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 (IIoT) 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 sets caused 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*

I. 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 (IIoT) 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 sets caused 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.

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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 studied.[13] in this study RC bridge of the corrosion of steel rebar affects by serviceability and increase by vulnerability in earthquakes.[14] 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. [15] Finally, this proposed a numerical tool, efficiency and accuracy are calculated.[16] RC Piers bridge is considered for quasi static and earthquake load are considered by global buckling load of longitudinal bars. [17] While the longitudinal bars are damage finally this damage are calculating by compression strain and material damage are analyzed. [18,19] RSS bridge is tested by the bridges at push out test and finite element analysis under cyclic loading.[20] RC beam bridge are measuring by digital image correlation, full field displacement, and shear strain on span of RC beams.[21] 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.

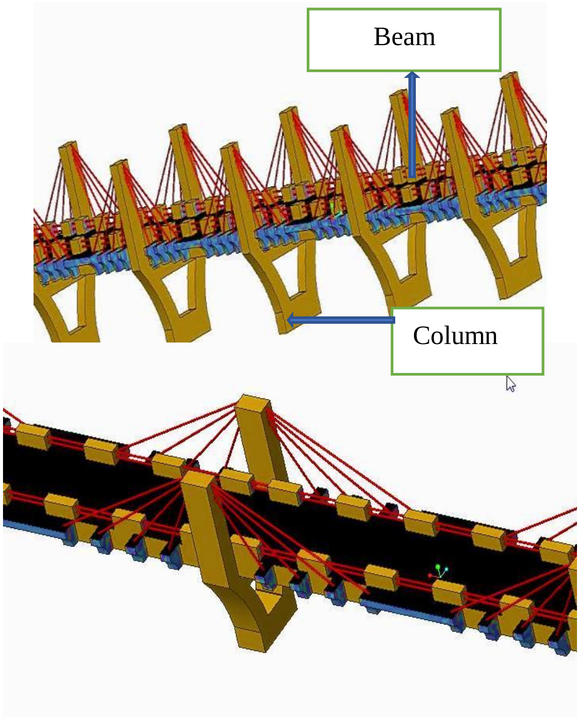

Fig.1 Construction of Y Beam bridge

Young's modulus of steel is mainly considered steel room temperature is typically between 190GPa and 215Gpa.youngs 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.

$$Young's\ modulus(Y) = stress/strain \qquad (1)$$

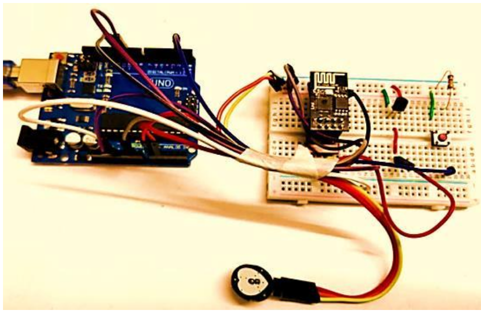

Fig 2 IIOT Sensor

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-allowable load in (N), r- Factor accounting for end conditions, Y- Young's modulus in N/mm^2, O- Moment of inertia in mm^4, L- Length of the column in mm.

$$N = r\pi^2 YO/L^2 \tag{2}$$

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 Nmm, T_o- Initial stiffness prior to loading of bridge Nmm, T_f - pre establishment secant of bridge Nmm. $€_c$ – Crushing stress N/mm^2, L_{cm} – ultimate strength, T_n- Total number of column stiffness

$$X = T_m - T_o/T_f - T_o \tag{3}$$

$$€_c = \frac{T_n-(F_n)^2}{1+(T-2)F_n} L_{cm} \tag{4}$$

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). ¥- Curvature of plastic, d_{ep}– Effective depth of pillars in mm, U- Overall column radius in mm, F_n- Number of cycles to the first fatigue crack in steel.

$$2¥U = \frac{0.113}{1-\frac{d_{ep}}{U}} F_n^{-0.5} \tag{5}$$

Crushing stress is calculated by using Eq (4) than to analysis the damage factor for brides, 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 ANSY 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+008mm^3, 1838.6kg respectively. Moment of inertia Ip1, Ip2, Ip3 are 7.1343e+007 kg·mm²,2.269e+009 kg·mm²,2.2611e+009 kg·mm² 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.

$$\frac{M_a}{M_e} + \frac{M_m}{M_y} = 1 \tag{6}$$

$$M_a = M_e[1 - \frac{M_m}{M_u}] \tag{7}$$

$$(\frac{M_m}{M_u})^2 + \left(\frac{M_v}{M_c}\right) = 1 \tag{8}$$

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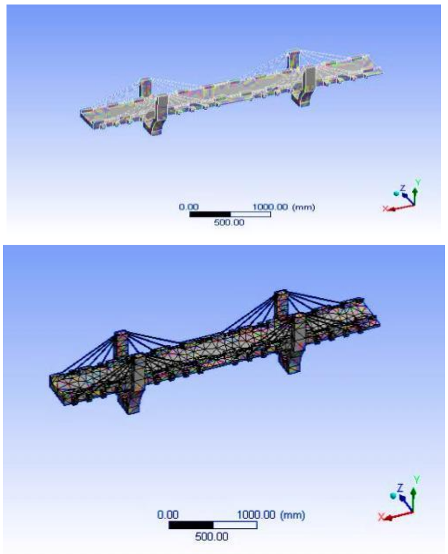

Fig.3 Design and meshing of bridge by using ANSYS

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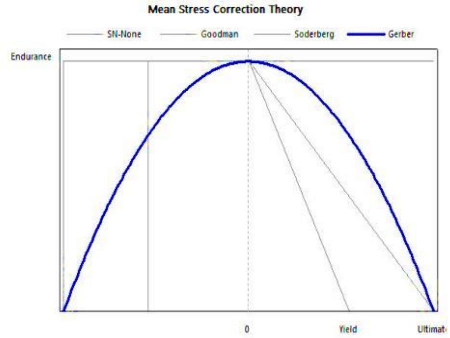

Fig 4 Amplitude of Y Beam Bridge

M_a- Amplitude of normal shear stress Mpa or alternating stress, M_e - Endurance limit at constant strength Mpa, M_y-Yield tensile strength in Mpa, M_m- mean cycle stress, M_u- Ultimate tensile stress in Mpa, three equation are used for to measure the safety factor. Total deformation is defined as the ration between the changes in dimension to its original dimension is known as called strain there is no unit. Minimum deformation is zero and maximum deformation is 6.2703e-2.as show in fig 5.

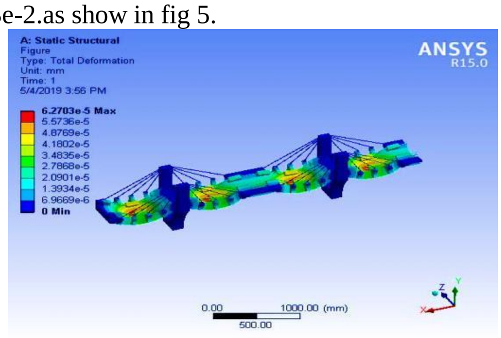

Fig 5 Analysis of total deformation

The factor of safety is defined as the ration between ultimate stresses to its working stress. this safety factor is to analysis the failure of the material. Safety factor min is zero and maximum is 15. Damage factor (A_C) i_c^{in}-inelastic strain, i_c^{pl}-plastic strain, M_t- tensile stress in N/mm^2, O_i- moment of inertia mm^4, C_L- Length of column mm, $W^{pl}=\frac{5.14F_g}{M_t}$, F_g-crack energy

$$A_c = \frac{1-\epsilon}{i_c^{in} i_c^{pl}\left(\frac{1}{d_{ep}}-1\right)+\epsilon} \quad (9)$$

$$d_{ep} = \frac{1-M_t\, O_i}{YW^{pl}\left(\frac{1}{a_{rea}}-1\right)+M_t\, C_L} \quad (10)$$

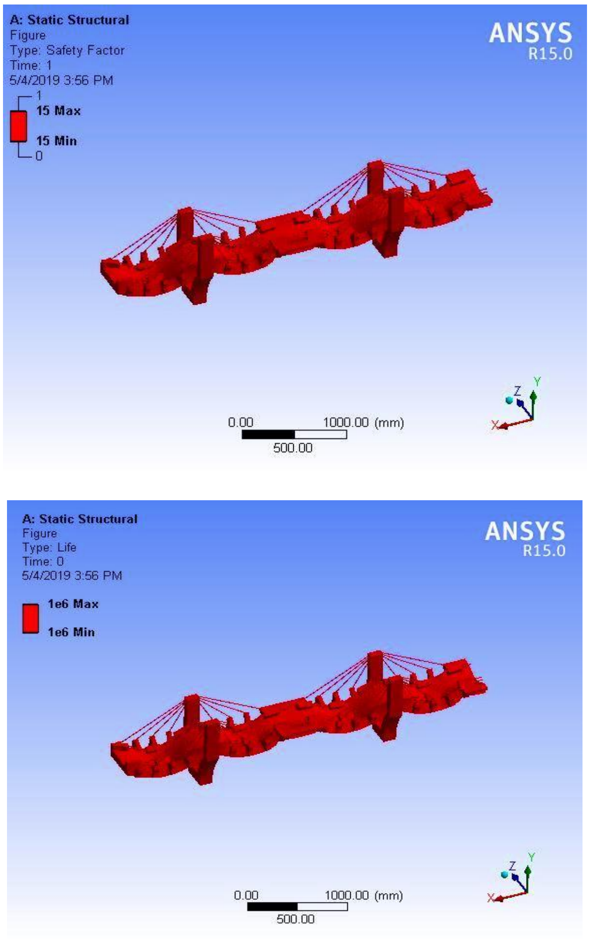

Fig 6 Analysis of safety factor and life

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, α_{xy}- shear stress on xy direction. Equation 11, 12 is only used for shear stress is less.

$$M_1, M_2 = \frac{M_x+M_y}{2} \pm \left\{\sqrt{\left(\frac{M_x-M_y}{2}\right)^2 + (\alpha_{xy})^2}\right\} \quad (11)$$

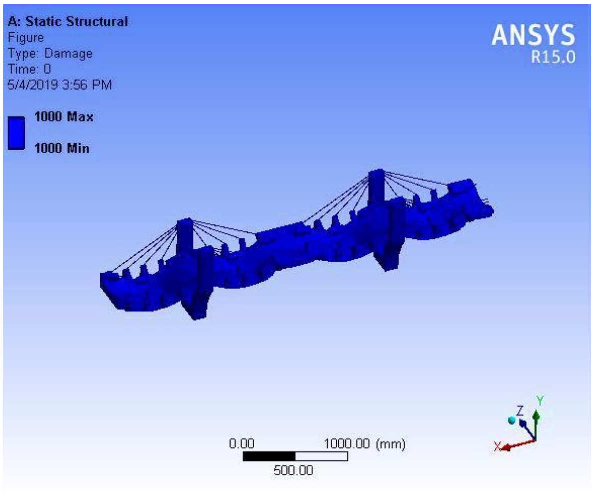

Fig 7 Analysis of damage factor

Maximum shear stress $\alpha_{max} = \frac{M_1 - M_2}{2}$ (12)

After the deformation bridge the angle crack and angle of deformation are calculated by Eq 13

$$2\theta_v = \tan^{-1}\frac{2\alpha_{xy}}{M_x - M_y} \quad (13)$$

Plane of maximum shear stress Eq 14

$$2\theta_s = \tan^{-1}\left(-\frac{M_x - M_y}{2\alpha_{xy}}\right) \quad (14)$$

Average stress (shear stress is maximum)

$$M_{avg} = \frac{M_x + M_y}{2} \quad (15)$$

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

$$M_e = \sqrt{M_x{}^2 + M_y{}^2 - M_x M_y + 3\,\alpha_{xy}^2} \quad (16)$$

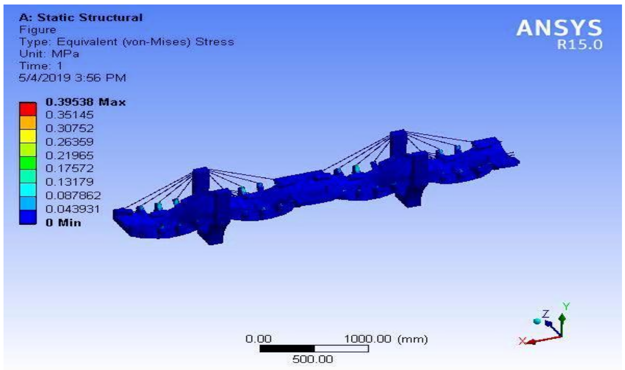

Fig 8 Analysis of von mises stress

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

$$M_e = \frac{1}{2}[1-\ni](M_x + M_y) + (1+\ni)\sqrt{(M_x - M_y)^2 + 4\,\alpha_{xy}^2} \quad (17)$$

Alternating mean stress value for steel is tabulated by table 1 and also graph drawn by same values fig 9.

Table 1

Alternating Stress Mpa	Cycles
3999	10

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2827	20
1896	50
1413	100
1069	200
441	2000
262	10000
214	20000
138	1.00E+05
114	2.00E+05
86.2	1.00E+06

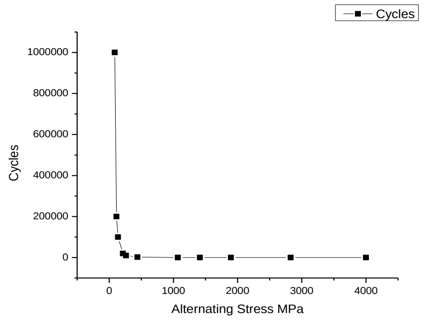

Fig 9 Analysis of deformation

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.

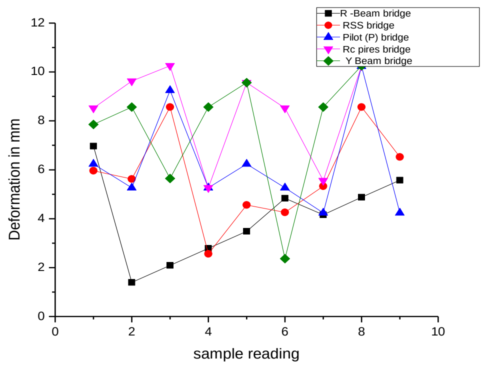

Fig 10. Sample Reading and Deformation

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.

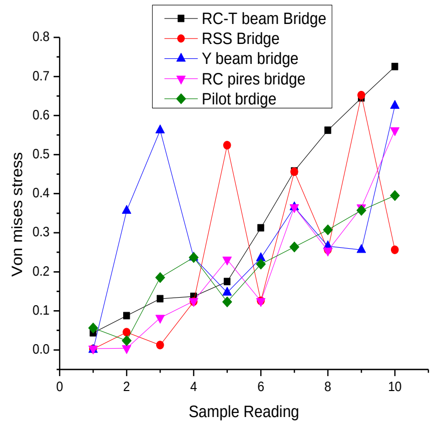

Fig 11 sample reading and von misses stress

Fig 12 X axis sample reading, Y axis Efficiency hence black color indicates the Y beam bridge here efficiency is high, red color indicates the RCC T-Beam bridge here efficiency is low compare to Y beam bridge, blue color indicates the pires bridge this type of bridge efficiency is low, Y beam bridge design is high efficiency. Finally, to sense the sensor by using IIOT senor this sensor is used for to measure the crack, corrosion, load, strength, take the value and plot the graph, as show in Fig 13.

$$LPR = \frac{P_N - P_r}{P_r} X\ 100 \quad (19)$$

$$T = \frac{T_P - T_1}{P - 1} \quad (20)$$

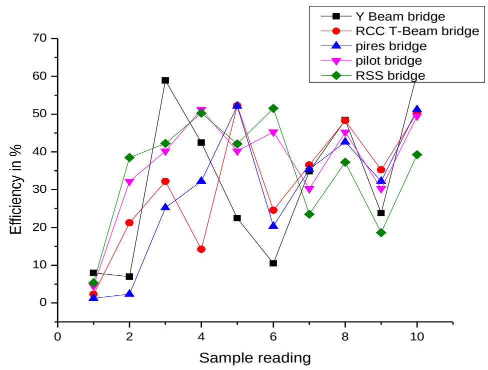

Fig 12sample reading and Efficiency

LPR -Data packet loss rate, T -Average time, P_N -Server received the P[th] packet, T_1 - Server time received 1[st] packet, N- Number of packets by using IIOT

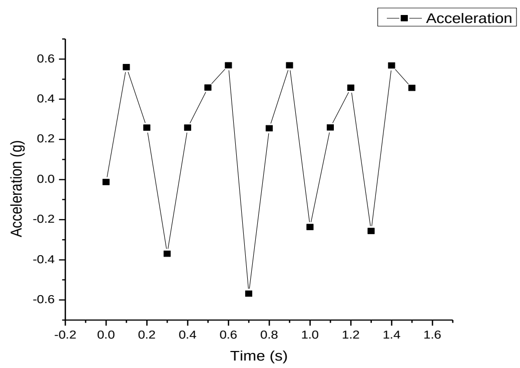

Fig 13 Times and Acceleration

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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.

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REFERENCES

1. Shakeel, P. M., Baskar, S., Sampath, R., & Jaber, M. M. (2019). Echocardiography image segmentation using feed forward artificial neural network (FFANN) with fuzzy multi-scale edge detection (FMED). *International Journal of Signal and Imaging Systems Engineering*, *11*(5), 270-278.
2. R. Liu, Y. Liu, Analysis of auxiliary ribs in steel–concrete joint of hybrid girder, J. Constr. Steel Res. 112 (2015) 363–372.
3. J. He, Y. Liu, B. Pei, Experimental study of the steel-concrete connection in hybrid cable-stayed bridges, J. Perform. Constr. Facile 28 (2014) 559–570.
4. Sundarasekar, R., Shakee, P. M., Baskar, S., Kadry, S., Mastorakis, G., Mavromoustakis, C. X., & Vivekananda, G. N. (2019). Adaptive Energy Aware Quality of Service for Reliable Data Transfer in Under Water Acoustic Sensor Networks. *IEEE Access*.
5. H. Hiragi, S. Matsui, K. Muto, Development of favorable stud shear connectors to flexible composite actions, J. Struct. Eng. JSCE 44A (1998) 1485–1496 (in Japanese).
6. [6] Manogaran, G., Shakeel, P. M., Fouad, H., Nam, Y., Baskar, S., Chilamkurti, N., & Sundarasekar, R. (2019). Wearable IoT Smart-Log Patch: An Edge Computing-Based Bayesian Deep Learning Network System for Multi Access Physical Monitoring System. *Sensors*, *19*(13), 3030.
7. R. Shimizu, T. Yoshihiro, Kitagawa Kouji, et al., Shear and pull out characteristics of synthetic delay stud, Proc. Procee. Jpn. Concrete Institute 25 (2003) 1609–1614 (in Japanese).
8. Highway Planning and Design Institute of the Ministry of Transport. GB/T 50283—1999 unified standard for the reliability design of highway engineering structures. Beijing: China Plan Press; 1999 [in Chinese].
9. Ministry of Communications of PRC. JTG D60-2004, general code for design of highway bridges and culverts. Beijing: China Communications Press; 2004 [in Chinese].
10. Ministry of Communications of PRC. JTG D62-2004, code for design of highway reinforced concrete and prestressed concrete bridges and culverts. Beijing: China Communications Press; 2004 [in Chinese].
11. Ragupathi, P., Sivaram, N. M., Vignesh, G., & Selvam, M. D. (2018). Enhancement of Impact Strength of a Car Bumper Using Natural Fiber Composite Made of Jute. *i-Manager's Journal on Mechanical Engineering*, *8*(3), 39.
12. Feng Xiangbo, Tsimplis MN, Quartly GD, Yelland MJ. Wave height analysis from 10 years of observations in the Norwegian Sea. Cont Shelf Res 2014;72:47–56.
13. Forristall George Z. On the statistical distribution of wave heights in a storm. J Geophys Res: Oceans 1978;83(C5):2353–8.
14. LonguetHiggins Michael S. On the distribution of the heights of seawaves: some effects of nonlinearity and finite band width. J Geophys Res: Oceans 1980; 85(C3):1519–23.
15. [14] CasasPrat Merc, Holthuijsen Leo H. Shortterm statistics of waves observed in deep water. J Geophys Res: Oceans 2010; 115(C9)..
16. Ponnusamy, R., Dennison, M. S., & Ganesan, V. (2018). EFFECT OF MINERAL BASED CUTTING FLUID ON SURFACE ROUGHNESS OF EN24 STEEL DURING TURNING OPERATION. *International Research Journal of Engineering and Technology (IRJET)*, *5*(2), 1008-1011.
17. X. Zhang , Q. Xu , Design of a new flexure-based XYZ parallel nanopositioning stage, in: Proceedings of the 2015 IEEE Conference on Robotics and Biomimetics, 2015, pp. 1962–1966 . [17] K.-B. Choi , H.J. Lim , G.H. Kim , J.J. Lee , A flexure-based scanner for a fully bidirectional operation driven by a differential piezo force, in: Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 228, 2014, pp.
18. 3186–3199 .
19. Vignesh, G., Prakash, M., Selvam, M. D., & Ragupathi, P. (2018). Frictional Performance of Dimpled Textured Surfaces on a Frictional Pair: An Experimental Study. *i-Manager's Journal on Mechanical Engineering*, *8*(4), 18.
20. W. Chen , X. Zhang , H. Li , J. Wei , S. Fatikow , Nonlinear analysis and optimal design of a novel piezoelectric-driven compliant microgripper, Mech. Mach. Theory 118 (2017) 32–52 . [20] S. Chakraborty , R. Chowdhury , A hybrid approach for global sensitivity analysis, Reliab.Eng.Syst.Safe.158(2017)50–57
21. Vecchio FJ, Collins MP. The modified compression-field theory for reinforced concrete elements subjected to shear. ACI J 1986; 83:219–31.

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