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Shaking Table Tests of a Small-scale Metafoundation Model to Reduce Vibrations of SSCs

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1. Introduction

In recent years, metamaterials have been developed to manipulate electromagnetic, acoustic, and elastic waves through various media. These engineered materials exhibit unique properties not found in nature by systematically arranging unit cells smaller than the controlled wavelength in one or more directions. Initially designed to control electromagnetic waves, metamaterials have since been extended to acoustic and elastic wave applications. The concept of elastic metamaterials has also been applied to seismic wave control, with laboratory experiments confirming their effectiveness [1]. Seismic metamaterials are categorized into buried mass-resonators, seismic soil-metamaterials, above-surface resonators, and auxetic materials [2, 3].

In this study, a series of shaking table tests are conducted on a small-scale metafoundation system to evaluate its effectiveness in reducing vibrations in a structural system caused by seismic waves [4]. An acrylic plastic metafoundation model is constructed, and its transfer functions for horizontal and vertical excitations are determined through white noise and sine sweep tests. The attenuation zones identified from the tests are analyzed and validated using frequency band gaps (FBGs) obtained from numerical simulations. In addition, a small-scale simple structure is mounted on the metafoundation, and the dynamic characteristics of the system are assessed using white noise and sine sweep signals as input motions to the shaking table. The seismic responses of the structural system are then examined to assess the ability of the metafoundation to mitigate the dynamic responses.

2. Small-scale model of a metafoundation

The unit cell of a metafoundation shown in Fig. 1 is considered in this study. The unit cell consists of a cubic concrete core, a cubic concrete cover box, and six square rubber pads. The material properties for the concrete and rubber in the prototype unit cell are given in Table I. The dimensions of the prototype are given in Table II.

A small-scale model of the metafoundation is constructed using the acrylic plastic and the EPDM (ethylene propylene diene monomer) rubber foam. The material properties and dimensions for the small-scale model are given in Tables I and II, respectively.

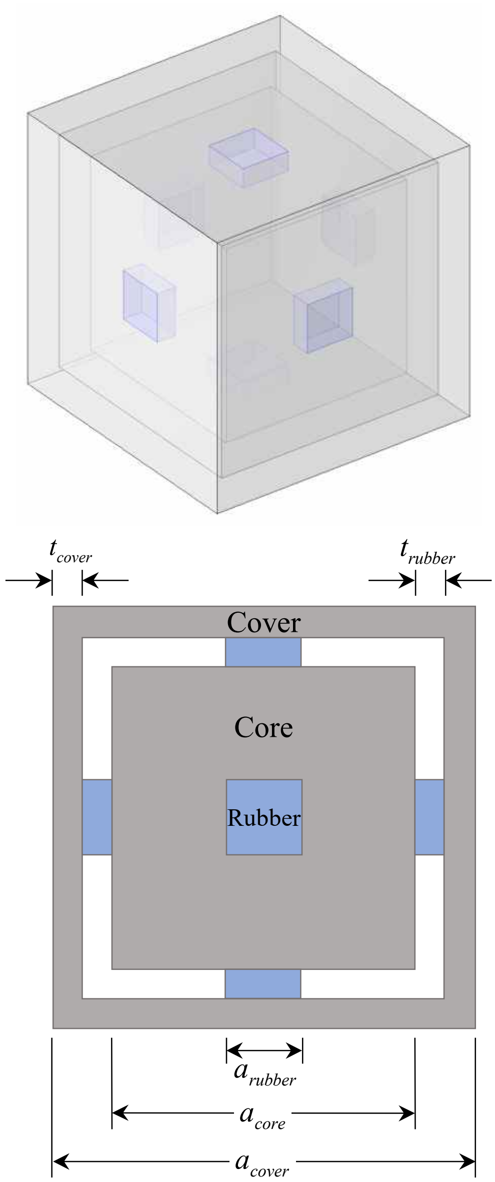

Fig. 1. Unit cell of the metafoundation.

Table I: Material properties of the prototype and small-scale model of the unit cell

Material property			Prototype	Model
Concrete (prototype) or acrylic plastic (model)	Young's modulus (GPa)		30	2.94
	Poisson's ratio		0.25	0.37
	Density (kg/m^3)	Cover	2400	1180
		Core	M1: 1845 M2: 2030 M3: 2200 M4: 2400	908 983 1073 1180
Rubber	Young's modulus (MPa)		2	0.199
	Poisson's ratio		0.49	0.49
	Density (kg/m^3)		1000	130

Table II: Dimensions of the prototype and small-scale model of the unit-cell

Dimension	Prototype	Small-scale model
a_{cover}	1.4 m	0.2 m
t_{cover}	0.07 m	0.01 m
a_{core}	1 m	0.14 m
a_{rubber}	0.25 m	0.035 m
t_{rubber}	0.14 m	0.02 m

By combining the above small-scale unit cells, a small-scale model of a metafoundation is fabricated. Fig. 2 shows the metafoundation system without a superstructure. A metafoundation system with a building in Fig. 3 is also considered in this study. A series of shaking table tests are carried out with the small-scale metafoundation system.

Fig. 2. Small-scale model of a metafoundation without a structure.

Fig. 3. Small-scale model of a metafoundation with a structure.

3. Conclusions

The shaking table tests on the small-scale metafoundation system show that the metafoundation effectively reduces the seismic response of SSCs. The frequency range in which this reduction occurs is determined by the attenuation zone or frequency band gap (FBG) of the metamaterial. Consequently, the dynamic response of a structural system can be controlled by designing a metafoundation with an optimized FBG and attenuation zone to achieve the desired performance. The metafoundation can be modified to create a metafloor system for vibration isolation of equipment in nuclear facilities.

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