博士論文（要約）

# Study on sound insulation characteristics of double-layer wall using vibration absorbers

# (動吸振器を用いた二重壁構造の遮音特性に関する研究)

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The Drywall (also called plaster board, gypsum board, or LAGYP) is widely used in architecture. The advantages are light weight, low cost and convenient for construction. The light weight property of the drywall is easy for conveyance and suitable for the earthquake﹣proof buildings, especially the tower buildings. In Japan, the drywall is used for saving the building cost in the detached house and is also used for the party wall in the apartments and mansions. However, the drywall was not applied popularly because of the humid climate in Taiwan. But recently, it is commonly used for earthquake﹣proof designs due to the increase of the tower buildings .

There is one disadvantage of the drywall which is the low sound insulation performance. The problem is serious when using the drywall as the party wall because of the lightweight. In Taiwan, the standards or legalizations of the sound insulation of the party wall have yet to establish perfectly. It is hard for the customers to know the sound insulation performance of the drywall before purchasing an apartment.

When a dispute with the noise problem due to the low sound insulation performance occurs, the builders increase the thickness of the drywall or plus an additional dry wall to construct a double-layer wall (DLW). In the view point of the sound insulation characteristics, the double-layer wall is better than the other structure if they cost the same construction space. Therefore the double-layer wall are widely used in the studios, rehearsal rooms or acoustics laboratories where the high sound insulation characteristics is demanded. In addition, the double-layer wall is also used to control the noise from the vehicles, trains, or home appliances in mechanical engineering.

The high sound insulation characteristics of the double-layer wall are due to separated walls to isolate the sound and vibration transmission. In spite of that, the air in the structure works like a spring and a resonance problem exists in the mass-spring-mass structure. When the structure encounters an incident sound with a specific frequency, the violent vibration of the walls occurs and the sound transmits through the walls totally. This phenomenon is called “mass-air-mass (MAM) resonance” and it causes the deterioration of the sound insulation characteristics of the double-layer wall.

For the controlling the vibration of the walls, the vibration absorber (or dynamic vibration absorber) is an efficient device.

In mechanical engineering, the unnecessary vibration can be controlled by the vibration absorber when the engine of a car runs. As the same principle, the vibration absorber is also applied in the home appliances such as washing machines, refrigerators and so on. In the optical drive, the vibration absorber is attached on the motor to reduce the vibration at the operation frequency in order to raise the precision of reading and writing.

The method of applying the vibration absorber to control the vibration is that adjusting the natural frequency of the vibration absorber equal to the problem frequency of the target system. However, this method causes the other vibrations occur at lower and higher frequencies than the problem frequency. Therefore, the vibration absorber is usually designed to make the other vibrations excited at the frequency which is out of the operation frequency range or out of the human perception frequency.

The main objective of the present thesis is to provide a simple structure vibration absorber to see the effect on the sound insulation characteristics of the double-layer wall. The targets to be controlled by the vibration absorber include the double-layer wall applied in architecture and mechanical engineering.

On the basis of the previous studies, the applications of the vibration absorber can raise the sound insulation performance at the MAM resonance frequency band but made the performance worse at the other frequency bands. Therefore, finding a solution to deal with the issue is also an important target.

Besides to provide an available vibration absorber, the thesis indicates the way to use the vibration absorber and shows the mechanism of the vibration absorber in the double-layer wall by comparing the various conditions. The comparisons are conducted by theoretical analysis, numerical analysis, and scale model experiments.

This thesis has presented the applicability of the vibration absorbers in the cavity and examined the effects on the sound insulation characteristics of the double-layer wall. The process to design the vibration absorber, the mechanism to affect the sound insulation characteristics and the guideline to use the vibration absorber were the main issues to investigate.

First, the effects of the vibration absorber mounted in the double-layer wall were verified elementarily by using the one-dimensional model in theory analysis. It indicated the improvement of the sound insulation characteristics at the original MAM resonance frequency and the movement of the MAM resonance due to the vibration control of the vibration absorber. Also, the movement of the MAM resonance was the problem should be dissolved when applying the vibration absorber.

Secondly, in order to makes the model closer to the real structure and verify more detail of the vibration absorbers, the numerical analysis by FDTD method was developed. As the results of the analysis, the mechanism of the effects on the sound insulation characteristics was identified due to the vibration control, sound absorption and obstacle factor of the vibration absorber. To consider the application of the vibration absorber in practice, two factors, the sound absorption of the damping material and the distribution pattern, were investigated. The analysis also indicated the selection of a damping material with general sound absorption could compensate for the deterioration of the sound insulation characteristics due to the movement of the MAM resonance and the distributed the vibration absorbers in a more dispersed pattern could obtain the better sound insulation characteristics.

Finally, for confirming the conclusions from the theoretical and numerical analysis, the experimental investigations were proceed by utilizing the scale model. By the experiments, the process to develop a vibration absorber was indicated that measuring the spring constant of the damping material and then tuning the vibration mass to let the natural frequency of the vibration absorber equal to the MAM resonance of the double-layer wall. According to the investigation of the materials, selecting a damping material with sound absorption could solve the problem due to the movement of the MAM resonance effectively. The two factors for applying the vibration absorber in practice were also examined in experiments and the conclusions were similar to the results verified in the numerical analysis. The other investigations in confirmation of the theoretical and numerical analysis also obtained the similar conclusions. Therefore, the function of the vibration absorber could be proved and its mechanism was identified clearly.