Advanced Sensor Dynamic Measurement and Heuristic Data Analysis Model for Bridge Health Monitoring System

G. R. Vijay Shankar, S. Deepa, M. Arun, G. Vignesh

Abstract: Presently the health and safety monitoring of a bridge is considered as a significant area of research where the attention has been paid by many researchers. In this article the bridge structural damages due to environmental fluctuations and other parameters has been analyzed using cutting-edge technologies. In this research the technology of advanced Intelligent Internet of Things (IoT) sensors with signal processing systems is designed and developed to monitor the health condition of the bridge using data analytic techniques. In the recent past these sensor systems has been used collect the vibration signal causes by the vehicles movement on the bridge. Further, these collected data sets are analyzed with the help data analytic approach using traditional independent analysis models which fails to produce optimum results in terms of reliability, efficiency, stability, corrosion and crack of the bridge. In this article to overcome this issue an improved heuristic nonlinear model has been developed to analyze the data sets using non-linear and linear separation analogy. This optimized data analytics technique with advanced sensing mechanisms is validated experimentally and the outcomes shows promising solutions to monitor bridge health in effective manner than traditional strategies.

Keywords: Intelligent Internet of Things Sensors, data analytic techniques, corrosion and crack, bridge health, non-linear and linear separation

1. INTRODUCTION

The bridge is normally used for to reduce the traffic, less time to travel, to control the air pollution, water pollution, noise pollution etc. This pollution is normally created by acid rain, corrosion of bridges, corrosion of steel and materials etc. Initially the bridge construction is started for lot of parameters are consider like, properties of material such as, strength, elasticity, plasticity, brittleness, malleability, reliability, stiffness, hardness, toughness, strain energy this property are considered. Young’s modulus, Poisson ratio, Modulus of rigidity, tensile tress, crushing stress, etc. Movable bridges are constructed by ship height has been consider. There is many equipment has used for construction including excavators, asphalt mixtures, frame work, fabrication. Bridges are constructed by steel material then few years are gone then wear resistance, corrosion, cracks, damages will occur that defects will be analyzed to sense the iiot sensor. This sensor is mainly used to sense the identify the damaging part and corrosion part. Intelligent Internet of Things (IoT) sensors with signal processing systems is designed and developed to monitor the health condition of the bridge using data analytic techniques. In the recent past these sensor systems has been used collect the vibration signal causes by the vehicles movement on the bridge. This sensor can be analyzed for cracks, corrosion of bridges, vibration, stiffness, strength, life time, vehicles movement are identified by thus sensors.

II. LITERATURE SURVEY

[1] In this research Melan equation is the proposed model for suspension bridges at linked cables are two, fully inextensible hangers. [2] Equations are nonlinear, nonlocal hyperbolic partial differential equations, deck of torsional rotation.

[3]Then we prove conducted on numerical experiments on isolated system, we propose a sensitivity analysis of bridge by mechanical parameters of torsional instability.[4] Result will display specific thresholds of torsional instability of longitudinal mode.[5] Theoretical predictions are increasing the particle volume fraction and the particle strength has effectively improve the toughness fracture of polymeric materials.[6] Polymers reinforced with micron sized particle; toughness fracture increased with particle size. The theoretical results are predicated by model agree well with the experimental data. [7] Results are dependence on toughness fracture of polymer particle composites on their microstructure, it is useful to design and optimization of composite material is advanced.[8] This paper used to novel composite concrete filled with rectangular chords and concrete slab with tubular truss bridge. [9] With joints reinforced with concrete and concrete slab plus truss system, profound leister rib, and double composite truss has been proved. [10] This research design method is based on probability theory is used for Chinese highway bridge design and codes which adopt by partial factors in the design equations. [11,12] The virtual bridge dataset (VBD) include the total number 8064 RC T-beam bridges designed based on probability theory design and codes are established. VBD design parameters are number of design lanes, reinforcement grade, concrete grade, girder spacing, span length is included and action on reliability of RC T – beam bridges are...
studies. In this study RC bridge of the corrosion of steel rebar affects by serviceability and increase by vulnerability in earthquakes. Numerical models are either solid elements with a damage model of corrosion, computational cost in practical application or fiber beam elements by an uncompleted corrosion damage model are calculated. Finally, this proposed a numerical tool, efficiency and accuracy are calculated. 

14 RC Piers bridge is considered for quasi static and earthquake load are considered by global buckling load of longitudinal bars. While the longitudinal bars are damage finally this damage are calculating by compression strain and material damage are analyzed. RSS bridge is tested by the bridges at push out test and finite element analysis under cyclic loading. RC beam bridge are measuring by digital image correlation, full field displacement, and shear strain on span of RC beams. Finally, we are calculated by angle of compressive stress, strain on compressive principle, and longitudinal strain are calculated. 

The main objective of this research is to
- Analysing the crack of the bridge.
- Analysing the load and corrosion in the bridge.
- Indicates when there are deformation and cracks, safety factor, bending moment in the bridge by using IIOT Sensor.
- To reduce the cost

### III. DESIGN PARAMETERS

Creo parametric makes the design very easier, faster and less time, Accuracy. Initially draw the diagram at column in bottom side then this column created by correct and proper dimensions. This bridge construction makes china Y Beam bridges model has been selected. We can sketch a frame, choose the section profile, and then quickly create multiple structural members. The are several types of bridges available such as, beam, arch, truss, suspension, etc. The beams are classified into cantilever, simply supported, overhanging beam, and continuous beam. The material has normally used for steel material and lot of factors has been consider such as factor of safety, Poisson ratio, tensile stress, compressive stress, young’s modulus, rigidity modulus, stress-strain analysis, elastic limit etc. The normal vehicles such as lorry, bus, cars, container, two-wheeler, loads initially the bridge structure to fail the few elements and major components. Analysis the components are using ANSYS software. Finally, to investigate conducted on bridges failures, bridges corrosion. Bridge design is monitoring by this IIOT sensor system, Analysis the crack, corrosion, safety factors, deformation, von-mises stress are done. Then implement of IR sensor, Load sensor, Flex sensor, vibrator sensor, IIOT sensor are this parameter can be the sense. The vehicle that has been enters bridge and keeps the number of vehicles on the bridges. Flex sensor is used due to detect the crack and load sensor used to detect the load, IIOT sensor is used to detect the corrosion etc.

Young’s modulus of steel is mainly considered steel room temperature is typically between 190GPa and 215Gpa. Young's modulus of carbon steel are mild, medium, high, alloys steel stainless steel and tool steels are considered and modulus of elasticity is taken. Material obeys hooks law stress is directly proportional to strain.

\[ \text{Young's modulus} (Y) = \text{stress} / \text{strain} \]

IIOT Sensor are normally used for to the corrosion, cracks, vibration, safety factor, are detected and also synchronizing motor can used for IIOT sensor shown in fig 2. The columns are generally subdivided into short column, long columns, intermediate column, the short column is mainly failed by crushing loaded is eccentrically a column has been lateral deflection, deformation by using ANSYS software. Long column fails by buckling a load is increased by critical value, intermediate column fails to crushing and buckling load has been added. Longs column analyzed by Euler formula are,

\[ N = \frac{r\pi^2YO}{L^2} \]

When the bridge damage calculation is calculated by analyzing software and
theoretical formula are using Eq (3). Damage index is derived by this equation. The X is the damage index, \( T_m \) -secant stiffness of the bridge N/mm, \( T_0 \) - Initial stiffness prior to loading of bridge N/mm, \( T_f \) - pre establishment secant of bridge N/mm, \( \epsilon_s \) - Crushing stress N/mm\(^2\), \( L_{em} \) - ultimate strength, \( T_m \) - Total number of column stiffness

\[
X = T_m - T_0/T_f - T_2 \tag{3}
\]

\[
\epsilon_s = \frac{1-\frac{T_f - T_0}{T_2}}{1+\frac{T_f - T_0}{T_2}} \tag{4}
\]

The plastic curvature has been calculated bridge construction, Normally the bridge analysis can be measured due to cracks holes, corrosion of steel material, life time, stress strain analysis etc. can be considered, and also theoretical calculation has been derived Eq (5). \( \Psi \) - Curvature of plastic, \( \beta \) - Effective depth of pillars in mm, \( U \) - Overall column radius in mm, \( f_{cr} \) - Number of cycles to the first fatigue crack in steel.

\[
2\Psi U = \frac{0.112}{1+\frac{T_f}{T_0}} f_{cr}^{0.1} \tag{5}
\]

Crushing stress is calculated by using Eq (4) than to analysis the damage factor for bridges, now consider for crack holes depth, corrosion materials, plastic strain, elastic strain, this stress and stress are analysis by ANSYS software and also calculated by theoretical formula method.

IV. ANALYSIS OF BRIDGES

Bridge is designed by Creo software then analysis the bridge is using ANSYS 15.0. Analysis the reference temperature is environment temperature is considered; steel material can choose. Length of the X axis is 3900 mm, length of Y axis is 927.72mm, and length of Z axis is 560.00mm. Let’s properties are considering as volume, mass, are 2.3422e+008 mm\(^3\), 2.2611e+009 kg respectively. Moment of inertia Ip1, Ip2, Ip3 are 7.1343e+007 kg-mm\(^2\),2.269e+009 kg-mm\(^2\),2.2611e+009 kg-mm\(^2\) respectively.

Second step give load density is 7.85e-006 kg mm\(^{-3}\), compressive yield strength is 250Mpa, tensile yield strength is 250Mpa, Tensile ultimate strength is 460Mpa, temperature is 22. This parameter is after analysis the bridge this value is getting and also same parameters are calculated by theoretical formula. They are considered for soderbeg equation, good man equation, Gerber equation are Eq 6, 7, 8 respectively.

\[
\frac{M_x}{M_y} \leq 1 \tag{6}
\]

\[
M_x = M_y \left[ 1 - \frac{M_{yy}}{M_{xx}} \right] \tag{7}
\]

\[
\left( \frac{M_{mm}}{M_{xx}} \right)^2 + \left( \frac{M_{mm}}{M_{yy}} \right)^2 = 1 \tag{8}
\]

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections A-D below for more information on proofreading, spelling and grammar.
Maximum shear stress \( \sigma_{\text{max}} = \frac{M_y - M_z}{2} \) \( \text{(12)} \). After the deformation bridge the angle crack and angle of deformation are calculated by Eq \( 13 \):

\[
2 \delta_y = \tan^{-1} \left( \frac{2 \sigma_{xy}}{M_x - M_y} \right)
\]

Eq \( 14 \):

\[
2 \delta_x = \tan^{-1} \left( \frac{M_x - M_y}{2 \sigma_{xy}} \right)
\]

Average stress (shear stress is maximum):

\[
M_{\text{avg}} = \frac{M_x + M_y}{2}
\]

According to shear stress energy theory or haunchy- von mises theory, equivalent stress, equivalent von misses stress is minimum zero and maximum stress is 0.39538 Mpa as show in figure.

\[
M_p = \sqrt{M_x^2 + M_y^2 - M_xM_y + 3 \sigma_{xy}^2}
\]

\( \text{Fig 6 Analysis of safety factor and life} \)

Strength of co efficient is 920Mpa, strength of exponent is -0.106, Ductility co efficient is 0.213, show in figure 7. Normally the stress can calculate by using Mohr’s circle method. This method is used for theories of failure of bridge has been calculated. \( M_1 \) - Maximum principle stress, \( M_2 \) - Minimum principle stress, \( M_x \) - stress acting on x axis, \( M_y \) - stress acting on Y axis, \( \sigma_{xy} \) - shear stress on xy direction. Equation 11, 12 is only used for shear stress is less.

\[
M_x, M_y = \frac{M_x + M_y}{2} \pm \sqrt{\left( \frac{M_x - M_y}{2} \right)^2 + \sigma_{xy}^2}
\]

\( \text{Fig 7 Analysis of damage factor} \)

Maximum strain theory (or) saint venant theory equivalent stress is

\[
M_p = \frac{1}{2} [1 - \varepsilon] (M_x + M_y) + [1 + \varepsilon] \left( M_x - M_y \right)^2 + 4 \sigma_{xy}^2
\]

\( \text{Table 1} \)

<table>
<thead>
<tr>
<th>Alternating Stress Mpa</th>
<th>Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>3999</td>
<td>10</td>
</tr>
<tr>
<td>2827</td>
<td>20</td>
</tr>
<tr>
<td>1896</td>
<td>50</td>
</tr>
<tr>
<td>1413</td>
<td>100</td>
</tr>
<tr>
<td>1069</td>
<td>200</td>
</tr>
<tr>
<td>441</td>
<td>2000</td>
</tr>
<tr>
<td>262</td>
<td>10000</td>
</tr>
<tr>
<td>214</td>
<td>20000</td>
</tr>
<tr>
<td>138</td>
<td>1.00E+05</td>
</tr>
<tr>
<td>114</td>
<td>2.00E+05</td>
</tr>
<tr>
<td>86.2</td>
<td>1.00E+06</td>
</tr>
</tbody>
</table>
Fig 9 Analysis of deformation
Graph indicates X axis alternating stress in Mpa and Y axis is cycles and also same values are calculated by using Eq16 and Eq17.

V. RESULT AND DISCUSSION
FIG 10 is X axis sample reading for bridge and Y axis deformation in mm black color indicates the RC-T beam analysis the deformation is very high, red color indicates the RSS Bridge also deformation is high, blue color indicates the pilot bridge, pink color indicates the RC Piers bridge, deformation is high compare to Y Beam bridge. Finally, Y Beam bridge design indicates the green color and less deformation y beam bridge is best.

Fig 10. Sample Reading and Deformation
Fig 11 is X axis sample reading and Y axis von mises stress in Mpa, black color indicates the RC-T Beam bridge, here less stress acting on the bridge RC T Beam bridge strength is week, then red color indicates the RSS Bridge, here the stress is low compare to Y Beam bridge method so blue color is high stress acting bridge strength is high y beam bridge is best.

Fig 11 sample reading and von misses stress

Fig 12 sample reading and Efficiency
LPR -Data packet loss rate, T -Average time, \( P_i \) -Server received the \( P_i \)th packet, \( T_i \) - Server time received 1st packet, \( N \) - Number of packets by using IIOT

\[
LPR = \frac{P - P_i}{P_i} \times 100
\]

\[
T = \frac{T_1 - T}{P - 1}
\]

VI. CONCLUSION
Finally compare this result to previous RC-T Beam bridge and RSS bridge. So, Y Beam type bridge and IIOT sensor is best, because the crack, corrosion, load analysis is very accuracy, error is no error, efficiency is high, so this Y Beam bridge and this IIOT sensor is best.

ACKNOWLEDGMENT
The Authors would like to thank Karpagam Academy of Higher Education Coimbatore for their valuable support.
REFERENCES


18. 3186–3199 .


AUTHORS PROFILE

Dr. VIJAY SHANKAR G R received his Diploma in Civil Engineering from N.L. Polytechnic, Coimbatore on 2001, BE degree in Civil Engineering from G.C.T, Coimbatore on 2007; ME degree in Structural Engineering from G.C.T, Coimbatore, on 2009. PhD is completed in karpagam university on 2017.He is currently working as Associate Professor, Department of Civil Engineering, Karpagam Academy of Higher Education, Coimbatore, India. His current research interests include Analysis and design of RCC & Steel Building structure.

Dr.D.S. DEEPA received his BE degree in Electronics and Communication Engineering from Maharaja Prithivi Engineering College, Coimbatore; ME degree in Wireless Communication from Karpagam University, Coimbatore, PhD is completed in karpagam university. She is currently working as Associate Professor, Department of Electronics and Communication Engineering, Karpagam college of Engineering, Coimbatore, India. His current research interests Wireless Networks.

ARUN M received his Diploma in Mechanical Engineering from Muthammal polytechnic Institution Raspuram on 2013, BE degree in Mechanical Engineering from Government college of technology, Coimbatore on 2016, ME degree in Engineering Design from Anna University, Coimbatore on 2018. He is currently working in Junior Research Fellow, Karpagam Academy of Higher Education, Coimbatore, India. His current research interests include CFD, Nano fluid, solar water heater.

G Vignesh received his BE degree in Mechanical Engineering from Loyola Institute of Technology, Chennai on 2012; M.E degree in Engineering Design from Anna University, Coimbatore on 2015. He is currently working as Assistant Professor in the Department of Mechanical Engineering, Karpagam Academy of Higher Education, Coimbatore, India. His current research interests include manufacturing engineering, tribology, surface morphology and tolerance stack-up analysis.