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SOUND TRANSMISSION THROUGH CASEMENT WINDOWS

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1. INTRODUCTION

This paper describes an investigation to quantify how the angle of opening in a open casement (hinged) window, affects the sound attenuation of the façade containing that window. Comparison was made between the open angle of the casement window and the area of a theoretical hole in the façade that would have the same deterioration in the whole façade sound attenuation. The area of this theoretical hole was referred to as the 'effective acoustic open area' of the window. To test the methodology the investigation was repeated with a sliding pane window, as this best resembled a theoretical hole in the façade.

Early on in the investigation it became apparent that the casement window was a clearly directional noise source, this directionality was also investigated.

2. Method

2.1 Calculating the 'Effective Acoustic Open Area'

A sound source was located in the room on the inside of the façade. The sound level incident on the inside of the façade was determined from sound pressure levels measured at a number of points in the room, and corrected to account for an increase in sound pressure immediately inside the façade.

$$L_{IS} = L_P + 10 \log_{10} (1 + (S.\lambda / 8.V)) \quad [1]$$

Where

L_{IS} is the sound pressure level incident on the wall/façade – dB
L_P is the average sound pressure level in the room – dB
S is the area of the boundary surfaces in the room – m^2
λ is the wavelength of the mid band frequency – m
V is the volume of the room – m^3

The sound level on the outside of the façade was predicted from measurements made at known distances from the facade, which were corrected using the Rathe method of predicting sound propagation from facades. The Rathe's method states that a façade behaves like a plane wave source up to a distance equal to the smallest dimension divided by Pi, then as a line source up to a distance of the largest dimension divided by Pi and as a point source at greater distances. Measurements were made at two distances to see if the façade was behaving as the Rathe method predicts.

From the difference in levels on either side of the façade the sound reduction of the composite façade was calculated. The sound reduction index was converted to an average sound transmission coefficients for the facade. It was assumed that the sound transmission through the brickwork was negligible compared to the sound transmitted through the glass and the open window.

The transmission coefficient of the glass was calculated from the sound reduction index of the façade with the windows closed.

$$T_{glass} = 10 \, Log_{10} \, (1 / R_{closed})$$

Where

T_{glass} is the transmission coefficient of the glass
R_{closed} is the sound reduction index of the façade - dB

Average sound transmission coefficients were calculated for different extents of window openings. From knowledge of the transmission coefficient of the glass, and assuming that the transmission coefficient of the open window was 1, the average transmission coefficients were used to calculate the 'effective acoustic open area' of the window.

$$S_O = \frac{(T_{facade} . S_{facade}) - (T_{glass} . S_{facade})}{(1 - T_{glass})}$$

Where

S_O is the 'effective acoustic open area' – m^2
S_{facade} is the area of the façade – m^2
T_{facade} is the transmission coefficient of the whole facade
T_{glass} is the transmission coefficient of the glass

The 'effective acoustic open area' was compared to the angle to which the window was opened.

2.2 Calculating the Directionality of Windows

The directivity of the window was assessed by measuring the sound pressure levels at 22.5° intervals in an arc 2m from the window. These measurements were used to calculate the Directivity Index, DI, for the window in 9 directions.

$$DI_\theta = L_{P\theta} - L_{Pave}$$

Where

DI_θ is the Directivity Index in direction of angle θ
$L_{P\theta}$ is the sound pressure level in direction of angle θ
L_{Pave} is the average sound pressure level in all directions

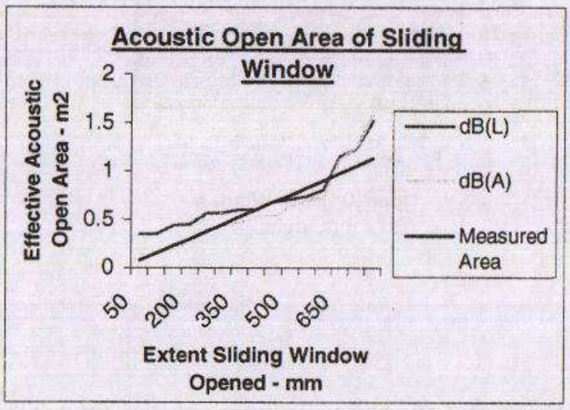
To give an overall indication of how directional the windows were, the magnitude of the Directivity Indexes in each direction were added logarithmically to give a Total Directivity Index, DI_{total}. This was used to compare the directionality of different extents of window opening and the different window types. The higher the Total Directivity Index the more directional in one or more directions.

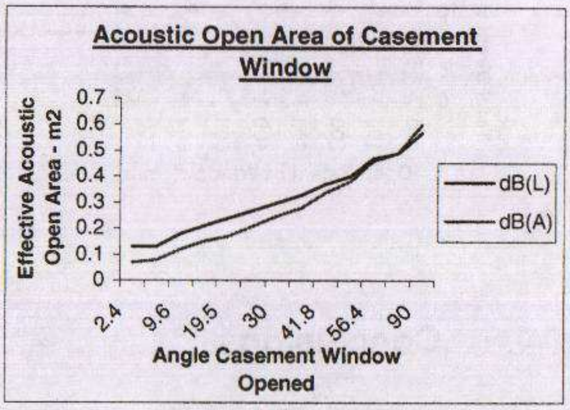
$$DI_{total} = 10.Log10 \, [10\text{^}(DI_1/10) + 10\text{^}(DI_2/10) + ... + 10\text{^}(DI_9/10)]$$

3. Results

3.1 'Effective Acoustic Open Area'

The calculated 'effective acoustic open area' of the sliding window increased in line with the measured area of the sliding window opening.

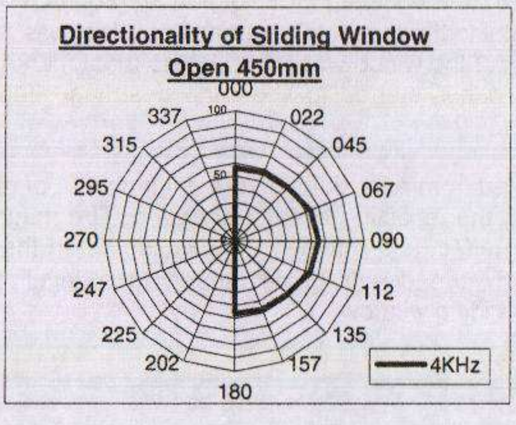


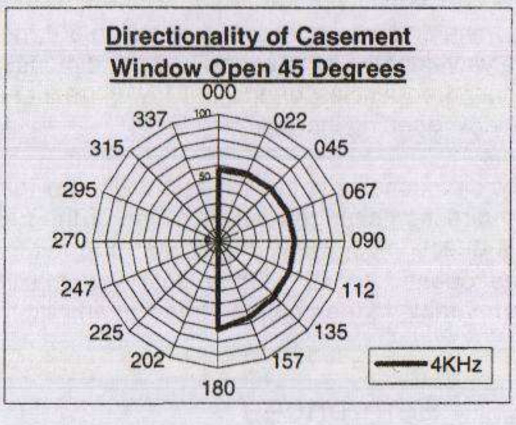


The 'effective acoustic open area' of the casement window increased as the open angle of the window increased. A maximum was reached when the open angle of the casement window was at 90°. If the casement window was opened beyond 90° the 'effective acoustic open area' remained at it's maximum value.

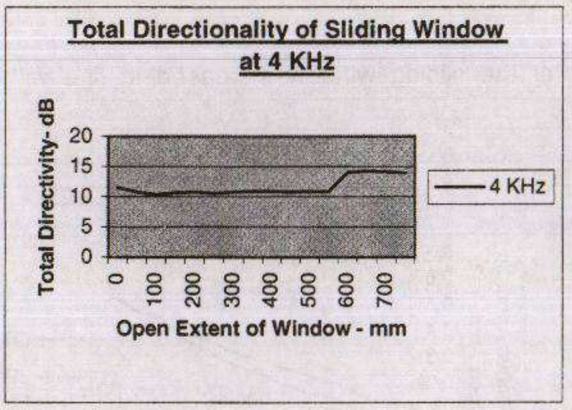
3.2 Directionality of the Windows

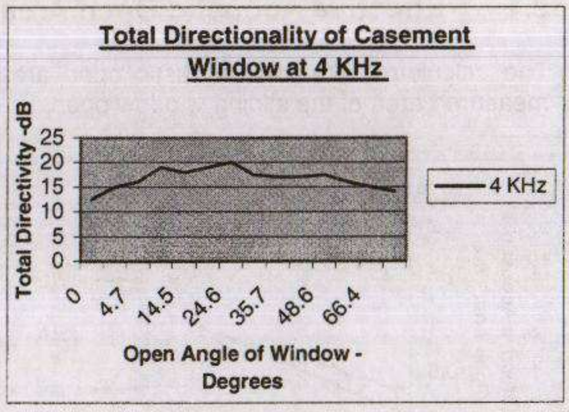
The directionality of the sliding window was greatest in the direction 90^0 to the façade. This did not change with the extent to which the window was opened. The total directivity remained at a constant level until the opening exceeded 0.45 m, at which point it started to increase dramatically.





Unlike the sliding window, the directionality of the casement window varied with the angle of the window opening. As the open angle of the window was increased the direction of greatest directivity moved from 180° to the façade, through to 90° to the façade, when the window was fully open. The total directivity also varied with the open angle of the window. The total directivity started at a value comparable to that of the sliding window but increased to a maximum when the window was opened to 45°, and then decreased again.





4. Conclusions

The 'effective acoustic open area' of a casement window opened to an angle of less than 90° was determined to be

$$S_E = S_C \cdot (\theta_C/90)$$

Where

S_E is the 'effective acoustic open area' - m^2

S_C is the area of the openable casement pane - m^2

θ_C is the open angle of the casement pane

When a casement window is opened to an angle greater than 90° then its 'effective acoustic open area' remains equal to the area of the openable pane.

Both the sliding and casement windows were found to be directional sources of noise breakout.

The directionality of the sliding window resulted from a beaming effect of sound through the window opening and was always in a direction 90°, normal to the facade. This beaming effect was related to the wavelength of the sound and the dimensions of the window opening. It was most marked for the higher frequencies bands but lower frequency bands started to show the beaming effect as the window opening increased.

The directionality of the casement window resulted from reflections on the angled pane of glass and the direction changed as the angle of the pane, the reflecting surface changed. The magnitude of this directionality was greater than the beaming effect and reached a maximum when the window was opened to 45°. Once past this maximum, the directivity decreased to a level that was comparable to the beaming effect seen with the sliding window.

5. References

[1] T. Emmanuel BRE, 'Measurement of the sound insulation of facades and façade elements – A comparison of the intensity technique with the traditional method.', *Proceedings of IOA Autumn Conference 1993 Vol 15 Part 8 (1993).*