral (PVB) interlayer, and 5 mm for pane 2. All specimens were installed as fixed windows.
- Testing method conforming to ASTM E90-09 [15] was employed in this study and a specific condition was applied based on Annex.3 on the use of composite wall system. This was due to intact glass sample that could not be inserted into the testing room's door. The standard requires minimum height of 2.4 m, whereas the laboratory's door is limited to 2.1 m tall. For other specimens, such as bricks, gypsums, etc., it is possible to construct intact partitions part by part within the testing room where proper joint between specimens or panels will not significantly affect the transmission loss. However, this is not the case for glass because glass sheets need to be arranged by using connectors such as thick sealant, which may cause significant deviation in the testing process, and thus affects transmission loss [23].
- Reverberation chambers conforming to ASTM E90-09 [15] was utilized to conduct the test, with room layout as in Fig. 3 and Fig. 4.
- In the composite wall system employed, the use of filler wall was developed. It is suggested to use filler wall with OITC of roughly 15 above the predicted OITC of the tested specimen. In this case, light bricks plastered both sides with total thickness of 252 mm were used (Fig.1, and Fig. 2). The filler wall was tested prior to specimen installation, which provides STC 48 and OITC 42. For a reference, 10 mm monolithic glass of Pilkington provides STC 33 [24,25]. Reference of 10 mm glass thickness STC was used since OITC for this type was not available.
- Equipment used for testing was Bruel & Kjaer 2- channel building acoustic system consisting of power amplifier type 2734 and 4292 omnidirectional loud speaker as sound source, 2 pieces of type 4189 omnidirectional microphone as sound sensor, and 2-channel hand held analyzer type 2270 as the main instrument data processor. The microphones were calibrated using type 4231 prior to testing stage.
- Room temperature as a replica of outdoor temperature was set in 2 conditions, i.e. standard (conforming to ASTM E90, which is 24-26°C) and warmer (31-32°C). Indoor temperature was set to remain at standard temperature as in common indoor temperature in Indonesia conditioned by air conditioner.
- Each glass type was tested twice for both outdoor-indoor room temperature of warmer and standard and standard and standard (as in Table 1).

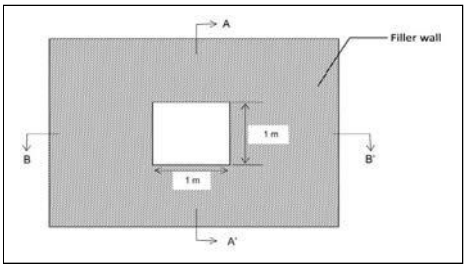

Fig. 1. Front view of the composite wall specimen

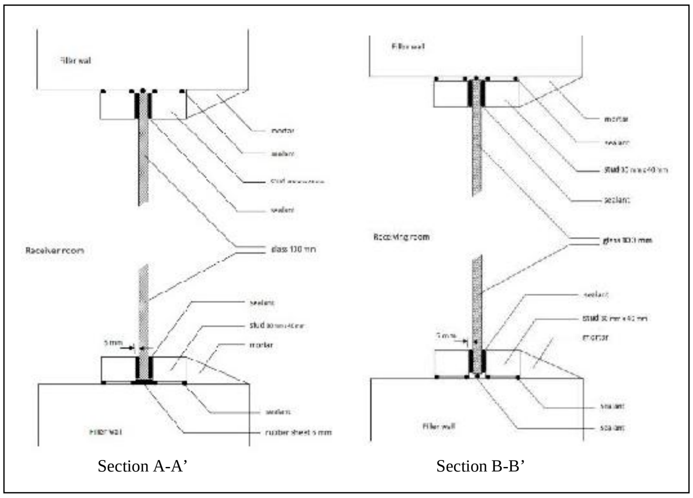

Fig. 2. Sections of the composite wall specimen

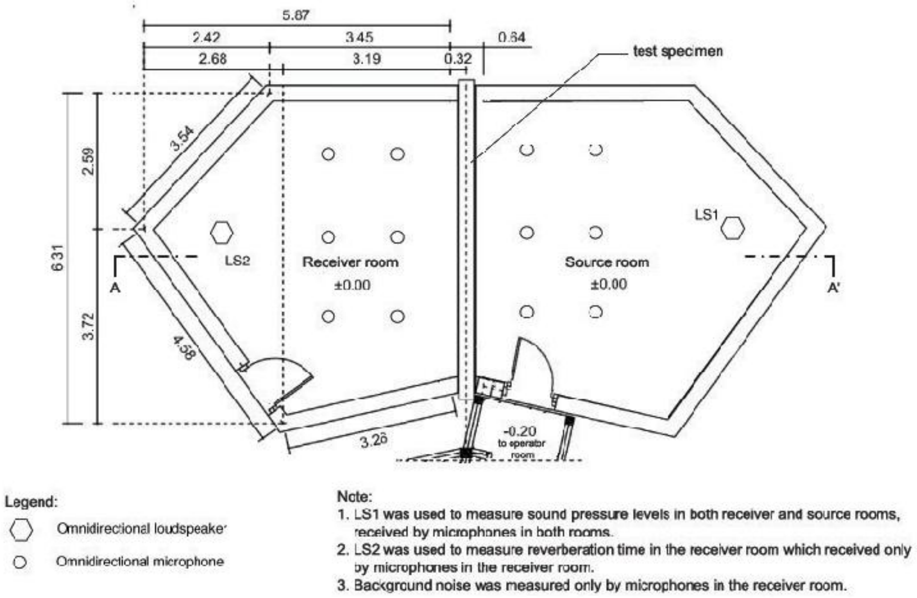

Fig. 3. Plan of the testing room and the equipment layout

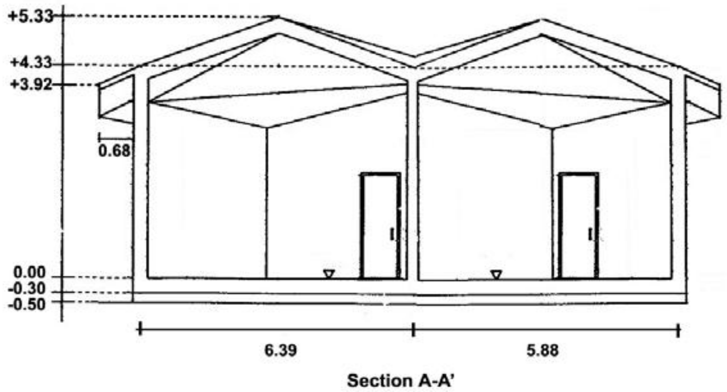

Fig.4. A-A' section of the testing room

Table 1. Specimen specification and variables

No.	Specimen	Specification	Room temperature (°C) and humidity (%)
1	Filler wall	Light brick + mortar, thickness 252 mm, density ± 180 kg/m^2	26 -27°C, 60-90%
2	Monolithic glass	1100 mm x 1000 mm, thickness 10 mm, density ±25 kg/m^2	26 -27°C, 60-90%
3	Monolithic glass	1100 mm x 1000 mm, thickness 10 mm, density ±25 kg/m^2	31-32°C, 60-90%
4	Laminated glass	1100 mm x 1000 mm, thickness 10 mm, density ±25 kg/m^2	26 -27°C, 60-90%
5	Laminated glass	1100 mm x 1000 mm, thickness 10 mm, density ±25 kg/m^2	31-32°C, 60-90%
6	Tempered glass	1100 mm x 1000 mm, thickness 10 mm, density ±25 kg/m^2	26 -27°C, 60-90%
7	Tempered glass	1100 mm x 1000 mm, thickness 10 mm, density ±25 kg/m^2	31-32°C, 60-90%

4. Findings and Discussion

Since composite wall system was used, particular formula to develop transmission loss (TL) of each 1/3 octave band frequency was utilized as follows [16].

$$\tau_c S_c = \tau_s S_s + \tau_f S_f \quad \text{or} \quad \tau_s = (\tau_c S_c - \tau_f S_f)/S_s$$

Sc is area of composite construction ($S_c = S_f + S_s$), S_f is area of filler element, S_s is area of test specimen, τ_c is transmission coefficient of composite construction, τ_f is transmission coefficient of filler element, and τ_s is transmission coefficient of test specimen. When the TL was drawn, OITC could be calculated. The OITC of glass is a single number rating representing sound TL data available on the test specimen in 1/3 octave band frequency from 80 Hz to 4000 Hz, inclusive, in accordance with ASTM E-90 as in Table 2 and Fig. 5. This spectrum has demonstrated reasonably reliable for aircraft and street noise on city streets [26]. It is calculated using formula as follows [27].

$$OITC = 100.13 - 10 \cdot \log\left\{\sum_{i=80Hz}^{4000Hz} 10^{\frac{(AWRS_i - TL_i)}{10}}\right\}$$

$AWRS_i$ is the A- weighted reference sound level, and TL_i is the sound transmission loss for 1/3 octave band, i, respectively. Calculation of OITC usually resulted lower single number rating from STC caused by low frequency noise spectrum where coincidence dips appears, particularly by thin sound blocking materials [7].

This study showed that within warmer environment, compared to monolithic and tempered glass, OITC of laminated glass dropped as low as 29, which is identical to OITC of monolithic glass as thin as 6 mm [5]. Fig.5 exhibits all specimens had similar contours with dips occurring at frequency 125 Hz, 200 Hz and 1600 Hz. The sharpest dip existed at 125 Hz for laminated glass tested within warmer outdoor environment. Apart from performance of better TL at frequency above 800Hz, this coincidence dip has notably contributed to the low OITC of laminated glass. At this stage, no alteration could be made to cure the coincidence dip; increasing material thickness does not effectively address the condition [28]. This statement represents that laminated glass of different thickness may have similar performance within the particular temperature assigned. The only solution is by replacing laminated glass with other glass types or other less stiff materials. When laminated glass is still in use, damping system can be introduced. Damping by the use of flexible mounting materials will also reduce the coincidence dip depth [7, 29].

Facts of earlier studies that laminated glass owns higher OITC compared to monolithic and tempered [30] were not borne out in this study. The finding of this study that laminated glass within warmer air had lowest OITC is the opposite of the earlier study using the same specimen for calculation of STC in which laminated glass had the highest STC compared to monolithic and tempered glasses [31]. From this study, it can be learned that sound travel media which in this case is warmer air played significant role on the way how sound strike the glass specimen and that the speed of the airborne incident match to the glass bending wave [28], which in cooler or standard air was not the case.

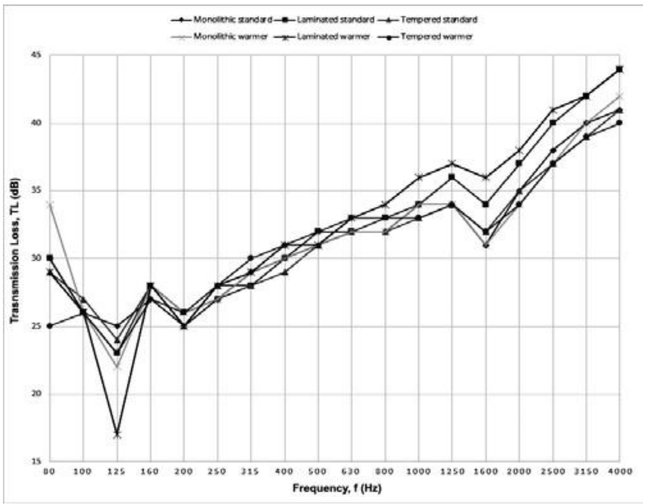

Fig.5. Transmission loss (TL) contour of glass specimen at normal temperature (26-27°C) and warmer temperature (31-32°C)

5. Conclusion

This study concludes that within warmer air temperature of approximately 5°C above temperature as outlined by ASTM E-90 (i.e. 31-32°C), a very significant dip existed in laminated glass that dropped its OITC accordingly. Thus, the selection of laminated glass for building façade within warmer environment may not be successful as in a standard or cooler environment [8,28,30,31]. More attention should be paid for real installation, since OITC rating from a laboratory test is usually higher than the OITC rating from field test, due to the flanking problems [8].

By this study it can be learned that warmer air as the medium of noise dispersion has a significant impact on the occurrence of coincidence dip of laminated glass.

Table 2. Transmission loss and OITC

1/3 Octave band frequency	Transmission Loss (TL) in dB & OITC against air temperature						
	Filler element solely	Monolithic		Laminated		Tempered	
	24-26 °C	24-26 °C	31-31°C	24-26 °C	31-31°C	24-26 °C	31-31°C
80	31	30	34	30	29	29	25
100	41	26	26	26	26	27	26
125	37	25	22	23	17	24	23
160	33	27	28	28	28	28	27
200	37	25	26	26	25	25	26
250	40	27	27	27	28	28	28
315	37	29	29	28	29	28	30
400	44	30	30	30	31	29	31
500	45	31	31	32	31	31	32
630	48	32	32	32	33	32	33
800	49	32	32	33	34	32	33
1000	51	34	34	34	36	33	33
1250	53	34	34	36	37	34	34
1600	54	31	31	34	36	32	32
2000	55	35	34	37	38	35	34
2500	53	38	37	40	41	37	37
3150	53	40	40	42	42	39	39
4000	55	41	42	44	44	41	40
OITC (ASTM E1332-90)	**42**	**30**	**30**	**31**	**29**	**30**	**31**

Acknowledgements

This study was fully funded by Ministry of Research, Technology and Higher Education Republic of Indonesia under the scheme of *Hibah Kompetensi* under the project "Acoustical Characteristic of Architectural Glass in Warm Humid Climate" with contract number 023.04.1.673453/2015 (made through *Kopertis Wilayah* VII).

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