Surface-mounted smart PZT sensors for monitoring damage using EMI-based multi-sensing technique

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Introduction

- Need of structural health monitoring to avoid the sudden failure & overcome maintenance problems.
- Lead Zirconate Titanate (PZT) act as actuator as well as sensor.
- "Electro-Mechanical Impedance Technique": Non-destructive technique.
- In this research, the proposal of the multi-sensing technique on the surface-mounted PZT sensors is offered.
- The effective methodologies to monitor the damage in the concrete structures, using multiple surface-mounted PZT sensors, are presented.
- This study considers the important aspects of SHM, damage detection and localization.

Introduction

1. Methodology for damage detection-

- ✓ The sensors are harmonically excited in the high-frequency range.
- ✓ Obtaining conductance signatures at different states and comparing them.
- ✓ Evaluating statistical metrics (namely root mean square deviation and correlation coefficient) for better understanding of trend of signatures.

Introduction

2. Methodology for damage localization-

- ✓ The group of sensors are assumed to be in parallel connection.
- ✓ MISO mode is preferred to obtain multiplexed signatures of particular combination.
- ✓ Three combinations: SSU2-3, SSU1-3 and SSU1-2-3.
- ✓ Evaluating dynamic metrics (namely moving RMSD and moving CC) for localization.
- ✓ The magnitude of moving RMSD and moving CC.

Numerical investigation

Smart sensing units (SSUs)

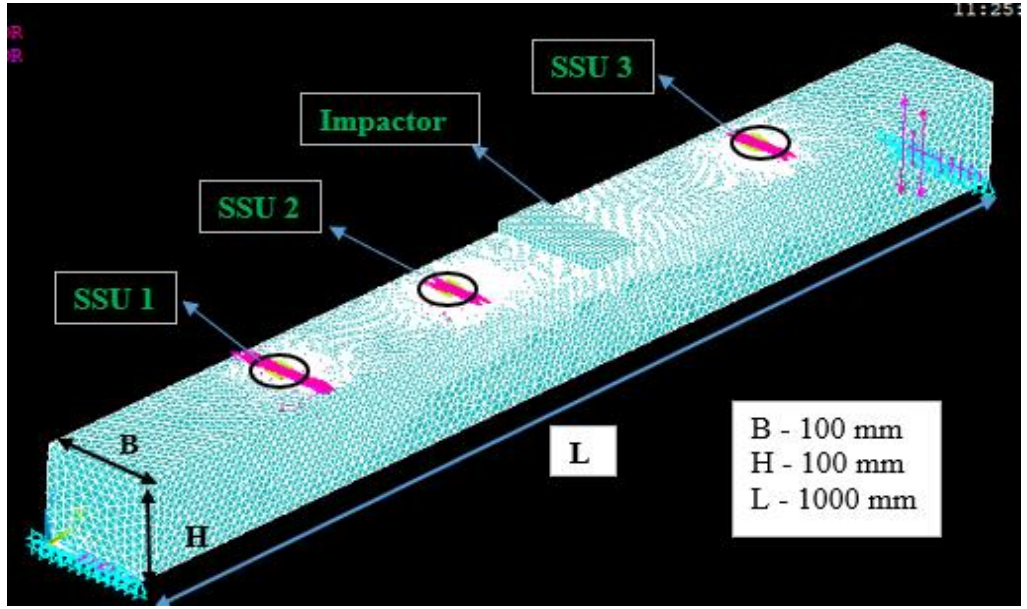
- Steel plate + adhesive layer + PZT patch = SSU
- PZT patch: PIC 151
- SSUs are harmonically excited [0-450 kHz]
- Distinct resonant frequencies of SSUs.

SSU	1	2	3
Thickness (mm)	0.75	1.5	3
Resonant frequency (kHz)	335	350	355

Numerical investigation

Concrete beam with multiple surface-mounted SSUs: Damage monitoring

- Damage: crack of length 20 mm.
- External loading: load impactor
  - ✓ 10 kN
  - ✓ 30 kN

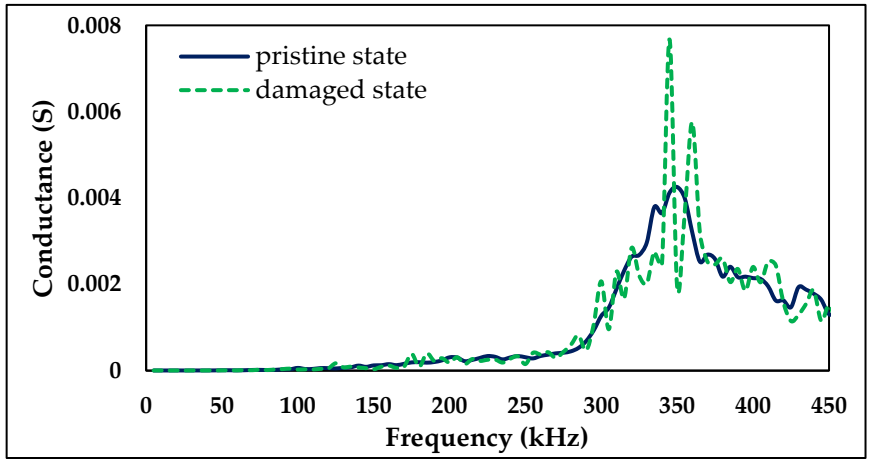


SSU No.	1	2	3
Distance from impactor (mm)	310	110	250
Distance from crack location (mm)	70	120	480

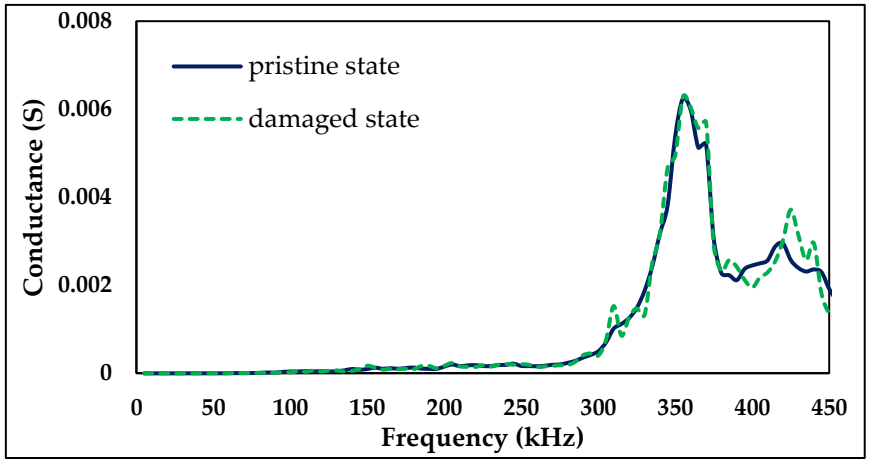
- Conductance signatures are obtained from each SSUs at different states.

Results

Damage detection study



(a)



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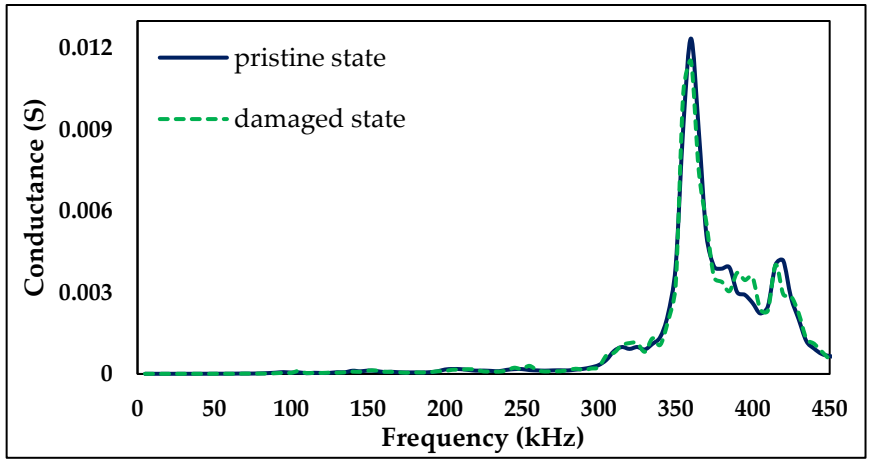
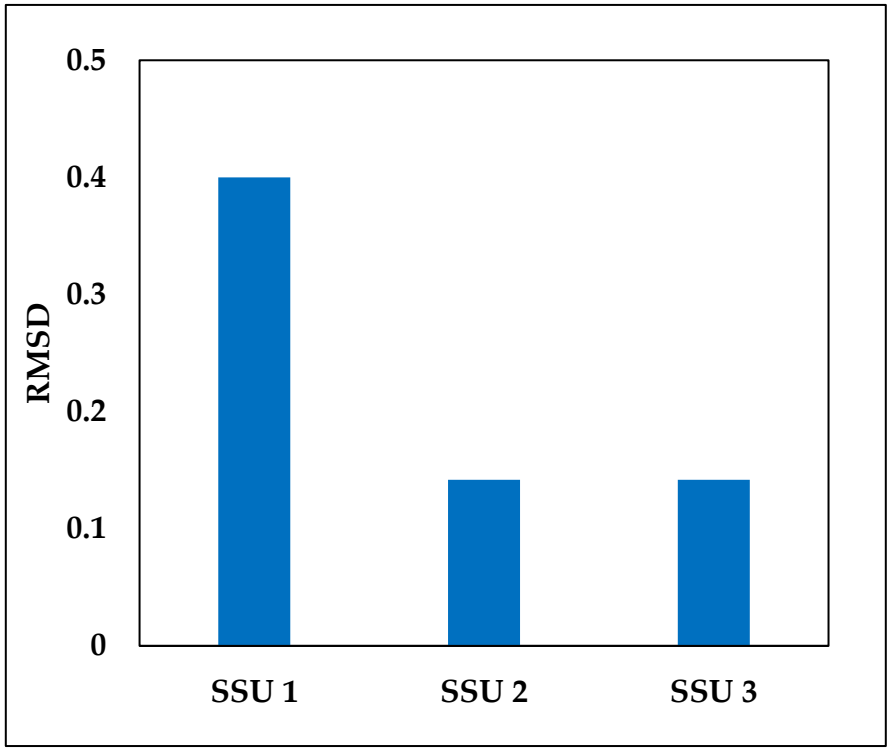


(c)

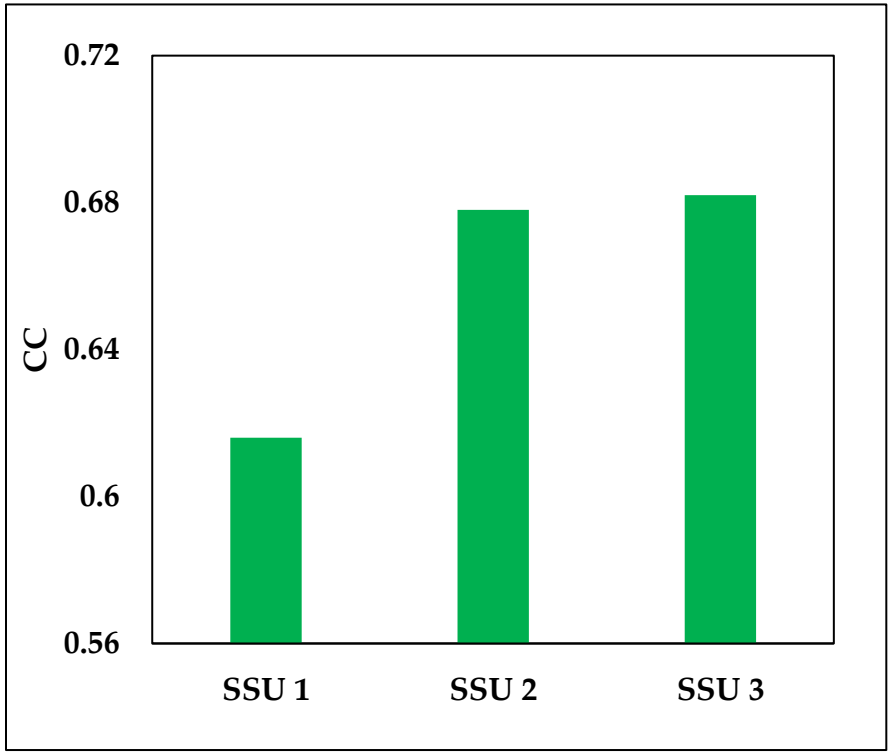
Conductance signatures obtained from (a) SSU-1; (b) SSU-2; (c) SSU-3 for the damaged concrete beam.

Results

Damage detection study



(a)

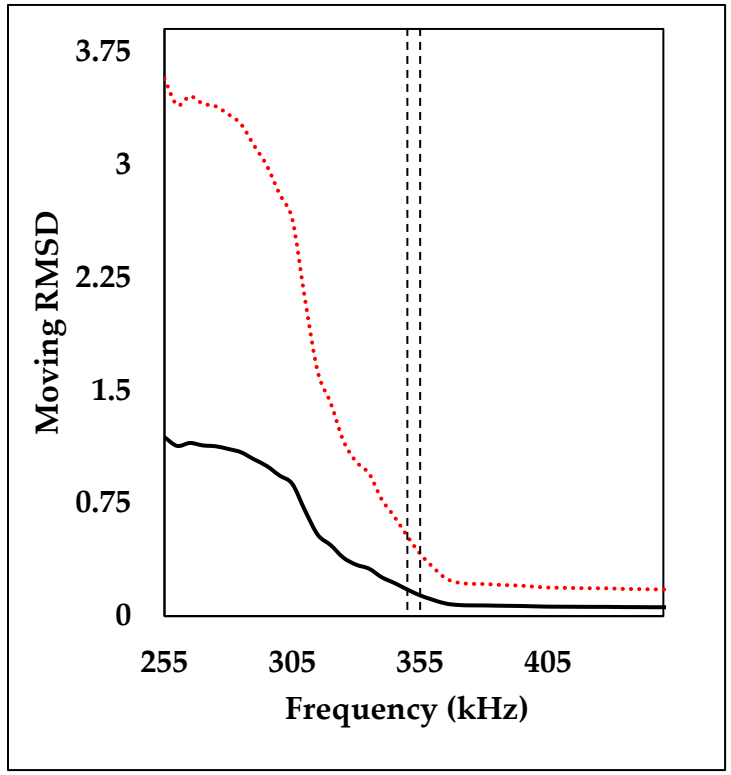


(b)

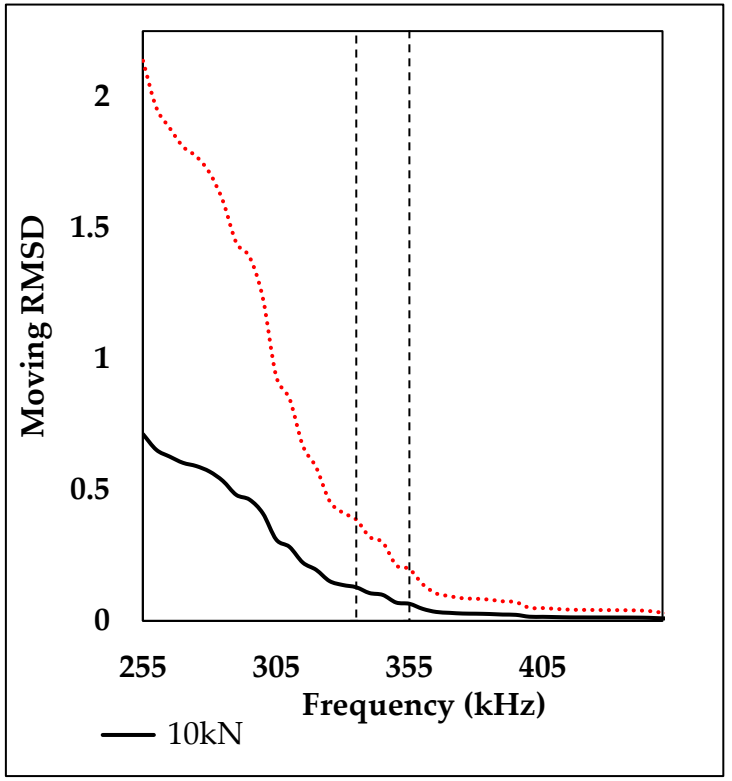
Various statistical metrics (a) RMSD; (b) CC evaluated for each SSU.

Results

Damage localization study



(a)



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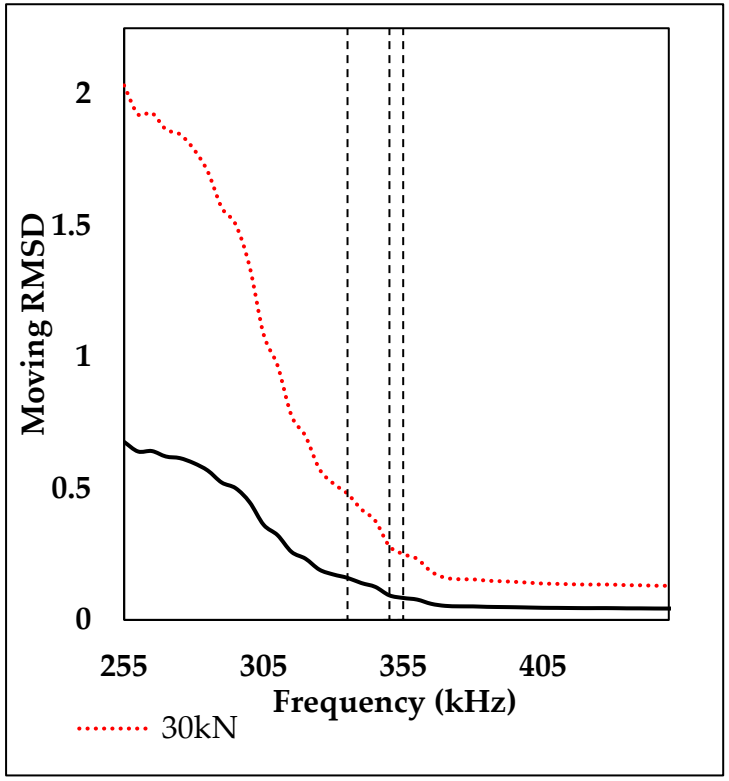
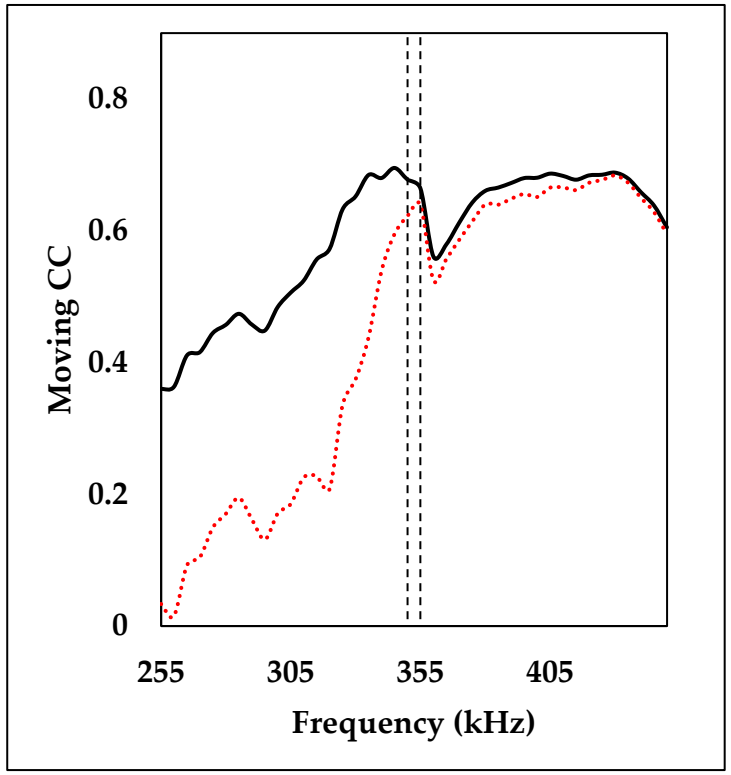


(c)

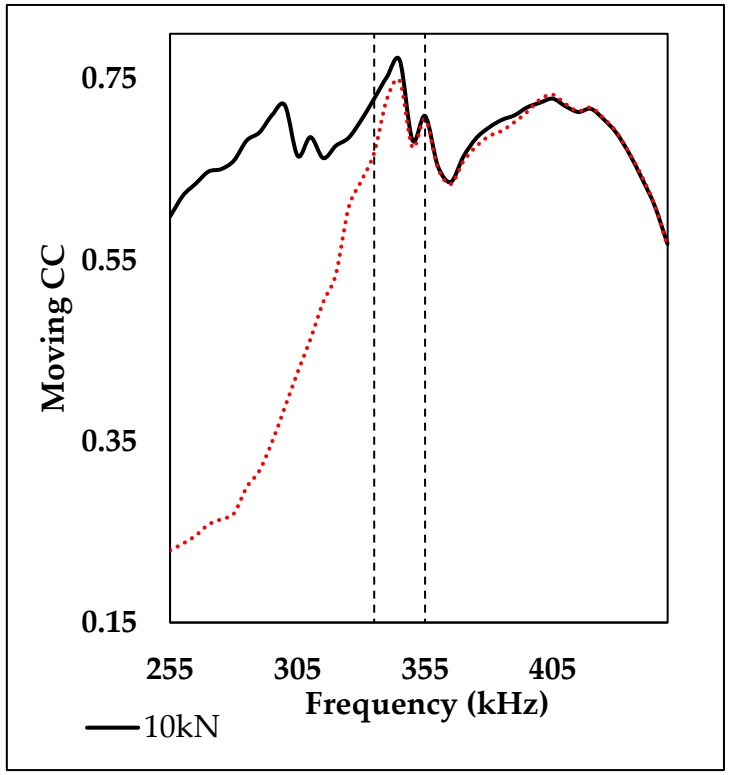
Moving RMSD plots for the combination (a) SSU 2-3; (b) SSU 1-3; (c) SSU 1-2-3 under different loading.

Results

Damage localization study



(a)



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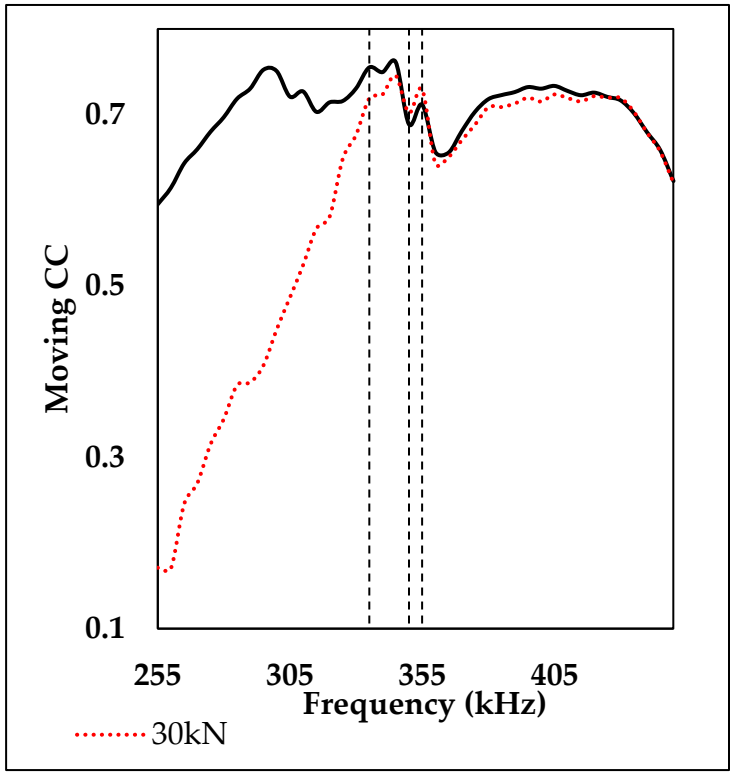


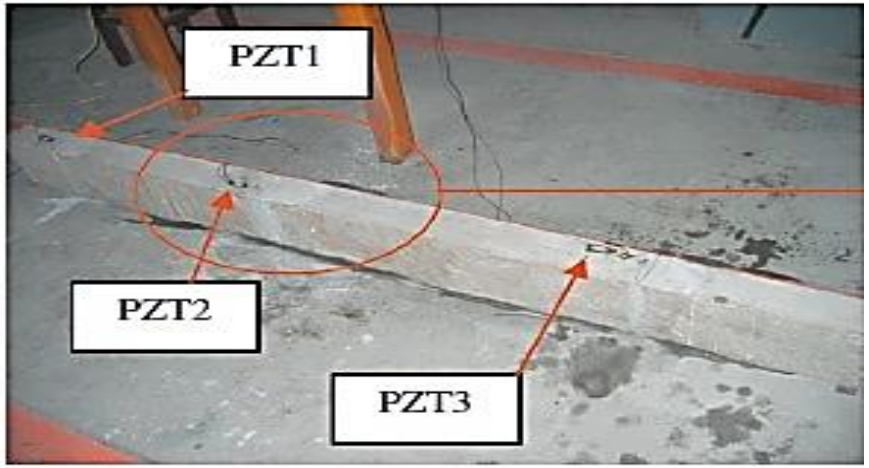
(c)

Moving CC plots for the combination (a) SSU 2-3; (b) SSU 1-3; (c) SSU 1-2-3 under different loading.

Experimental validation

Concrete beam with multiple surface-mounted SSUs: Damage monitoring

- Plain concrete beam: (100 x 200 x 2000) mm^3
- Three similar type of PZT sensors
- Damage: crack induced at different location
  - ✓ Case I: 10 mm long crack
  - ✓ Case II: 28 mm long crack



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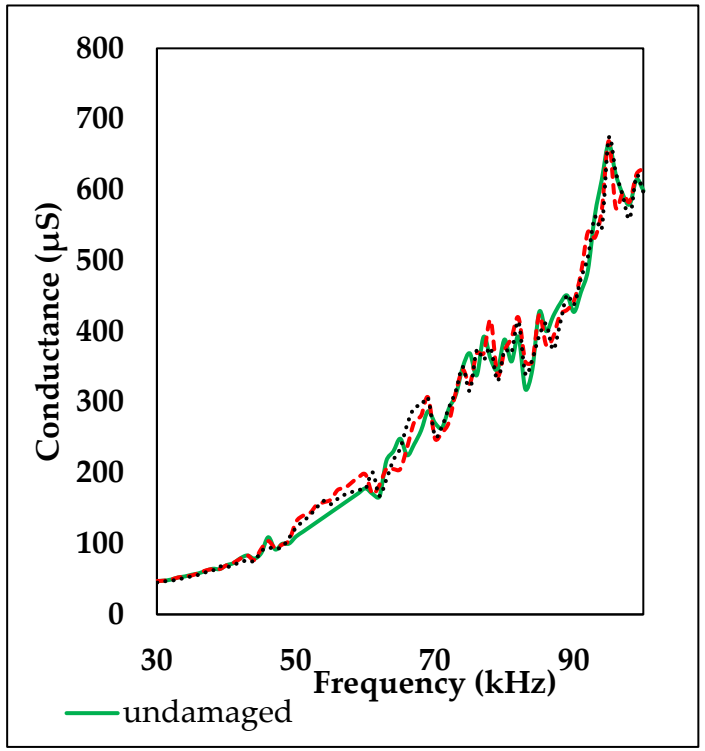
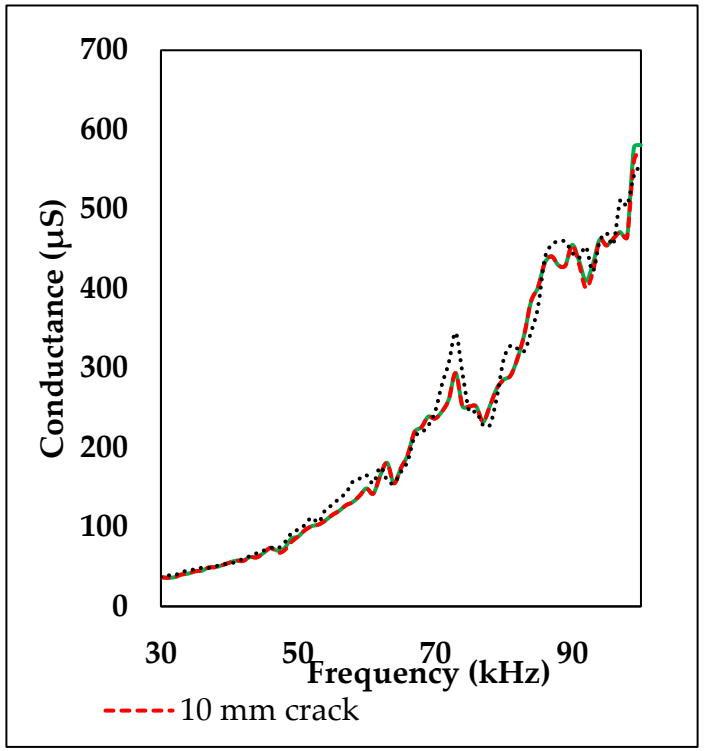
PZT No.	1	2	3
Distance from first crack (mm)	75	580	1390
Distance from second crack (mm)	723	68	742

Experimental validation

Damage detection study



(a)



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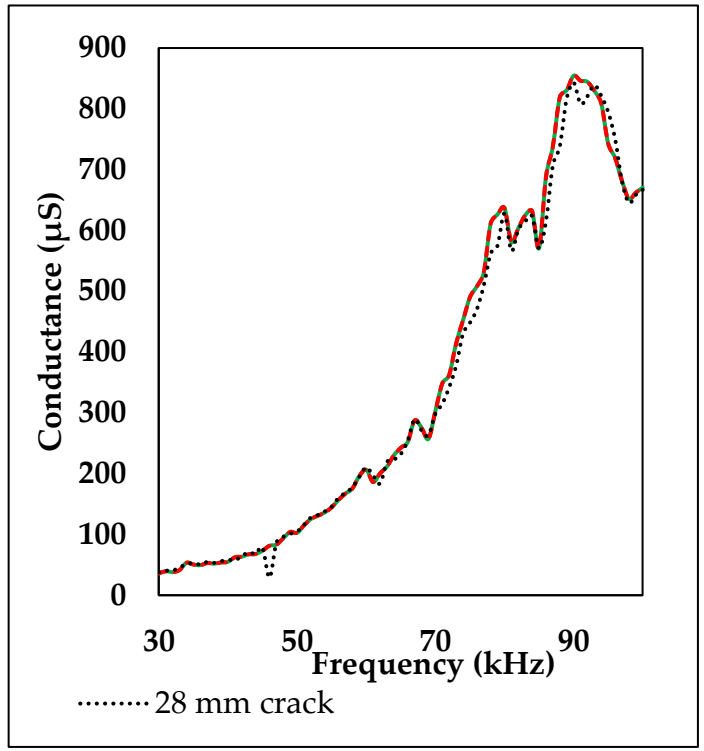
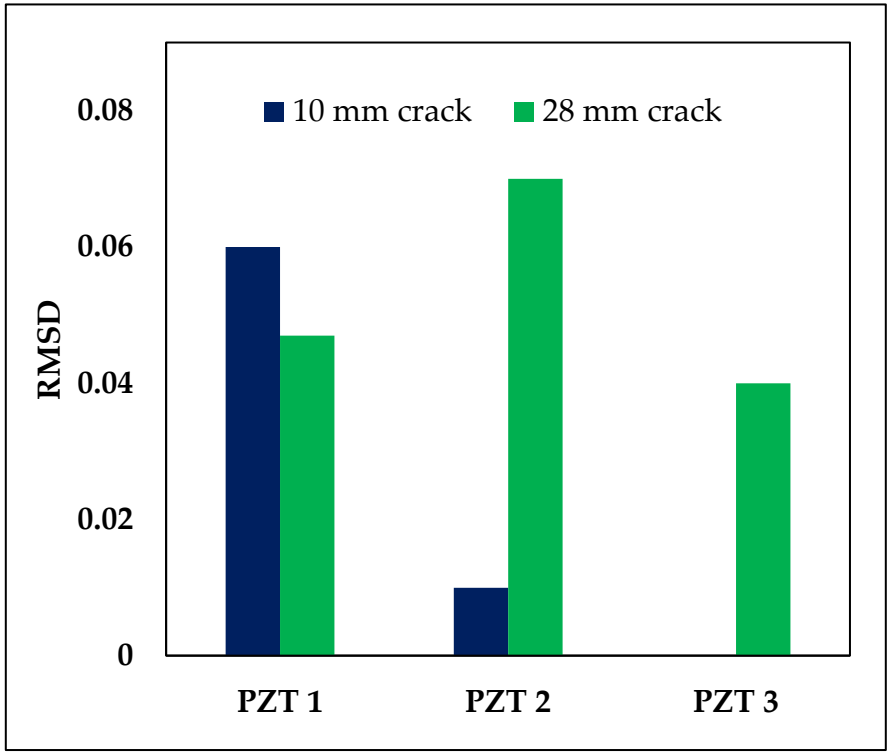


(c)

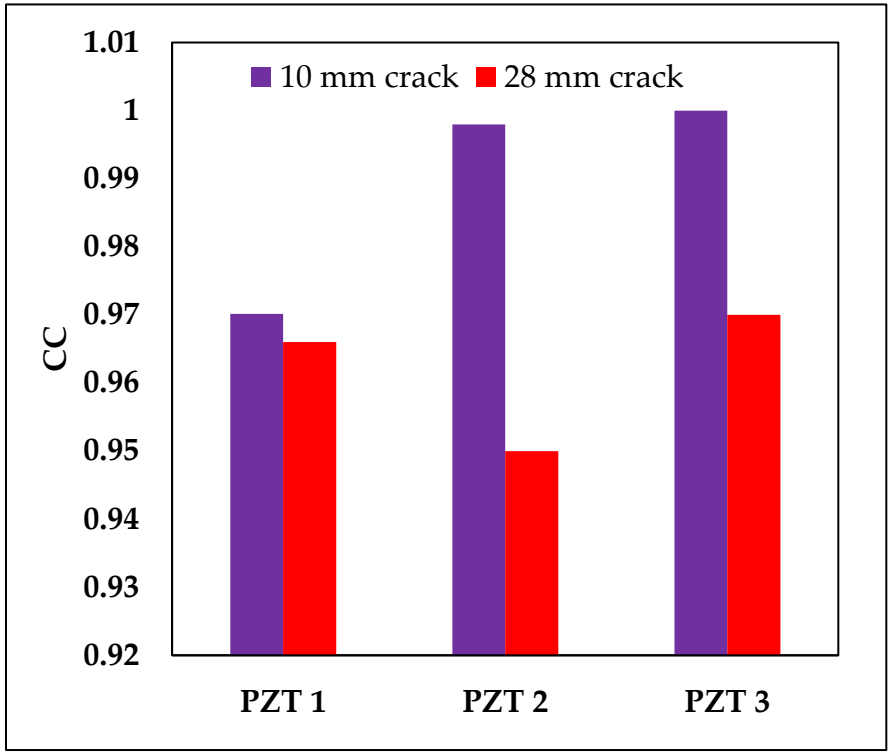
Conductance variations measured for (a) PZT-1; (b) PZT-2; (c) PZT-3 bonded to concrete beam.

Experimental validation

Damage detection study



(a)



(b)

Statistical metrics (a) RMSD; (b) CC evaluated for various PZT sensors.

Conclusion

- The trend of experimental results shows a good correlation with the numerical results.
- Surface-mounted SSUs are working well in the concrete structures.
- The proposal of the multi-sensing technique on the surface-mounted PZT sensors is recommended for effective SHM.
- The studies based upon damage detection and localization have been performed.

Thank you for the kind attention.

Any questions?

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