Acoustics Breadth

Overview:

As part of my re-design of the lecture hall, I elected to re-design the ceiling for the space. As stated earlier, I had two goals for this design: to better work with the overall geometry and furnishings of the lecture hall; and to create an acoustically efficient space. The first goal has been discussed previously. This acoustical breadth will explore the second.

The success of the new ceiling in relation to acoustics will be measured by the following standards:

- Ability to distribute sound to all seating areas of the space
- Ability to maintain reverberation times at appropriate levels
- Contribute to the solution of any sound transmission issues from and to other spaces

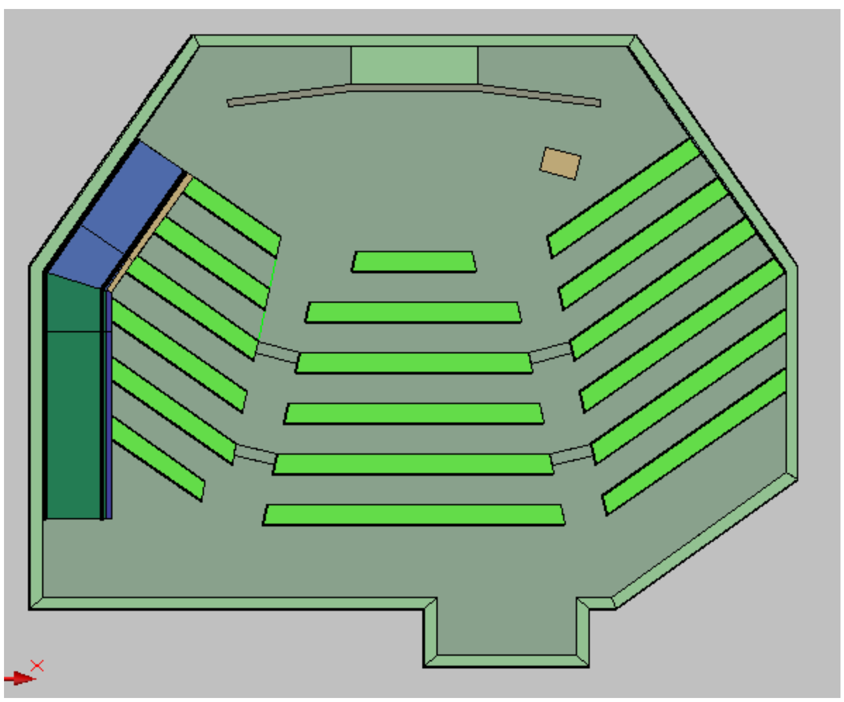

Figure 10.01 *Lecture Hall Model – Plan View*

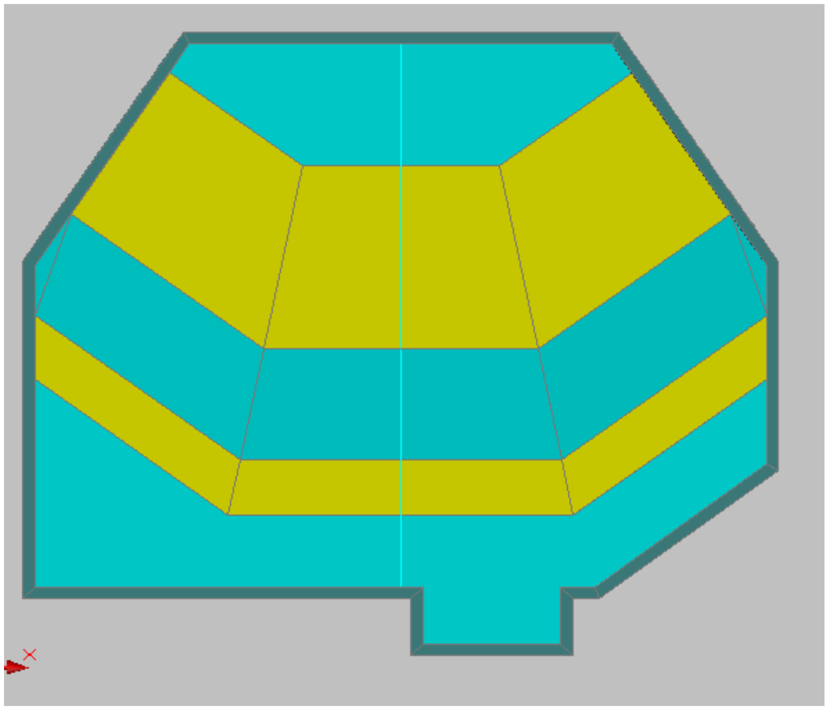

Figure 10.02 *Lecture Hall Model – Plan View of Ceiling*

Figure 10.03 *Preliminary Color Rendering of Lecture Hall – From Speaker*

Analysis of Sound Reflection:

This lecture hall has a couple of things working against it acoustically. The height of the space is generally low, which means the slope of any ceiling reflectors can't be too great without risking making the space feel too enclosed. Also as a result of the height restrictions, it's not feasible to raise the height of the stage or further slope the floor to improve the line of sight with the speaker. One of the aspects of the design that is conducive to sound distribution is the seating, which is unfixed. This allows students to essentially "self-stagger" their seating and improve their line of sight with the speaker.

In order for the space to work as optimally as possible, ceiling reflectors have to be oriented so that more sound is reflected to the back of the space. The listeners in the front benefit from being closer to the speaker and from having a less obstructed view, so this is not a critical area for the ceiling to reflect to. Below illustrates how sound is distributed across the space with the new ceiling.

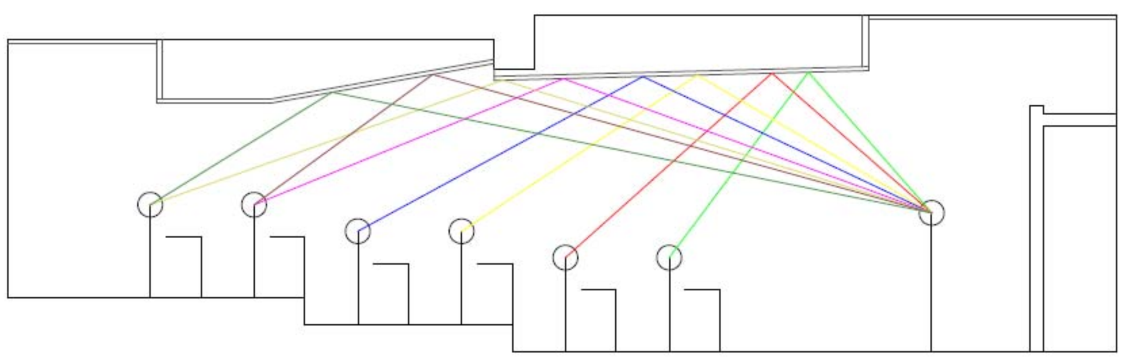

Figure 10.04 *Section of Lecture Hall – Proposed Ceiling with Sound Reflection*

Overall, the ceiling seems to be distributing sound well to the rear of the classroom. Both sloped sections of the ceiling can reflect sound to the last two rows of seating without interference, which should help the speaker project to the entire space more easily.

Analysis of Sound Absorption:

In order to determine an appropriate material for the new ceiling, I needed to calculate the reverberation time for the space. From these calculations I was then able to determine a range for the sound absorption coefficient for each frequency. The optimal range of reverberation time for this space is 0.7 to 1.1 seconds (AA P&D, p.218).

Frequency (Hz)	Lowest Acceptable α	Highest Acceptable α
500	0.68	1.50
1000	0.26	1.05
2000	0.15	0.50
4000	0.08	0.43

Table 10.01 *Range of Acceptable Sound Absorption Coefficients (α) For Solid Ceiling*

Frequency (Hz)	Lowest Acceptable α	Highest Acceptable α
500	0.54	0.98
1000	0.42	0.86
2000	0.30	0.75
4000	0.23	0.66

Table 10.02 *Range of Acceptable Sound Absorption Coefficients (α) For Porous/Gapped Ceiling*

From this calculation, I found some general materials that would be appropriate for the space, based solely on sound absorption coefficients. These included perforated metal with fiberglass backing, pegboard over fiberglass, and fiberboard. Aesthetically, I feel that the perforated metal will be the strongest in appearance, so I selected this product. A copy of the specifications for this product is available in Appendix C. The ceiling will be considered a solid ceiling, since the insulation for the product helps to cover the perforations from above, and thus doesn't allow enough air through to be considered porous.

Frequency (Hz)	500	1000	2000	4000
Sound Absorp. (α)	0.81	0.85	0.93	0.88
Reverb. Time (sec)	0.65	0.57	0.51	0.50

Table 10.03 *Sound Absorption Coefficient Data for Perforated Metal Ceiling Material And Corresponding Impact on Reverberation Time for Lecture Hall*
Source: Architectural Acoustics – Principles and Design, 1999, p.411

Although the reverberation times are below my desired range of 0.7 to 1.1 seconds, they are still acceptable by most standards (0.5 seconds being the absolute acceptable minimum). They are also relatively close to each other, meaning that ending consonants of words won't reach the listeners before vowels, and vice versa. Speech will be relatively intelligible, and while the room would be considered relatively "flat" for a lecture hall, it would be neither detrimental to the success of lectures nor distracting for listeners. As a result, I have concluded that the new ceiling design meets the criteria for appropriate sound absorption.

Analysis of Airborne Sound Insulation:

The current structural assembly was studied to determine if additional sound insulation would be required to reduce the impact of airborne sound. The target Sound Transmission Class (STC) levels for the lecture hall are as follows:

Area Studied	Nearest Equivalent	Adjacent Area	Nearest Equivalent	Recommended STC
Lecture Hall	Classroom	2nd Floor Laboratory	Laboratory	50
Lecture Hall	Classroom	1st Floor Corridor	Corridor	50

Table 10.04 *Recommended STC Values for Selected Occupancies*
Source: Architectural Acoustics – Principles and Design, 1999, p.176

Testing in a laboratory setting of a 6" solid concrete slab revealed a STC of 56 (AAP&D, p.420). The concrete slab over the lecture hall is actually a 6-1/2" composite deck. Since it can be assumed that the addition of 1/2" of concrete and metal decking will only improve the sound insulation, I can conclude the current assembly will easily meet the STC standard between the 2nd floor laboratory and the Lecture Hall.

Testing of a standardized metal stud assembly (5/8" gypsum board on each side, 3 5/8" studs 24" o.c., 2" fiberglass insulation) results in a STC of 51 (AAP&D, p.414). The only area that would not have a similar assembly to the above is the door. That said, the vestibule at this entry should create enough of a barrier to meet the criteria. Again, no changes need to be made to the current assemblies to meet STC criteria.

Analysis of Structure-Borne Sound Insulation:

The current structural assembly was studied to determine if additional sound insulation would be required to reduce the impact of structure-borne sound. The target Impact Insulation Class (IIC) between the Lecture Hall and the 2nd Floor Laboratory is 50.

For a typical VCT floor assembly, the IIC is only 34. Therefore, I am recommending that the vinyl composite tiles above the lecture hall be replaced with a more sound-insulating material: cork. Besides being a better acoustical insulator, the cork offers thermal and moisture insulation, and when properly sealed, cork is durable enough to meet the usage needs of the lab environment. In addition, cork is a rapidly renewable resource, making it a better choice for the environment as a whole. A floor assembly with cork floor tiles, 8" concrete slab, and dropped ceiling has an IIC of 73. Even taking into consideration that there is only a 6 ½" slab, the IIC would still remain over 50. With this simple change, the space now meets recommended criteria for structural-borne sound insulation. A cutsheet for a suitable cork flooring option is available in Appendix C.