

Review on Integrated Structural Health Monitoring and Energy Harvesting Potential of Building

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ABSTRACT: This paper reviews the development of energy harvesting for low-power embedded structural health monitoring (SHM) sensing systems. A statistical pattern recognition paradigm for SHM is first presented and the concept of energy harvesting for embedded sensing systems is addressed with respect to the data acquisition portion of this paradigm. Piezoelectric materials have so far proven their efficacy for both energy harvesting and structural health monitoring (SHM) individually. Piezoelectric ceramic (PZT) patches, operating in d31-mode, are considered best for SHM. However, for energy harvesting, built up configurations such as stack actuators are more preferred. The main objective of this research was to explore the possibility of employing the same piezo sensor for SHM as well as energy harvesting on real-life civil structures such as bridges. Experiments have been carried out in the laboratory environment to measure the voltage and the power generated by PZT patches in surface bonded as well as embedded configurations. In embedded form, the PZT patches have been considered in the form of concrete vibration sensor (CVS), operating in the normal axial strainmode. Beam structure has been considered for modelling as well as lab experimentation owing to the energy harvesting potential offered by real-life Structure. Utilization of the same patch for energy harvesting as well as for SHM through a combination of the global vibration and the local EMI techniques has been experimentally demonstrated. Proof-of-concept demonstration of normal plate type piezo in axial strain mode in place of commercial expensive transducers for energy harvesting from real-life civil structure has been the original aspect of this study. It is expected that the outcomes of this research will pave way for dual use of the ordinary piezo patch in SHM as well as energy harvesting. With recent advancement of Internet of Things (IoT) and client-side web technologies, wireless integrated sensor devices nowadays can process real-time raw sensor signal data into target measurements, such as displacement, and then send the results through a standard protocol to the servers on the Internet (i.e., the cloud). The monitoring results are further processed for visualization purpose in the servers and the computed results are pushed to connected clients like browsers or mobile applications in real-time.

KEYWORDS: SHM, piezometer, beam, piezo patch.

1. INTRODUCTION

1.1 BACKGROUND

Structural Health Monitoring (SHM) implies monitoring the performance of structures using sensors to get an advance warning of the loss of structural capacity or potential collapse. Wireless-sensor based monitoring system is found to be advantageous over traditional wire-based system because of their ease of implementation and maintenance. However, power supply is an important concern for wireless sensors used in monitoring of civil engineering structures. Everything around us is getting smarter and changing. The change is taking step toward a better and smart future. The major role of engineering focus to play a pivotal role in bringing those changes to make a point-breaking understanding of the technologies around us in a better way. A smart home can make a smart city, likewise a smart industry can revolutionize the process for a smarter maintenance. It is a small step in making smart industries by reducing the complexity of wired communication with replaceable—connecting devices and cloud platform for analysis and control. This also solves the problem of complex hardware architecture by replacing structural complexity with logical devices and advanced communication devices. This paper aims to deploy computing techniques in creating a barrier to integration, complexity, to provide more financial gains and energy savings. Sustainability of resources in many small- and medium-scale industries is a current dominant issue. Automated process is a very efficient and effective process on installing very-high-configured equipment, which is

a possible constraint in small and medium industries. Consistent growth in market defines targets, but lack of resources has become a possible challenge in many ways. A simple consideration of a mushroom harvesting plant, where the production process takes minimum of 14 weeks for the yield and most of the approach, is manual.

1.2 MOTIVATION

All structures are subjected to slow and continued deterioration, caused by several factors, such as environmental degradation, fatigue, excessive loads, vehicle impacts and prolonged extensive usage. Even a minor incipient damage carries the potential to grow out of proportion, culminating in collapse, thereby leading to disruption of services and/or loss of life and property. External loads due to construction, occupancy, vehicle movement, blast/ impact, and the associated stresses and deflections along with structural response, if monitored for occurrence of damages, the process is called as structural health monitoring (SHM).

1.3 PIEZO SENSORS FOR STRUCTURAL HEALTH MONITORING (SHM) AND ENERGY HARVESTING

In specific technical terms, SHM is defined as the measurement of the operating and the loading environment and the critical responses of a structure to track and evaluate the symptoms of operational incidents, anomalies, and/ or deterioration or damage indicators that may affect operation, serviceability, or safety reliability states that SHM denotes a reliable system with ability to detect and interpret adverse changes in the structure due to damage and normal operation. In most general terms, SHM implies acquisition, validation and analysis of technical data to facilitate the life cycle management decisions.

1.4 SHM is important for critical structures owing to following reasons:

- (a) To timely detect structural damages and take remedial actions
- (b) To ensure design validation, since structural design is often based on parameters affected by statistical variation and uncertainties.
- (c) Evaluation of structure after major retrofitting during design life.
- (d) To provide an alternative to conventional visual inspection, this is time as well as cost ineffective.

By monitoring of external loads, stress distributions and deflections, SHM can enable better understanding structural behaviour.

1.5 SHM Damage Detection Techniques

Damage detection in SHM systems is classified into two types: local-based and global-based damage detection. Local based damage detection is used for screening structures and global-based damage detection is used for vibrational characteristics. Various sensors are used to detect the size and location of the damage in SHM systems. Sensors like piezoelectric, optical fiber, ultrasonic, laser, image detection, and vibrational sensors are commonly used because of their leverage over other sensors. Piezoelectric sensors are the most commonly used sensors; they can transmit and receive guided waves such as lamb waves in solids that can be used for damage detection. These lamb waves are much more cost effective as well as reliable as they are sensitive to change in structures. To identify the damage, the difference signal is acquired and compared with a damage-free signal. For structural damage localization, irrespective of the geometrical or imaging method used, the key to this process is the acquired time of flight and amplitude of the response to the signal.



Figure. 1.1 Network of intelligent devices through IoT



1.6 PRESENT REPAIR PRACTICES-OVERVIEW:

Since 1950s, the construction activity in India has been increasing geometrically without matching increase in the availability of quality inputs, in terms of materials and skilled workmen. The gap between the quality planned and the quality achieved continues to become wider. The factors contributing to damages/distresses in buildings have, thus, become intrinsic right from the construction stage. Often these are concealed under external renderings and the defect takes time to manifest itself.

Why Repair of structures arise?

1. Understanding gap between Quality Planned and Quality achieved in past, present.
2. We do take cube test but How far its significance is taken during progress of work how far is the co-relation maintained with such results.
3. Construction documents have specifications and instructions but they remain on paper sometime due to lack of understanding.
4. Procedures for Periodic Inspections of building and maintenance are not followed or maintained.
5. Budget estimates are prepared by un-experienced engineer or someone else.
6. Buildings remain several years without any attention.

1.7 CAUSES OF DETERIORATION OF STRUCTURES:

1. Site Selection and Site Development Errors
2. Design Errors
3. Construction Errors
4. Material Deficiencies
5. Operational Errors

1.8 CONDITION SURVEY AND NON-DESTRUCTIVE TESTING

1. It is examination of concrete for the purpose of identifying and defining area of distress.
2. Identify cause of distress and sources.
3. Access extent of distress due to corrosion, fire, earthquake, any other reasons.
4. Access residual strength of structure and inhabitability.

1.8.1 CLASSIFICATION OF DAMAGES:

Grade for Assessment of the building: Based on the inspection and observation the distress level of the selected buildings may be categorized as mentioned below:

1. **G1 – No distress observed.**
2. **G2 –** Minor distress observed in few structural members, which can be repaired under the advice of a structural engineer.
3. **G3 –** Medium distress observed in few structural members, which can be repaired / rehabilitated including strengthening with the advice of a structural engineer.
4. **G4 –** Severe distress observed in some of the structural members, which can be rehabilitated including strengthening with the advice of a structural engineer.
5. **G5 –** Severe distress is observed which could prove dangerous, hence evacuation at an early date is required.

1.8.2 REHABILITATION AND RENOVATION-THE WORK:

1.8.2.1) Principles of rehabilitation:

a) Elimination:

Remove the materials that cause damage to buildings. This is no easy matter, because everything from the floor to the roofing may contain various undesirable materials in the form of additives and admixtures.

b) Separation:

Something just can't be eliminated, but can still be protected. Use sealants or foil backed drywall to separate structures from damage causing sources.

c) Ventilation:

Controlled, filtered ventilation may be the only way to insure that the air we bring indoors is ideal. High humidity air or extremely low humidity air can cause significant damage to concrete, plaster and brick walls.

➤ **Rehabilitation work involves the following steps:**

a) Access arrangements:

Special gadgets may be required to get access to that part of the structure where the work is to be carried out. The

access arrangements may be in the form of suspended platforms, scaffoldings, jacking arrangements, anchoring systems, etc.

b) Materials required:

In choosing the materials, the following points may be kept in mind: Timely availability of the material, safe handling, adverse effect on the structure, surface preparation required availability of the equipment and financial implications.

c) Sequence of operations:

The process of rehabilitation has to carry out in such a manner that the safety of the structure is not jeopardized. Therefore it is necessary to plan the operations properly and then carry out it accordingly.

➤ **General areas of repair/rehabilitation work:**

1. Repair, removal, replacement and maintenance of mechanical supports, sanitary treatment plant and pipelines.
2. Repair and modifications to diffuser ports, aeration systems, and discharge pipelines.
3. Repair of columns and beams.
4. Installation and maintenance of dewatering structures.
5. Pile restoration and wood pile concrete encapsulation.
6. Anode installation for cathode protection.
7. Repair and replacement of trash-rack and debris screen.

DIFFERENT TYPES OF REPAIRS AND REHABILITATION WORKS FOR DIFFERENT STRUCTURAL COMPONENTS:

1.8.2.2) Repair for Plaster of walls:

Should you repair or replace? It is usually better to go in favour of repairing plaster walls, regardless of what they look like. But honestly, this is not always possible. Basically, if:

- There is more than 1 large hole per 4 x 8 Sq.ft, or
- There are more than 3-4 cracks in 100 Sq.ft, or
- The cracks are more than 1/4" wide

Then replace the section of wall. It will take more time and failed attempts to repair this wall than it is worth. Old plaster should be cherished - it is stronger and more sound proof than current walls made of gypsum board or sheetrock. Even cracking or crumbling plaster walls should be repaired, not replaced.

a) Plaster Damage (Non-Structural Problems)

Plaster is pretty tough stuff, but like any wall, it's going to get banged or gouged, and age will take its toll.

1. Impact Damage can be a serious problem in an old house. Over the years, the walls are going to get banged and dented as shown in the figure (8.1). Generally we have to replace the plaster 6-12" from the visible hole to reach plaster that is still keyed to the lath tightly.
2. Nearly every wall has a few nail holes. These can usually be fixed with a tiny bit of spackle applied with the finger. Not perfect, but they will be unnoticeable when the wall is painted.
3. Water is the enemy of plaster. Brownish stains on the walls or ceilings are evidence for bowing out of plaster. Water-damaged plaster can be very friable.
4. Old walls and old houses often have cracks. Stress cracks are a sign of possible structural shifting, extreme temperature changes, incorrect plaster mix, improper curing or leaks. Diagonal cracks over doorways signal settlement, or a nearby source of vibration, such as a highway or railroad.
5. Bulging plaster is an indication that the plaster keys have broken off and allowed the plaster layers to separate from the lath behind them. Bulging can be repaired with plaster washers.



Figure 1.2 Plaster Damage (Non-Structural Problems)

6. For repair of minor cracks, use fiberglass mesh tape then go over with a wide trowel and joint compound. There are also plaster patch compounds available that are excellent.
7. For larger cracks and holes, we need to remove all the debris and enlarge the crack until we reach solid plaster and fill the crack with joint compound or plaster patch.

If we choose to put wallboard over the plaster, use the following tips:

8. Apply wallboard horizontally.
9. Use the largest boards available.
10. Use screws, not nails, 12" apart in ceilings, 16" on walls.
11. Use a floating joint - the wall holds up the ceiling sheets.
12. Use corner clips at all corners.
13. Use fiberglass mesh tape, not paper, and special compound that is available for plaster walls..

Shotcrete/Guniting:

Shotcrete is the process of pneumatically applying concrete onto various surfaces at high velocity as shown in the figure (1.4). There are two primary application methods: the wet process pumps mixed concrete through a hose to the nozzle where compressed air is added to provide high velocity for placement and consolidation; the dry process, commonly known as guniting, uses compressed air to blow pre-blended dry materials through a hose at high velocity to the nozzle, where water is added. The effects in most cases are almost identical. The materials used in both processes are generally the same as those used for conventional concrete are Portland cement, aggregates and water. Various additives can enhance strength and reduce cracking. As a result, shotcrete /guniting has high-strength, durability, low permeability, and excellent bonding characteristics. Shotcrete/guniting application also provides almost limitless possibilities for complex shaping and forming in new construction and renovation projects.

a) Other key benefits include:

- Little or no form work is required.
- Cost-effective method for placing concrete.
- Ideal for irregular surface applications.
- Allows for easier material handling in areas with difficult access.



Figure 1.3 shows the pneumatically applying concrete on repair surface

b) Types of shotcrete:

- i) Dry mix shotcrete (Guniting).
- ii) Wet mix shotcrete.

i) Dry mix: (Guniting)

Dry mixing involves premixing of binders and aggregates which are fed into special mechanical feeder metering the premixed materials into a hose. The mix is jetted out along with compressed air from a nozzle connected to the hose having a water ring outfitted to it as shown in the figure (10.3). This mix is injected to the repair spot. The resultant hardened properties include increased flexural, compressive strengths and more durability.

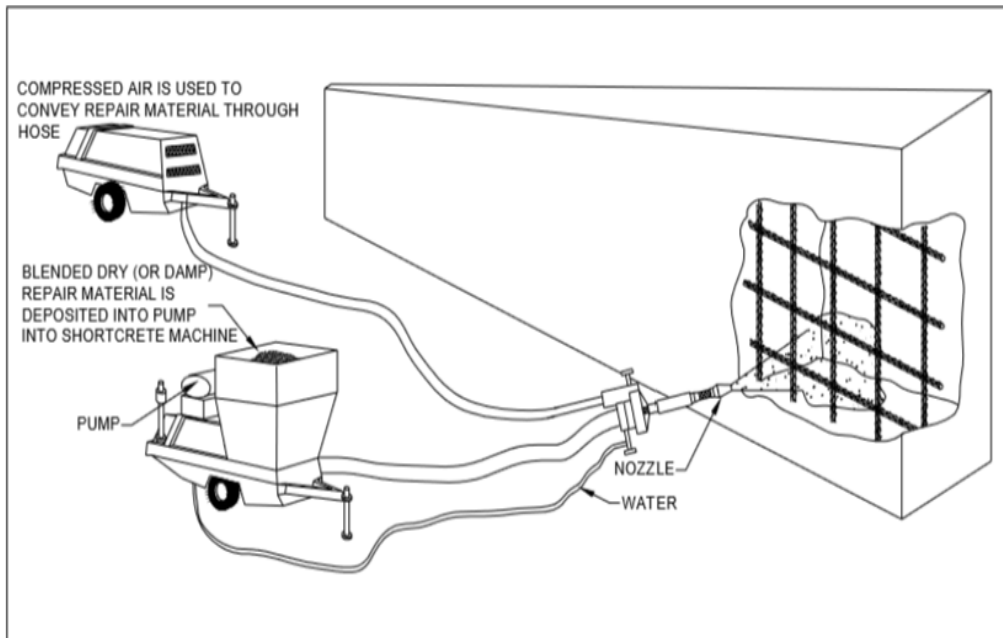


Figure 1.4 Layout of Dry mix Shotcrete

ii) Wet mix:

Wet mix Shotcrete is a method that involves premixing of all ingredients including binder, water, aggregates and admixtures. The premixed repair materials are deposited into a pump which transports the materials to an exit nozzle where compressed air is introduced as shown in the figure (10.4). The repair material is propelled onto the substrate with compressed air. Admixtures can be used to enhance durability. Air entrainment is required for freeze thaw resistance. The effect is smooth and unnoticeable.

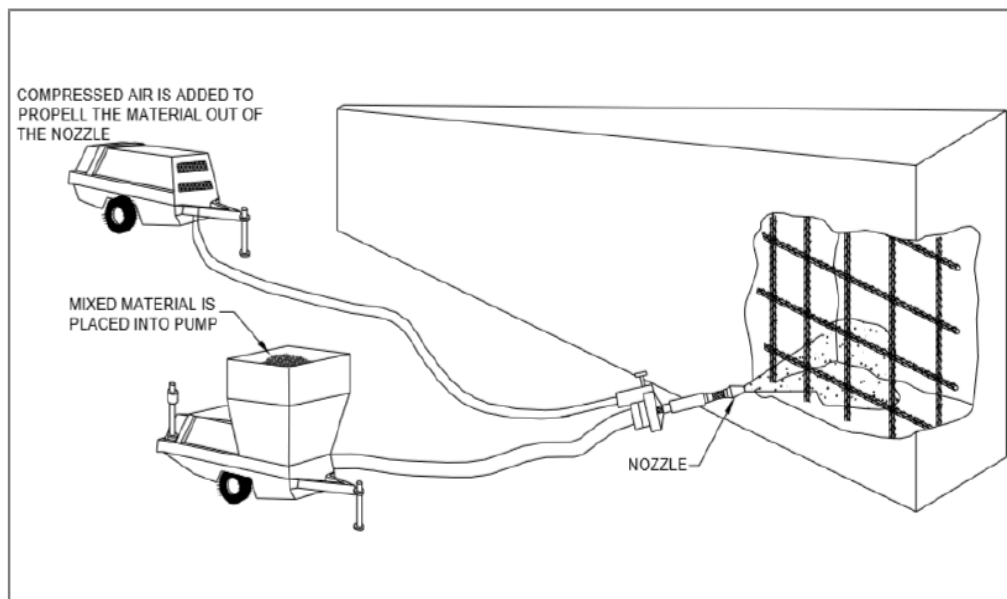


Figure 1.5 Layout of Wet Mix Shotcrete

1.6 PROBLEM STATEMENT

Piezoelectric materials have so far proven their efficacy for both energy harvesting and structural health monitoring (SHM) individually. Piezoelectric ceramic (PZT) patches, operating in d31-mode, are considered best for SHM. However, for energy harvesting, built up configurations such as stack actuators are more preferred. The main objective of this research was to explore the possibility of employing the same piezo sensor for SHM as well as energy harvesting on real-life civil structures such as bridges.

1.7 SCOPE OF PROJECT

So far, the piezo sensors have been independently employed for SHM and energy harvesting. Keeping in view the background given above, it is justified to pursue the present study to develop a conceptual framework which can integrate the two functions using same PZT patch. The main objective of this thesis is to investigate the potential of utilizing the same PZT patch for SHM as well as energy harvesting employing axial strain actuation (d31) mode

1.8 OBJECTIVE

- 1- To developing and validating analytical suitable for computation of harvestable energy from the piezo patches operating in d31-mode, either in surface bonded or embedded configurations, including
- 2- The effect of losses such as the mechanical loss, the dielectric loss and the shear lag loss and to extend the analytical model to real-life structures.
- 3- To performing detailed parametric studies to work out the optimum size and parameters of the patches from energy harvesting considerations.
- 4- To Use of normal plate type piezo in axial strain mode in place of commercial expensive transducers for energy harvesting has been the innovative aspect of this study.

II. LITERATURE REVIEW

BrindaChanv et al. [1] presented Structural Health Monitoring stands out as the appearing field in civil engineering which provides the possibility for continuous and regular assessment of the security and integrity of civil infrastructures. It includes method of determining and detecting damages and weaknesses in the infrastructure because of aging or almost any other reason, good in time therefore a preventive maintenance is usually performed before it collapses. It is able to also provide warning about present state of the framework. Internet of little things (IoT), is the system of smart sensors that combine sensing and wireless transmission of important security parameters of buildings and components, to distant computing devices of which continually perform the processing and monitoring of these variables. This particular paper surveys the state of the existing exploration in the solutions plus implementation methods and tries to perform a comparative analysis.

DebajyotiMisra et al. [2] In this paper, we've suggested a smart creating health monitoring system to stay away from undesirable mishaps. Some accidents take site without any warning. The job within this newspaper provides an internet of little things (IoT) based building health monitoring (BHM) program. The program comprises

piezoelectric sensors, ESP8266 Wi-Fi module and Arduino. Piezoelectric sensor (PZT) is used to produce and also get Lamb waves and also the received wave is even further examined to identify the health of the concrete structure. The strategy is different and utilizes cloud and mobile app based monitoring. You will find two essential features of the suggested system; it monitors the destruction in concrete construction and uploads the information on the cloud server. The extraordinary method takes the help of cloud sever method because of its positive location of data usability, ease of access as well as disaster recuperation. This proposed system generates all details related to structural health of a certain building and will inform on the responsible authority for remedial measures. So that it is able to avoid mishaps and save properties, money, and lives.

Yang et al. [3] presented this paper for the finite element simulation of the interaction between a PZT patch and a host structure, including the bonding layer, utilizing the EMI technique with varying temperature. He performed the simulation of the PZT–structure interaction at the high frequency range (up to 1000 kHz) using FEM software, ANSYS version 8.1.

Duan et al. [4] reviewed the implementation of piezoelectric transducers in health monitoring. The analysis of plain piezoelectric sensors and actuators and interdigital transducer and their applications in beam, plate and pipe structures for damage detection are reviewed in detail.

Yang et al. [5] implemented Piezo-electric ceramic Lead ZirconateTitanate (PZT) based EMI technique for SHM to various engineering systems. In this paper he used the structural mechanical impedance extracted from the PZT electromechanical conductance signature as the damage indicator. A comparison study on the sensitivity of the electromechanical admittance and the structural mechanical impedance to the damages in a concrete structure is conducted. Results show that the structural mechanical impedance is more sensitive to the damage than the electromechanical admittance thus a better indicator for damage detection.

Zhang et al. [6] studied the EMI technique for health monitoring. In this paper, he presented an impedance model for predicting the electromechanical impedance of a cracked beam. He analysed a coupled system of a cracked Timoshenko beam with a pair of PZT patches surface bonded to the top and bottom of the beam. He introduced the shear lag model to describe the load transfer between the piezoelectric patches and the cracked beam. He simulated the beam crack as a massless torsional spring.

Yang et al. [7] applied Piezo-electric transducers, working on the EMI technique for health monitoring in aerospace, civil and mechanical engineering. The piezoelectric transducers are usually bonded on the surface of the structure and subjected to excitation so as to interrogate the structure at the desired frequency range. The interrogation resulted in the conductance signatures which can be used to estimate the structural health or integrity according to the changes of the signatures.

Chhabra et al. [8] dealt with the Active Vibration control of structures with piezoelectric patches bonded on top and bottom surfaces of the beam. The patches are located at the different positions to determine the better control effect. The study is demonstrated through simulation in MATLAB.

Peng [9] studied the mechanical properties of steel fiber reinforced concrete crack for SHM. Since working environment is very harsh, the steel fiber reinforced concrete is prone to crack and a small crack on beam may result in severe damage. Hence, it is important to examine the mechanical properties of steel fiber reinforced concrete crack to detect early crack semiotics. He inspected the mechanical characteristics of steel fiber reinforced concrete crack by experimental tests on four specimens. He considered the effect of the loading position in the tests.

Hong et al. [10] modelled a strain-based load identification for beam structures subjected to multiple loads. In his model, he measured the contribution of each load to the strains by strain sensors. In this paper, the longitudinal strains measured from multiplexed fiber Bragg grating (FBG) strain sensors are utilized in the load identification.

Parameswaran et al. [11] studied the response of the mechanical systems from undesirable vibrations during their operations. Their occurrence is uncontrollable as it depends on various factors. However, for efficient operation of the system, these vibrations have to be controlled within the specified limits. Light weight, rapid and multi-mode control of the vibrating structure is possible by the use of piezoelectric sensors and actuators and feedback control algorithms. In this paper, direct output feedback based active vibration control has been implemented on a cantilever beam using Lead Zirconate-Titanate (PZT) sensors and actuators. Three PZT patches were used, one as the sensor, one as the exciter providing the forced vibrations and the third acting as the actuator that provides an equal but opposite phase vibration/force signal to that of sensed so as to damp out the vibrations. The designed algorithm is implemented on Lab VIEW 2010 on Windows 7 Platform.

Hu et al. [12] studied the application of Piezo-electric lead zircon tetitan ate (PZT) as a new smart material for health monitoring. To study the damage detection properties of PZT on concrete slabs, simply supported RCC slabs with PZT patches surface bonded to the host structure were chosen as the objective of the research and the electromechanical impedance technique was adopted for research. Five different kinds of damage were analysed to test the impedance values at different frequency bands.

Neel Mania et al. [13] studied The smart phones nowadays equip themselves with in-built sensors, such as Samsung Note 4 with heartbeat sensors including gyro meter and accelerometer incorporated in smart phones

signals with remote servers, which can accelerate medical services in spatial-temporal dimensions. The latency reduction is one of the necessary features of computing platforms which can enable completing the healthcare operations, especially in large-size medical projects and in relation to providing sensitive and intensive services.

Segun O et al. [14] studied To address the scarceness of energy, wireless energy transfer (WET) techniques that exploit radio frequency (RF) signal to transfer RF energy has recently emerged for powering IoTSNs. This line of research is referred to as wireless power sensor networks (WPSNs). Consequently, an EE optimization problem is formulated for the successive WPSN system and solved by exploiting the problem structure and through a meta-heuristic algorithm. The new system is validated through the numerical simulation results presented in this work by thoroughly analysing, evaluating and comparing the proposed meta-heuristic based WPSN system with the baseline state-of-the-art WPSN systems that combined a meta-heuristic algorithm, two additional meta-heuristic algorithms including genetic algorithm (GA) and ant-colony optimization (ACO) algorithm as well as a non-meta-heuristic algorithm – specifically an iterative based Dinkelbach algorithm

Oliver Mörth et al. [15] studied Realizing performance improvements requires actual and relevant information about the current production provided to the management. However, the huge amount of data hinders a fast and correct decision making of the production manager as the extraction of the relevant information still appears to be a major problem the basis for the required decisions builds the proper providing of relevant information. IoT application are considered as one solution for realizing an efficient and effective monitoring a concept for IoT based monitoring of environmental conditions in the production area. Fulfilling the defined constraints scalability, adaptability and cost-effectiveness, a corresponding demonstrator has been developed and implemented in the LEAD Factory

Donato Abruzzese et al. [16] explained The importance of efficient Internet of Things (IoT) platforms for structural health monitoring of buildings and civil engineering infrastructures (CEIs) is nowadays widely recognized, measuring the stress state inside structural elements (columns, beams, connections) simultaneously with the recording of the accelerations at the same location (thus avoiding complications given by the inverse problem), so as to obtain a reliable map of the current safety level of those structural elements and of the structure as a whole. Once equipped with such system, each construction can become part of the Internet of Things, permitting users and authorities to be alerted in case structural safety is diminished or compromised. A crucial aspect is the unaltered preservation of measurement data over time, which cannot just rely on third parties, and for which it is necessary the exploitation of suitable data-protection technologies. This study have been carried out by experimental testing and validation, both in lab and on site, of the monitoring devices designed and realized. Results show that it is possible to realize low-cost monitoring systems, and related installation techniques, for integration in every new or existing buildings and CEIs

Michal Dziendzikowski et al. [17] explained Commonly applied as elastic waves actuators and sensors are transducers based on lead-zirconate-titanate (PZT) ceramics, i.e., PZT transducers the idea underlying the definition of DIs was to maintain most of the information carried by the voltage induced on PZT sensors by elastic waves. In particular, the DIs proposed in the paper should be sensitive to all types of damage which can influence the amplitude or the phase of the voltage induced on the sensor. Properties of the proposed DIs were investigated experimentally using a GFRP composite panel equipped with PZT networks attached to its surface and embedded into its internal structure. Repeatability and stability of DI indications under controlled conditions were verified in tests.

Qiu Lei, Yuan Shenfang et al. [18] researches The active Lamb wave and piezoelectric transducer (PZT)-based methods have been studied by many researchers in recent years Lamb wave and PZT network-based integrated multi-channel scanning system (PXI-ISS) is developed for the purpose of practical applications of SHM, which is compact and portable, and can scan large numbers of actuator-sensor channels and perform damage assessing automatically. A PXI-based 4 channels gain-programmable charge amplifier, an external scanning module with 276 actuator-sensor channels and integrated SHM software are proposed and discussed in detail. The experimental research on a carbon fiber composite wing box of an unmanned aerial vehicle (UAV) for verifying the functions of the PXI-ISS is mainly discussed, including the design of PZTs layer, the method of excitation frequency selection, functional test of damage imaging, stability test of the PXI-ISS, and the loading effect on signals. The experimental results have verified the stability and damage functions of this system

Hongduo Zhao et al. [19] researches this paper, the synergistic performance of piezoelectric transducer and asphalt pavement is studied through finite element analysis. Results show that the energy conversion efficiency of the transducers decreases with increasing burial depth and modulus of surface course. Under the vehicle loading, the piezoelectric transducer and asphalt pavement are easily separated by shear stress. For the asphalt pavement, the change in the stress of pavement structure and surface deflection is very small, which means that the differential deformation has no effect on fatigue cracking. Furthermore, an energy harvesting system composed of transducers array and asphalt plate is made and evaluated in a laboratory. Results show that the transducers within asphalt pavement have acceptable efficiency and high durability.

Christian Falconi et al. [20] studied Piezoelectric devices are already ubiquitous. For instance, the frequency selectivity of piezoelectric electro-mechanical resonators is typically orders of magnitude better than RLC resonators; for this reason, almost all electronic systems contain several piezoelectric resonators for timing and frequency control, so far, no systematic analysis of these advantages and of the associated challenges has been reported. Here, we critically review 16 unique advantages of piezoelectricity at nanoscale and also consider some of the most important open challenges, together with promising general strategies to address them. Our analysis confirms that nanotechnology can open the way to piezoelectric transducers with unprecedented performance for several applications, including mechanical energy harvesting, piezotronics, piezophotonics, implantable systems, wireless piezoelectric Nano transducers, and more.

III.CONCLUSION

In this particular work, two specimens with a post installed RC wall were evaluated under cyclic loading to analyze the SHM of these an RC wall underneath the seismic loading. A multi-functional transducer unit (post embedded PZT sensor) is utilized for Local damage detection and SHM in this particular experimental test. The experimental results indicate the sensors were useful for the SHM of the entire structure and in identifying neighborhood damage of RC wall structures. With regard to retrofitted RC participants, the interface disaster or maybe cracks between 2 structural users (one current and one added) are essential and also influence the usefulness of the retrofit. Moreover, cracks or interface failure can't be noticed during renovation during retrofitting work.

The experimental success in this effort show that PZT receptors could be utilized to recognize interface failure or maybe cracks between 2 structural users in retrofit building as well as assistance engineers to identify the degree of damage to a structure because after an earthquake. On account of the benefits of piezoelectric sensors, like their productive sensing, cost that is low, accessibility in several shapes, simplicity of ability and implementation to identify small splits from high frequency responses, piezoceramic based sensors have greater opportunity for any SHM detection of harm in RC wall structures compared to typical SHM methods. For comfort of implementation, potential labor must elucidate the connection between crack patterns, lengths or widths as well as the harm indices which are obtained by using PZT sensors

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