International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 04 | Apr 2026 www.irjet.net p-ISSN: 2395-0072

INVESTIGATION OF RAILWAY BRIDGE USING ACCELEROMETER AND STRAIN GAUGES

Dr. Mulpuru Madhuri, Bandi Sameer, Kanuri Devi Sri Lakshmi Prasanna, Maddu Ganesh Manikanta, Pothina Rakesh

Department Of Civil Engineering Sanketika Vidya Parishad Engineering College
(Approved by AICTE, New Delhi, Accredited by NAAC-A and Affiliated to Andhra University)
P.MPalem, Behind International Cricket Stadium,VISAKHAPATNAM-530041

***

Abstract – *Heavy trains cross railway bridges, pushing them with moving forces that might lead to issues like bending, tiny breaks, or material wear over time. Because of this stress, watching how these structures behaves matters - safety depends on it. Looking closely at two different kinds - a metal one near Yelamanchili and a solid concrete type in Kadapa - helps spot differences through health-tracking methods. Sensors that catch shaking and sensors measuring internal stretch recorded data when trains passed by. The flexible steel version reacted with more movement, whereas the rigid concrete model stayed calmer, showing less shake during use. When sensors like accelerometers team up with strain gauges, measurements get sharper for checking how bridges behave. Evidence shows these tools catch shifts in structure, shape upkeep schedules better, while quietly boosting both safety and lifespan on train spans.*

Key Words: **Railway Bridge, Accelerometers, Strain gauges, Structural health monitoring, vibration analysis, Dynamic loads, Stiffness, Bridge safety.**

1. INTRODUCTION

Heavy trains pass over railway bridges, so these structures face shifting pressures that may lead to cracks or wear. Because of this stress, watching how they behave matters a lot. One example looked at a metal bridge near Yelamanchili, another at a concrete one in Kadapa. Scientists applied tools like motion sensors and tension detectors. These recorded how each bridge shook and stretched when trains moved across. What happens underneath reveals what the eye cannot see. From the data, it becomes clear - steel bridges shake more because they bend easier. On the flip side, concrete ones stay calmer thanks to their rigid nature. Monitoring through sensors works well, catching issues early. This approach helps track how structures behave over time. Problems get spotted before they grow serious. Maintenance improves when guided by real measurements. Safety climbs as a result of constant observation.

1.1 Importance of Railway Bridges

Heavy trains cross rivers, roads, or deep gaps on railway bridges - these crossings must hold up under constant stress. Built tough, they face both steady weight and sudden forces all day long. Safety depends on their ability to last without weakening over time.

1.2 Need for Structural Health Monitoring (SHM)

Over time, repeating loads along with weather shifts slowly wear down materials in train bridge parts. Watching how these structures behave day by day offers clear signs when something begins to weaken. Spot checks happen less often now since live data streams show problems before they grow. Fixing small issues early keeps bigger breakdowns from happening later on.

1.3 Behavior of Bridges under Train Loads

When trains move across bridges, shaking happens along with shifts in shape and changes to internal forces. Because of this motion, engineers watch how weight spreads through materials, notice weak spots, then check if everything works as expected.

1.4Aim of the Study

From vibrations and strain readings captured by monitoring tools, differences in how steel versus concrete rail bridges respond are examined. Because trains create shifting forces, the way each material handles stress becomes clearer over time. When movement patterns change, signs of wear or harm might show up early. Through these measurements, upkeep needs come into view without waiting for visible flaws. Safety grows when hidden shifts in structure reveal themselves ahead of failure. Long term trust in bridges depends on catching small issues before they grow large. Maintenance works better when based on real responses instead of fixed schedules alone.

SCOPE OF THE PROJECT

Looking into two railway bridges forms the core here - one made of steel located at Yelamanchili, another of concrete at Kadapa - both examined through Structural Health Monitoring methods. Vibration and strain are captured while trains pass, thanks to sensors like accelerometers and strain gauges fixed onto the structures. From these readings, patterns in how each bridge moves and handles force begin to emerge clearly. Though built differently, their real-world reactions under load reveal distinct traits when studied closely. Data shapes the comparison between the metal and concrete spans, showing how each manages stress over time. What stands out is not just material but response, measured precisely across repeated trials

OBJECTIVES OF THE PROJECT

1. To study the concept of structural health monitoring in railway bridges.

2. To understand the working of accelerometers and strain gauges.

3. To measure vibration responses using accelerometers.

4. To measure strain in bridge components using strain gauges

5. Looking at how steel and concrete bridges respond when trains pass over them.

6. To compare the performance of Yelamanchili (steel) and Kadapa (concrete) bridges.

7. Checking how well sensors spot shifts in structure.

8. To improve bridge safety and maintenance planning

SENSORS CONNECTION LAYOUT

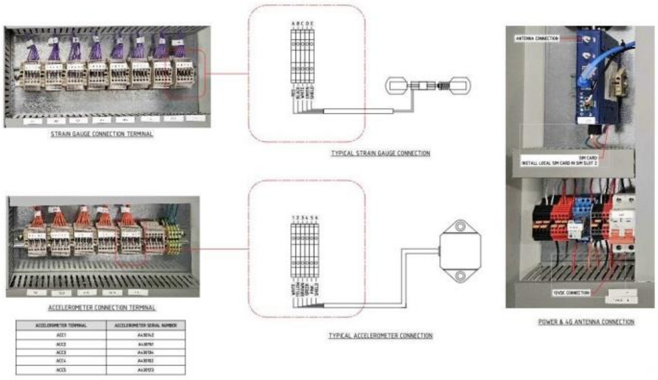


Fig -1: Sensor's connection layout

Here comes the setup - strain gauges linked with accelerometers for checking bridge health. Wires meet terminals just right, showing how each piece hooks up. Diagrams guide the layout, clear but not fancy. Power flows where needed, arranged so nothing misses a beat. Vibration rides alongside strain, both tracked steady. Data piles up from rails above, feeding checks on how well things hold. Safety leans on these numbers, quiet but firm. Performance gets its proof here, one reading at a time.

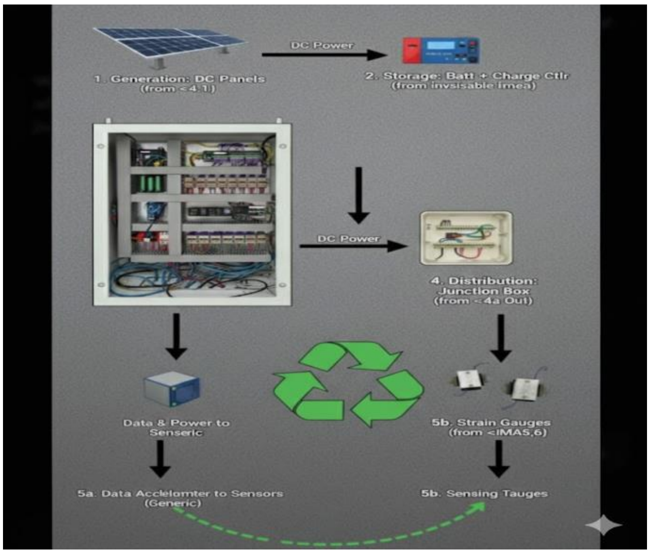


Fig -2: Sensor's connection layout

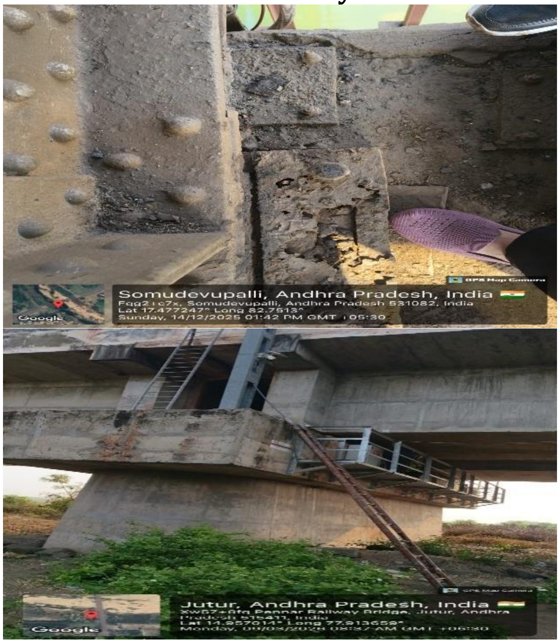
Sunlight feeds the setup through photovoltaic cells. Stored energy moves under control to keep things running steady. Sensors on the bridge - ones that track vibrations and ones measuring tension - gather details constantly. Power flows without interruption thanks to smart management of reserves. This way, readings come in nonstop while using minimal resources. Safety climbs because changes show up early. Long spans of usage test how well everything holds up over years. Information builds slowly, painting a clear picture of structural health.

METHODOLOGY

Process 1: Selection of Railway Bridge

Process 2:.Installation of sensors

- **Visual Condition Study**

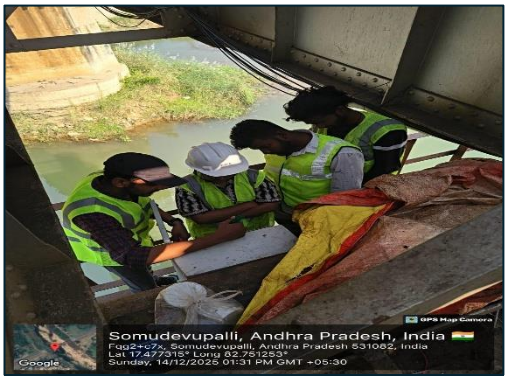


- **Surface Cleaning and Preparation**

- **Fixing strain gauges on both bridges**

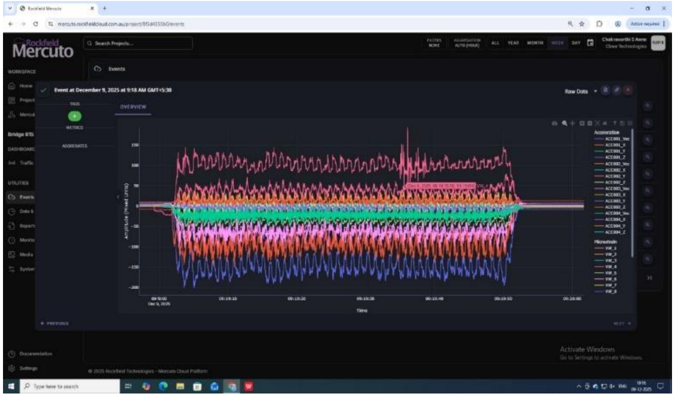
- **Placement of Accelerometers and sensors**

Process 3: Data Collection During Train Movement

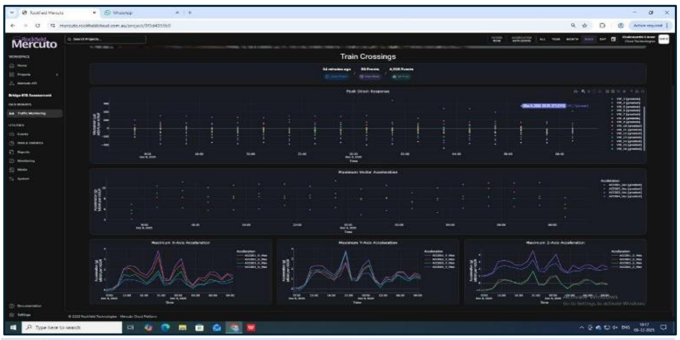


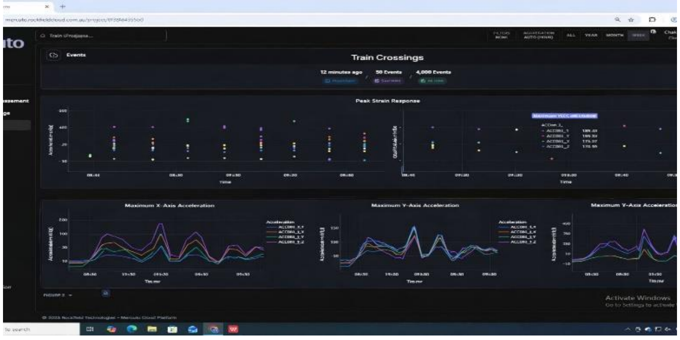
Process 4: Data acquisition system

Process 5: Graph Generation at steel and concrete bridge



Process 6: Identification of Maximum Strain and Time Period from Graph at steel and concrete bridge





Process 7: Stress Calculation Using Hooke's Law

Under the given loads, safety performance emerged clearly. From strain data, stress levels in structural parts followed Hooke's principle of elasticity. Where steel reacted sharply, concrete held steady without notable shift. Load effects stayed well within secure margins throughout testing. $\boldsymbol{\sigma = E \times \varepsilon}$

Stress is calculated using Hooke's Law, where stress is directly proportional to strain.

σ = Stress (N/m^2 or MPa) E = Modulus of Elasticity of material

(for steel ≈ 200 GPa, for concrete ≈ 25 GPa)

ε = Strain Using the maximum

Steel Bridge (Yalamanchili):
Strain = 150 με = 0.000150, E = 200,000 MPa
Stress = 30 MPa → Higher but safe
Concrete Bridge (Kadapa):
Strain = 150 με = 0.000150, E = 25,000 MPa
Stress = 3.75 MPa → Safe and stable

Process 8 : Natural Frequency Calculation

The natural frequency of each bridge was determined from the acceleration-time data. The steel bridge demonstrated higher stiffness, whereas the concrete bridge was more flexible but stable, reflecting their respective dynamic characteristics.

Formula: $f = 1 / T$
Steel Bridge (Yalamanchili):
T = 0.05 sec
f = 1 / 0.05 = **20 Hz**
Concrete Bridge (Kadapa):
T = 0.125 sec
f = 1 / 0.125 = **8 Hz**

Process 9: Dynamic Amplification Factor (DAF)

Surprisingly, the DAF analysis revealed how movement changes things when stacked against still loads**.** One thing became clear - when vibrations enter the picture, both bridges react in ways standard tests miss entirely. The metal structure? It danced more under shifting forces than its counterpart ever did.

Formula: DAF = Dynamic Response / Static Response
Steel Bridge (Yalamanchili):
Yd = 10 mm, ys = 5 mm → DAF = 10 / 5 = 2.0

Concrete Bridge (Kadapa):
Yd = 6 mm, ys = 4 mm → DAF = 6 / 4 = 1.5

Process 10: Allowable stress and safety comparisons

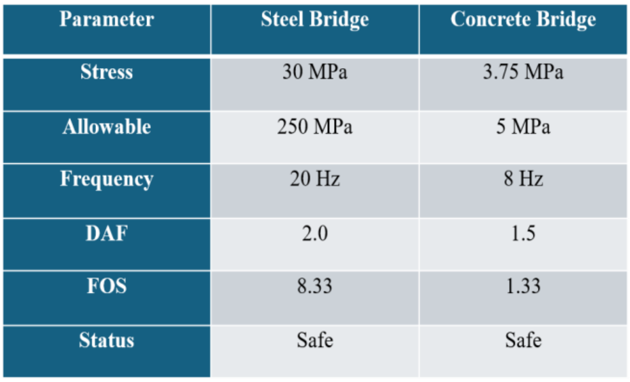
Under pressure tests, each bridge handled force as expected. Safety margins lined up with required standards, showing no risk of failure. Where steel stood strong, concrete did too - both coping well under demand. Load performance matched design goals without issue. Stress levels stayed below maximums set by guidelines.

Allowable Stress & Safety Comparison
Steel Bridge (Yalamanchili):

Clculated Stress = 30 MPa
Allowable Stress = 250 MPa
Status: Safe
Concrete Bridge (Kadapa):
Calculated Stress = 3.75 MPa
Allowable Stress = 5 MPa
Status: Safe

Process 11: Safety actor calculations

The bridge's ability to handle weight safely shows up in a number called the safety factor. This value comes from dividing strength by expected load. Heavy traffic demands higher margins. Engineers check materials closely before deciding on numbers. Real-world conditions change how much stress a structure can take. Past performance helps guide future designs **FOS means you take the stress something can handle, then divide it by what it actually faces**. What you get shows how much extra load it could survive before failing. When FOS increases, safety improves too. The greater the number, the less likely failure becomes. Strength goes up as that figure climbs. Safety grows right along with it. A bigger margin shows things can handle more stress. The Yalamanchili steel bridge stands strong, its factor of safety measured at **8.33**. Safety like that doesn't come by accident - built in through careful design. This number means stress levels stay far below failure points under normal loads. Engineers checked every part before giving approval. High margin? Yes - but needed for long-term reliability. Eight point three three isn't just a figure - it reflects real-world toughness.



Parameter	Steel Bridge	Concrete Bridge
Stress	30 MPa	3.75 MPa
Allowable	250 MPa	5 MPa
Frequency	20 Hz	8 Hz
DAF	2.0	1.5
FOS	8.33	1.33
Status	Safe	Safe

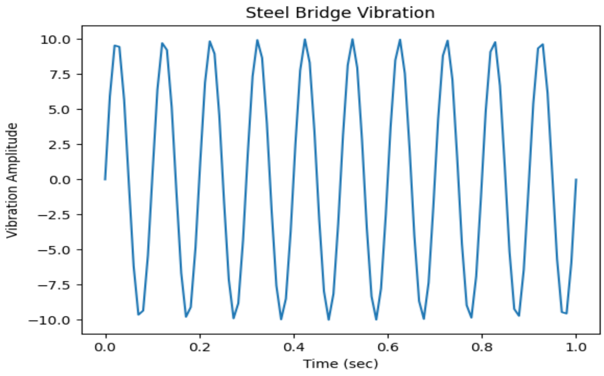
The Kadapa concrete bridge holds steady with a factor of safety at **1.33** - its strength stands up when tested against real-world forces. Safety here isn’t assumed; numbers back how well it bears load after load.

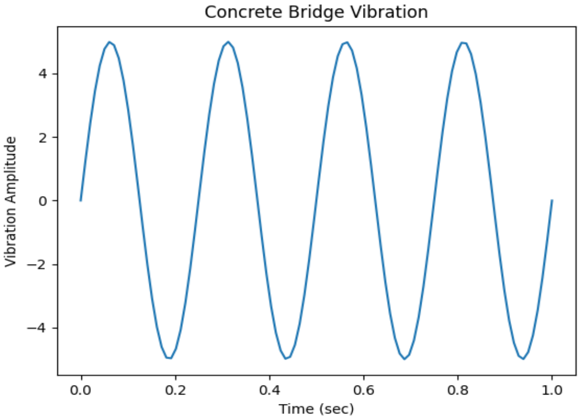
Process 12 : Structural safety evaluations

Checking bridge safety involved looking at stress levels alongside what those levels should stay under. Natural vibrations gave clues about structural behavior instead of just static measures. Impact effects appeared through something called DAF rather than pure load numbers. Strength margins showed up in FOS values, offering another layer beyond basic capacity. Each factor played a role apart from the others, yet together they shaped the full picture. **Steel Bridge** Yalamanchili stress frequency DAF safety factor within limits **Concrete Bridge** Kadapa stress frequency DAF safety factor within limits.

Process 13: Final assessment of bridge

Stress checks, how often they vibrate naturally, their reaction to moving loads, and safety margins were used to test the Yalamanchili steel bridge along with the Kadapa concrete one. Though built from different materials, each stayed below maximum permitted stress levels during testing. Vibration patterns sat well within ranges considered secure, meaning shaking won’t grow out of control. Responses under load changes remained predictable, thanks to low dynamic amplification readings. Safety numbers came back solid - no red flags there. With greater rigidity, the metal structure reacted more firmly when tested. Meanwhile, the concrete version handled everything steadily, without surprise shifts. Built differently, yet both stand ready for regular traffic without concern.





OBSERVATION OF STRUCTURAL RESPONSE

The structural response of the two railway bridges was observed using accelerometers and strain gauges during train movements. Key observations include:

Vibration Response: The steel structure near Yalamanchili swayed more, being less rigid. On the opposite end, Kadapa's concrete crossing stayed steadier thanks to its firm build.

Strain Response: Midway along the beam, sensors showed greater tension building up. Where forces piled on most, especially by the ends, stretching reached its peak. Readings shifted noticeably depending on which part of the structure was measured.

Dynamic Behavior: Flexing slightly when trains passed, each bridge held up without issue. Not once did they sag too much or shake in strange ways - proof enough they’re sound. A smooth ride every time meant all was well underneath

Load Effects: The bridges showed predictable increases in strain and vibration with higher train speeds or heavier loads.

Sensor Performance: Sensors that measure movement along with devices tracking material stress delivered precise updates instantly - this made it possible to watch how the bridge responded at all times.

From these findings, it's clear that using sensors helps track how railroad bridges react at any given moment. Tracking stress spots becomes possible when data flows continuously from monitoring tools.

Safety assessments gain accuracy once live measurements are taken into account across entire structures.

CONCLUSION

1. Study conducted on steel bridge (Yelamanchili) and concrete bridge (Kadapa)
   - Natural Frequency:
     Steel: 20 Hz
     Concrete: 8 Hz
   - Dynamic Amplification Factor (DAF):
     Steel: 2.0
     Concrete: 1.5
   - Stress Values:
     Steel: 30 MPa (Safe)
     Concrete: 3.75 MPa (Safe)
   - Factor of Safety (FOS):
     Steel: 8.33
     Concrete: 1.33
2. Steel bridge shows higher vibration (flexible)
3. Concrete bridge shows less vibration (stiffer)
4. Sensors provided accurate real-time measurements
5. Both bridges are structurally safe under train loads
6. SHM system is effective for monitoring and safety improvement

REFERENCES

Strength of Materials & Mechanics of Materials

- Bansal, R. K. – Strength of Materials Used for basic concepts of stress, strain, and Hooke's Law (σ = Eε).
- Hibbeler, R. C. – Mechanics of Materials Used for understanding material behavior, deformation, and elasticity.

Structural Analysis

C. S. Reddy – Structural Analysis Used for load distribution and behavior of structural members.

Structural Dynamics

• S. Rajasekaran – Structural Dynamics Used for natural frequency, vibration, and dynamic response analysis.

Structural Health Monitoring (SHM)

•C. R. Farrar & K. Worden – Structural Health Monitoring Used for sensor-based monitoring and bridge performance analysis.

• Various research papers on SHM Used for advanced concepts of damage detection and monitoring.

Indian Standard (IS) Codes

The following codes are published by the Bureau of Indian Standards (BIS), India and used for design and safety evaluation:

• IS 800:2007 – General Construction in Steel Used for steel design and allowable stress limits.

• IS 456:2000 – Plain and Reinforced Concrete Used for concrete design and structural behavior.

• IS 1893 (Part 1):2016 – Earthquake Resistant Design Used for dynamic analysis and vibration effects.

P. Cawley and R. D. Adams
(United Kingdom – Imperial College London), "The location of defects in structures from vibration measurements," Journal of Strain Analysis, 1979.

Rytter (Denmark – Aalborg University), Vibration Based Inspection of Civil Engineering Structures, PhD Thesis, 1993.

S. W. Doebling, C. R. Farrar, M. B. Prime, and D. W. Shevitz (USA – Los Alamos National Laboratory),
"Damage identification and health monitoring of structural systems," 1998.

H. Sohn (South Korea/USA – KAIST / Los Alamos National Laboratory) and **C. R. Farrar (USA – Los Alamos National Laboratory),** "Damage diagnosis using time series analysis," Journal of Sound and Vibration, 2001.

Y. Fujino (Japan – University of Tokyo), "Vibration, control and monitoring of bridges," Journal of Sound and Vibration, 2002.

J. M. Ko and Y. Q. Ni (Hong Kong – Hong Kong PolytechnicUniversity),
"Technology developments in structural health monitoring," Engineering Structures, 2005.

J. P. Lynch (USA – University of Michigan) and **K. J. Loh (USA – University of California, San Diego),** "Wireless sensor networks for structural health monitoring," Shock and Vibration Digest, 2006.

C. R. Farrar (USA – Los Alamos National Laboratory) and **K. Worden (United Kingdom – University of Sheffield),** "An introduction to structural health monitoring," Philosophical Transactions A, 2007.

K. Worden and G. Manson (United Kingdom – University of Sheffield), "Machine learning in structural health monitoring," Philosophical Transactions A, 2007.

V. Giurgiutiu studied the use of piezoelectric sensors for structural health monitoring. His research demonstrated that these smart sensors can actively detect and locate small cracks or damages in structures. The study emphasized the effectiveness of piezoelectric materials in real-time monitoring systems,2008.

A. Mita and T. Yokoi developed an accelerometer-based monitoring system for bridges. Their work focused on measuring vibration responses caused by moving loads. The results confirmed that accelerometers are reliable tools for analyzing dynamic behavior and identifying structural changes, 2010. 62

R. H. Scott et al. applied fiber optic strain sensors for monitoring prestressed concrete railway bridges. Their research involved measuring strain variations under loading conditions and identifying possible cracks. The study proved that fiber optic sensors are effective for long term monitoring, 2013.

P. Watters, S. Kim, and J. P. Lynch proposed a wireless sensor network system for bridge monitoring. Their system allowed real-time data transmission and reduced the need for complex wiring, making SHM systems more efficient and cost-effective, 2014.

S. Yoon, H. Sohn, and C. R. Farrar used distributed fiber optic sensors to measure strain in railway bridge girders. Their research demonstrated that continuous strain monitoring helps in early detection of structural damage and improves maintenance planning, 2016.

A. P. Adewuyi, Z. Wu, and M. Serker conducted real-time monitoring of bridges using accelerometers and strain gauges. Their study showed that combining both sensors provides more accurate and reliable results for structural health assessment,2017.

R. Van der Kooij, M. J. Whelan, and K. Worden investigated distributed fiber optic sensing systems for railway bridges. Their research highlighted the ability of these systems to monitor large areas of structures with high precision, 2018.

Y. Wang and J. Li studied strain monitoring for fatigue assessment in bridge structures. Their research showed that continuous monitoring helps in predicting the remaining life of bridge components,2019.

Z. Ye, X. Bao, and J. Chen focused on distributed fiber optic sensing for measuring strain and temperature variations. Their study improved the understanding of environmental effects on bridge performance,2020.

M. Kumar, R. Sharma, and P. Singh studied bridge monitoring using accelerometers and telemetry software. Their work demonstrated that data analysis tools can effectively interpret vibration data, 2021.

J. Lorenzen, M. Krüger, and P. Andersen developed a method for detecting train axles using accelerometer data. Their research showed that vibration signals can be used to track train movement,2022.