Noise Reduction in Shooting Range with Recycled PET Bottle

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Abstract

Normally acoustical concern has less interested for most people. For Royal Thai Navy Shooting Range (established 1970) is now facing noise problem since the expansion of Bangkok city area. Within a decade, houses, townhomes and condominiums were built besides and around shooting range which clearly known at the date of bought that those properties will face to shooting noise problems. The new Thai constitution gives more human right without any compromises, therefore, people and neighborhood have raised more complains to shooting noise. All sounds from allowed bulleted were measured from 25 to 2000 Hz. It has about 110-118dBA in 1000-4000 Hz, 108-110dBA in 8000 Hz, and 95-97dBA in 20000 Hz. After4 square meters of 42 kg/cu.m. glass fiber installed, it has about 110 dBA in 1000-4000 Hz, 95-105 dBA in 8000 Hz, and 89-95 dBA in 20000 Hz. Using 4 square meters of 5 cm. thick recycled polystyrene drinking bottle, sound reduction is similar.

Keywords : Shooting range, acoustics, Recycle, Polyethelene plastic bottle (PET)

1. Significance and background of the problem

Royal Thai Navy Shooting Range was established for decades since 1970, originally it is a shooting range located in the open space away from the community dozens of kilometers while its surrounding area had not been developed. Thus it had no noise issue that may impact against the development of Bangkok. At present, since there are communities living in closer area, therefore, preventing and reducing noise arising from the shooting range are required.

In improving to reduce the noise from the shooting range, it is necessary to study and follow the academic principles for reference and being provable.

2. Research Objectives

1) To study and collect data on loudness, sound resonance at the shooting range and noise in the range of 25 meters as occurred from different sizes of bullet allowed to be used at the shooting range.

2) To calculate sound reduction rate and to test sound absorbing material suitable for practical use at the site as well as to collect data for analyze and fundamental evaluation.

3) To propose preliminary guidelines in reducing the loudness and resonance that occurs to be close to standard values and to offer more comfort against noise.

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3. Literature Review

Physical characteristics of the sound associated with human hearing consist of sound level, and the frequency of the sound. Sound level is defined as the level of intensity (IL) in decibel (dB) unit. It refers to the volume between the intensity of the sound and the intensity of threshold of hearing which is 10-16 watts per square centimeter, or 1 dB. Due to the fact that there are various frequencies of sound occur in the actual environment, thus, in measuring the level of sound that responds to human hearing, it requires using A major Scale which is in A-weighted decibel (dBA) unit. Humans can feel the level of loudness from hearing different sources of sound. According to the table in the classroom, if the level of speaker voice in the position of the listener is greater than the background noise more than 6 dBA, this means that the listener just starts to feel the level of sound heard (Just noticeable difference, JND). If we want to make that sound of the speaker to be heard clearly, it requires the difference of sound about 10-20 dBA which means 2-4 times louder.

Sound frequencies required for designing the audio environment are the frequencies in the range that human ear can respond to which is between 20-20,000 Hz (Hertz, Hz). In design and calculation, the frequency range is divided into sub ranges including 63Hz, 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz. The speech characteristics (Speech sound) are characterized in the ranges as shown in Figure 1 and sound characteristic in the environment are shown in Figure 6.

Table 1. Hearing sensation in decibel (Flynn1988)

Different sound levels (dB)	Feeling of the different	Different sound energy
1	Basic Sound Measurement Unit	1.25
3	Difficult to feel the difference.	2
6	Just noticeable difference (JND)	4
10	Recognize the difference 2 times louder	10
20	Recognize the difference 4 times louder	100
30	Recognize the difference 8 times louder	1000
40	Recognize the difference 16 times louder	10^4
100	Recognize the difference 1000 times louder	10^{10}

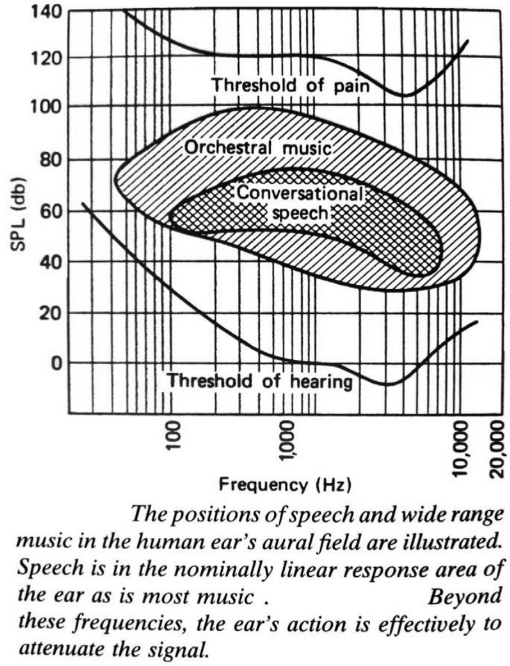

Figure 1 Threshold of hearing (Stein and Reynolds, 2000)

Acoustical comfort theory and the improvement of Sound environment

Sound factor makes the residents feel either impressed or satisfied with the stimulus as well as the integrity in communication. If in case of lack of a good environment adjustment, sound environment being heard can be changed from sound to be heard (sound) into annoying sound (noise) which is a barrier in communication and difficult to endure condition.

In case of the shooting range, gun noise occurs has a very high level of sound which may cause damage to nerve and eardrum. In the long term, this will cause deterioration and deaf eventually.

Hearing comfort

Hearing comfort (acoustical comfort) is a pleasant feeling with sound environment, in the possibility in hearing the desirable sound and in communicating clearly with appropriate sound level, not too loud and not too quiet while noise level can be adjusted to proper level with sound protection, sound absorption and sound reflection approaches.

Sound movement is caused by the movement of the sound source, both stationary source and moving source. In designing of acoustic environment, sound movement must be in to consideration as it is a part of the communication between the source of sound and the listener. In the shooting range, source of sound is stationary while inside the building, there are both stationary and moving residents living in the building.

Noisiness (Lively) and the silence (Dead) of the sound environment is one of the important qualities of the room environment (room acoustics) which reflect the reverberation and level of noisiness and silence in the room. This property is discovered to be calculated and estimated using the method of Wallace Clement Sabine in 1895. This property is called" the reverberation time (RT)" which refers to time interval when the noise occurs and decreases by 60 dB in the environment. RT60 is another of its abbreviation which is very important factor in improving the sound quality in the shooting field.

In case of there is absorbent material installed inside the building or room, this provides low reverberation time which means the acoustic environment in the room will be silent while in case there is reflexive material installed inside the, this provides higher reverberation time which means the acoustic environment in the room will be noisy. Reverberation time can be calculated by equation (1) as follows;

$$T = 0.049\frac{V}{a} \quad (1)$$

(Egan, 1972)

Where	T	is	reverberation time (RT60) in seconds
	V	is	room volume (ft3)
	a	is	sound absorption (sabins)

Remark: 0.16 is used as SI unit.

Sound absorption calculation in room acoustics explained in formula 2.

$$a = \sum S\alpha \quad (2)$$

Where	a	is	total absorption in the room (sabins)
	S	is	inside room surfaces (cu.ft. or cu.m.)
	α	is	absorption coefficient of each material (Egan, 1972)

The property of reverberation in each room setting is different. In case silence is required like in sound recording studio, reverberation time must be relatively low. In case high reverberation is required such as in concert hall, reverberation time must be high. In general room, reverberation time should be around 0.7 - 1.2 seconds.

As for key variable, in equation 1, it indicates that room volume is important variable as well as internal noise absorption. That is, in greater volume, the longer reverberation time occurs easily than those in small volume room. Therefore, in the design of large classrooms, special consideration should be given to these variables.

Physical characteristics of the sound associated with human hearing consist of sound level, and the frequency of the sound. Sound level is defined as the level of intensity (IL) in decibel (dB) unit. It refers to the volume between the intensity of the sound and the intensity of threshold of hearing which is 10-16 watts per square centimeter, or 1 dB. Due to the fact that there are various frequencies of sound occur in the actual environment, thus, in measuring the level of sound that responds to human hearing, it requires using A major Scale which is in A-weighted decibel (dBA) unit.

Humans can feel the level of loudness from hearing different sources of sound. According to the table in the classroom, if the level of speaker voice in the position of the listener is greater than the background noise more than 6 dBA, this means that the listener just starts to feel the level of sound heard (Just noticeable difference, JND). If we want to make that sound of the speaker to be heard clearly, it requires the difference of sound about 10-20 dBA which means 2-4 times louder.

Table 2. Loundnesssensation of human ear (Flynn, 1988)

Different sound levels (dB)	Feeling of the different	Different sound energy
1	Basic Sound Measurement Unit	1.25
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6*	Just noticeable difference (JND)	4
10	Recognize the difference 2 times louder	10
20	Recognize the difference 4 times louder	100
30	Recognize the difference 8 times louder	1000
40	Recognize the difference 16 times louder	104
100	Recognize the difference 1000 times louder	1010

Sound frequencies to be considered for designing sound environment design consist of frequencies in human hearing range between 20-20,000 Hz (Hertz, Hz). In design and calculation, the frequency ranges will be divided into 63Hz, 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz. Sound of speech will fall in the range between 400-600Hz. As for noise derived from gunshot which varies, thus, it requires collecting data from actual location.

Hearing Factor as improved by the environment

Location is a very important factor since buildings located on different sources of sound may cause different noise, such as in a living space, close to public traffic lanes, residential area near the shooting range according to the expansion of the urban areas which cause either more or less noise, or undesirable noise. These affect the design and efficiency of building utilization as well.Noise protection (noise control) is important, as mentioned earlier in the previous section about noise. Protection can be achieved by multiple methods such as the use of soundproofing materials, soundproof wall, clay mound, by reducing gaps or cracks of wall where sound can pass through, etc.

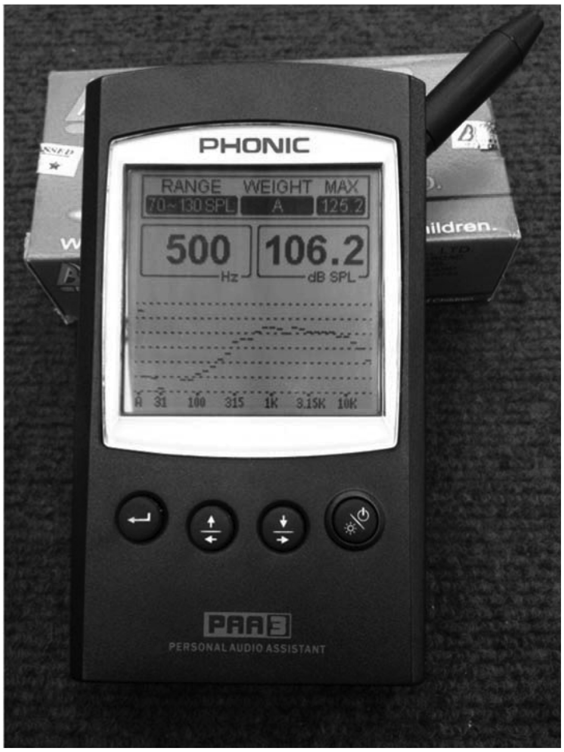

Figure 2 Sound measurement of loudness (Hz.) and reverberation time (RT-60).

The distance between the source of gun-shot sound and the listener outside the shooting field can be determined by standard length of each shooting field, visible distance between the shooter and the target. Or It can be determined by the level of sound heard by the listener. In addition, the distance between the sound source and the listener must allow seeing the target area clearly which is necessary for rehearsal as well since any time the distance is 2 time longer, the volume of the sound is reduced to 6 dB.

Size and shape of the room should be designed to be in lined with standards of the shooting range, numbers of rehearsal participant, properties of firearms used, frequency and volume of gunfire sound that occur. In addition, shape and size of the shooting field also affect the psychology of residents in the building as well.

Sound reflection will result in the design of sound absorption at the source of sound to reduce the sound energy that spreads to outside of the building. In general, smooth surfaces usually provide a resonance from the origin of sound source and reflect across surrounding areas.

Sound absorption must be designed to be consistent with the sound reflection. That is, the acoustic absorption must not cause sound to echo which results the energy of sound to increase. Also, this may be caused by installing some good sound absorbing materials that absorb only the frequencies that do not match with the frequencies of the sound that arise in the area

Position of materials installed must be designed to be in consistent with the general materials, reflective material and sound absorbing materials accordingly.

Direction of material as well as other previous mentioned factors; these must be designed to be in consistent between general materials, reflective material and sound absorbing materials. In particular, the direction of the reflective material requires careful consideration regarding to inclination of the surface plane.

4. Methodology in sound data collecting

4.1 Study, measure and gather physical data of the shooting range in the distance of 25 meters

4.2 Define sound sources that are noisy, sound level in each type of ammunition used, namely 9mm., .38 mm., and 45 mm., using the following guns

4.2.1 Kimber5” .22 LRHV

4.2.2 CZ 4” 9 mm.(blank bullet)

4.2.3 CZ 4” 9 mm. 115 Grain (live bullet)

4.2.4 Revolver 4 “.38 (blank)

4.2.5 Revolver 4 “.38 (live bullet)
4.2.6 Revolver 4 “.38, Special Super + P
4.2.7 Revolver 4 “.357 Maxnum
4.2.8 Kimber5” .45 LRHV (blank bullet)
4.2.9 Kimber5” .45 LRHV (live bullet)

4.3 Evaluate the sound absorption of materials used the field surface in the range of shooting of 25 meters

4.4 Collect information regarding to volume level in each frequency, the level sound before and after using sample sound insulation with the absorption area about 4 square meters at the sound source.

4.5 Perform initial interview with observers in the shooting field before and after the application of sound insulation.

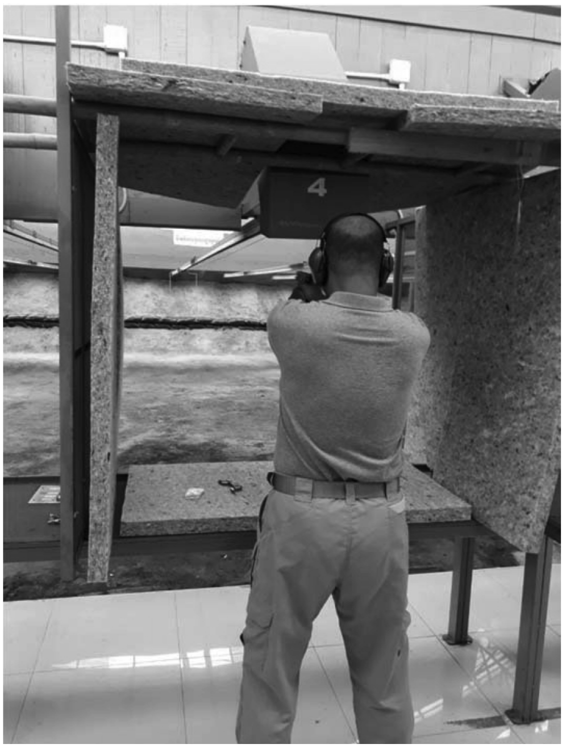

Figure 3 Using 4 square meters of 5 cm. thick recycled polystyrene drinking bottle as sound absorption material.

5. Results in the improvement of shooting range

According to research results and collection of noise data from guns and ammunition, researchers collect data related to sound and the reflection in the range of 25 meters in the shooting field which indicate that the RT60 in the range of 25 meters has the value ranging from 0.79-1.42 seconds (calculated value is approx 0.92 seconds).

Researchers use sound insulation as a case study and perform testing sound absorption using 4 sheets of 1 square meter fiberglass insulation materials (total area of 4 square meters) having a density value at least 48 kg per cubic meter or equivalent.

Results from data collecting indicates that the reflection value of the sound field after installing sound absorbing material using 4m2 fiberglass insulation, the RT60 value obtained ranges between 0.71-0.94 seconds, decreasing by 0.08-0.48 seconds (calculated value is 0.89 seconds).

In comparison of the results before and after using of 4 square meters insulation, the results reveal that;

- The loudness of.22 ammunition has an average value decreased to 5 to 10 dBA
- The loudness of.38 ammunition has average value decreased to 2 to 5 dBA
- The loudness of.45 ammunition has average value decreased to 2 to 5 dBA

When installing soundproof insulation near and at the back wall behind the firing lane, ceiling, shoulder pole in front of the firing lane, the NRC value obtained is approximately from 1.05. Thus, in the total area140-150 square meters, it can be capable of reducing average noise and the reflection time RT-60 for about 0.56 seconds according to the calculated value.

Results from this case study indicate that by using sound absorbing material of 4 square meters, both of fiberglass insulation and recycled plastic fiber insulation, the sound absorption properties of two materials are similar. This can be concluded that application of sound absorbing materials as specified by the researcher can reduce the acoustic noise by 2 to 10 decibels and reduce the reverberation time of the room for about 0.05 seconds. Using only 4 square meters of insulation is only about 3 percent of the whole areas for sound absorption.

Besides, researchers suggest using sound absorbing materials installed on the ceiling, back wall, side wall near the firing lane which will help reduce the noise. In using the firing range in normal circumstances, sound sources that produce the most loudness come from 8 points and when all shooters fire simultaneously, the overall energy of sound and noise increase not exceeding to 10dBA.

Therefore, installation of sound absorbing materials as proposed by the researcher can also absorb sound properly according to the amount of sound source. When users apply ear protection devices, this will help to prevent the noise for a certain level.

Reduction of noise from the shooting range to prevent disturbing the outside environment can be implemented if the level of noise does not approaches to more than 80 to 90 decibels which is the same level of the public road where sources of noise come from cars, motorcycles and public trucks in which people living in surrounding areas hear this level of noise every day.

Table 3 Information about noise level of guns and ammunition in various sizes from the firing field in the distance of 25 meters

Frequency (Hz.) and reflection values of the shooting range in the distance of 25 meters (RT-60) Octave band	25	63	125	250	500	1000	2000	4000	8000	16000	20000	Total	RT 60
Kimber 5” .22 LRHV	80.9	74.7	83.4	101.5	105.1	111.7	111.7	112.5	108.9	98.3	95.7	123.9	0.79
CZ 4” 9 mm.(blank bullet)	79.2	71.5	87.1	104.8	107.7	116.2	115.9	113.1	108	98.7	97.2	125.7	0.71
CZ 4” 9 mm. 115 Grain (live bullet)	79.5	80.7	94	103.9	109.1	117.8	115.6	112.6	110.1	105.7	97.6	126.5	0.71
Revolver4” .38 (blank bullet)	80.6	74.7	83.5	103.1	105.5	108.7	110.5	113.7	110.3	98.5	91.5	120.5	0.84
Revolver4” .38 (live bullet)	81	76.5	88.2	104.5	108.1	113.5	115	111.7	110.7	102.9	94.9	124.9	0.76
Revolver 4” .38 Special Super + P	81.4	81	88.5	106.9	111.1	116.1	113.9	112.9	113.4	103.2	95.3	125.5	0
Revolver4” .357 Maxnum	81.1	77.1	86.9	107.6	110.2	117.7	118.7	114.2	112.1	101.1	97.3	127.2	1.17
Kimber 5” .45 LRHV (blank bullet)	81.6	79.5	91.9	101.3	108.8	116.3	115.5	113	110.3	100.2	93.7	125.9	0.93
Kimber 5” .45 LRHV (live bullet)	79.7	0	91.6	103.2	111.1	117.5	114.3	113.9	109	100.3	95.1	123.6	1.42

Table 4

Information about noise level of guns and ammunition in various sizes from the firing field in the distance of 25 meters, as of 15 October 2013 at 10-11.30 hours with application of 4 square meters glass fiber insulation with density value not less than 48 kg per cubic meter or equivalent.

Frequency (Hz.) and reflection values of the shooting range in the distance of 25 meters (RT-60) Octave band	25	63	125	250	500	1000	2000	4000	8000	16000	20000	Total	RT 60
Kimber 5” .22 LRHV	53.6	66.6	73.2	81.9	84.4	92.3	91.8	94	94.7	89.4	87.6	102	0.73
CZ 4” 9 mm.(blank bullet)	80.3	75.2	85.6	101.7	101.9	110	110	111.2	108	95.1	92	122.4	0.78
CZ 4” 9 mm. 115 Grain (live bullet)	78.5	74.5	83	102.1	103	109.4	111.5	110.1	105.8	99.1	92.2	122.3	0.72
Revolver 4” .38 (blank bullet)	80.3	77	89.9	101.3	102.6	108.9	110.1	109.3	105.9	97.2	90.7	120.1	0.71
Revolver 4” .38 (live bullet)	78.2	83.8	89.2	104.7	105	115.6	114.5	113.5	110.2	98.1	93.9	126.3	0.94

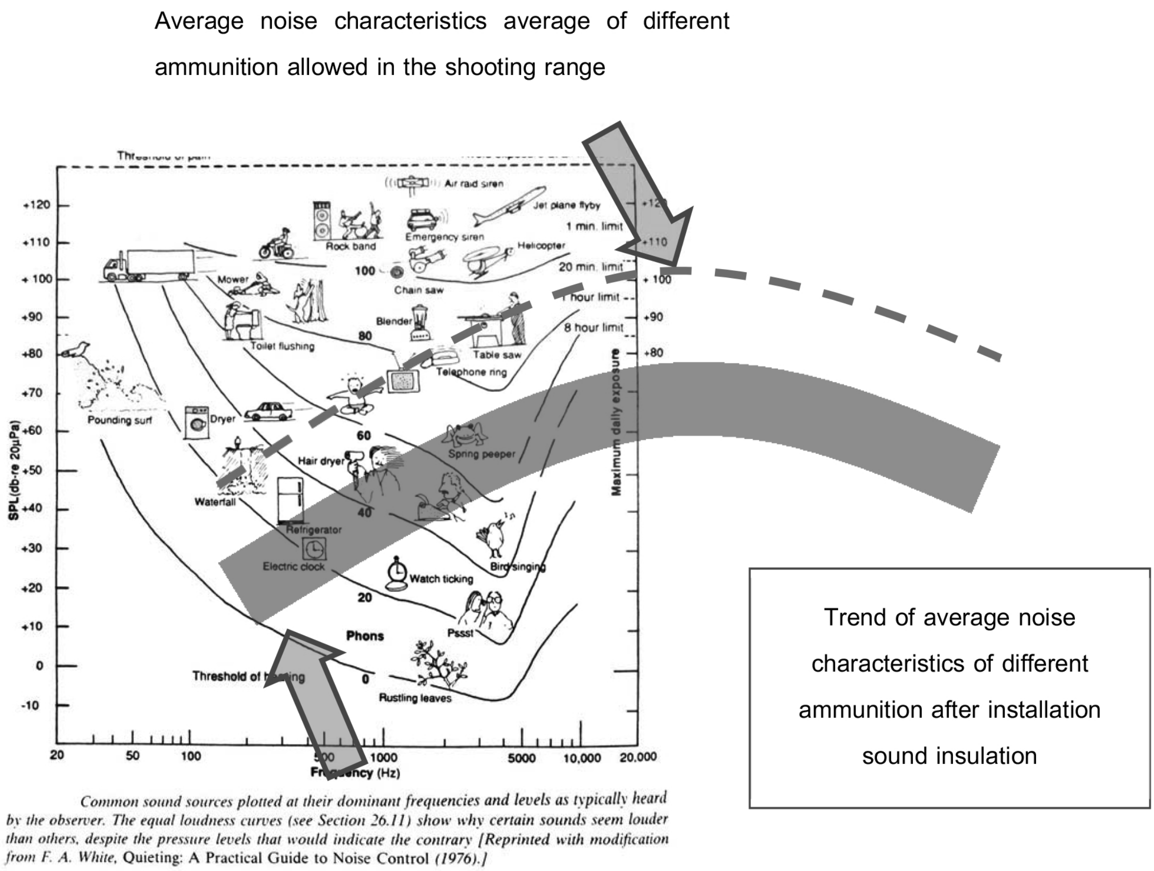

Figure 4 Average noise level of guns and ammunition used for testing in the shooting field in the range of 25 meters, compared to the noise found the environmental settings of Stein and Reynolds (2000)

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