[Yadav*, 5(3): March, 2016]
ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EXPERIMENTAL STUDY ON THE STRUCTURAL HEALTH MONITORING ON A R.C.C. BEAM BASED ON PIEZOELECTRIC MATERIAL

Praveen Kumar Yadav*, Mr. R. D. Patel
P.G. Scholar Department of Civil Engineering M.M.M.U.T Gorakhpur Uttar Pradesh, India
Associate Professor Department of Civil Engineering M.M.M.U.T Gorakhpur Uttar Pradesh, India

DOI:

ABSTRACT

There are various structural health monitoring approaches has been investigated or discovered which are based on the piezoelectric smart sensor. Guided wave propagation based non-destructive active monitoring method is one of them which is preferable for damage detection in reinforced concrete structures. In order to detect the basic mechanical properties and generated damage of reinforced concrete structure, piezoelectric material (sensor/ actuator) based guided wave propagation method was done experimentally in the lab using the experimental specifically designed setups. In the beam structure energy attenuation of stress wave was measured by the relative index between the output voltage of sensors and excitation voltage at the actuator [1].

On the basis of experimental results of R.C.C Beam specimen the effect of excitation amplitude excitation frequency wave propagation paths are evaluated on the output signature of sensors. The value of relative voltage attenuation coefficient RVAC as a result at as an effective indicator. For the purpose of measuring attenuation of waves through the interior damage of reinforced concrete beam. The parameter RVAC in the guided wave propagation gives the damage of the interior and exterior in beam elements.

KEYWORDS: Pzt , Attenuation. RVAC , Actuator.

INTRODUCTION

In civil infrastructures the reinforced concrete structure are widely used like as dams, bridges high –rising building due to their cost effectiveness, durability and long service life under various loading and environmental conditions. The concrete structures gets detoriated with respect to time due to arising cracks and structural damage. So the necessity of structural health monitoring get arises. The structural health monitoring is needed for the real – time health monitoring of concrete structure. Due to the development of non-destructive technologies, are attention of researches focused on the field of the structural health monitoring due to the development of "smart material" like as piezoelectric transducers , shape memory- alloys etc. have plays very effective role in the monitoring of civil infrastructure.[1,2].

There are three basic piezoelectric material based health monitoring approaches are introduced in them, at the starting the pzt patch based electro-mechanical impedance technology was introduced by Soh and Bhalla [3].
For predicting the strength of concrete to proof of EMI . Their experiment shows their validation as a story relation . exists between the resonant frequency and compressive system of concrete.

Kaniecki [4] studies the workability of damage detection by using piezoelectric transducer attached to the surface of a concrete specimens damage was produce by placing the concrete with different loading conditions by experimental analysis gives that there is an effective correlation between size, location and natural frequency . oddity has presented in these signals were repeatable and had different characters when they were caused by damages

Shin et al. [5,6] have further, investigated using a cylindrical specimen with different installation techniques . as conclusion it was found that RMSD (root mean square deviation). Index is used as suitable indicator for monitoring of strength gaining of specimen.
Waving et al. [8] and Wu and Chan [7] . studies to detect the debondary which created between the reinforced bar and specimen with piezoelectric bonded patch on the steel bars A5 peak fragmented stress wave with the peak value of 200V was applied to the actuators .the arrival of amplitude of signals increased in a linear propagation to the bonding steel bar size from the structure.

Tawie and lee [8] evaluated the effect of parameter in mix-proportion of prepared concrete specimen and EMI response spectra in situ monitoring of concrete using the low cost pzt patches and relation between the compressive strength of specimen and incides of correlation coefficient deviation (C.C.D) , Root mean square deviation (RMSD) and mean absolute percentage deviation (MAPD)of EMI spectra were analyzed. H.Gu et al [9]. Proposed piezo-based strength monitoring system using embedded type piezo-electrics transducer into the concrete specimen at time of casting . F. Song et al [10] investigated the wave propagation in concrete beam by using surface bonded pzt numerically and experimentally.

The stress waves that excited by actuator are complex because of reflection , attention and transmission when they are propagated inside the concrete specimen the size , maximum proportion, cracks , wave form, amplitude and frequency of excitation signal all these affect the velocity and attention of output which will be received by the sensor further studies must be carried in wave propagation methodology.

In this paper is an experimental study to wave propagation in reinforced concrete beam specimen the RVAC (Relative voltage attenuation cofficient) is used to evaluate than attenuation of stress wave different effect of frequency amplitude and excited signal were investigated.

WAVE PROPAGATION IN REINFORCED CONCRETE SPECIMEN

Lump wave have proved useful tool for structure purpose and damage detection in concrete structure to their capability to generate long distance with less energy loss compound to bulk waves and due to their sensitivity to small defects in structure.

The pzt actuator generates stress waves that has carry the information of the attached host structure therefore can be used to evaluate the existence and presented damage nature the wave propagation of stress wave in concrete structure can be viewed as one dimensional longitudinal wave propagation .

The wave equation is expressed as :-

$$\partial^2 y / \partial x^2 = (1/C_b^2)\ (\partial^2 u / \partial x^2) \text{------------------- (1)}$$

Where $C_b^2 = (E/\rho)$ u represent displacement of element , E modulus of elasticity and ρ represents density of material power of the harmonic response with respect to time can be written as :-

$$\rho = (\varepsilon\ A^2 w^{2/2}\ C_b) \text{--------------------(2)}$$

As the equation (2) shows that the harmonic amplitude is directly by modulus of elasticity of materials specimen.
With the aging the concrete strength increases with respect to increasing modulus of elasticity . the amplitude of stress decreases with increasing in the value E .

Modulus of elasticity considered to be very effective parameter for the purpose of strength determination on the basis of the observation of amplitude charge of stress waves the strength evaluation of concrete specimen is possible.

EXPERIMENTAL ANALYSIS

To verify the efficiency of wave propagation technique for concrete strength and damage assessment purpose the experimental validation is checked on the concrete beam specimen specification of test specimen is described :-

3.1 Specimen Specification:-

3.1.1. Specimen composition:-

Table 1 composition of specimen:-

Component	Composition (kg/m^3)	Description
Water	191.6	Tap water
Cement	416	Opc-43 grade
Sand	659	Well graded
Coarse	1146	Size 20 mm

There are 6 reinforced concrete (base 18 cubes were and specimen) casted and cured for the experimental analysis the mix was M25 with respect to which the constituent quantity were used as shown in table .the test specimen size of beam (40 * 60 * 750) mm and 18 cube (70.6)mm size were casted and cured four pzt patch of size (10 * 10 * 0.2)mm^3 were attached to the beam and cube specimen as shown in fig 1. The attachment of pzt was done 1 day after the curing with high strength epoxy adhesive and leave if for 12 hours to ensure fixing the pzt . the cube specimens were fixing the pzt . the cube specimens were tested at age of 7, 14, 28 days for compressive strength and R.C.C. beam specimen for evaluating flexural strength at same days. The cube specimen were tested for compressive and Young's modulus strength .

3.2 Experimental setup:-

3.2.1 Pzt Patch Installation :-

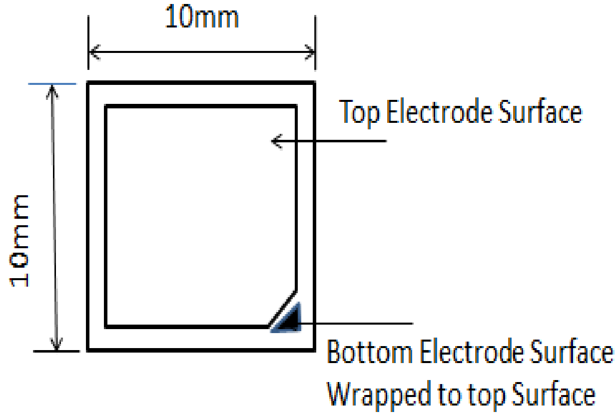
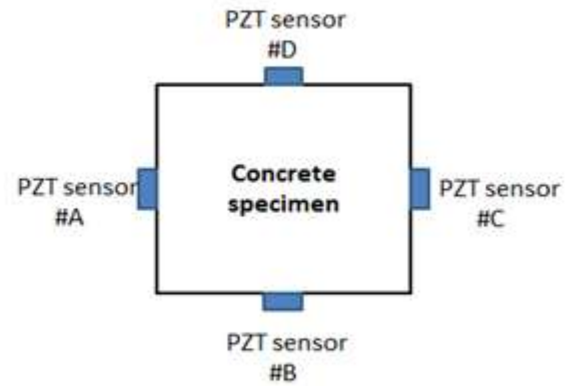
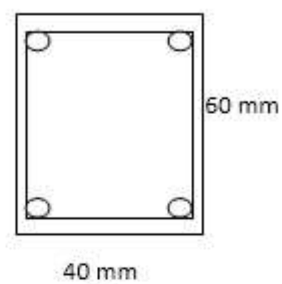


Figure 1 :- Geometry of pzt patch

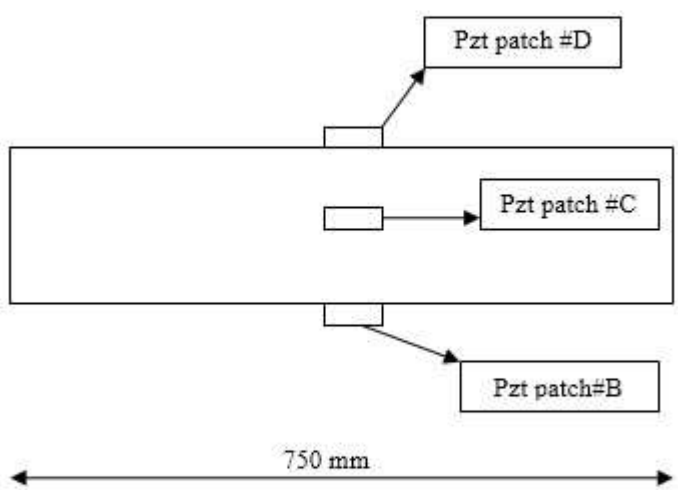
ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785



(a)



(b)



Reinforced concrete beam (40×60×750)mm
(c)

Figure 2:- (a) concrete cube specimen with surface bonded pzt patch (b) cross section detail of Rcc beam (c) Rcc beam with attached pzt patch

The pzt pacth is attached to the surface of beam and cube specimen is 10 mm in width 10 mm in depth and 0.2 mm in thickness are polarized in lateral and thickness directon . fig 2.
Shows a typical available commercial size of pzt.

Fig 2 (a) & (c) shows the configuration of the pzt patch bonded to surface of concerete beam and cube specimen similarly . the pzt patch actuator and sensor are located on the profile of the specimen , three sensors (B,C,D) and one act as actuator .

Table 2 . Properties of used Pzt Patch

Physical Parameters	**Values**
Density /kg*m^{-2}	7700
Young's modulus /N*m^{-2}	6.667*10^{-10}
Poission ratio υ	0.3
Dielectric matrix [ε]/ (c*v^{-1}*m^{-1})	$\begin{bmatrix} 6.45 & 0 & 0 \\ 0 & 6.45 & 0 \\ 0 & 0 & 5.62 \end{bmatrix}$ *10^{-9}
Piezoelectric matrix [e]/(c*m^{-2})	$\begin{bmatrix} 0 & -6.5 & 0 \\ 0 & 23.3 & 0 \\ 0 & -6.5 & 0 \\ 0 & 0 & 0 \\ 17 & 0 & 0 \\ 0 & 0 & 17 \end{bmatrix}$
Stiffness matrix [c]/P$_a$	$\begin{bmatrix} 13.9 & 6.78 & 7.43 & 0 & 0 & 0 \\ & 13.9 & 7.43 & 0 & 0 & 0 \\ & & 11.45 & 0 & 0 & 0 \\ & & & 3.56 & 0 & 0 \\ & & & & 2.5 & 0 \\ \text{symmetry} & & & & & 2.56 \end{bmatrix}$

3.2.2 Experimental Monitoring System :-

In this section the experimental monitoring system demonstrated for the purpose of monitoring of stress wave amplitude and frequency requirement of digital oscilloscope ,wave form generator and personal computer needed . The wave signal decays in concrete very early so an power amplifier are used to amplify signals .

3.3 Procedure :-

The pzt actuator was excited from 15V to 75V with excitation frequencies 1, 2 ,5 , 10 , 20 , 30 , 50 KHz were used for source for attached surface pzt. Actuator for composion purpose . frequency range was chosen 1-50 khz for study.

At curing period of 7, 14, 28 days the compressive strength of cube and flexural strength of beam member were tested . in the wave – propagation patch A used as actuator and reaming three (B , C and D) as sensor signal of sensor pzt were captured by oscilloscope.

3.4 Result:-

The concrete cube and beam with piezoelectric sensor were tested by using wave – based monitoring techniques. Results verified that harmonic amplitude were dropped with strength gaining of specimen. on the basis of competed RVAC (Relative voltage attention coefficient) result can be discussed .

$$RVAC = (A_s / A_0)$$

As sensor output voltage and A_0 amplitude of actuator voltage .

RVAC is a function of dimension of pzt and host structure , the material properties , frequency of actuation and the distance between the sensor and actuator results are presented below :-

3.4.1 Pzt Reponse :-

The response obtained with the receiving piezoelectric element as shown in figure 3 can give the sensitivity and validation of pzt with beam specimen

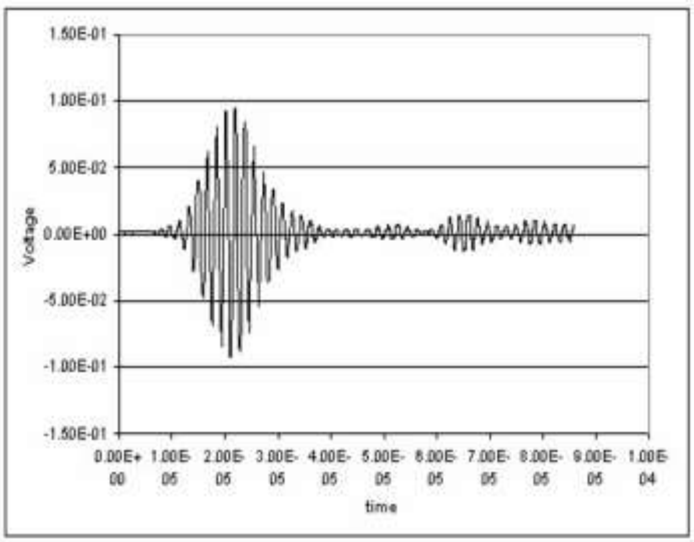


Fig 3:- Typical response obtained with the receiving

3.4.2 Time Dependent Sensor Output Voltage :-

To verify the strength gain monitoring of concrete specimen the wave propagation method were tested on cube and beam was tested by universal compressive test to obtained compressive strength of cube and obtained the flexural strength of beam to determine the compressive strength and Young's modulus as shown in fig 4 below

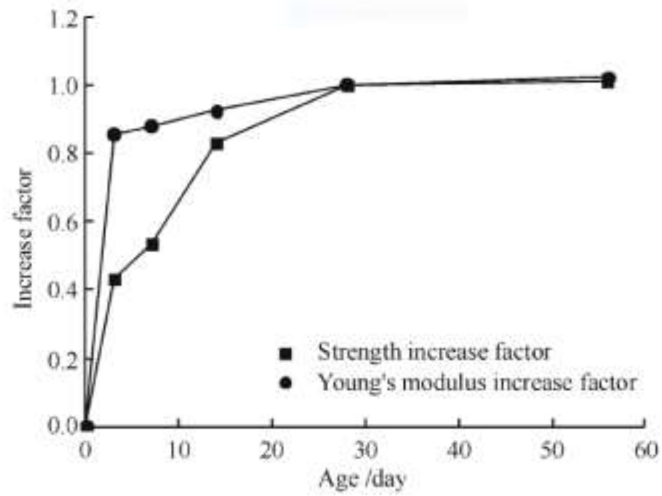
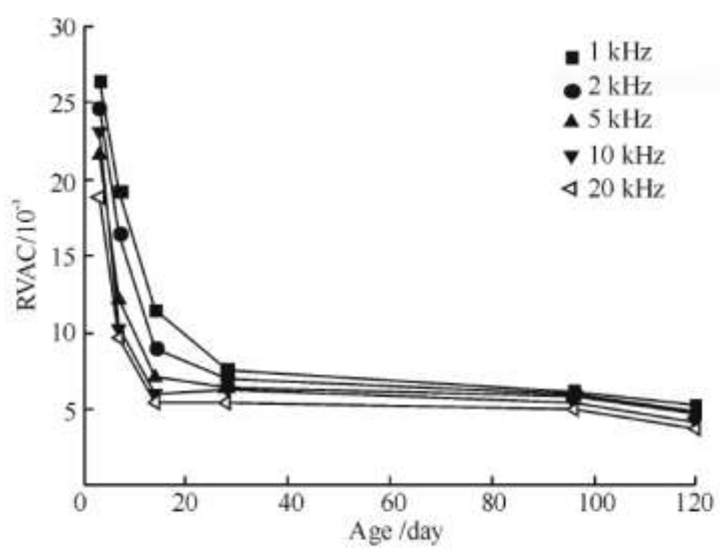
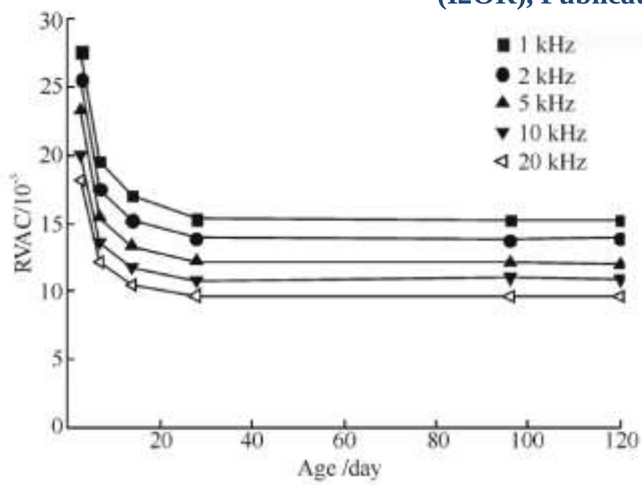


Fig 4:- compressive strength and young's modulus versus curing time

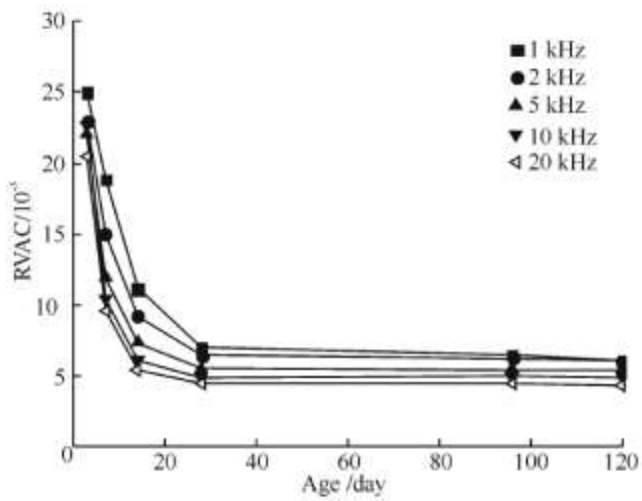
Fig5 shows the measured RVAC at different – different curing age for the different attenuation wave paths propagation of A-B ,A-C and A-D respectively below in fig it shows that RVAC decreases to level after the curing time of 28 days for all of the propagation mode .



(a) A-B



(b) A-C



(C) A-D

Fig 5 Time dependent RVAC of different paths

3.4.3 Effect of Excitation Amplitude :-

In the fig 6 shows the typical RVAC of received sensor match of A-C with different excitation frequency ,index of RVAC is observed to be independent of the amplitude of excitation signal . the amplitude of excitation voltage only effect the intensity of signals depending upon the distance of sensor actuator .

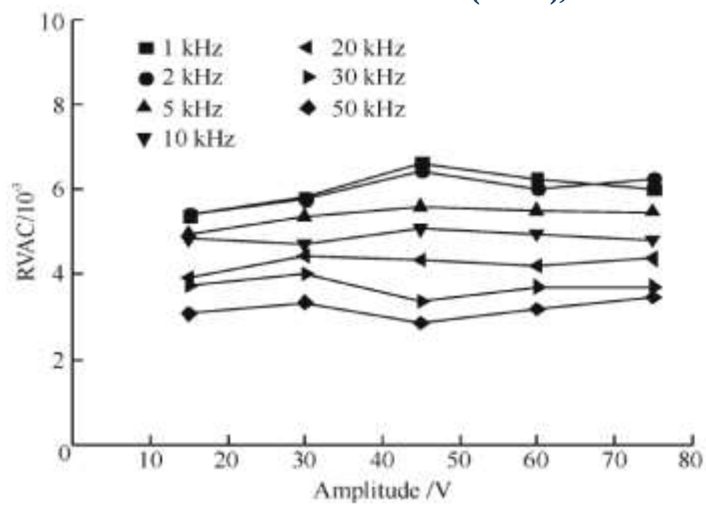
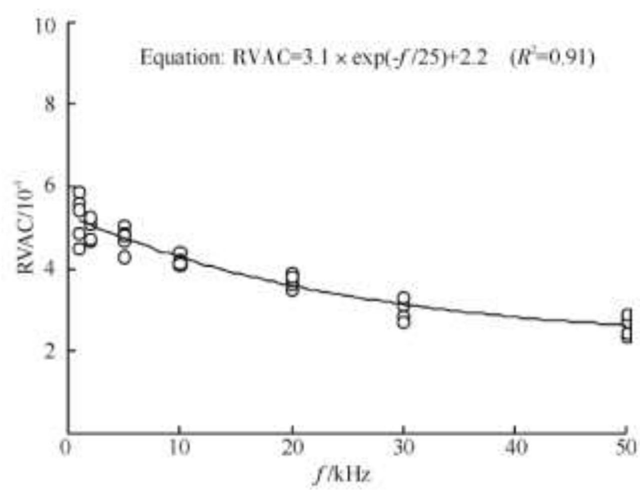


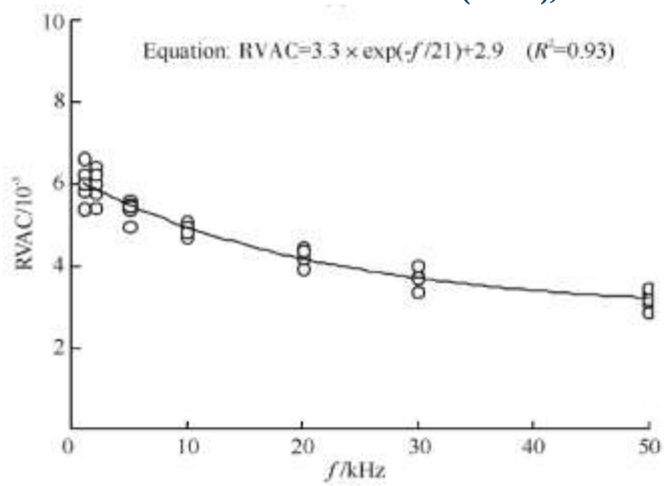
Fig 6 RVAC at different amplitude

3.4.4 Effect of Excitation Frequency:-

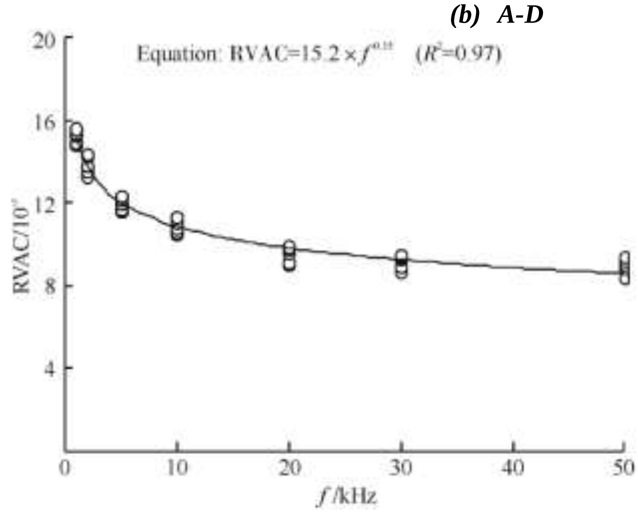
To investigate the frequency of the input signal on the RVAC , the input frequency was varied over the range of 1-50 khz . in the fig 7 the output of measured RVAC of sensor at different excitation shown in fig 7. it can be concluded that frequency increases and RVAC decreases.



(a) A-B



(b) A-D



(c) A-C

Fig 7 :- RVAC of measured output voltage of sensor at different frequencies

CONCLUSION

In this presented experimental work , the pzt based wave propagation method is used to monitor the damage and mechanical properties of specimen . the RVAC is very effective indicator for measuring the attenuation of stress wave in the concrete specimen. On the basis of test specimens the RVAC decreases to a stead level after the curing period of 28 days and RVAC of output from sensor is independent of amplitude of excitation signal at piezoelectric sensor . sw

REFERENCES

[1] ZHU Jinsong & He Likun , Piezoelectric Actuator/Sensor Wave Propagation Based Nondestructive Active Monitoring Method of Concrete Structures.

[2] S. Park & S. Ahmad & C.-B. Yun & Y. Roh, Multiple Crack Detection of Concrete Structures Using Impedance-based Structural Health Monitoring Techniques.

[3] C K Soh, S Bhalla. Calibration of Piezo-impedance Transducers for Strength Prediction and Damage Assessment of Concrete[J]. Smart Mater. and Struct., 2005, 14(4):671-684

[4] G. Kawiecki, "Feasibility of applying distributed piezotrans-ducers to structural damage detection," *Journal of Intelligent Material Systems and Structures*, vol. 9, no. 3, pp. 189–197, 1998.

[5] S W Shin, A R Qureshi, J Y Lee, et al. Piezoelectric Sensor Based Nondestructive Active Monitoring of Strength Gain in Concrete[J]. Smart Mater. and Struct., 2008, 17(5):055002

[6] S W Shin, T K Oh. Application of Electro-mechanical Impedance Sensing Technique for Online Monitoring of Strength Development in Concrete Using Smart PZT Patches[J]. Constr. and Build. Mater., 2009, 23(2):1 185-1 188

[7] F. Wu and F. K. Chang, "Diagnosis of debonding in steel-reinforced concrete with embedded piezoelectric elements," in *Proceedings of the 3rd International Workshop on Structural Health Monitoring: The Demands and Challenges*, F. K. Chang, Ed., pp. 670–679, CRC Press, New York, NY, USA, 2001.

[8] R Tawie, H K Lee. Monitoring the Strength Development in Concrete by EMI Sensing Technique[J]. Constr. and Build. Mater., 2010, 24(9):1 746-1 753

[9] H Gu, G Song, H Dhonde, et al. Concrete Early-age Strength Monitoring Using Embedded Piezoelectric Transducers[J]. Smart Mater. and Struct., 2006, 15(6):1 837-1 845

[10] F Song, G L Huang, J H Kim, et al. On the Study of Surface Wave Propagation in Concrete Structures Using a Piezoelectric Actuator/Sensor System[J]. Smart Mater. and Struct., 2008, 17(5): 055024.