

Pews & Cushions & Carpets – Oh My!

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This article reviews the effects of pew cushions and carpets on the experience of music, speech, and hymn singing in worship spaces. Recommendations are provided to optimize the listening environment.

Four primary acoustic parameters determine the performance of listening spaces – the rise and decay of sound, the lateral fraction, the binaural quality index, and speech intelligibility. The rise and decay of sound is characterized by a variety of metrics, chief among them being reverberation time, or RT60. Also important are the early decay time, clarity index, and definition. These determine the “liveness” of speech and music heard in the room. The lateral fraction refers to the ratio of sound arriving from the sides versus that arriving from the front and rear of the listener; it also determines the apparent acoustical width of the source. The binaural quality index is related to the inter-aural correlation coefficient, which expresses how different the sound is at each ear. It is related to the perception of spaciousness. Speech intelligibility is primarily determined by the reverberation time and background noise, although discrete echoes also impair intelligibility.

In spaces used for traditional worship, attention is given to the effect of RT60 on both music and speech. Choirs and pipe organs, in particular, benefit from fairly long reverberation times, while speech intelligibility benefits from shorter reverberation times. This disparity often leads to conflicts between the organ designer and the sound-system designer (see Figure 1). Some acousticians who serve both roles have been said to suffer from a split personality!

In addition to the effects on music and speech, worship services are participatory, and the effect of acoustics on hymn singing is important. It has been observed that congregation members do not like the sensation of singing alone, and that consequently, better hymn singing results if each singer feels supported by hearing others singing.

Two finish details that may affect the experiences of music, speech, and hymn singing in a worship space are the placement of cushions on pew seats and backs, and carpeting under the pews. (The effects of carpeting in the aisles are straightforward and need no elaboration.) The present modeling study evaluates the effects of pew cushions and under-pew carpeting on reverberation time, speech intelligibility, and hymn singing. The approach employed was to use CATT-Acoustic to model the rectangular room shown in Figure 2 with very reflective boundaries and then introduce pews, aisle carpeting, seat cushions, back cushions, and under-pew carpeting one at a time.

Reverberation

The empty room had an RT60 in excess of 40 seconds at 500 Hz, decreasing to about 8 seconds, presumably due to air absorption, at 4 kHz. Pews were modeled as double-sided planes of wood: one plane for the seat, one for the back, and two for the ends. Adding the pews as shown decreased the RT60 to the range of 8 to 4 seconds across the 125-Hz to 4-kHz octave bands.

Figure 3 shows the effect of various pew treatments with carpet in the aisles but bare wood under the pews. The top red line shows the RT60 in the test room with pews and no carpet. The green line shows the effect of adding carpet to the aisles with the pews still bare. As expected, the RT60 is decreased mainly above 500 Hz. Adding seat cushions, but no back cushions (blue line), decreases RT60 across all frequencies, and adding back cushions (green line) affects mainly the frequencies below 500 Hz, as compared to the effect of pew seat cushions alone. The orange curve at bottom shows the effects of seating an audience on the pews, where the

Objective Measures:

- RT60 (modeled as T30)
- STI (0.3=bad; 0.3-0.45=poor; 0.45-0.6=fair; 0.6-0.75=good; >0.75=excellent)
- SPL produced by one singer, heard at different locations

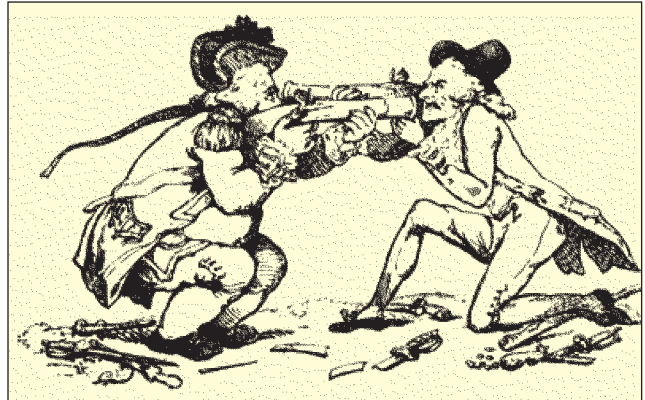


Figure 1. An organ designer and sound designer discuss acoustics.

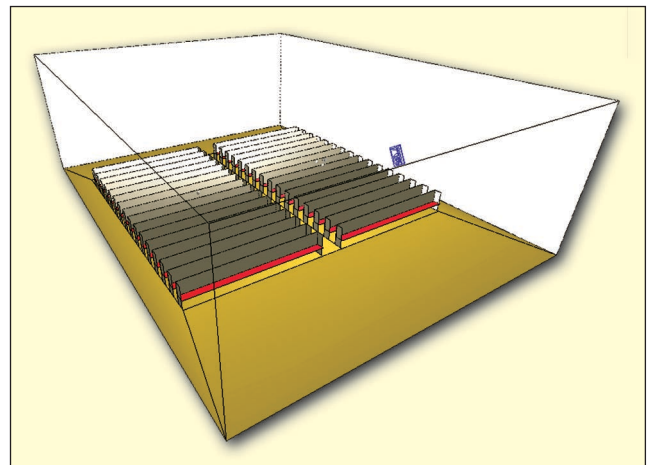


Figure 2. Model of test room.

effect of cushions is essentially nil, since the cushions are covered with more absorptive material (people).

The effect of adding carpet under the pews as well as in the aisles is shown in Figure 4. The red curve shows the RT60 of the room with carpeted aisles and under-pew areas, but with bare pews. The other three curves illustrate that reverberation is reduced by adding cushions, but the difference between seat-only cushions, seat-back cushions, and an audience is small.

Figures 5 and 6 compare the RT60 of the room with and without under-pew carpet, both with and without an audience. In either case, carpeting under the pews clearly has little effect on reverberation.

Intelligibility

To assess the effects of carpeting and pew cushions on speech intelligibility, the Speech Transmission Index (STI) was calculated for each case. The results are shown in Figure 7.

In examining absolute STI values, remember that this room was created to be almost impossibly reverberant: the walls and ceilings are even less absorptive than brick or dry wall. So the fact that maximum STI only nudges into the “fair” range should not be surprising. Also, no particular pains were taken to design an

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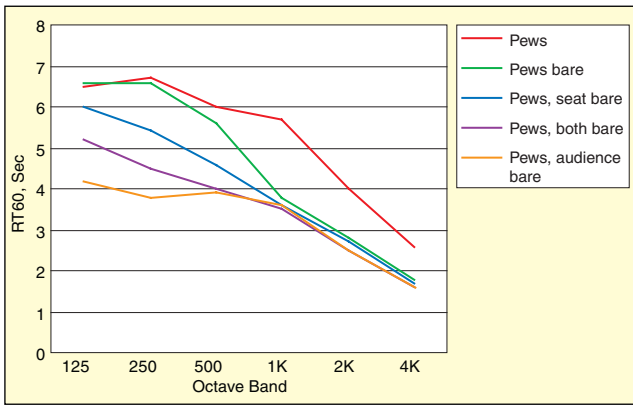


Figure 3. RT60 with carpet in aisles only.

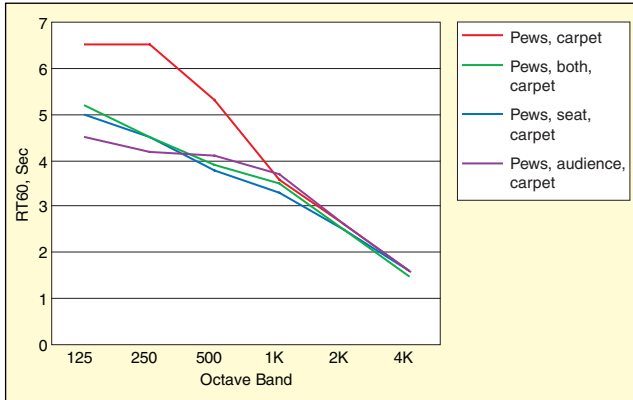


Figure 4. RT60 with carpet in aisles and under pews.

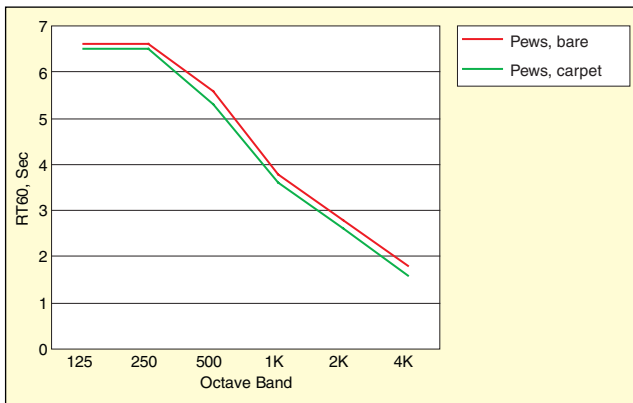


Figure 5. Effect of under-pew carpet, no audience or cushions.

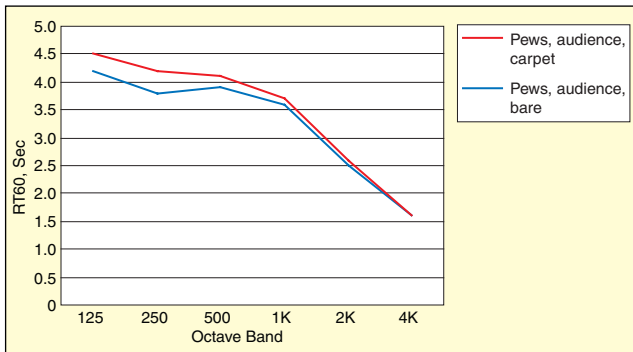


Figure 6. Effect of under-pew carpet with audience.

optimum sound system for modeling in this room.

The importance of the graph is to show the comparative effects of the different pew and floor treatments. Moving from left to right, we begin with an STI of about 3.5 for the room with only pews in it. Adding carpet in the aisles (“pews-bare”) brings us up to 4.0. Adding seat cushions, then back cushions, and then an

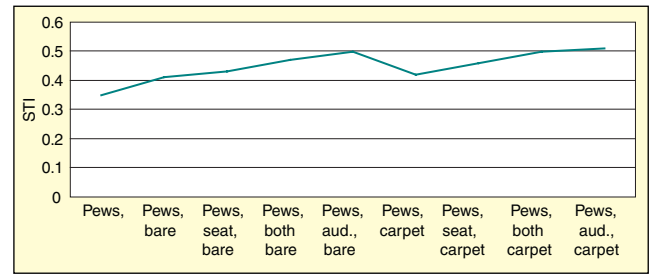


Figure 7. STI comparisons.

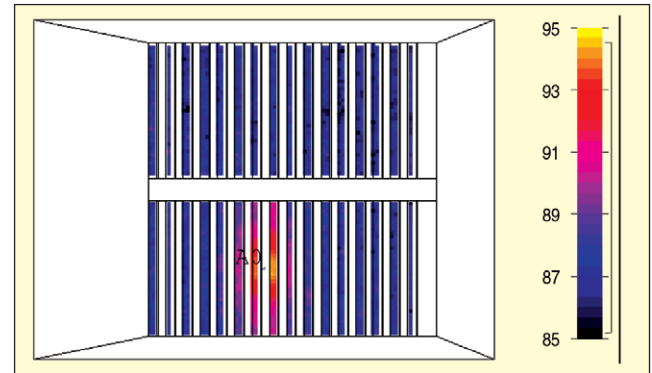


Figure 8. One singer, no carpet or cushions.

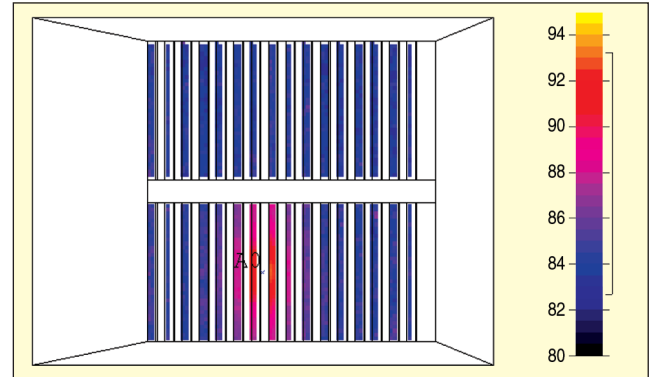


Figure 9. One singer, carpeted aisle, seat cushions.

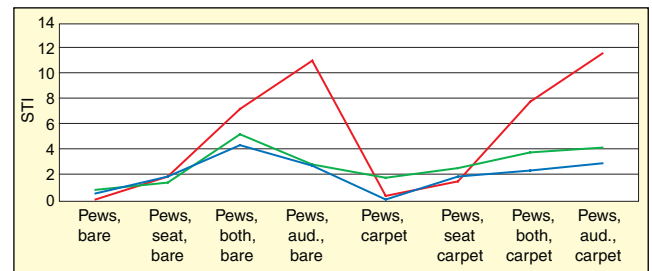


Figure 10. SPL loss from one singer under different conditions.

audience progressively improves the STI until at last a value of 0.5 is reached.

Next, we look at the room with pews, plus carpet in the aisles and under the pews, giving us an STI of about 0.42. Again, adding seat cushions, then back cushions, then an audience progressively improves the STI until at last a value of 0.51 is reached. The effect of carpeting under the pews would seem to have little effect upon speech intelligibility.

Hymn Singing

To assess the probable effects of pew and floor treatments on congregational singing, we will examine the SPL at the ear of a putative listener produced by a singer in a nearby pew. The raw data for one listener near one singer in an empty room with no carpet or pew cushions is mapped in Figure 8. Figure 9 shows the level under the same conditions but with the aisle carpeted and

the pew seats cushioned.

Clearly, SPL maps are not the best way to view this data. To make the effects clearer, Figure 10 shows the decrease in SPL heard by the listener from a lone singer in three different locations and with various pew and floor treatments. In each case, the dB value shown is referenced to the SPL that would be heard in an empty room with no carpet or pew cushions. The listener location in reference to the singer is color-keyed to the graph lines as indicated at the right of the figure.

Starting at the left-hand side of the graph, we see that adding aisle carpeting only reduces SPL by about 1 dB. Adding seat cushions only brings the loss up to just under 2 dB. However, adding both seat and back cushions substantially reduces the SPL, especially for listeners located behind the singer. If an audience is added (without which there would be no hymn singing to concern us, the reduction in SPL is slightly less than for seat and back cushions, except for listeners located behind the singer, where the SPL reduction is quite large.

Now we move to cases with carpeting under the pews. With no seat cushions, again the SPL is substantially at the reference level, except for the case of a listener located two pews in front of the singer, where the SPL loss is about 2 dB. Adding seat cushions makes little difference. But if pew-back cushions are added, the listener experiences a significant loss in SPL, especially if the listener is located behind the singer. As with the uncarpeted under-pew case, adding an audience does not have a large effect, compared to the case with seat and back cushions, except for listeners behind the singer.

Conclusions

When there is no audience and pews are uncushioned, carpeting under the pews has very little effect upon RT60. When an audience or pew cushions are present, carpeting under the pews can reduce reverberation time by about 10% at frequencies below 500 Hz.

Pew seat cushions reduce RT60 significantly at frequencies below 1 kHz. Adding seat cushions provides broadband reductions in RT60, but additional cushioning or an audience have little additional effect above 1 kHz. However, back cushions and an audience do provide additional RT60 reduction at frequencies below 1 kHz. Therefore, much of the most noticeable effects of reverberation – those above 1 kHz – are effectively “tamed” by adding seat cushions, resulting in a room that has much less variance for the empty (“choir practicing” or “small-attendance”) state

than for the fully occupied state.

Concerning speech intelligibility – if a room performs poorly, any absorption helps, and more absorption helps more, but not necessarily by a lot. Carpeting under pews has little effect upon intelligibility.


Assuming that congregational participation in hymn singing depends primarily upon how well congregation members can hear their neighbors singing, seat cushions will hurt only slightly – about 2 dB. Using both seat and back cushions costs about 4 dB. In an empty room, carpeting under the pews costs about 3 dB, but if the room is fully occupied, the SPL reduction due to carpeting under the pews is only about 1 dB.

Looked at another way, seat cushions reduce the RT60, don't hurt hymn singing much, and help STI significantly in an empty room. Back cushions reduce RT60, hurt hymn singing, and don't help STI much. Carpet under the pews makes little difference in RT60 and in STI but can slightly hurt hymn singing when the room is empty.

Caveats

Dr. Leo L. Beranek has pointed out that the absorption data on any material is strictly accurate only for the space in which the material is measured. The “generic” absorption data used in this study can therefore be expected to have limitations that will differ for different actual rooms.

In acoustical modeling programs, audiences are modeled as geometric blocks having a specific surface absorptivity. There is no data – indeed, it would be difficult to use data – that takes into account the actual geometry of individual audience members and their mutual interactions. This fact could introduce errors in this study, especially for evaluating the effects of under-pew carpeting, since the region under the pews actually will have legs, shoes, and clothing not accounted for in the model. The upper-body geometry is likely to affect the absolute accuracy of the modeled SPL effects of different pew treatments, since both singer and listener were modeled as being about head height, above the rows of pews (the “audience block”).

Despite these limitations, the comparative data derived from this study are considered to be accurate in their general trends, and the author hopes that this data will prove helpful in the design or refitting of worship spaces. 

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