Speech Privacy outcomes from Green star Design and As-Built v1.1 rating tool

Philip Setton[1] and David Yates[1]

[1]WSP | Parsons Brinckerhoff, Melbourne Australia

ABSTRACT

The Green Building Council has consolidated several rating tools to form the Design and As-Built rating tool. The tool provides up to 3 points for acoustics, one of which is for Acoustic Separation. The point is achieved under 10.3A when R_w45 walls are specified for 'enclosed spaces'. The AAAC Guideline for Commercial Building Acoustics rates R_w45 as a 'good' level of sound reduction and R_w50 as 'very good'. Alternatively, the credit is achieved under 10.3B using the measured D_w and L_{Aeq} to estimate speech privacy. This is based on a method from British Standard BS8233:1999.

The approaches in 10.3A and 10.3B use different descriptors to evaluate acoustical separation performance. Application of 10.3A or 10.3B may not necessarily result in equivalent outcomes for acoustical speech privacy. In this paper, the comparative acoustical speech privacy outcomes from typical wall constructions are compared using the analysis method provided in Australian Standard AS2822 *Acoustics – methods of assessing and predicting speech privacy and speech intelligibility.*

The analysis has indicated that while the R_w descriptor is a generally good comparison for plasterboard-based wall constructions, evaluating masonry wall constructions using this method may not result in commensurate speech privacy outcomes. Furthermore, the low frequency performance of certain wall constructions may have a tendency to affect the R_w rating by allowing a reduced performance at speech frequencies whilst maintaining the overall performance and thus over-estimate the speech privacy outcomes of the wall.

1. INTRODUCTION

The Green Building Council has consolidated several rating tools to form the Design and As-Built rating tool (Green Star Council, 2015). The rating tool provides up to 3 points for acoustics, one of which is for Acoustic Separation. The point is achieved under 10.3A when R_w45 walls are specified for 'enclosed spaces'. The definition of enclosed spaces is somewhat loosely defined as:

> *"Enclosed space - Meeting rooms, private offices, classrooms, residential units and any other similar space, where it is expected that noise should not carry over from one space to the next."*

The AAAC Guideline for Commercial Building Acoustics (AAAC, 2011) rates R_w45 as a 'good' level of sound reduction and R_w50 as 'very good'. Furthermore the guideline states:

> *To achieve reasonable acoustic separation, it is preferable for walls to extend full height and this would be considered mandatory for separate tenancies. Where this does not occur, achieving the design goals may not be possible.*

Alternatively, the Green Star credit is achieved under 10.3B using the measured D_w and background noise L_{Aeq} to estimate speech privacy. This is based on a method from British Standard BS8233 (British Standards, 1999).

$$D_w + L_{Aeq} > 75 \qquad (1)$$

Note that Equation 1 has been removed from the 2014 version of BS8233 standard.

From the outset, it would appear that the approaches in 10.3A and 10.3B are not exactly equivalent as they use different descriptors to evaluate acoustical separation performance.

The end-goal of this achieving point is not explicitly stated, however one may assume (for the purposes of this paper) that it is related to speech privacy to a reasonable degree.

R_w curves are used to provide a single number rating for wall systems. Such rating systems are widely published for different wall constructions and the building industry in general is familiar with them from Building Code of Australia (BCA) requirements. In general, a wall with higher R_w performance will provide better isolation between spaces. The shape of the R_w curve has been selected to roughly follow the shape of transmission loss curves. However, the R_w curve has not been developed for considering only voice as the noise source. R_w curves are also used to evaluate the reduction of noise from non-voice noise sources. Therefore, application of 10.3A of the Green Star tool may not necessarily result in desired outcomes for acoustical speech privacy.

AS2822:1985 (Standards Australia, 1985) is a standard for assessing the comparative speech privacy outcomes in a variety of situations and from a variety of sources. The subjective methods, which involve a person (speaker) reading lists of words and another person (listener) identifying them from a list of possible words. Such a test is impractical to carry out for every project and could not inform the design as the construction must be completed in order to conduct the tests.

Other objective tests from AS2822 use a 'count-the-dots' method where the spectrum of noise from speech is mapped against a field of dots. The ratio of dots above the curve to the total number of dots is the Articulation Index (AI). A precursor to Speech Intelligibility Index (SII), AI is a value from 0 to 1 which can be mapped against subjective speech privacy outcomes. This method does not account for the reduction provided by a partition, although other studies have considered this method with respect to open plan offices (Bradley & Gover, 2003). The method has its origins in audiological studies and are used in the evaluation of hearing aids (Pavlovic, 1989).

Section 8 of AS 2822 provides the most applicable method of determining the speech privacy in this case. This method calculates the excess signal level, *X,* as follows:

$$X = P + L_{A,v} + \Delta L_{A,s} - A_{eff} - N \quad (2)$$

Where:

P is the privacy requirement, between 9 and 15 dB;
$L_{A,v}$ is the vocal effort, SPL at 1 m, between 60 dB(A) for conversational voice to 78 dB(A) for shouting;
$\Delta L_{A,s}$ is the correction factor for source room;
A_{eff} is the effective attenuation between the spaces; and
N is the ambient sound pressure level in the receiving space

The resulting excess signal level, *X*, can be mapped against a 'degree of dissatisfaction', using Figure 7 in AS2822.

The A_{eff} is the most important variable to consider, as the methods of evaluating this term may significantly change the estimation of excess signal level and, thus, speech privacy. AS2822 offers several methods of estimating A_{eff}, using a combination of the ratio of receiving room floor area to common partition areas and the furnishings of that space (Figure 5 of the standard), as well as:

> *"(i)The overall airborne sound transmission loss (I) shall be expressed either as the average airborne sound transmission loss over the one-third octave bands centred on 100 Hz to 3150 Hz or 125 Hz to 4000 Hz, or as the sound transmission class (STC) of the partition determined in accordance with AS1276. …"*

By using the STC curve (a precursor to the R_w curve) it would seem the standard seeks to estimate the overall reduction provided by the wall by mapping against a curve, thus weighting different frequencies to differing degrees.

The average of transmission loss method would consider noise from the 100 Hz band onwards equally. Studies on voice spectra have been conducted for a variety of accents (Byrne, 1994) in which male and female voices typically peak at the 400 to 500 Hz range, regardless of the accent.

The dynamic range of voice was also considered in this and other studies (ANSI, 1969), was found to be between 10 and 12 dB.

The differences in A_{eff} will determine different excess signal levels which will be mapped against a 'degree of dissatisfaction'. By considering A_{eff} as either the R_w rating or level difference between spaces, speech privacy outcomes from different wall constructions can be evaluated.

2. METHODOLOGY

The one third octave band insertion loss values, as measured in real office environments are applied to a typical voice spectrum. The input spectrum was based on an average of male and female speakers (Byrne, 1994) and was normalised to an overall SPL of 65 dB(A). The spectrum shape agreed well with previous voice spectrum studies. The transmission loss for each band and a typical wall area of 4 m X 2.7 m (total area 10.8 m^2) was used to calculate the direct sound pressure level 1m from a wall. Transmission loss values were calculated using INSUL prediction software (version 8.0.0). The constructions were selected for each wall type to result in R_w ratings of 40, 45 and 50 respectively. Table 1 outlines the wall types and their general construction type; Appendix A specifies the constructions for each wall type in more detail. These wall constructions represent four drywall constructions and one masonry construction.

Table 1: Nominated wall construction types and ratings

Construction type	R_w40	R_w45	R_w50
Steel Stud	W1	W6	W11
Staggered Steel Studs	W2	W7	W12
Separate Studs	W3	W8	W13
Timber Stud	W4	W9	W14*
Masonry	W5	W10	W15

* Note that W14 is 1 dB short of achieving R_w50. This is considered roughly equivalent for the purposes of comparison.

The A-weighted difference in noise level was used as the A_{eff} term in the privacy calculation. *N* was set to 35 dB(A), in line with the internal noise level criteria from Green Star Design and As-Built Rating Tool for a private office. As the input voice spectrum was at 65 dB(A), the vocal effort $L_{A,v}$ was therefore 65 dB(A). This is very close to AS2822's 66 dB(A) being a 'raised voice' level. The speech privacy requirement *P* was selected to be 9 dB – normal speech privacy.

3. RESULTS

The predicted overall noise level associated with speech propagation though each wall construction was compared against its R_w rating. As previously discussed, the noise level below 200 Hz may have little impact on the overall speech privacy provided by a partition. The predictions were therefore made once with noise below 200 Hz excluded (Figure 1), and once with noise below 200 Hz included (Figure 2). The resulting noise levels show very different outcomes.

If noise below 200 Hz is excluded, the overall A-weighted noise level in the adjacent room is generally higher for a concrete partition than it is for a drywall. Differences in overall level are almost 6 dB for the extreme case. The remaining drywalls roughly follow a slope with gradient -1 between R_w and overall noise level.

If noise below 200 Hz is included, the concrete wall performs better than the plasterboard walls (by approximately 5 dB) for R_w40 ratings, and the timber stud wall performs worse than plasterboard walls (by approximately 3 dB) for R_w50 constructions. All other results approximately follow a slope with gradient -1 between R_w and overall noise level.

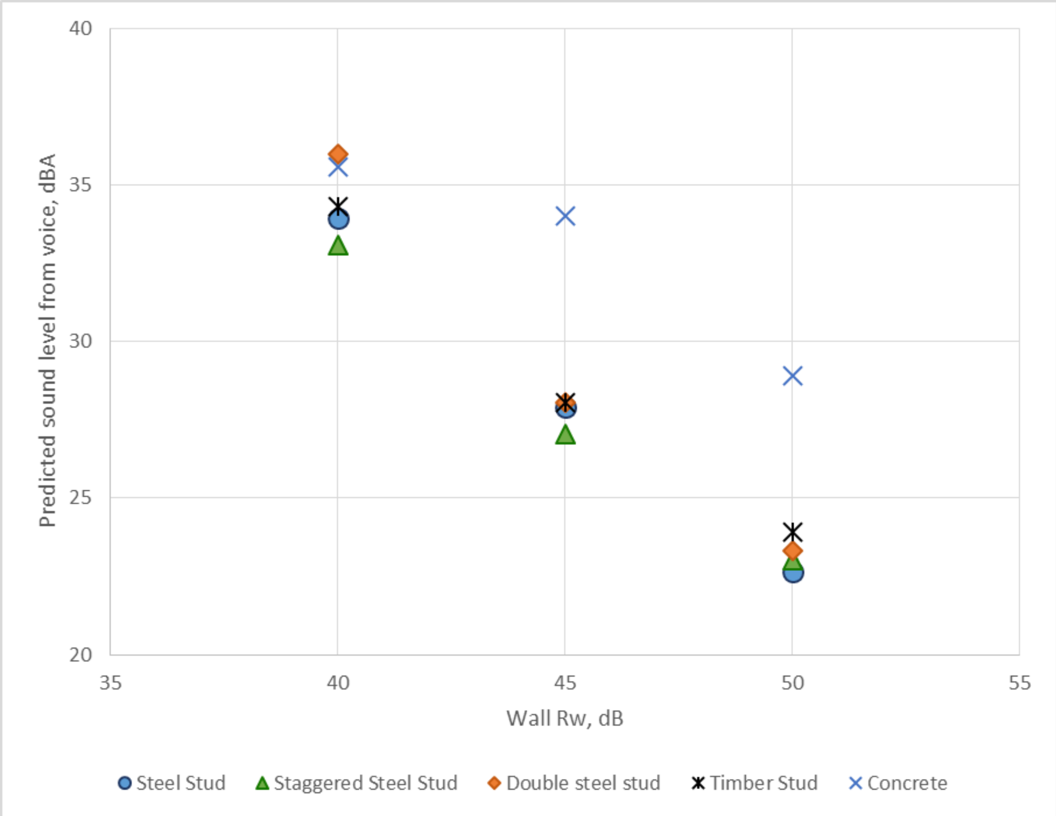

Figure 1: Overall voice noise level vs R_w for different wall types (200 Hz and above)

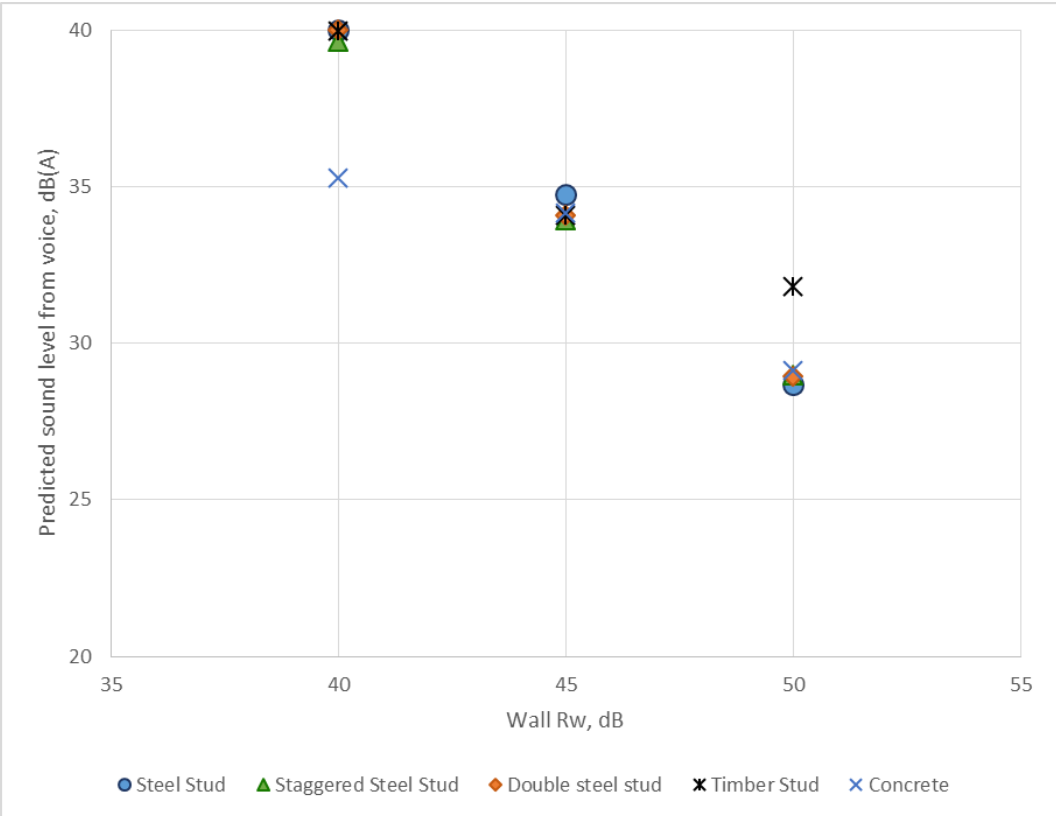

Figure 2: Overall voice noise level vs R_w for different wall types (100 Hz and above)

The speech privacy rating was calculated and the subjective 'degree of dissatisfaction' was determined from Figure 6 of AS2822. This has been reproduced in Figure 3.

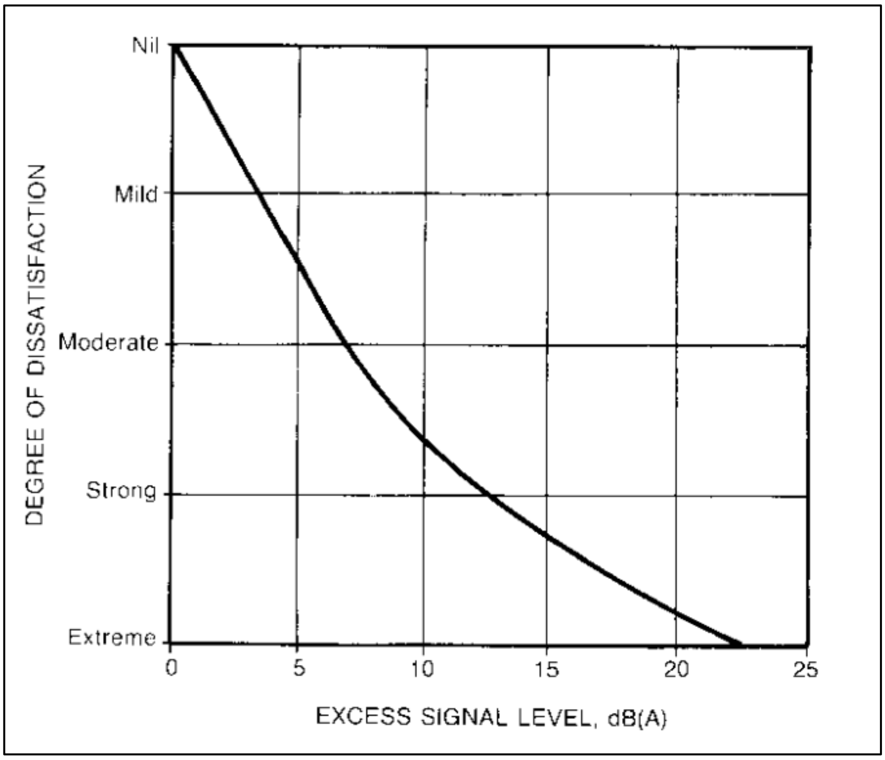

Figure 3: Degree of dissatisfaction with speech privacy condition – reproduced from AS2822 (Standards Australia, 1985)

The excess signal level was calculated using the R_w values plus the effective attenuation factor, K, to determine A_{eff}. The resulting excess signal levels are shown in Table 2.

Table 2: Excess signal level and degree of dissatisfaction based on R_w values

R_w	Excess signal level (X)	Degree of Dissatisfaction
40	9.0	Moderate to Strong
45	4.0	Mild to Moderate
50	-1.0	Nil

The same process was undertaken using the sound pressure level difference based on the assumed input voice spectrum and the transmission loss of each wall type, as discussed. These results are shown in Table 3.

Table 3: Excess signal level and degree of dissatisfaction based on level difference for voice spectrum

Wall Type	200 Hz and above		100 Hz and above	
	Excess signal level (X)	Degree of Dissatisfaction	Excess signal level (X)	Degree of Dissatisfaction
W1	9.6	Moderate to Strong	9.6	Moderate to Strong
W2	12.4	Moderate to Strong	19.1	Strong to Extreme
W3	15.3	Strong to Extreme	19.6	Strong to Extreme
W4	13.7	Strong to Extreme	19.4	Strong to Extreme
W5	14.9	Strong to Extreme	14.7	Strong to Extreme
W6	9.6	Moderate to Strong	9.6	Moderate to Strong
W7	6.4	Mild to Moderate	13.3	Strong to Extreme
W8	7.4	Moderate to Strong	13	Strong to Extreme
W9	9.0	Moderate to Strong	14	Strong to Extreme
W10	13.4	Strong to Extreme	14	Strong to Extreme
W11	9.6	Moderate to Strong	9.6	Moderate to Strong
W12	2.4	Nil to Mild	8.4	Moderate to Strong
W13	2.7	Nil to Mild	8.4	Moderate to Strong
W14	3.3	Nil to Mild	11	Moderate to Strong
W15	8.3	Moderate to Strong	8.5	Moderate to Strong

The effect of including the low frequency noise component to the final degree of satisfaction is not consistent across all wall types. Generally speaking, inclusion of the noise below 200 Hz resulted in the excess signal level increasing (and therefore the degree of dissatisfaction increasing).

4. DISCUSSION

4.1 The suitability of the R_w curve

From the outset, the R_w rating and the given speech intelligibility performance for a wall would appear to be fundamentally different. That said, it seems to generally hold true that a higher R_w walls provide higher levels of privacy. The application of the method in AS2822 shows a far more intricate relationship, especially when the degree of dissatisfaction becomes a factor. One may be tempted to observe the predicted overall noise levels from R_w45 to be around 35 dB(A) and conclude that it would be at or below background noise in the room. However, this does not account for the variability in the frequencies associated with voice speech noise level. With the dynamic range in voice sound pressure level being 10 to 12 dB(A), the simplified method using the R_w value for A_{eff} results in mild to moderate dissatisfaction.

4.2 Relative importance of low frequencies

The R_w curve evaluates transmission loss starting from the 100 Hz band, with the 'sum-of deficiencies' rule giving equal importance to all frequency bands. The evaluation of speech privacy begins at the 200 Hz band, with a lesser importance of lower bands. For typical constructions of R_w45 walls, the deficiencies in performance are usually in the 100 Hz to 250 Hz range. Therefore, low-frequency performance may have a larger effect on the rating of a wall than is required for the purposes of establishing speech privacy.

Evaluating the overall sound reduction for frequencies between 100 Hz and 200 Hz may be required for consideration of disturbance from noise in adjacent spaces. However the suitability of including these frequencies for assessing speech privacy may be questionable, especially when considering that the AI method only considers noise from the 200 Hz band and above. Furthermore, the number of dots in the lower bands is fewer, resulting in a lesser sensitivity to the final AI result from noise at those frequencies. The R_w curve is shaped to require a lower transmission loss at lower frequencies, however a deficiency of 1 dB at low frequencies contributes the same as 1 dB at higher frequencies.

4.3 Drywall vs concrete

Concrete walls have a very different transmission loss curve shape than the drywalls considered. Acousticians' intuition may be that the heavier construction would result in a better speech privacy outcome, however this is not the case. The reduction in transmission loss in the 315 Hz band to 500 Hz band range is where much of the energy of the voice spectrum occurs. This is true for both R_w45 and R_w50 walls, when not considering the 100-200 Hz range. The use of concrete walls (particularly if bare) may therefore be unsuitable for where speech privacy is critical.

Most wall constructions for offices are plasterboard walls, precast concrete would most likely come up when the wall is specified for structural reasons.

4.4 Green Star

The wording of the assessment tool is such that the purpose of providing acoustic separation is not known. The intent of the tool may be around speech privacy or, disturbance from adjacent offices, or both. The language around the nature of an enclosed space, that *"it is expected that noise should not carry over'* would seem to be a catch-all for a variety of noise sources. However, where voices are the primary source of noise in offices and where private offices are intended to serve as places for confidentiality, it would seem beneficial to view the credit as being predominantly related to speech privacy.

It should be noted that achieving credit 10.3A in the design phase is no guarantee of achieving a suitable speech privacy outcome without also considering other flanking paths including doors and ceilings. Consideration of these paths appear even more critical as the Green Star tool does not include any comments about whether the wall should be built 'full-height'. This means that an R_w45 wall with no above-ceiling treatment may be evaluated as achieving the requirement while in reality providing limited acoustic privacy outcomes.

4.5 Limitations of this study

This study used theoretical transmission loss values for the wall types, based on INSUL software. Laboratory testing for all wall types could not be sourced and so the use of prediction software was considered adequate for the purposes of comparison.

4.6 Further studies

This study does not account for flanking paths. In the real world, these may be more important than the laboratory certified R_w rating for a given construction. Further studies could be undertaken in a similar manner, using the measured D_w of a partition to more accurately understand where common deficiencies in performance lie and their impact on speech privacy.

5. CONCLUSION

The R_w descriptor is a generally good comparison for drywall constructions. The Green Star target of R_w45 may result in a 'mild to moderate' degree of dissatisfaction but as a minimum standard would seem reasonable. Higher R_w ratings generally result in better speech privacy outcomes.

Evaluating masonry wall constructions using this method may not be suitable. Furthermore, the low frequency performance of certain wall constructions may have a tendency to affect the R_w rating and thus over-estimate the speech privacy outcomes provided by the wall.

The limitations of timber stud drywalls, due to the structural connection of the leaves may compromise speech privacy outcomes for higher R_w ratings.

Green Star requirements should clarify that the outcomes for a given wall construction also depend on control of noise through flanking paths. These clarifications could be considered in an updated version of the Design and As-Built rating tool.

ACKNOWLEDGMENTS

The authors would like to thank the makers of INSUL software for their assistance.

APPENDIX A – CONSTRUCTION DESCRIPTIONS

Wall Type	Construction description	R_w, dB
W1	1 X 10mm Fire-rated plasterboard, 64mm steel studs, 50mm insulation 14kg/m^3, 1 X 10mm Fire-rated plasterboard	40
W2	1 X 10mm standard plasterboard, 64mm staggered steel studs (92mm track), 50mm insulation 11kg/m^3, 1 X 10mm standard plasterboard	40
W3	1 X 10mm standard plasterboard, 64mm steel stud, 20mm clearance gap, no insulation, 64mm steel stud, 1 X 10mm standard plasterboard	40
W4	1 X 13mm standard plasterboard, 90mm timber studs, 75mm insulation 10kg/m^3, 1 X 13mm standard plasterboard	40
W5	50mm concrete	40
W6	1 X 13mm Fire-rated plasterboard, 76mm steel studs, 50mm insulation 14kg/m^3, 1 X 13mm Fire-rated plasterboard	45
W7	1 X 13mm standard plasterboard, 64mm staggered steel studs (92mm track), 50mm insulation 14kg/m^3, 1 X 13mm standard plasterboard	45
W8	1 X 10mm standard plasterboard, 64mm steel stud, 20mm clearance gap, 50mm insulation 14kg/m^3, 64mm steel stud, 1 X 10mm standard plasterboard	45
W9	2 X 13mm Fire-rated plasterboard, 90mm timber studs, 50mm insulation 10kg/m^3, 1 X 13mm Fire-rated plasterboard	45
W10	70mm concrete	45
W11	2 X 13mm Fire-rated plasterboard, 76mm steel studs, 75mm insulation 10kg/m^3, 1 X 13mm Fire-rated plasterboard	50
W12	1 X 16mm Fire-rated plasterboard, 64mm staggered steel studs (92mm track), 75mm insulation 10kg/m^3, 1 X 16mm Fire-rated plasterboard	50
W13	1 X 13mm standard plasterboard, 64mm steel stud, 20mm clearance gap, 50mm insulation 11kg/m^3, 64mm steel stud, 1 X 13mm standard plasterboard	50
W14*	2 X 16mm Fire-rated plasterboard, 90mm timber studs, 75mm insulation 14kg/m^3, 3 X 16mm Fire-rated plasterboard	49
W15	110mm concrete	50

*Note that W14 is 1 dB short of achieving R_w50. This is considered roughly equivalent for the purposes of comparison for different wall types.

REFERENCES

AAAC, 2011. *Guideline for Commercial Building Acoustics,* s.l.: Australian Association of Acoustical Consultants.

ANSI, 1969. *ANSI S3.5 American National Standard Method for Calculation of the Articulation Index,* s.l.: American National Standards Institute.

Bradley, J. & Gover, B., 2003. *Describing Levels of Speech Privacy in Open-Plan Offices,* Canada: Institute for Research in Construction.

British Standards, 1999. *BS8233 Guidance on sound insulation and noise reduction for buildings.* s.l.:s.n.

Byrne, D. T. e. a., 1994. International comparison of long-term average speech spectra. *Journal of the Acoustic Society of America,* pp. 2108-2120.

Green Star Council, 2015. *Green Star Design and As Buit v1.1,* s.l.: s.n.

Pavlovic, C., 1989. Speech spectrum consideration and speech intelligibility predictions in hearing aid evaluations. *j. Speech Hear. Disord.,* Volume 54, pp. 3-8.

Standards Australia, 1985. *AS2822 Acoustics - Methods of assessing and predicting speech privacy and speech intelligibility.* s.l.:s.n.