論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Material Property Estimation and Liquid Detection for Multi-layered Media based on Ultrasonic Nondestructive Testing
著者(和文)	沈洋
Author(English)	Yang Shen
出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第10257号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:廣瀬 壮一,三上 貴正,鎌 直樹,アニール ワイジェ,佐々木 栄一
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第10257号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	情報環境学 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 学術 ）
学生氏名： Student's Name	沈洋 SHEN YANG	指導教員（主）： Academic Advisor(main)	廣瀬壮一
		指導教員（副）： Academic Advisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

During the service life of reinforced concrete (RC) slabs, damages and deteriorations can be caused due to overloading, aging, and corrosion. One of the reinforcement approaches is to add a steel plate on the bottom of a RC slab to enhance its flexural capacity. To make steel and concrete function more collaborative, epoxy is sometimes injected as adhesive into the interface between steel plate and concrete, together with anchor bolts. However, using epoxy as the adhesive will bring deterioration due to its aging and delamination on the interfaces. To prevent the failure of adhesives, we need to estimate the material property of epoxy, so that the extent of the aging of the adhesive material in service can be assessed through the historical data comparison. Ultrasonic Nondestructive Evaluation (NDE) is an advantaged approach to detect the delamination or the bonding quality of the layered medium. The elastic property of the adhesive material can also be estimated properly by obtaining the phase velocity of surface wave propagating in the layered medium through NDE test.

This research proposes an effective approach to estimate the elastic property of epoxy layer in a steel-epoxy-concrete bonding layered medium based on the wave dispersion theory. The dispersion properties of different multi-layered media, including free steel plate, steel-epoxy-concrete, steel-water-concrete, steel-spring-concrete, and steel-water-epoxy-concrete are analyzed in this study. Firstly, the boundary conditions are presented, and the dispersion equations are deduced and solved to plot the analytical dispersion curves, also the wave structure of different wave modes are obtained. Through a discussion about the influence factors to the modes and shapes of those dispersion curves, a clear understanding of wave dispersion in the steel-epoxy-concrete bonding layered medium is reached. Then, an ultrasonic NDE test on a casted steel-epoxy-concrete specimen is conducted following the idea of Spectral Analysis of Surface Waves (SASW), by which the experimental dispersion curves can also be plotted. Through the inversion process of the analytical and experimental dispersion curves, the elastic property of epoxy layer can be successfully estimated. Then based on the estimated elastic constants, wave propagation in the steel-epoxy-concrete layered medium is simulated using Explicit Finite Element Method (EFEM), from which the numerical dispersion curves are obtained.

It has been decades since the steel plate strengthening method for RC slabs was applied on infrastructures, hence quite a lot of the strengthened slabs have already met the problems of material's aging, layers' delamination, or even worse: water's invasion. If water penetrates into the top surface of a steel plate through an additionally damaged concrete slab, serious corrosion will be caused. Therefore, it is of great importance to detect the existence of water layer in the steel-concrete or steel-epoxy-concrete layered media and acquire information on thickness and distribution area of the invaded water layer.

In this study, an ultrasonic multi-reflection approach through oblique incidence is developed for thin liquid layer detection. Firstly, the reflection factor equations are deduced, and the reflection and transmission coefficients of multi-layered media including a liquid layer are calculated theoretically. Four interfaces that would appear in the experimental study are emphasized: steel-water, water-steel, water-concrete and water-epoxy. Then, experiments on multi-layered configurations are conducted with different water layer thicknesses and bottom layer materials. By analyzing the experimental results, the existence of water layer can be clearly distinguished. The effects of incident angles, water layer thicknesses, and the material properties of bottom layer have been tested and presented with numbers of waveforms from the experiments on different multi-layered configurations. The explanation of those experimental phenomenon is given according to the reflection and transmission coefficients. Through comparison with the theoretical wave travelling time in the water layer, the thickness of the water layer can be estimated from the time interval of reflected wave groups. This method of water layer thickness estimation is tested with acceptable errors, whose possible causes are given.

Moreover, an approach of identification of the region of the liquid layer beneath the solid layer is developed. The procedures of the identification approach are presented, and the relative NDE tests are conducted on the casted multi-layered specimen to confirm every step of the identification to be feasible. Two transducer approaching orientations for detecting the boundary of the liquid layer are tested: parallel approaching, in which the line of transmitter and receiver is parallel to the boundary; vertical approaching, in which the same line is vertical to the boundary. This identification approach of region of water layer can be effectively applied in the practical detection as well.

In summary, this research investigates the nondestructive evaluation of multi-layered media, in which two main objectives are included: to estimate the material property of epoxy layer in steel-epoxy-concrete layered media, and to detect water layer beneath the solid plate. Both the objectives have been achieved successfully through the theoretical research and the experimental work.