Study on Structural Vibration Control Using Wave Barriers

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論文内容要約

Wave vibration is general physical phenomenon in everyday life. Earthquakes generate ground vibration. Traffic traveling on rails and roadways, operations of construction equipment, maintenance operations can also be a source of such vibration. Severe vibration caused by earthquake can damage structures. Even its amplitudes are not high enough; vibration has the potential to cause the cosmetic damage such as surface cracks in plaster, or disrupt the operation of vibration-sensitive equipment such as electron microscopes, advanced technology production and research equipment. Wave vibration and vibration-borne noise can also be a source of annoyance to individuals who live or work close to vibration-generating activities.

Many countermeasures have been taken to reduce the vibration according to research done by scholars and engineers. Resistance, mitigation, and isolation have been the three most common methods in the field of structural engineering. But few people noticed that methods of vibration reduction can also be classified by its vibration domain. In fact some waves can only be propagated in a specific spatial domain or a specific frequency domain. Therefore, it provides a suggestion for vibration reduction that the unwanted wave can be screened by specific domain as a filter. In this study, the vibration propagation problems are divided into a guided wave propagation problem and a cutoff frequency problem. The guided wave propagation problem is a problem discussed the wave propagation in a spatial domain. The cutoff frequency problem is a problem discussed the wave propagation in a frequency domain. This thesis contains six chapters. Chapter 2-5 constitute the main contents of thesis.

The guided wave propagation problem caused many accidents in earthquake. But no scholar had pointed out the cause of damages and accidents from the theory of vibration propagation until Motosaka

firstly noticed it in 2006. In chapter 2, a generalized partial differential equation model is used to describe these problems. The solutions of bending beam model and bending shear beam model are discussed. It shows that wave vibration can propagate through the beam if the value of stiffness is smaller than the critical threshold or the value of circular frequency is larger than the critical threshold. In a reality case, it shows that the vertical vibration energy of earthquake can propagate through the building horizontally when the stiffness of pile foundation is smaller than the critical threshold determined by the property of the building; and the vertical vibration energy of earthquake can also propagate through the building horizontally when the value of circular frequency is larger than the critical threshold determined by the property of the building. This vibration energy caused the building vibrate wavy and damaged the constructional elements during the earthquake. The effective countermeasure to avoid the accidents is also given.

The study of wave barriers is the focus of vibration isolation. The periodic wave barriers are considered to can screen the ground-transmitted vibration effectively. But the screening effectiveness of two- and three-dimensional models has not been investigated by anyone. In chapter 3 and chapter 4, studies of periodic wave barriers using two-dimensional FEM and three-dimensional TLM are introduced. The screening effectiveness of different parameters of wave barriers is investigated. It shows the wave barrier of which the depth is larger than the Rayleigh wavelength contacts as a screen has the advantage of screening effectiveness; the wave barrier of which the width is larger than half of the Rayleigh wavelength contacts as a screen has the advantage of screening effectiveness; the periodic wave barriers have the better advantage of screening effectiveness than a single wave barrier; the soft wave barrier (with low velocity) has the advantage of screening effectiveness in low frequency domain and the hard wave barrier (with high velocity) has the advantage of screening effectiveness in high frequency domain. Energy conservation among incident, reflected and transmitted wave is also discussed in the two-dimensional model. It shows that the vibration may be amplified at another point when wave barrier screens the ground-transmitted wave and reduces the structural vibration at an expected point. A combined wave barrier is proposed for avoiding this phenomenon.

Another big problem for wave barriers is how to find the optimization of screening effectiveness. No one gave the method to solve this problem. In chapter 4, the genetic algorithm is used to the screening effectiveness problem. A methodology how to choose a suitable fitness function for the problem is discussed. A methodology how to evaluate the screening effectiveness considered cost is also discussed.

The wave barriers can reduce the vibration of surface wave caused by such as traffic and construction equipment. But the wave barrier has little effect of earthquake vibration reduction if earthquake vibration propagates from the bottom directly. In chapter 5, a novel vibration control system is put forward to solve this problem. This system draws on the experience of electromagnetic and optical science. It can reduce the vibration caused by both earthquake and traffic. A simulation plan of vibration reduction for a real building using this system is proposed. The nonlinear response analysis of this building during the earthquake is also introduced.

In this study, it is the first time that some accidents caused by the wave propagation problem have been modeled to a generalized partial differential equation model. The cause of these accidents is figured out and the effective countermeasure is given. It plays a great role for the future prevention for these accidents. The two- and three-dimensional models of periodic wave barriers are also firstly investigated. It is the first time that the energy conservation among incident, reflected and transmitted wave through wave barriers has been discovered. The genetic algorithm is used to solve the optimization problem for screening effectiveness of wave barriers. It is the first time that the optimization method has been given to solve this problem. Some methodologies are firstly given to help engineers determine the suitable fitness function and the suitable cost function for this problem. It provides engineers with a feasible method how to choose an optimal wave barrier in practical engineering. A novel vibration control system is also firstly put forward to screen the vibration of any frequency domain. It is an enlightening discovery for the future study of wave barrier.