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Original Article

A Study on Soundproofing Efficiency According to Sound Barrier Type

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Abstract *- A sound barrier is a wall that serves to provide a high-quality hearing environment to people living in a nearby living area by blocking noise generated from a car-only road. The Sound barrier can be divided into reflective, sound-absorbing, interference, and resonance types according to the soundproofing method. There are transparent, metal, non-metallic, vegetation, and solar panel types depending on the soundproofing material. Among the sound barrier, the reflective type is mainly installed in terms of cost, and the transparent type, wood material or steel material sound barrier is mainly used for aesthetics. In this paper, the sound insulation level of the Flat Type of Transparent Sound Barrier was tested among the reflective sound barriers currently used mainly for automobile roads. Among the interference type sound barriers, Steel Material Interference Type Sound Barriers and Wood Material Interference Type Sound Barriers were tested to determine the most efficient sound barriers. Through this study, it is intended to help select and install appropriate sound barriers for urban aesthetics as well as soundproofing efficiency between automobile roads and living areas. In addition, it suggests the need for research on soundproofing environments in various ways, going beyond soundproofing research between automobile-only roads and living areas, which rely only on sound barrier Future.*

Keywords *- Sound barrier, Transparent type, Flat Type Transparent Sound Barrier, Steel Material Interference Type Sound Barrier, Wood Material Interference Type Sound Barrier, Soundproofing efficiency, Automobile roads, Living areas.*

1. Introduction

Recently, in Korea, civil complaints related to road noise have been increasing every year to the extent that the proportion of civil complaints related to road noise exceeds 40% of the complaints related to noise received by the Seoul Metropolitan Government. In addition, since road noise causes damage such as sleep disorders and psychological stress, the importance of sound barriers is gradually increasing. The importance of soundproofing walls promotes research on soundproofing methods and materials for soundproofing. Since sound barriers should be installed around general residential areas along general roads or highways in residential areas, they should be carefully installed so as not to harm the aesthetics around residential areas or the scenery around highways. Of course, to improve the quality of life of citizens complaining of damage due to road noise, it is necessary to accept damage to the aesthetics and scenery around the road to some extent. According to the soundproofing method, the currently installed sound barrier can be divided into reflective, sound-absorbing, interference, and resonance types. There are transparent, metal, non-metallic, vegetation, and solar panel types depending on the soundproofing material. Recently, plants have been used, or design elements have been added to consider urban aesthetics, but efforts to fundamentally reduce road noise require research considering cost-effectiveness. This paper tested the level of sound insulation of flat-type transparent sound barriers among the reflective sound barrier currently used mainly for automobile roads. The sound insulation level of the steel-type sound barriers and wooden-type sound barriers were tested among the interference-type sound barrier. According to the result, the most effective sound barrier type is determined. As a research method, to find out the degree of sound insulation of the three types of sound barriers presented above, actual road noise was recorded from behind each sound barrier and compared using an acoustic analysis program. The results obtained through comparative studies will be valuable data for installing sound barriers that reduce noise in roads and living areas and do not spoil aesthetics in the future.[1][2]

2. Sound Barrier

A sound barrier refers to a soundproofing fence installed to reduce direct transmission of noise generated by vehicles running at high speed on an automobile-only road to nearby residential areas and business facilities. Sometimes, a sound barrier is not aesthetically pleasing and obstructs views. However, they are necessary facilities in that they prevent the

quality of life from being impoverished due to suffering from noise. Recently, The shape of the sound barrier is also been diversifying in the direction of paying attention to urban aesthetics, such as applying a design that fits the surrounding landscape. Reflective transparent material, a sound barrier, is mainly used on roads with the beautiful surrounding scenery. Opaque material, a sound barrier, is used in various ways to protect the privacy and secrets of residential areas and major public facilities. In addition, to surely increase soundproofing efficiency, interference-type sound barriers made of wood or steel are also popularly installed, even if it costs a little more.[3][4]

2.1. Types of the Sound Barrier

A Sound barrier is installed using appropriate materials in an appropriate way according to the situation and topography in consideration of the surrounding environment. The sound barrier must be constructed and installed with strong durability and safety so that they do not corrode for a long period of time and maintain the aesthetics of the city. The sound barrier can be divided into types according to soundproofing methods and types according to the sound barrier materials. Types according to soundproofing methods can be divided into reflection type, sound absorption type, interference type, and resonance type, and types according to the sound barrier materials include transparent type, metal type, non-metal type, vegetation type, and solar panel type.[5][6]

2.1.1. Type According to the Soundproofing Method

The soundproofing method should be installed appropriately considering the surrounding conditions and topography of the place where it is necessary to install the sound barrier. Depending on the surrounding environment, places with cultural heritage, tourist destinations, special management areas, and natural environment protection areas need to pay more attention to and install sound barriers to not harm the surrounding aesthetics. In addition, it is necessary to know the surrounding terrain well and choose an effective soundproofing method is necessary. There are reflective types, sound absorption types, interference types, and resonance types of sound barriers according to the sound insulation method.[7]

2.1.2. Types According to Soundproofing Materials

The soundproofing material should be selected in connection with the soundproofing method designed in 2.1.1 above. The selection of materials should also consider the surrounding environment and topography. However, since materials are an important break-even point in terms of cost and efficiency, they should be selected carefully, paying attention to cost-effectiveness. There are transparent, metal, non-metal, vegetation, and solar types of sound barrier material.[8]

Table 1. Types of the sound barrier

Division by the sound barrier	Sound barrier installation details	Contents
Sound barrier installation method	Reflective type	How to reflect noise
	Absorption type	How to absorb and reduce noise
	Interference type	A method of reducing noise by making the reflective surface multifaceted so that the reflected noise interferes with each other
	Resonance type	The way in which the sound resonates in the empty space of the soundproof wall and then gradually diminishes
Sound barrier material	Transparent type	Reflects noise using transparent materials such as polycarbonate and laminated glass
	Metal type	A method of absorbing noise by perforating metal materials
	Non-Metal type	A method of reflecting or absorbing noise using materials such as ceramic, synthetic resin, concrete, and wood
	Vegetation type	Method to prevent heat island phenomenon by improving vegetation landscape and controlling temperature and humidity using ivy, etc.
	Solar generator type	A method of pursuing both noise reduction and energy generation effects at the same time by mounting solar power generators on the sound barrier, both sides or on top of the wall
Soundproof tunnel	Method for maximizing soundproofing effect by installing in an area where high-rise buildings are concentrated	

2.1.3. The Soundproof Tunnel

As for the soundproofing method, the method of installing barrier walls is mainly used, but in areas where high-rise buildings are concentrated, The soundproofing tunnel is installed to maximize the soundproofing effect while preserving the urban aesthetics. When installing a soundproof tunnel, the average sound absorption rate is about 70% efficient, and the visible light transmittance of 85% or more must be secured to secure the field of view in the tunnel. The soundproof tunnel does not unconditionally dig tunnels underground but uses a method of blocking the outside world by making walls and roofs on the ground. In the case of soundproof tunnels, there is a disadvantage that it may be difficult to ventilate in case of traffic congestion and to process in case of accident or arson. Not long ago, in Korea, there was an accident in which a fire ignited by a truck running in a soundproof tunnel was transferred to an acrylic soundproof wall material, resulting in 5 deaths and 41 injuries. (December 29, 2022, 2nd Gyeongin Expressway Fire Incident in the Republic of Korea) Since then, the risk of soundproof tunnels has also emerged.[24,25]

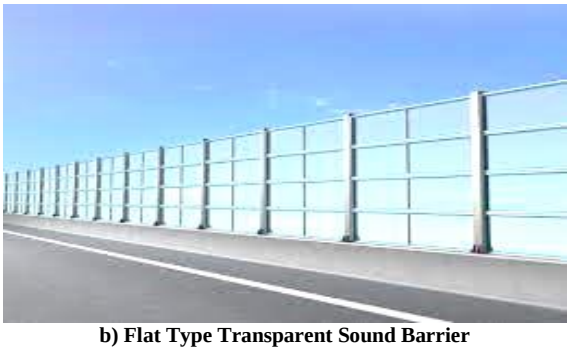
3. Structural Design Study by Sound Barrier

For a comparative study on the soundproofing efficiency of each type of sound barrier, the structural designs of the reflective transparent sound barrier, interference-type steel sound barrier, and interference-type wooden sound barrier, which are most commonly installed in the Republic Of Korea. This study confirmed each sound barrier's installation environment and structural characteristics, and the need for a sound barrier to be installed was analyzed.[11][12]

3.1. Flat Type Transparent Sound Barrier

The Flat Type Transparent Sound Barrier is a general reflective sound barrier and is made of a canopy, transparent acrylic, or tempered glass. It is a sound barrier made of transparent flat panel material so that one can feel the surrounding scenery in a place where no living area is close to a highway or car-only road and consists of fields. If a black coating film is applied, it will be stuffy and disgusting. Sometimes birds collide with each other, so birds or stickers with various patterns are attached here and there.[13]

a) Reflective transparent sound



b) Flat Type Transparent Sound Barrier
Fig. 1 Flat Type Transparent Sound Barrier

3.2. Steel Material Interference Type Sound Barrier

The soundproofing method of the interference-type sound barrier made of steel is a sound barrier with irregular reflection surfaces by digging various grooves in the metal material. Since it is made of steel, it is durable, but it is a sound barrier that is used for the purpose of thoroughly blocking the interior by giving a heavy and stuffy feeling or focusing only on soundproofing rather than urban aesthetics.[21]

a) Steel panel of steel interference Type Sound Barrier

b) Steel Material Interference Type Sound Barrier
Fig. 2 Steel Material Interference Type Sound Barrier

3.3. Wood Material Interference Type Sound Barrier

The Interference-type sound barrier made of wood has the same soundproofing method as an interference-type sound barrier made of metal, but they use softwood and cancel out noise by making the reflective surface irregular. Above all, interference-type soundproof walls made of wood are the most aesthetically pleasing among the opaque

materials used for privacy in living areas. They have excellent sound-absorbing power to absorb noise, so they are often installed along roadsides adjacent to living spaces, educational facilities, and office spaces.[15][16]

a) interference sound barrier wood material

b) Wood Material Interference Type Sound Barrier

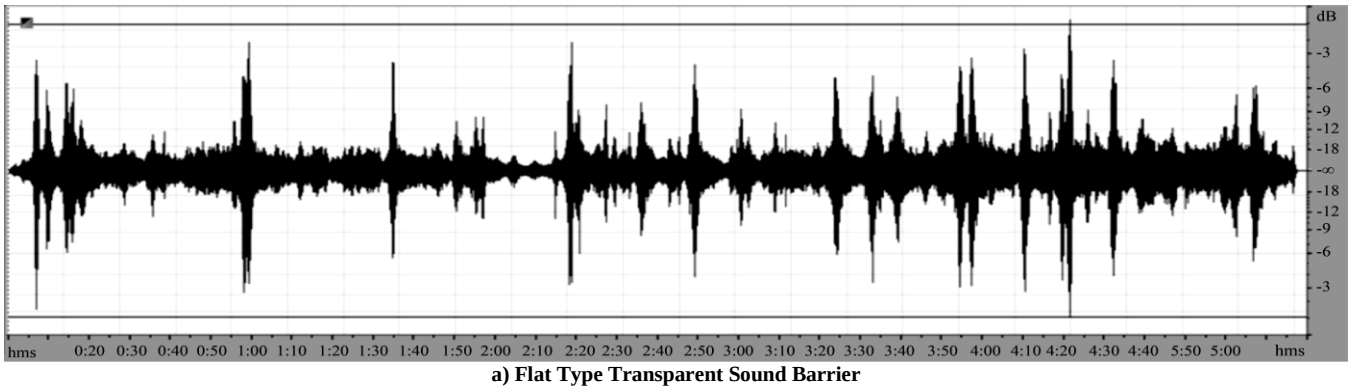
Fig. 3 Wood Material Interference Type Sound Barrier

4. Comparative study on Soundproofing Efficiency by Type of the Sound Barrier

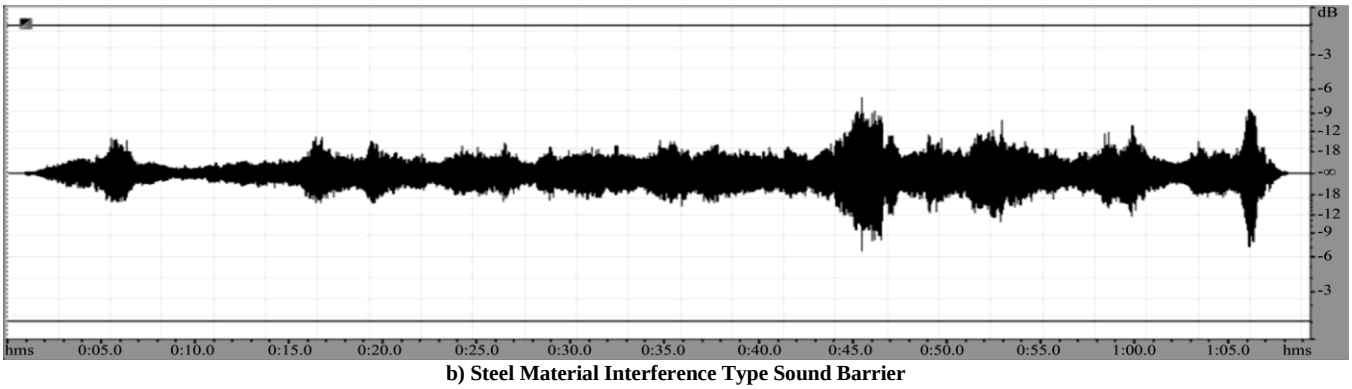
The soundproofing efficiency of the Flat Type Transparent Sound Barrier of reflective sound barriers and Steel Material Interference Type Sound Barrier, Wood Material Interference Type Sound Barrier of interference-type sound barriers among the three major models of the sound barrier in Korea were studied. Time domain analysis, spectrogram analysis, and comparative spectral analysis were performed to study the sound insulation efficiency of the three sound barriers above. The sound source for analysis was recorded at the place where each of the three sound barriers was installed, and the sound source was analyzed using Adobe's audition program. The recorder used for recording was a digital Handy recorder H2 recorder from ZOOM

4.1. Time Domain Graph Comparison

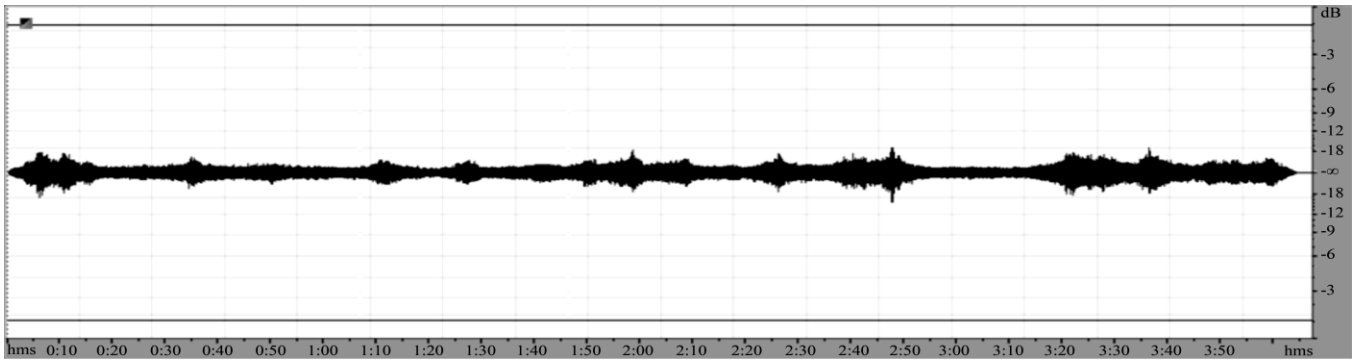
Time domain analysis is an analysis using a graph that can identify the characteristics of loudness by time period by analyzing the change in volume over time. The horizontal axis of the time domain graph represents time, and the vertical axis represents volume (dB). To study the efficiency of sound barriers, the soundproofing efficiency of Flat Type Transparent Sound Barrier among reflective sound barriers and Steel Material Interference Type Sound Barrier and Wood Material Interference Type Sound Barrier among interference-type sound barriers were analyzed with time domain graphs.[23]



a) Flat Type Transparent Sound Barrier



b) Steel Material Interference Type Sound Barrier



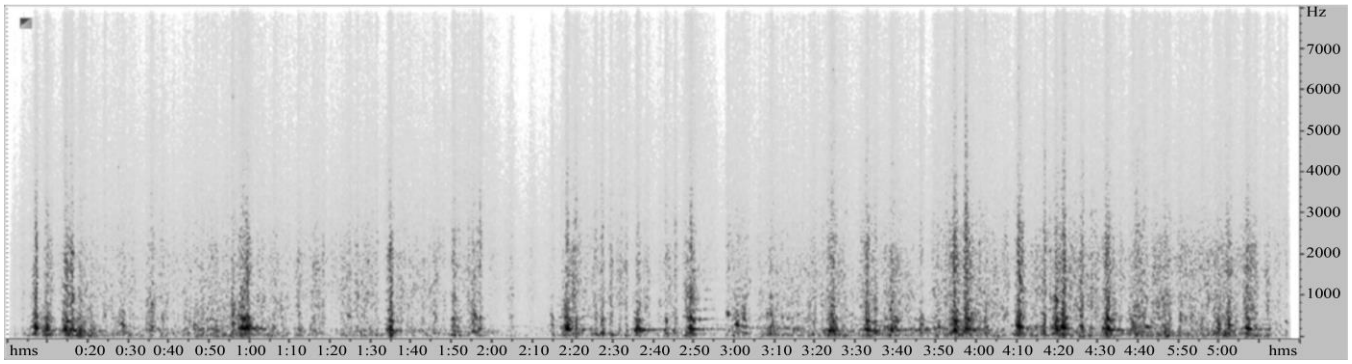
c) Wood Material Interference Type Sound Barrier

Fig. 4 Comparison of time domain graphs

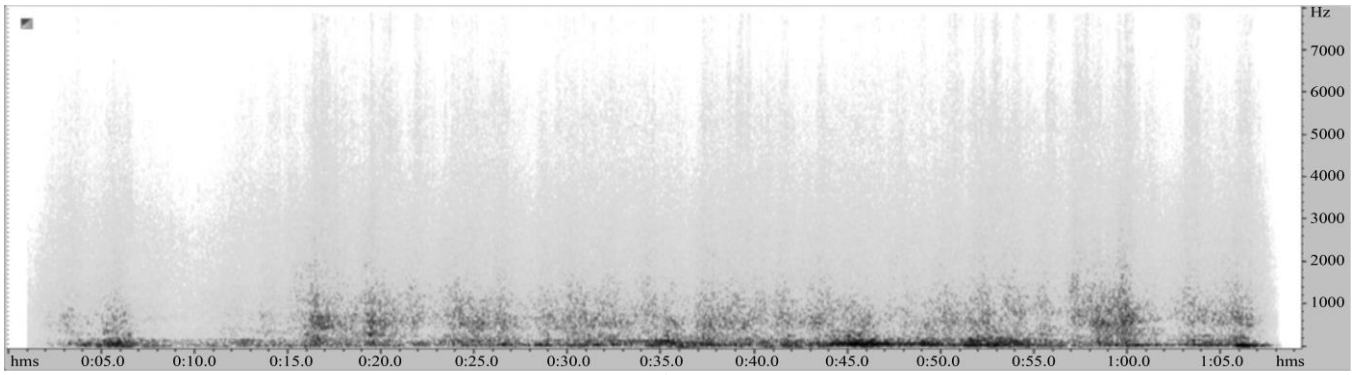
A is a time-domain graph of a Flat Type of Transparent Sound Barrier, and a graph in which the volume of each time period is higher than that of the other two sound barriers is formed. This graph shows that a. The Flat Type Transparent Sound Barrier has lower sound insulation efficiency than the other two types of sound barriers. b is a time domain graph of the Steel Material Interference Type Sound Barrier, and the width of the volume by time period is smaller than a bit larger than c. The b. graph shows the second largest noise among the three sound barriers above. c is a time-domain graph of the Wood Material Interference Type Sound Barrier. Among the three sound barriers, the change in volume over time is low, which shows that the soundproofing efficiency is the best. Looking at the results shown in the time domain graphs of the three sound barriers above, the order of excellence in sound insulation efficiency was c. Wood Material Interference Type Sound Barrier > b. Steel Material Interference Type Sound Barrier > a. Flat Type Transparent Sound Barrier.

4.2. Spectrogram Graph Comparison

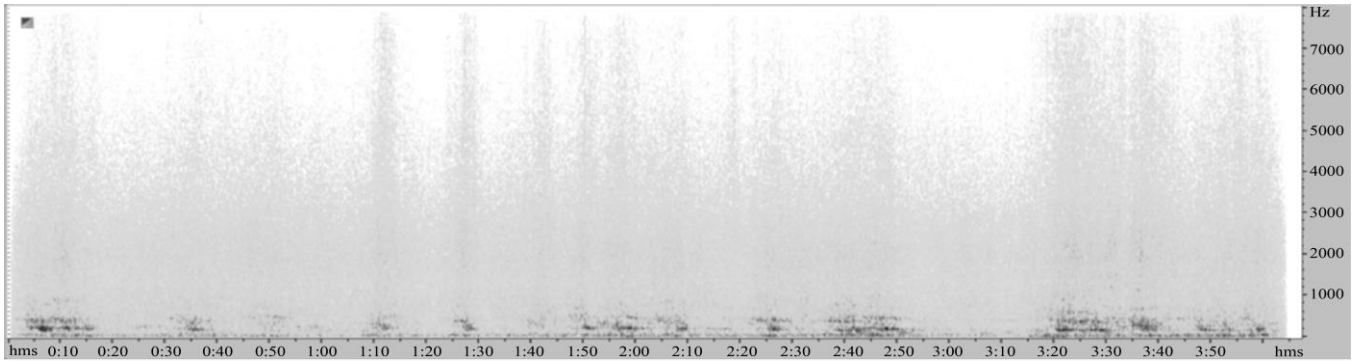
The spectrogram graph is a graph showing the energy distribution of acoustic components according to frequency changes over time. The horizontal axis of the spectrogram graph is composed of time, and the vertical axis is the frequency (Hz). The distribution of sound energy is described by varying the density of light and shade by using red color for sound density. The three spectrum graphs below are a. Flat Type Transparent Sound Barrier, b. Steel Material Interference Type Sound Barrier, c. Wood Material Interference Type Sound Barrier. a is a spectrogram graph of the Flat Type Transparent Sound Barrier, and in the frequency band of 4,000Hz or less, sound energy is stronger than b. Steel Material Interference Type Sound Barrier, and c. Wood Material Interference Type Sound Barrier. This means the a. Wood Material Interference Type Sound Barrier has lower soundproofing efficiency than the other two sound barriers. b is a spectrogram graph of the Steel Material Interference Type Sound Barrier, and the sound energy is smaller than that of a. the Flat Type Transparent Sound Barrier. However, the sound energy below 2,000Hz is greater than that of the c. Wood Material Interference Type Sound Barrier shows a large graph with a large noise. c is a spectrogram graph of the Wood Material Interference Type Sound Barrier. The sound energy is expressed as low among the three sound barriers, so the soundproofing efficiency is the best. Judging from the results shown in the spectrogram graphs of the three sound barriers above, as in the comparative analysis of the time domain graph, the order of excellence in sound insulation efficiency is c. Wood Material Interference Type Sound Barrier > b. Steel Material Interference Type Sound Barrier > a. Flat Type Transparent Sound Barrier appeared in order.[18]



a) Flat Type Transparent Sound Barrier



b) Steel Material Interference Type Sound Barrier



c) Wood Material Interference Type Sound Barrier

Fig. 5 Spectrogram graph comparison

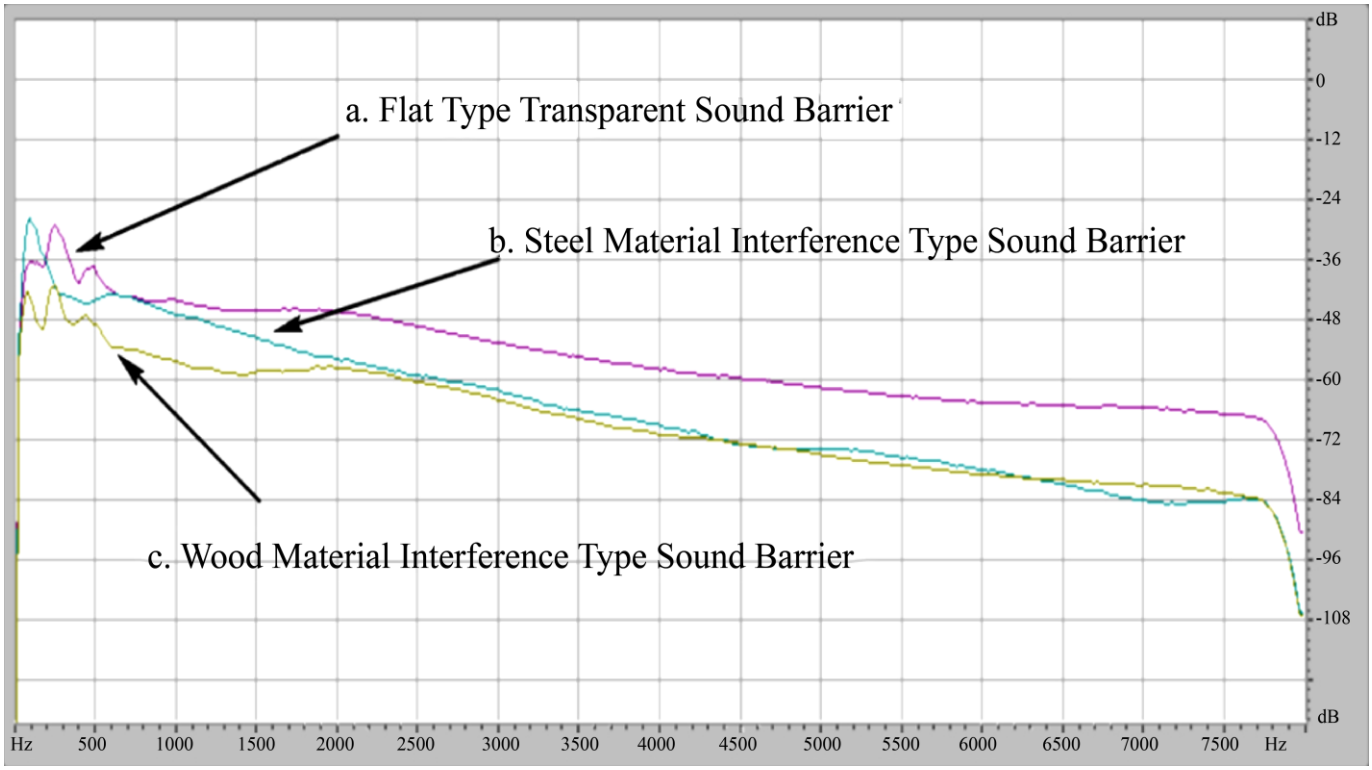


Fig. 6 Spectrum comparison graph for each type of sound barrier

4.3. Spectral Analysis for Comparison of Sound Insulation Efficiency by Type of Sound Barrier

It is a sound barrier installed at the boundary between a car-only road and a living area to minimize noise generated by driving. Flat Type Transparent Sound Barrier, Steel Material Interference Type Sound Barrier, and Wood Material Interference Type Sound Barrier are representatively installed and operated. There are various types of sound barriers, but these three types of sound barriers are strictly selected in terms of urban aesthetics and sound insulation efficiency. Of course, these sound barriers have characteristics for each installation site regarding structure and material, but it is necessary to check their efficiency first. This is because the sound barrier is a semi-permanent facility in cost and location selection, so it must be decided carefully. A spectrum analysis was performed to compare the sound insulation efficiency of each type of sound barrier. Spectrum analysis is a graph that calculates the average frequency range of sound and derives and compares the overall sound change.[19]

Looking at the spectrum comparison graph for each type of sound barrier in Figure 6, a. The Flat Type Transparent Sound Barrier shows high decibels in the low-frequency band and the entire audible frequency band—second b. Steel Material Interference Type Sound Barrier show high decibels, and third, c. Wood Material Interference Type Sound Barrier show the lowest decibels. Therefore, in order of sound insulation efficiency, c. Wood Material Interference Type Sound Barrier > b. Steel Material Interference Type Sound Barrier > a. Flat Type Transparent Sound Barrier can be listed in order. As a result, the spectrum comparison graph for each type of sound barrier shows that the interference-type sound barrier has higher sound insulation efficiency than the reflective-type sound barrier. Among the interference type sound barriers, the Wood Material Interference Type Sound Barrier has higher sound insulation efficiency than the Steel Material Interference Type Sound Barrier.[20]

5. Conclusion

Currently, noise reduction measures in automobile-only roads and living areas rely heavily on installing sound barriers. However, the problem is that sound barriers cannot be a complete countermeasure. In particular, noise complaints are occurring in high-rise apartments near expressways, even though they have sound barriers because soundproof walls cannot significantly reduce noise in high-rise buildings. In addition, as citizens' environmental awareness and aesthetic sense are gradually improved, the importance of urban aesthetics is on the rise, so functional soundproof walls considering aesthetics are preferred over general sound barriers. In order to meet such a part, the most commonly installed sound barriers these days are Flat Type Transparent Sound Barriers, Steel Material Interference Type Sound Barriers, and Wood Material Interference Type Sound Barriers. In this paper, as a result of studying the soundproofing efficiency of the above three sound barriers, the order of soundproofing efficiency was analyzed in the order of Wood Material Interference Type Sound Barrier, Steel Material Interference Type Sound Barrier, and Flat Type Transparent Sound Barrier. However, various studies are needed since only sound barriers cannot completely solve road noise. As an alternative method, research has been conducted on how to pave the road in the corresponding section with low-noise pavement materials in order to focus on managing noise in high-speed or high-vehicle traffic sections. In particular, since road pavement materials must be durable, developing special materials and special road pavement methods must be studied in parallel. In addition, since road noise is not only caused by the road surface, it is necessary to study various aspects such as the surrounding environment and traffic volume adjustment.

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