Non-Conventional Methods for Acoustical Control: Renovation of the Intel CV1 Cafeteria

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Abstract

In modern urban life, noise is an ever increasing problem. Escalating noise levels and noise intensities in all types of environments have proven to be disruptive to efficiency and productivity, and to be psychologically and physically harmful to the body. Noise can also be downright annoying, and can interfere with any activity, especially rest and relaxation. Thus, noise should be controlled not only in spaces where sound is an essential component, like recording studios or theaters, but also in places meant for relaxation, like private homes, restaurants, and even cafeterias.

Although in designing large office buildings, the architect usually considers noise control and good overall acoustics for the conference and seminar rooms, the library, or even the work areas, little attention is given to non-work oriented spaces like the cafeteria. Without the proper acoustical attention, these spaces can cause discomfort and can deprive their users of the rest their minds and bodies need in between work hours.

Because good acoustical conditions are often disregarded at the onset of design stages, acoustical improvements are only considered after the problem has been actually realized and experienced. At this point, standard measures to solve the problems of noise are sometimes difficult to implement, for one reason or another.

It is not unusual for large spaces like a cafeteria to have parallel walls and floors, a low floor to ceiling height, and very little surface absorption. These physical characteristics guarantee sound and noise in this space will endure a lengthy reverberation time. Additionally, if the space is constantly full of activity, the problem of noise levels and intensities increases.

Initially then, the designer tasked to solve these problems would probably look into the possibilities of reducing the floor area, increasing floor to ceiling heights, and simply replacing surface materials with highly sound absorptive alternatives. Though theoretically these measures would work, in reality these are usually easier said than done. Ceiling heights may be fixed permanently; enclosing surfaces like walls and ceilings may not provide enough absorption, even if replaced with very absorptive material; and restrictions related to the type of space might disallow the application of conventional acoustical treatment. Thus, there would be only minor changes in the reverberation time, and consequently insignificant improvements in noise control.

However, non-conventional methods to reduce sound levels and to ultimately improve the acoustical conditions can be introduced. Such methods can include providing openings through dropped ceilings, directing sound to absorptive surfaces, and providing additional absorption through "space absorbers," absorptive furniture, and partitions.

This paper will present a case study of how these methods were introduced in the new design of the Intel CV1 Cafeteria. Other possible methods, whether utilized or not, will also be introduced. As a conclusion this paper will project how acoustical conditions in this, and other similar spaces, will be improved.

Introduction

In modern urban life noise is an ever increasing problem. Escalating noise levels and noise intensities in all types of environments have proven to be disruptive to efficiency and productivity, and to be psychologically and physically harmful to the body. Continuous exposure to noise above 70 decibels may produce nervousness, fatigue, and even indigestion. Excessive exposure to noise has also been implicated in heart diseases, hypertension, and stomach ulcer. And noise long endured may result in temporary or permanent loss of hearing.[i] Noise can also be downright annoying, and can interfere with any activity, especially rest and relaxation. Thus, noise should be controlled not only in spaces where sound is an essential component, like recording studios or theaters, but also in places meant for relaxation, like private homes, restaurants, and even cafeterias.

The fundamental objective of noise control is to provide an acceptable acoustical environment indoors and outdoors so that the intensity and character of sounds within the building will be compatible to the building's use. Although in designing large office buildings, the architect usually considers noise control and good overall acoustics for the conference and seminar rooms, the library, or even the work areas, little attention is given to non-work oriented spaces like the cafeteria. Without the proper acoustical attention, these spaces can cause discomfort and can deprive their users of the rest their minds and bodies need in between work hours.

Because good acoustical conditions are often disregarded at the onset of design stages, acoustical improvements are only considered after the problem has been actually realized and experienced. Retrofitting becomes the course of action. However, at this point, standard measures to solve the problems of noise are sometimes difficult to implement, for one reason or another. If these measures can not be applied, then non-conventional methods will have to be introduced.

Intel CV1 Cafeteria

The Intel CV1 cafeteria is located at the ground level of the Intel office building at the Gateway Business Park in the Municipality of General Trias, Cavite. The dining area measures approximately 820 square meters in floor area, with an additional 240 square meters for the adjacent servery. Its maximum capacity is 400 to 450, though the highest number of users at one time is normally within the 300 to 320 range. Though there is adequate space to comfortably seat this number of people, Intel personnel have complained that the sound conditions in the space is beyond comfortable levels (some even comparing the cafeteria to a market) and, therefore, does not encourage rest and relaxation.

Equipped with a sound level meter, we visited the site and measured the sound intensity, or the rate at which sound energy is transmitted, at various times of the day. At 10am, when approximately 50 people were taking their break, the sound level was an average of 70 decibels. At 3pm, with around 70 people the average sound level was at 75db. The sound levels reached its peak during lunch hours, with a packed dining area, at a staggering 87 decibels. These figures are way above the usual sound levels for this type of space. Table 1 demonstrates the usual sound levels of corresponding sound representatives. Though these figures are obviously subjective, they are accepted tools to provide an understanding of decibel sound levels. We can see from this table that a school cafeteria which, with children or teenagers is predictably louder than an office cafeteria, maintains an average sound level of only 80 decibels. We can also see that a crowded store, which the Intel cafeteria has been likened to, normally generates only 70 decibels and an average conversation, probably the predominant activity in a cafeteria, is 50 decibels. Furthermore, what can be considered as moderate sound, ideal for relaxation, falls within the 50 to 60 decibel range. Thus, we can deduce from this information that a sound level of 87 decibels for a cafeteria, is above average and is consequently unfavorable for the type of activity the space is intended for.

Sound Representatives	Sound Lvls (db)	Audible Sensation
Airplane take-off	130	Deafening / threshold of pain
Artillery fire	120	
Rock band	110	
Busy city street	100	Very loud
Police whistle	90	
School cafeteria	80	Loud
Crowded store	70	
Average radio	60	Moderate
Unassisted speech w/ audience	50	
Ave. conversation	40	Faint
Ave. residence w/o radio	30	
Average whisper	20	Very faint / Threshold of audibility
Human breathing	10	

Table 1- Average sound levels for various sources of sound

Having accepted that there is indeed a problem of noise, and having quantified the problem to some extent, the next step was to determine why the space produced above average sound intensities. This process began by locating the sources of sound. There was no significant noise of mechanical or electrical origin and neither was external noise observed. The predominant noise sources were human voices engaged in casual conversations, with occasional outbursts of laughter, clicking of heels, and high frequency sounds from utensil contact with bowls and plates. Separately, these sounds generate rather low intensity levels, but combined the intensity levels increase. Additionally, because of the constant noise, the users had a tendency, whether consciously or otherwise, to overpower the background levels by further raising their voices. Obviously, this contributed to the overall noise level.

Considering however, that the cafeteria population was normal for its size, and sound sources were not exactly out of the ordinary, the problem was evidently not limited to noise sources. Attention was then shifted to the time it took for sound energy to die down after it was released. Scientifically, this phenomenon is directly related to the concept of reverberation time. Technically, reverberation time is defined as the "time in seconds for sound to decay by 60 decibels after the sound source has stopped[ii]," but simplified it is merely the time that sounds remain audible in a room.

Reverberation Time and Absorption

There are several formulas to compute for the reverberation time of an indoor space, though the simplest and most widely used by acousticians correlates reverberation time to the volume of a room divided by its total absorption, and multiplied by a constant of 0.16. In mathematical form the formula is represented as:

$$RT = 0.16\,V \;/\; A$$

Where **RT** is reverberation time in seconds, **V** is the volume of the space in cubic meters, and **A** is the total absorption measured in Sabins.

With this formula we can clearly establish that the reverberation time is directly proportional with volume, and thus increases in large spaces, and is inversely proportional with absorption, decreasing with a high amount of absorption within the space. Accordingly, the amount of absorption is proportional to the area of surfaces and with the contents of the room. For instance, with larger walls there is more absorption (regardless of absorptive capabilities), and there is, likewise, more absorption with more people. The same principle applies to furniture, fabric, etc. Though with these, the increase is rather minimal.

All architectural finishes have assigned sound absorption coefficients (sac) based on the actual material and construction method. These coefficients however, vary depending on sound frequencies that come in contact with them. Sound frequencies are inversely proportional to their wavelength, and so porous materials with small openings can better absorb high, rather than low frequency sounds.

In everyday situations we are generally exposed to frequencies ranging from a low of 125 hertz (or 2 cycles per second) to a high of 4000 hertz. However, we are more frequently exposed to frequencies from 250 to 2000 hertz. Because of this relatively wide range, a reasonably formulated average should be used to measure surface absorption. This is the Noise Reduction Coefficient (nrc), which is the arithmetic average of sound absorption coefficients at the standard frequency octaves of 250, 500, 1000 and 2000 hertz, expressed to the nearest multiple of 0.05.

To compute for the total absorption (A) in a space, the area of each surface is first multiplied by its noise reduction coefficient to obtain its surface absorption. The total surface absorption for each surface (i.e. walls, ceilings, floors) is then computed, together with assigned coefficients for people, furniture, and fabric.

Acoustical Conditions of the Cafeteria

The Intel cafeteria is enclosed by four concrete walls, a concrete floor with vinyl tiles, and a suspended ceiling constructed with gypsum boards. Being hard, rigid, and flat, all these surfaces are highly reflective of sound, and, therefore, have very low absorptive qualities. Walls in the space are limited to the perimeter. Other than a small divider separating the servery from the dining area, there are no interior partitions. The tables and chairs are, likewise, made of hard reflective material with very minimal sound absorptive qualities.

Table 2 presents the total absorption computed in the existing Intel cafeteria based on standard noise reduction coefficients for each corresponding surface, and the resulting reverberation time as determined using the RT formula previously mentioned. As is standard procedure, non-absorptive furniture, because it covers the floor, is excluded from the computations while only the average number of people is considered. The computed reverberation time can then be compared with the optimum reverberation time determined by a standard formula.

	Surface	Material	(m^2)	NRC	Absorption
1	**Walls**				
	dining area	plastered concrete	175.00	0.05	8.75
	servery	ceramic tiles	119.34	0.05	5.97
2	**Flooring**	300mm x 300mm vinyl tiles	1051.65	0.05	52.58
3	**Ceiling**	suspended gypsum boards	1051.65	0.13	136.71
		Plus 300 people		0.25	75.00
		TOTAL ABSORPTION (sabins)			**279.01**
		VOLUME of SPACE (m^2)			**2840.00**
	RT (sec)	=0.16(volume)/total absorption 1.6286			**1.63 secs**

Table 2 - Total Absorption in the Intel CV1 Cafeteria

The Reverberation Time in the cafeteria was computed at 1.63 seconds, ideal for large music halls, but relatively long for other types of spaces, including cafeterias. The optimum reverberation time of a room is computed using the following formula:

Optimum RT = 0.3 log Volume / 10

Optimum RT = 0.735 seconds

Thus, the existing reverberation time in the Intel CV1 cafeteria is approximately 0.9 of a second longer than what is considered ideal, considered an eternity when referring to good acoustics. This explains why noise levels appear to be higher than normal.

Another major acoustical concern in the CV1 cafeteria is the potential for flutter echo. Flutter echo is defined as a "rapid succession of noticeable small echoes observed when a short burst of sound is produced between parallel sound reflective surfaces".[iii] With a highly reflective and flat ceiling and floor, and with a very low floor to ceiling height of only 2.70 meters, it is highly probable for this acoustical defect to occur. Though flutter echo is a repetition of sound and not a prolongation, it can nevertheless contribute to a longer perceived reverberation time.

Design Objectives

Though the primary purpose of renovating the CV1 cafeteria was to improve the acoustical conditions, Intel management was also keen on changing the overall appearance to one with a more exciting architectural character than the original. Furthermore, Intel requested that some additional spaces be included for specialized activities. The design objectives established were therefore as follows:

- To improve the acoustical conditions in the room in order to create an atmosphere conducive to rest and relaxation;
- To develop a new layout with functional considerations adherent to circulation patterns of a cafeteria;
- To provide for additional specialized areas, such as laptop stations and one-on-one private booths; and
- To create an atmosphere conducive to rest and relaxation with an aesthetically pleasing and exciting architectural character.

Before zeroing in on the acoustical improvements we first planned the new cafeteria layout. The concessionaire's stall (see Figure 1) previously located at one side of the cafeteria, was moved to the center of the room with at least three meters of free space surrounding it. This allowed for a more functional arrangement as far as queuing lines were concerned, plus it provided a focal point in the room, sorely missing in the existing scheme.

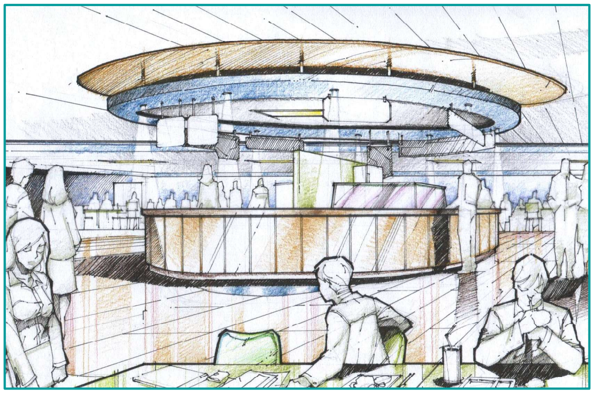


Figure 1: The concessionaire's stall

The laptop stations, for Intel personnel who would want to work during lunch hours, had minimal requirements of accessible internet connections, semi-private space, and a work area that was clearly intended for use by a single person. The private booths were proposed for one-on-one meetings, likewise during breaks, and shared the basic requirements of the laptop stations. To accommodate these requirements, both spaces were situated at ground level, for a psychological feel of extra distance. The laptop stations (see Figure 2) were designed in the form of a semi-circular counter complementing the shape of the concessionaire's stall, while the private booths (see Figure 3) were designed to comfortably fit only two people, strengthening the isolation. As will be discussed later, by nature of the intended activities, these spaces also required extra acoustical attention.

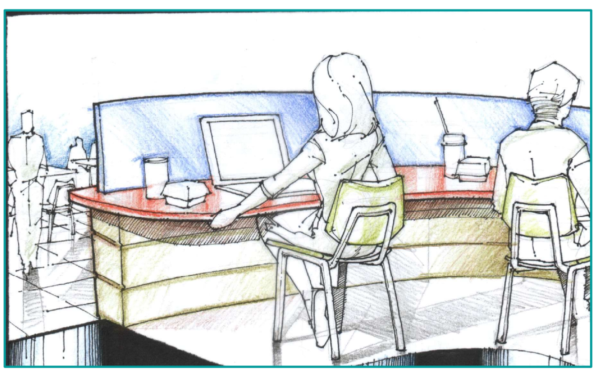


Figure 2 – Laptop station

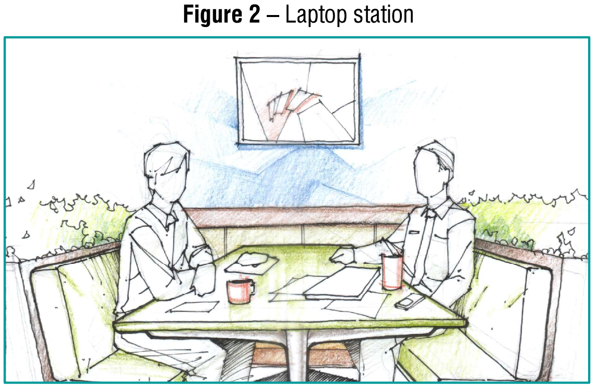


Figure 3 – One-on-one

The rest of the cafeteria was designed to maximize space and allow for the greatest number of tables, while still adhering to comfortable space requirements. For a more ordered layout, several clusters of six to ten tables were located throughout the dining area, and were defined by 1.2 meter high partitions. These partitions were also to contribute to better acoustical conditions.

Improving Acoustical Conditions

Having achieved the architectural design objectives of the project, we then concentrated on the main objective, that of improving the acoustical conditions, obviously the greatest challenge of the project (and the main focus of this paper). The acoustical design objectives were as follows:

- To reduce the reverberation time in the room;
- To increase sound absorption;
- To direct sound towards the highly absorptive surfaces; and
- To eliminate or at least reduce the potential for flutter echo

Most acoustical consultants commissioned to improve sound conditions, particularly to control noise, would immediately turn to conventional methods. The most often used remedy to problems of noise is simply to replace existing materials with more absorptive alternatives. Naturally, we started off with the same method, replacing the gypsum ceiling with acoustical boards and the concrete walls with acoustical fabric covering highly absorptive acoustical blankets in the upper portion and plywood at the lower portion (see figure 4). Despite the dramatic change of absorptive qualities of existing to proposed surfaces, the absorption was way below the requirements.

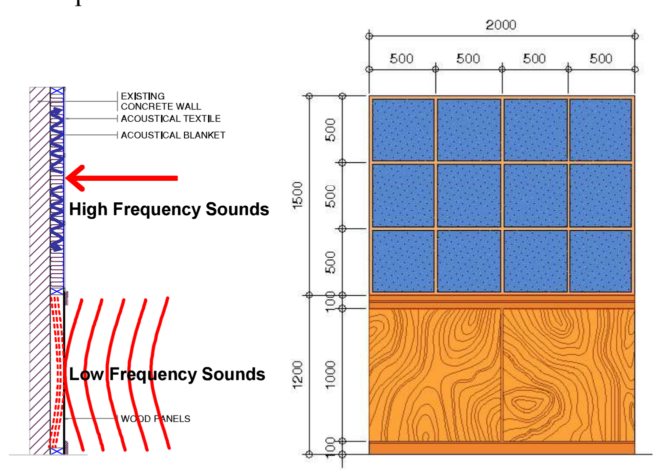


Figure 4 – Dining Area Wall

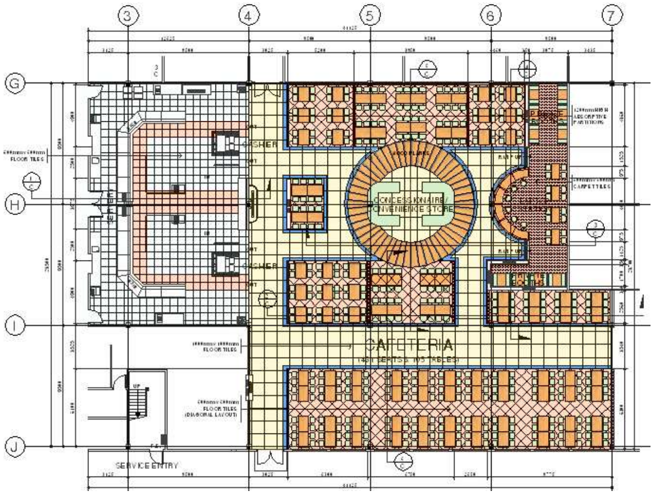


Figure 5 - Proposed plan of Intel CV1 Cafeteria

To determine the required amount of absorption, we inserted the established optimum Reverberation Time of 0.735s into the RT formula used, and solved for the total absorption (in sabins).

$$0.735 = 0.16V / A$$

$$A = 618.231 \text{ sabins}$$

The targeted amount of absorption to achieve the optimum reverberation time was therefore about 618 sabins. When multiplying the walls and ceiling areas by the corresponding noise reduction coefficients of the specified materials, the total absorption was a little less than 440 sabins. Using more absorptive finishes was an option, but these materials were not ideal for the cafeteria because of the following reasons. First, materials with high absorption qualities are softer and more susceptible to destruction, thus being vulnerable in a space with a lot of activity. This for example, explains why acoustical fabric over blankets was specified only for the upper portions of the walls. Secondly, certain absorptive finishes with higher coefficients than the materials we specified, like acoustical sprayed cellulose fiber had the tendency to shred (as do certain types of porous acoustical boards), and this was not permitted by the strict control standards of Intel, especially because food contamination was a possibility. In fact, the use of highly absorptive materials with any tendency to shred was strictly prohibited in the servery area. Finally, because of potential problems in maintenance and cleanliness, the use of carpets, which are practically the only applicable absorptive material for floors, was discouraged.

However, we were able to convince Intel management to permit the partial use of carpets in a limited space, specifically the laptop and private booths area. Because of the raised flooring, the transition from ceramic tiles of the main floor to a carpeted floor was easy and the change did not look odd. Though still not very highly absorptive, carpet floorings on raised wooden floors do provide better absorption than ceramic tiles, with a noise reduction coefficient of 0.25 compared to a rather insignificant 0.02 for ceramic tiles. Additionally, carpet floorings provide a psychological effect of tranquility, suitable for the nature of activities envisioned for the area, that which requires less noise than the others.

The total absorption provided by the floor therefore amounted to approximately 30 sabins, broken down to roughly 15 sabins each for the 938 square meter area with ceramic tiles and 60 square meter area with carpets. The total absorption brought about by surface finishes then amounted to about 470 sabins.

The average number of human bodies during peak hours would also contribute a significant amount of absorption, approximately 75 sabins, increasing the total to 545. But this would still be about 75 sabins less than targeted, and with non-absorptive furniture, there were no more possible sources of absorption.

Another problem concerned the potential for flutter echo. Under normal circumstances the straightforward solution would be to increase absorption of the parallel surfaces, but it had already been established that most of the floor area would not have any absorptive treatment. Increasing the floor to ceiling height was another possible method of at least minimizing the problem. However, utility systems such as air ducting, sprinklers, and electrical lines filled the interstitial space, and Intel management preferred that only minimal, if any at all, adjustments be made on these.

It appeared, therefore, after all standard noise control procedures were exhausted, that non-conventional methods would have to be introduced.

Non-Conventional Methods for Acoustical Control

The first move was to increase absorption in the room by introducing new surfaces. Partitions were proposed to separate table clusters, not only for a more ordered layout, but more importantly to have additional surfaces, and ultimately more absorption in the room. Each partition would be constructed 1.20 meters high with the upper 300cm portion made of acoustical fabric covering an acoustical blanket on a wood frame. The lower portion would be of sturdier material - perforated wood veneer on a wood frame with a hollow space to absorb sound (figure 6). Plant boxes with the same type of construction as the lower parts of the partitions would also be distributed along the space (figure 7). With a linear total of about 35 meters for the partitions and 25 meters for the plant boxes, and with surface absorption on both sides, these elements would contribute about 60 sabins more absorption.

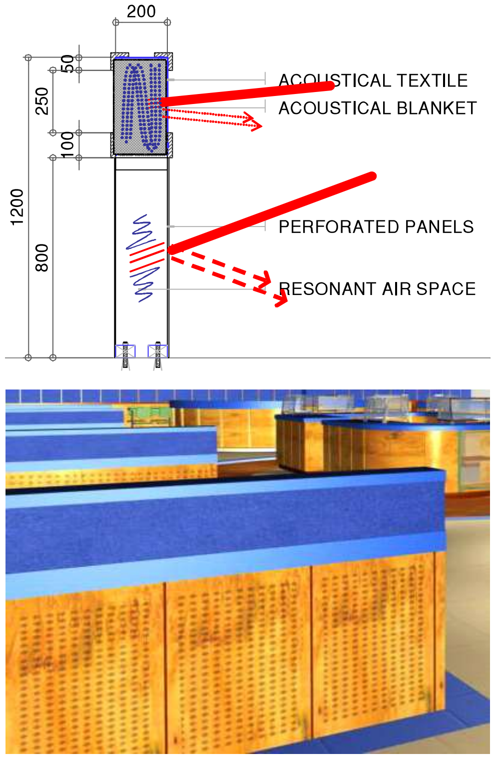


Figure 6 - Sample partition with acoustical fabric over acoustical blankets above and perforated panels below

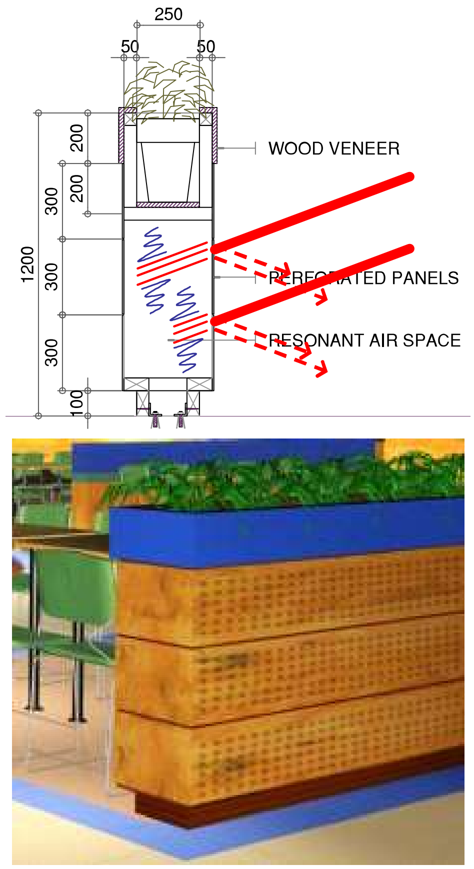


Figure 7 – Sample plant box

Still lacking about 15 sabins of absorption, we then re-explored the possibilities of generating this from the ceiling. Having settled with acoustical boards, the most practical material for the surface, we decided to provide openings for additional absorption, considering especially that openings have the highest possible sound absorption coefficient of 1. We were constrained, however, by the Intel safety regulation that openings directly above the floor area were prohibited. Thus, the ceiling had to be designed to provide openings that did not face down directly to the floor. We did this with three types of ceiling configurations, as can be seen below (figures 9a, b, and c). These openings can be located in the reflected ceiling plan (figure 8) - the three circles represent dropped panels with openings above them (see figure 9a), while the tilted panels in the servery are represented by figure 9b, and the tilted panels between grids 6 and 7 and grids I and J are represented by figure 9c.

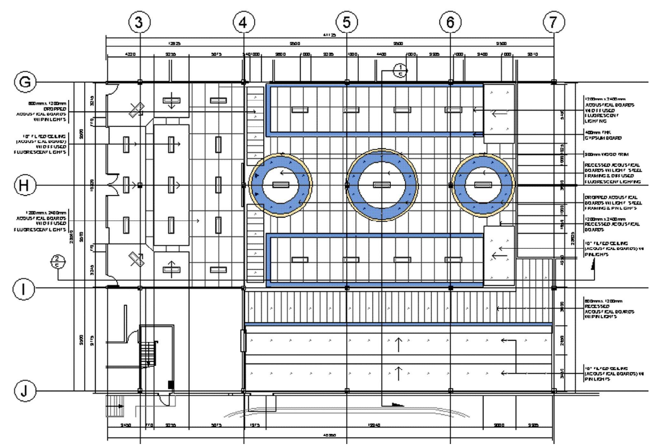


Figure 8 - Proposed reflected ceiling plan of Intel CV1 cafeteria

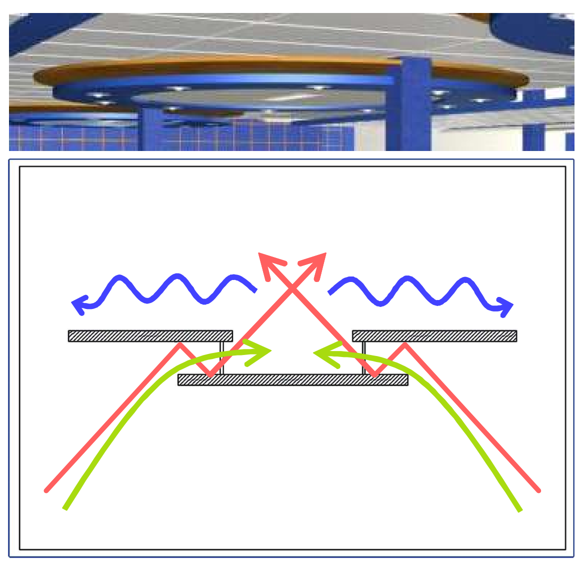


Figure 9a – Dropped panels

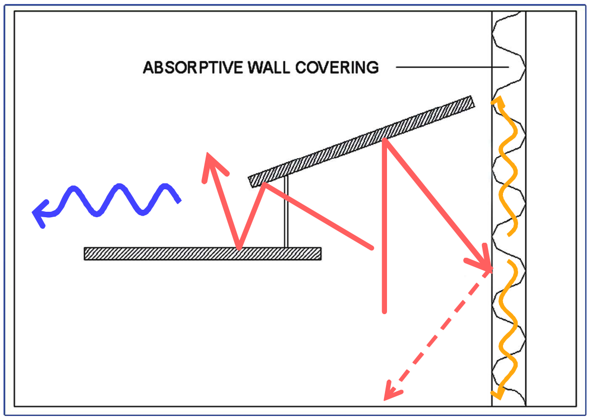
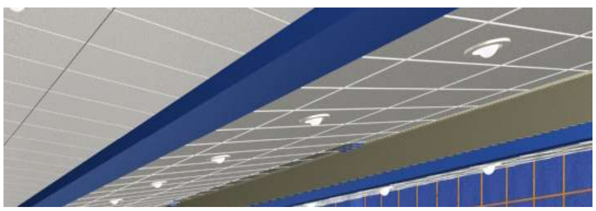


Figure 9b – Tilted panels in servery



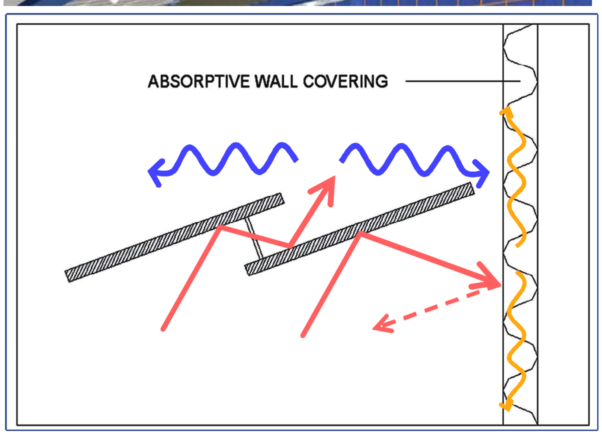


Figure 9c – Tilted panels between grids

Figure 9a shows the ceiling configuration above the concessionaire's area and the laptop stations. The openings are covered by a circular panel with reflective material in the hidden portion (the upper face). Because of the basic principle of sound reflection that the angle of incidence is equal to the angle of reflectivity, sound emanating from the areas below will bounce off the ceiling and the upper face of the dropped panel, and will enter the interstitial space between the ceiling and floor slab above. There the sound will dissipate.

Figures 9b and 9c share the same concept as the previously discussed configuration, but with the additional role of directing sound towards absorptive material. These panels are to be located at the areas of the cafeteria that require a little more noise control than the rest, specifically the laptop and private booths section and that of the servery. Sound emanating from these areas traveling above will either dissipate into the interstitial space or will bounce off these panels and be directed towards the highly absorptive walls. Another advantage to using these is that tilted ceilings, consequently not parallel with the floor, may also be beneficial for eliminating or at least reducing flutter echo. With a total linear measurement of approximately 130 meters in the dining area and 30 meters in the servery, a standard opening of 0.10 meters, and with a sound absorption coefficient of 1, the absorption of these openings add up to 16 sabins, thus effectively producing the required amount of total absorption. Table 3 below illustrates in detail how the total absorption was achieved.

	Surface	Material	(m^2)	NRC	Absorption
1	Walls				
a	upper portion	acoustical fabric with 2" acoustical blanket	78.00	0.70	54.60
b	lower portion	1/4" plywood with 4" air space	97.50	0.20	19.50
c	servery (upper)	mounted acoustical boards	39.78	0.30	11.93
d	servery (lower)	1/4" plywood with 4" air space	79.56	0.20	15.91
2	Flooring				
a	dining floor	600mm x 600mm ceramic tiles	987.00	0.02	14.81
b	laptop stations / booths	600mm x 600mm carpet tiles	58.00	0.25	14.50
3	Ceiling	suspended acoustical boards	1050.0	0.325	341.25
4	ceiling openings		16.00	1.00	16.00
5	Partitions				
a	upper portion	acoustical fabric with 2" acoustical blanket	21.00	0.70	14.70
b	lower portion	Perforated plywood panels	56.00	0.45	25.20
6	plant boxes				
a	upper portion	Wood veneer	15.00	0.05	0.75
	lower portion	Perforated plywood panels	40.00	0.45	18.00
	Plus 300 people			0.25	75.00
		TOTAL ABSORPTION (sabins)			622.15
		VOLUME of SPACE (sq.m)			2840.00
	RT (sec) = 0.16 (volume)/total absorption				0.730 secs

Table 3: Total Absorption in the Proposed Intel CV1 Cafeteria

With the specified finishes shown above, the projected reverberation time will be 0.737 seconds, a mere 0.005 seconds difference from the calculated optimum reverberation time. Considering that the optimum reverberation time formula allows for a ten per cent discrepancy, being this close just about guarantees that the reverberation time after renovation will yield favorable acoustical conditions in the room. An additional plus is the specified absorptive elements which will cater to the entire frequency range.

The act of absorbing sound comes in three classifications: frictional absorption, flexural absorption, and resonance. Frictional absorption occurs when sound brushes along or makes direct contact with porous surfaces. It is more effective with high frequency sounds that have small wavelengths. The upper portions of the walls and the partitions that are made of blankets with a fabric covering, plus the acoustical boards and the carpet floorings are all good frictional absorbers. Flexural absorbers are thin panels that flex or bend when hit by low-frequency sounds (with correspondingly large wavelengths). In the proposed cafeteria, the lower portions of the walls, plus the plant boxes and partitions, all qualify as flexural absorbers. Finally, resonating absorbers have actual air passages for sounds to enter, and are consequently effective for almost the entire frequency range. Examples of these are the small but numerous openings in the panels of the plant boxes and partitions, and obviously the openings in the ceiling. With all three types of absorbers present in the proposed cafeteria, there will be a uniform absorption of sound for the entire frequency range.

With all these data at this point of the design process, we had already developed a solution that was certain to improve the acoustical conditions. Nevertheless, in spite of all the positive projections, additional features were still suggested.

Additional Acoustical Improvements

Figure 108 - Water feature

The computed RT took into account both the dining hall and the servery, and considered them as one space because they were directly connected to each other without any solid separating panel between them. But because of the prohibitions of certain acoustical materials in the servery, this area would have slightly less absorption and consequently a slightly longer reverberation time than the dining area. This was not a cause for concern though, because the intended activity here didn't really prefer or require a quiet environment. However, there was a tinge of concern for those who would sit in the dining area very close to the servery. Though the acoustical conditions there would already be better, the space may appear noisier because of its close proximity to the servery. This psychological effect can be brought about by the users' awareness of the space and its characteristics, and its visibility. Thus, to perhaps control this "psychological problem" we proposed to provide a large water fountain in between the spaces (figure 10) that could mask the noise of the servery with the pleasant sound of splashing water. Technically this would actually contribute, though rather insignificantly, to the total noise levels, but psychologically it should be quite effective.

In the process of determining the right materials and methods to achieve the optimum reverberation time, we considered other possible ways to increase absorption. While introducing partitions and plant boxes as sound absorbing elements will prove to be an effective move, we can actually take this step a little bit further if eventually deemed necessary. As partitions act as sound absorbers in the middle of the room, these are at the lower elevations of the space. At the upper portions we can introduce space absorbers, blankets, rock wool, etc. (figure 11). With a reasonable amount of these, and with proper spacing for better efficiency, the total absorption in the room can be significantly increased. And with their design flexibility, they can be custom made to blend in with the cafeteria's architectural character.

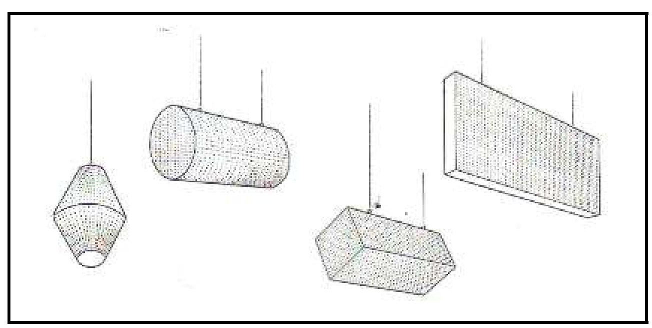


Figure 11 - Functional absorbers in various shapes and sizes

Other absorptive elements we considered included constructing "absorptive tables" out of perforated panels with absorptive lining, much like the partitions and plant boxes. However, these would be too large and bulky and would take up too much space, thus making it difficult to maximize the number of users. Upholstered seats would have also provided a lot of absorption but this proposal was immediately rejected by Intel management because of cleanliness and maintenance concerns, as well as for financial reasons.

Filling the plant boxes with sound absorbing plants was another possibility. Our research uncovered that certain indoor plants with velvety leaves such as the "creeping charley" or "calathea" do have sound absorbing capabilities. However, unless they came in very large quantities, they would not provide very much absorption, and if any, only for high frequency sounds. They were apparently also difficult to maintain. For these reasons then, the proposal was likewise considered impractical.

As earlier indicated, with or without these additional features, the Intel CV1 cafeteria is projected to have a pleasant acoustical environment. The reverberation time will be close to what is theoretically considered optimum; there will be enough absorption to control noise, and a variety of absorptive elements to cover all types of sounds; the problem of flutter echo will be minimized; and certain materials like carpets and the water fountain will psychologically separate quiet areas from those that are less quiet. A good acoustical environment, combined with a functional layout and aesthetically pleasing finishes (with a wood motif highlighted by the Intel color blue), the CV1cafeteria will allow Intel personnel to spend their breaks in a space conducive to rest and relaxation.

Figure 12 - Perspective of the proposed Intel CV1 cafeteria

Conclusion

Thus, even though through retrofitting, which is frequently a difficult task, the acoustical problems of the Intel CV1 cafeteria can be solved. The phenomenon of sound is rather complex, but once understood, it is relatively easy to manipulate, either through widely accepted conventional methods, or because of sound's flexibility, through non-conventional methods presented earlier. It must be stated though, that acoustical conditions in a room should never be overlooked in the design process, as eventually the problem of excessive noise can surface. And retrofitting, though always possible, concerns a great deal of financial resources. The renovation of the Intel CV1 cafeteria is projected to cost close to ten million pesos. For Intel, however, this is a worthwhile project, as experiencing an acoustically pleasant environment during rest hours will ultimately prove to be beneficial to work efficiency and production.

Endnotes

[i] Leslie L. Doelle, *Environmental Acoustics* (McGraw-Hill Inc.), p. 138.

[ii] K. Anthony Hoover, *An Appreciation of Acoustics*. (Cavanaugh Tocci Publishing), 48.

[iii] Leslie L. Doelle, *Environmental Acoustics* (McGraw-Hill Inc.), 59.

References

Doelle, Leslie L. *Environmental Acoustics* (McGraw-Hill Inc.), p. 138.

Hoover, Anthony. *An Appreciation of Acoustics*. (Cavanaugh Tocci Publishing), p. 48.