MEEM 4704: Acoustics and Noise Control

Final Project

CLK Gym Acoustics

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Matt Riutta, CLK Schools

Abstract

The Calumet, Laurium, and Keweenaw (CLK) Gym Acoustics project intends to improve the acoustic quality of their middle school gym environment for sports and theatrical performances. This report will detail the background, testing, results, and recommendations for acoustic treatment of their gym/stage space moving forward. The gym is currently used for various events, such as physical education (PE) classes, basketball games, and assemblies. As described by our customer Matt Riutta and the CLK Public Schools, the current space is very reverberant with lots of hard surfaces and is a large space.

CLK school district is now looking to use the space for new types of events, including band and theater performances, which would be performed on the gym's stage. The current reverberation time within the space is not suitable for these types of performances. An effective solution will seek to reduce this reverberation while not impeding the space needed for basketball or gym classes.

Background and Objective

The CLK middle school gym, shown in Figure 1, is a large multipurpose room with hard cinder block walls and a hardwood sports flooring. The stage sits at one end of the room, approximately 4 feet higher than the main level, with soft padding on its front face and curtains above and to the sides. Within the space are 4 extendable bleachers that seat up to 400 people in total.

Figure 1: Gym with bleachers and wall overhang

Figure 2: Front-facing photo of the stage in the gym

Our first virtual meeting with our customer, Matt Riutta, helped establish the purpose of this project as well as the constraints the team would be working within. Currently, the gym is used extensively for physical education classes, basketball games, and assemblies. Matt voiced that during activities, particularly sports with bouncing balls, the room became an "echo chamber" that made it difficult to understand spoken voice and was overall uncomfortable to be in. He stated that the district is interested in using the space for band and theater performances in the future. Historically, when they'd tried to use the space for this purpose, they were impressed with how much the voices and instruments on stage carried to the audience without microphones. This passive amplification was something that he hoped to preserve as we looked into potential solutions.

From this conversation, the team focused on 2 primary objectives: reducing the reverberation time to an acceptable gym value and implementing a flexible solution that could deaden echo during activities and reintroduce some passive amplification during performances while allowing for the space to be used as it currently is. A budget constraint to not exceed $20,000 was the final consideration from Matt.

Testing Methodology

The team decided that accurate room dimensions, an octave band analysis, and an impulse RT60 test would be required to evaluate the current acoustic performance of the environment.

To gather accurate room dimensions, the team planned to use a Bosch Blaze laser measure to record the gym, stage, bleacher, and truss dimensions [1]. From these values, accurate surface area (SA) and volume (V) values could be determined.

Before testing, we calibrated our SLM Model 831 to make sure we were able to run both tests efficiently and accurately.

The octave band analysis uses a sound level meter to analyze the sound pressure level (SPL) of frequency bands. The team planned to take octave band measurements during a school PE class to develop a better understanding of the sound profile during gym use. This type of measurement would also be used to take noise floor measurements of the empty gym as a reference for other testing.

Impulse RT60 testing is a practical way to measure a room's reverberation time (T_{60}). The team planned to use a clapper shown in to generate a loud burst of sound and an SLM Model 831 shown in Figure 3 to measure the T_{60} time across ⅓ octave bands. The clapper is capable of producing impulses in excess of 115dB, which would require a noise floor of approximately 50dB. From these experimental T_{60} values, the environment's current total acoustic treatment

(A), measured in Sabines, can be calculated using the equation $A = \frac{.161V}{T_{60}}$. According to the Architectural Acoustics textbook, the ideal T_{60} range for a multipurpose auditorium is 1.6-1.8 seconds. From these values, the total acoustic treatment equation can calculate the treatment required to achieve the optimal reverberation performance. The difference between the optimal treatment and the current treatment will be the required treatment our team needs to recommend for the gym.

Figure 3: Clapper and SLM Model 831 for Data Acquisition

Results and Discussion

The team captured and recorded the gym, stage, bleacher, and truss dimensions in Table 1, which are the values for the gym in its open configuration with the bleachers retracted.

Table 1 - Recorded Dimensions of the Gym

	Gym	Stage	Bleachers (1 set)	Divider
Width (m)	21.34	4.95	1.12	0.61
Height (m)	9.25	8.33	1.24	2.74
Length (m)	27.41	12.29	10.92	21.34
Surface Area (m^2)	2070.78	409.14	54.38	146.42
Volume (m^3)	5406.24	507.28	15.19	35.68

From these values, the team calculated the net surface area and volume of the gym as 2347.52m^2 and 5817.08m^{3,} respectively.

The team captured 2 sets of octave band data during the PE class and a noise floor for reverberation testing. The PE class data includes 20-second averaged measurements while approximately 30 kids were running across the gym, participating in an activity, and with the kids talking during half-time. Both measurements were taken from the same location in the far right corner of the gym from the stage, approximately 15 feet from the walls. This data, shown in Figure 4, shows that both types of gym use create similar overall SPL values of approximately 69 dB re 20µPa. The SPL distribution is relatively even across the 125 to 1000 Hz octaves before it starts to drop toward 8000Hz. This reading shows that spoken voices excite similar frequencies in this reverberant environment to running and dribbling. The 20-second averaged noise floor measurement, shown in Figure 5, highlights an overall SPL of 48.8 dB re 20µPa. Preliminary testing of the clapper showed a peak impulse of 115dB at the measurement distance, so this noise floor is adequate for RT60 testing.

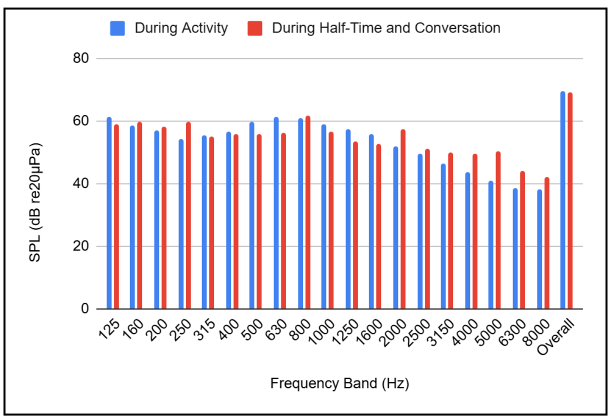

Figure 4: PE octave band analysis comparison of the environment when kids are running and when kids are talking.

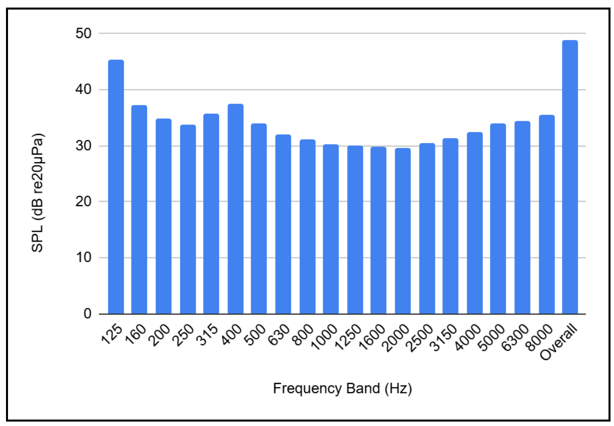

Figure 5: Noise floor of the gym taken before RT60 testing.

The team captured 3 sets of RT60 data once the PE class had ended. The measurement locations are annotated in Figure 6. Almost immediately after the impulse for the first RT60 test, the school bell chimed, and students filled the halls, raising the noise floor well above the 50dB required for a valid and accurate set of data. After the test was manually ended after 30 seconds, approximately half the ⅓ octave bands had yet to decay 60dB. This shows just how important it is to ensure that the environment is controlled to the best of our abilities. The remaining 2 data sets were captured after classes had resumed and the noise floor returned to its previous level.

The T60 times were recorded, and the current absorption coefficients were calculated per ⅓ octave band using the

equation $\overline{\alpha} = 1 - e^{\frac{.161V}{-SA*T_{60}}}$, which is shown in Table 2. The averaged T_{60} time for the gym based on both trials is 5.57 seconds.

From the measured SA and V values of the environment, the team is able to calculate the total treatment required to achieve the ideal acoustic performance of the room from the equation $A = \frac{.161V}{T_{60}}$. This value is based on a value of 5817 m^3 and an ideal reverb time of 1.7 seconds. This value is calculated as 551 metric sabines. The current room situation, with the same volume but an average reverb time of 5.57 seconds, currently has 168.1 metric sabines of acoustic treatment. That means that our recommended solution needs to have an equivalent of 382.9 metric sabines for the empty gym.

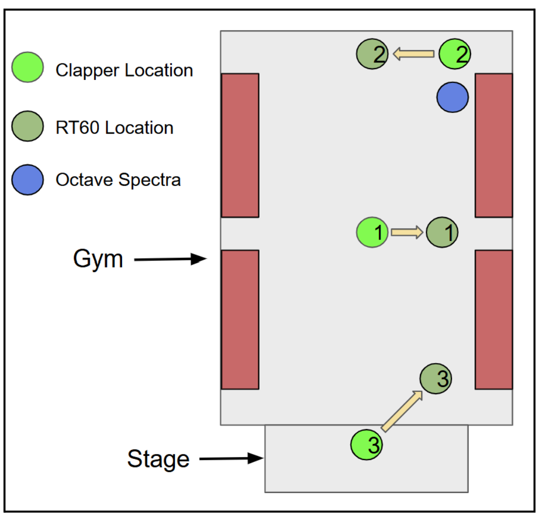

Figure 6: Location of RT60 and Octave Spectra tests.

Frequency (Hz)	T60 (s)	Averaged absorbtion coeffecient (Norris-Eyering)
125	6.67	0.17
160	6.46	0.18
200	6.64	0.17
250	6.92	0.17
315	6.64	0.17
400	5.95	0.19
500	7.11	0.16
630	6.41	0.18
800	7.41	0.16
1000	7.08	0.16
1250	6.85	0.17
1600	6.52	0.17
2000	5.98	0.19
2500	5.07	0.22
3150	4.12	0.26
4000	3.37	0.31
5000	3.41	0.31
6300	1.82	0.50
8000	1.33	0.61

Table 2: Averaged T_{60} and absorption coefficients.

Another factor that can have an impact on room absorption during performances and games is the spectators, performers, and players. Between tests, Matt stated that it's common for the room to have up to 400 occupants during these events that they were targeting. Based on an approximate absorption of 0.5 sabines per person, supported by a 2013 research paper [2], 200 people would add 100 metric sabines of treatment. This assumption attempts to balance the performance of the space when it's empty and full. Going into recommendations, the team will propose economical methods to attack the required 282.9 sabines of treatment.

Recommendations

Many existing acoustic treatment solutions exist for gymnasiums and theaters; however, with a budget constraint of $20,000, the team focused on economic treatment methods. Due to the nature of custom-manufactured acoustic treatment options that are required for this scale of project, the team was not able to get accurate costs for treatment options, but was able to gauge the relative price to performance of multiple solution methods. Our final treatment recommendation focuses on ⅔ wall acoustic curtains that run the side walls of the gym.

During a discussion, Matt mentioned that it would be nice to control the lighting that enters the gym from the 8 groups of large windows that run the side walls. The team proposes 4 groupings of acoustic curtains on each side wall, hung between the ceiling trusses, that provide acoustic treatment and additionally cover the windows shown in Figure 8. Acoustic curtains like the ones produced by AmCraft Industrial [3] have a rated NRC of 1.05. With each curtain approximately 6m by 6m to fit between the trusses and clear the bleachers, this modification would add approximately 300 metric sabines of treatment. At a surface density of 4.3lbs/m^2, each curtain would weigh approximately 150lbs. While it is important to consider their weight and their impact on the structure, it is outside of the scope of our project. These total absorption factors are summed in Table 3, which shows that this design recommendation of 568.1 metric sabines is very similar to the treatment of 551 required for the 1.7-second reverberation time.

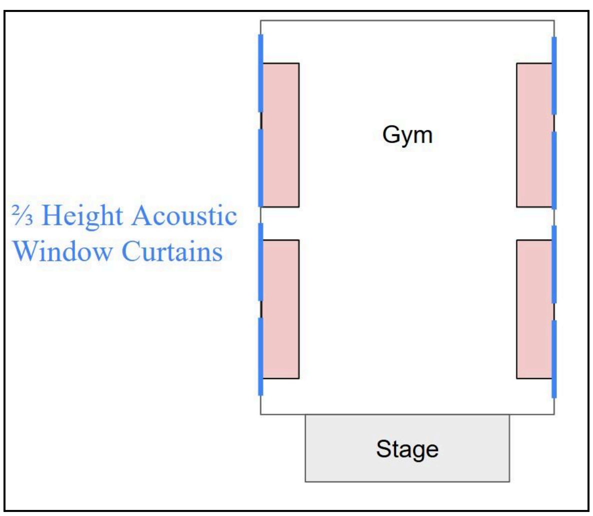

Figure 7: Acoustic Curtain recommendation for CLK gym

Absorbtion Factors	Treatment Effect (Sabines)
Current room	168.1
200 people	100
2/3 height acoustic window curtains	300
SUM	**568.1**

Table 3: Calculation for the total acoustic treatment for the CLK gym

One consideration is the potential variance in absorption depending on how many people are in the gym at any given time. Assuming that there is only 1 person in the gym, the total acoustic treatment would be 468.6 sabines, which would equate to an expected T_{60} of 2 seconds, which is not ideal for the multipurpose auditoriums but is within reason of the 1.6 to 1.8 second range. With 400 people in the gym, the total acoustic treatment would be 668.1 sabines, which would equate to an expected T_{60} of 1.4 seconds. This would be considered too dead for a performance or musical environment, but reverberance could be added back into the space by partially or fully opening the curtains.

Conclusions

Overall, we are confident that this design recommendation has the potential to optimize the acoustic performance of the CLK gym while still providing the district with the flexibility to adapt it to changing occupancy levels. Moving forward, the CLK district would likely work with a contractor to analyse the feasibility of hanging the 150lb curtains from the walls and securing a quote from a relevant manufacturer. Based on market prices of similar products, we believe that this implementation could be accomplished within the district's $20,000 budget. If these recommendations are implemented, then a follow-up measurement could confirm the acoustic effect on the space.

Acknowledgements

The team would like to acknowledge Matt Riutta for his help on this project, providing us with rough dimensions of the space, helping us gain access to the space, and working with us to better understand the needs of the project so we could tailor our testing and provide meaningful results and data. He also helped by letting us know some of the things they had tried previously to improve the acoustics of the space. Additionally, we would like to thank Dr. Chad Walber for supplying the required testing and measurement equipment.

References

[1] **Bosch Power Tools**, “BLAZE Laser Measure Tools,” *Bosch Tools USA*, Accessed: Apr. 17, 2026. [Online]. Available:

[2] N. M. D. Chagok, L. D. Domtau, E. Agoyi, and E. E. Akpan, “Average Sound Absorption per Person at Octave Band Frequencies Between 125 Hz and 4000 Hz in an Enclosure,” *Journal of Natural Sciences Research*, vol. 3, no. 2, pp. — , 2013

[3] **AmCraft Industrial Curtain Wall**, “Multi-Absorption Acoustic Curtains,” *AmCraft Industrial Curtain Wall*, Accessed: Apr. 17, 2026. [Online]. Available: https://amcraftindustrialcurtainwall.com/acoustic/curtains/multi-absorption/

Appendix

Sound Level Meter: Model Number: Model 831, Serial Number: 0001195