Damage Identification of Bridge Model by using Natural Frequency

P.C. Hawale[a] and Y. R. Suryawanshi[b]

[a]PG Student, Dept of Civil Engineering, JSPM's Imperial College of Engineering and Research Wagholi, Pune-412207

[b]Assistant Professor, JSPM's Imperial College of Engineering and Research Wagholi, Pune-412207

---***---

Abstract : *This work presents a method for the calculating the damages occurs in warren truss bridge using frequency change correlation which based on analytical result of modal analysis. We used the SAP 2000 programme to evaluate natural frequencies for up to six mode shapes for both undamaged and damaged cases of bridge. After analysis, it is discovered that the measured obtaining value of frequencies are decreases as the diameter section decreases and increases as diameter of the section increases. The goal of this work is to find simple as well as effective method for identify structural degeneration. Following research, it was determined that the value of frequencies are changes as a result due to occurrence of damage in the Warren truss bridge in structure.*

Keywords: ***Natural Frequencies, Damage Detection, Modal Participation Factors, Health Monitoring.***

1. Introduction and literature review

The recognition of damages occurring in structures such as buldings, bridges, dam, and tunnel is a topic for researchers that has gotten a huge amount of attention in the year and, so there's a lot of work to be done in this area which use different type of new methods and technology used for detect occurring damages in structures they perform poorly and cause potential danger losses in human life. The goal of this study was to utilise an analytic approach with SAP2000 data to detect damages in a bridge model. Adams and Crwly work on identification of structural damages in the year 1970s by using frequency in a different state. A new method of frequency damage identification method has been invented by Oyadiiji and Zong [21].

Vimal Mohan et al. For the first four modeshapes, a analytical model of a cantilever beam was created using finite element method for three distinct damage positions, and the values of natural frequencies for both undamaged and damaged structural states were determined. They came to the conclusion that the value of frequencies varies when damage occurs, and that this value of frequencies is utilised to show a correlation between damages and frequency value [1]. Kute and colleagues A method for detecting cracks in cantilever beams based on frequency monitoring has been proposed in this study. Using FEA software, they did modal analysis to measure the vibration characteristics of a cantilever beam. They came to the conclusion that crack depth in a cantilever beam can be calculated using frequency changes [2]. Widjajakusuma and Wijaya are conduct study on value of frequencies and forms of modes of pratt truss bridges are identified in this work. After doing research, they discovered that the value of natural frequency drops as the number of spans in a bridge rises, and that the value of natural frequencies increases when damage to the bearing pads of a bridge occurs. [3]. Yoshioka et al. In this study, vibration characteristics of diagonal member were analysed by using FEM eigen value analysis. As a result, they conclude that reductions in natural frequencies of higher modes are significant enough to assess corrosion in truss bridge [4] .Wang and Zhichun For this purpose, numerical and experimental damage detection were performed in this study, and they used a new damage detection method based on natural frequency vectors (NFV). As a result, they concluded that natural frequencies accurately measure structural damage when compared to other modal parameters. [5]. Mehrjoo and Khaji et al. In this study, numerical analysis of two truss bridges is carried out by using artificial neural networks. As result they conclude that the damage location in the bridge joints can be determined with high precision using the proposed method [6]. Abdellah, In this study, the author designed a Warren Truss bridge model by using SAP 2000 under 7 load cases. As result he show When the design is complete, the selected sizes and stress ratios are displayed on the model.[7].Kumar and Koushik In this study, describes RSM-based damage detection technique. In which a six-story building model was used for the simulation study. They conclude that in a simulation analysis with noise, the results were found to be satisfactory. The RS model is capable of both localising and measuring damage with reasonable accuracy, according to the findings of the experiments[8]Patel and Dewangan In this study, presents a review of various damage detection approaches for determining the unknown damage parameter in a beam. They conclude that after detail study of review local-based damage detection method is very useful for the beam. Also, this method involves the contact-based technique, in which the damage detection parameters can be identified but not located[9].

Muhammad et al. In this study, experimental and numerical studies were carried out on steel column members in a structure by using vibration-based analysis. Multiple cracks are simulated by using numerical analysis. After analysis, they concluded that observed value of frequencies decreased due to cracks developing in the column.

[10]. Diaferio et al. In this study, discuss methods for damage identification in complex structures by using measured vibration parameters for undamaged and damaged cases of that structures. As result they were concluded that it's observed that in various discussed methods value of frequencies are decreases after occurrence of damages in structure [11]. Mekjic,In this study, the damage is determined by using the measured value of frequencies after experimental work. He concludes that, the research results show that structures such as bridges can use high-frequency vibrational responses for structural damage assessments[12].Jiaquan et al. n this study, proposed method is Frequency domain decomposition which used to identify damages which occurring in beam under different weather conditions. They were concluded that structural failure can be easily determine by using rapid changes in strain mode shape. [13]. Dubey and Denis In this paper, we used a strategy for developing physical damage properties based on bending stiffness reduction. This used strategy has been given successful results when tested on an experimental cantilever beam with occurring cut damage. After the study, researchers concluded that using frequency parameter damage identification is done in this work. [14]

After studying various research related to damage detection of the bridge using various methods and techniques, we observe that the above study only focuses on natural frequency parameters for detecting the damages in steel bridges. Until there is a lack of conduct study of other vibration characteristics behavior due to occurrence of damages in structures, we decided in present work we conduct a study on natural frequency and modal participation factors behavior under the occurrence of damage. In the present work, we discussed the behavior of both modal participation factors and obtained the value of frequencies for six mode shapes under three different damage cases in detail.

2. Analytical investigation

The analytical investigation is conducted on a bridge model which was designed by using mild steel pipe having a Poisson's ratio is 0.3 and modulus of elasticity is 2.1×105 kN/m2 and Warren truss bridge having a 1200 mm span with 150mm width , 260 mm height and having four bases of 200 m. This bridge was also designed to accommodate the six different steel sections used in the current project. This work made use of mild steel pipe with diameters (D) of 10 mm to 20 mm and wall thicknesses of 0.2 mm there is six sections are designed for this work . We performed a modal analysis to determine the behaviour of vibration characteristics after damages occurred. The following Fig.1 and Table.1 show the details of these structures.

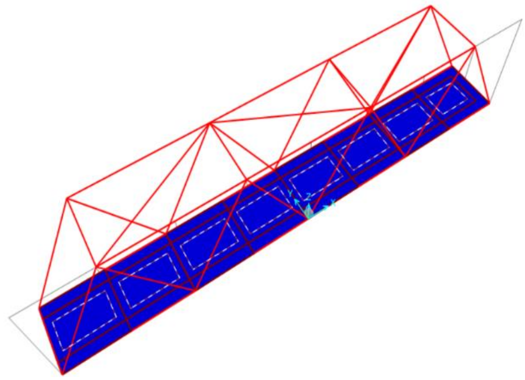

Fig. 1 3D view of bridge model

Table 1: Structural details of bridge

Specification	**Details of bridge**
Total Span of bridge model	1200mm
Width of bridge model	200mm
Height of bridge model	260 mm
No of bases	4
Load combination	DL + LL
Poisson's ratio	0.3
Material	Mild steel

3. Methodology

3.1 Design of Bridge Model

First, we design a warren truss bridge in SAP 2000 software by using Indian standards and norms. Design mild steel bridge of 1200mm long. After modelling the warren truss,we performed a modal analysis in which we consider six mode shapes and three type of damages. .Fig.2 show warren truss bridge model which designed for this study by using SAP2000 software.

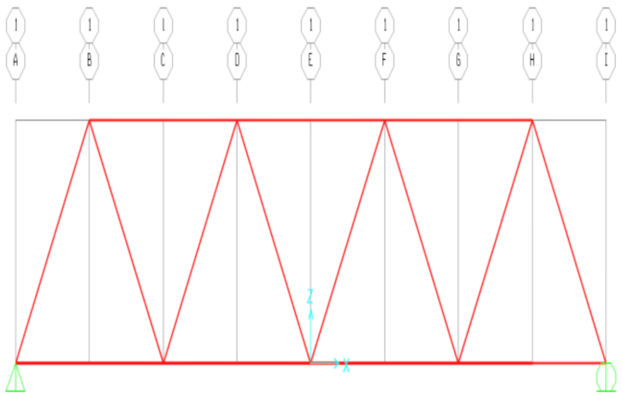

Fig. 2 2DPlan of bridge model

3.2 Load Cases

Consider a small vehicle passing over the bridge in this study to apply loading on the bridge. Because that vehicle has whhels weighing two-two kg, we consider six different load cases on bridge. These wheel loads act on the bridge's joints. The load cases used in the bridge model's work are based on the research of Ait [10].

3.3 Consideration of Damage Cases

In this study we consider damage D1 is considered at the elimination of element number 15, damage D2 is considered at the elimination of element number 20, damage D3 is considered at the elimination of element number 21 of warren truss bridge then carried out a study of six mode shapes for damage cases for six different steel frame section then it observes their changes in natural frequencies due to occurrence of damage. These damages are shown in Fig.3.We consider damage cases by removing that member this method we used from the reference of Zishan Yang [5].

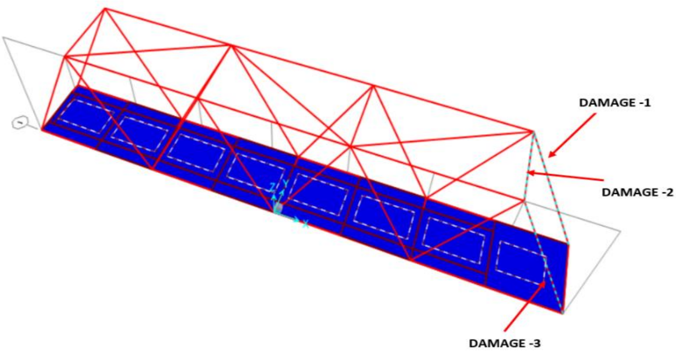

Fig. 4 Damage cases in a bridge model

3.4 Static analysis

The Bridge model is analyzed in sap2000 by using non-linear analysis after analysis bridge model satisfies all checks of steel design which results in the bridge model are safe and all frames pass stress capacity check. That state of the bridge is an undamaged case of the bridge which show in following Fig.4

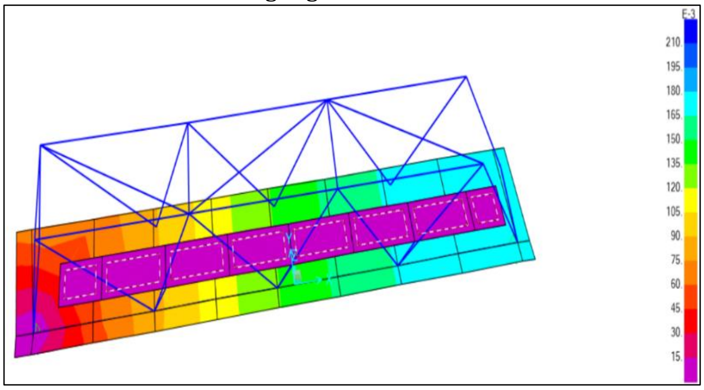

Fig. 5 Stress/capacity check for bridge model

4. Validation of work

We also conduct a study for checking the accuracy of this method for detecting damage. For this purpose, we analyze the model done by author M. Mehrjo et.al [6]. To check the validation of software Louisville bridge is modeled and analyzed in the SAP2000, then conduct Modal analysis and then response was checked in terms of frequency. After analysis results are compared with The Louisville bridge having a length of horizontal member is 12m and inclined length is 8.5m and mass density is 8000kg/m3

4.1 Result of validation work

Following Table. 2 shows that result obtained from the analytical calculation, M.Mehrjo [6].

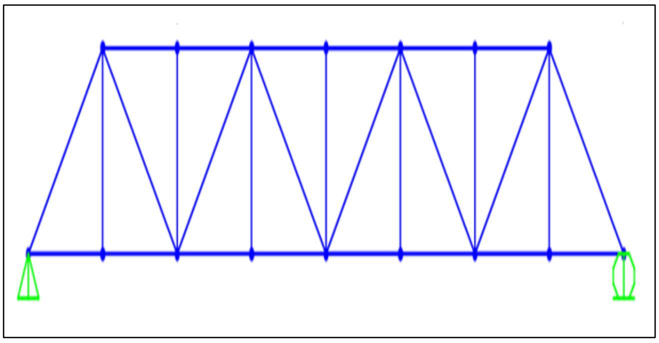

Fig. 6 Louisville bridge model

Following Table 2. shows that results obtained from analytical calculation after using SAP 2000 software are compared with reference paper results then observed they are nearby same thus the validation of software is done from the above result

Table 2 Analysis result

Response	Reference Paper Frequency (Hz)	Software Results Frequency (Hz)
Mode Shape -1	5.512	5.551
Mode shape -2	8.431	8.379
Mode Shape- 3	12.533	12.545
Mode Shape- 4	10.450	10.412
Mode Shape -5	27.580	27.502

5. Expected Outcome

• Evaluate the global structural condition by using vibrational measurement method. Des
• Carry a comparative study of value of modal parameters at both undamaged and damaged state of the
structure.
• Develop an effective and economical methods for detection of damages occurs in structure by using
less cost.
• For this study, value of natural frequency is used as a diagnostic parameter for bridge assessment
procedure.
• It provides an economical method for detecting damage that occurs in structures by using
dynamic data structures like frequency, mode shapes, modal participation factor

6. Result and discussion

The current study uses SAP 2000 software to analyze bridge model with six different sections and three different damage cases to evaluate the value of frequencies. The value of frequencies decreases because of occurring damages in to the bridge, according to the observation of the analytical analysis, when the size of the of the section changes the obtaing value of dynamic parameters are also changes.

Conclusions

After the study of analytical The result proved that value of frequencies and will change after sudden occurrence of damages. After the study of six mode shapes at six different frame sections for undamaged and damaged cases of bridge observed that the value of obtaining natural frequencies decreases after occurrence of damage in the bridge model. After analysis, it observes behaviours of mode shapes are change during the occurrence of damages in the bridge model.

Based on the result of this work help to determine the health of bridges according to sudden changes in natural frequencies and modal participation factors by using this system we can locate the damage location. After study of this work, it is concluded that with decreases in natural frequencies and modal participation factors we can monitor bridges for damage scenarios to take precaution before bridge failure.

References

1. Mohan Vimal, Parivallal, S., Kesavan, K., Ahmed, A and Ravisankar, K., (2014), "Studies on damage detection using frequency change correlation approach for health assessment", Procedia Engineering Journal, Volume-86, Pages 503-510. https://doi.org/10.1016/j.proeng.2014.11.074
2. Kute Deepak and Mishra Hredeye, (2018), "Two crack detection in tapered cantilever beam using natural frequency as basic criterion", Global Journal of Engineering Science and Research, Pages 228-232. https://doi.org/10.5281/zenodo.1311656
3. Widjajakusuma Jack and Helen Wijaya, (2015), "Effect of geometries on natural frequencies of pratt truss bridges", Procedia Engineering Journal,bVolume-125, Pages 1149-1155. https://doi.org/10.1016/j.proeng.2015.11.144
4. Yoshikaand T., Takahashi M., Yamaguchi. H. and Matsumoto. Y., (2015), "Damage assessment of truss diagonal member based on frequency changes in local higher modes", Procedia Engineering Journal, Volume-14, Pages 3119-3126. https://doi.org/10.1016/j.proeng.2011.07.392
5. Zhichun Yang and Wang Le, (2016), "Structural damage detection by changes in natural frequencies", Journal of Intelligent Material System and Structures, Volume-21, Pages 309-319. https://doi:10.1177/1045389X09350332
6. Mehrjoo, M., Kaji. N., Moharrami, H. and Khaji, N., (2011), "Damage detection of truss bridge joints using artificial neural networks", Expert System with Applications Journal, Volume -35, Pages 1122-1131. https://doi:10.1016/j.eswa.2007.08.008
7. Abdellah Ait (2005), "Application of sap2000: analysis of warren truss bridge", La Guardia Community College Newyork. https://lagccmec.online/engineering/courses/mae101/docs/SAP2000Project.pdf
8. Ahiwale Dhiraj and Khartode Rushikesh, (2020), "Parametric study for long span roof truss subjected to vertical ground motion",

Asian Journal of Civil Engineering, Volume-22, Pages 381-404. https://doi.org/10.1007/s42107-020-00320-5

9. Kumar Anjneya and Roy Koushik, (2020), "Response surface-based structural damage identification using dynamic responses", Structures Journal, Volume-29, Pages-1047-1058. https://doi.org/10.1016/j.istruc.2020.11.033
10. Patel Bhawna and Dewangan Umesh, (2021), "Damage detection techniques to identify the unknown damage parameters from structural response data in beam: a review", Journal of Recent Trends in Civil Engineering, Volume-77, Pages 175-183. https://doi.org/10.1007/978-981-15-5195-6_13
11. Khan Muhammad, Akhtar Kareem, Ahmad Naveed, Shah Feroz and Khattak Naeem, (2020), "Vibration analysis of damaged and undamaged steel structure systems: cantilever column and frame" Journal of Earthquake Engineering and Engineering Vibration, Volume -19, Pages -735-737. https://doi.org/10.1007/s11803-020-0591-9
12. Disferio Mariella, Vincenzo Sepe and Bellizzotti Gabriele (2019), "Modal identification of localised damage in beams and trusses: experimental and numerical result" International Journal of Advanced Structural Engineering, Volume-11, Pages 421-437. https://doi.org/10.1007/s40091-019-00243-9
13. Ivana Mekjavic (2015), "Identification of structural damage in bridge using heigh-frequency vibrational responses", Journal of Shock and Vibration, Volume-2, Pages 121-129. https://doi.org/10.1155/2015/906062
14. Jiaquan Wu, Hongyan Li, Fei Ye and Kun Ma, (2019), "Damage identification of bridge structure based on frequency domain decomposition and strain mode" Journal of Vibro-Engineering, Volume-21, Issue 8. https://doi.org/10.21595/jve.2019.20154
15. Das Swagato , Punam Shah and Patro Sanjaya , (2016) ,"Vibration based damage detection techniques used for health monitoring of structure: a review" Journal of Civil Structural Health Monitoring ,Volume-6,Pages 477-507. https://doi.org/10.1007/s13349-016-0168-5
16. Swagat Pan and Navdeet Singh et al. (2018) A novel method of vibration modes selection for improving accuracy of frequency-based damage detection. Composite's part B: Engineering, Volume -159, Pages 120-129. https://doi.org/10.1016/j.compositesb.2018.08.13
17. Beshkyroun Sherif, Wegner Leon and Sparling Bruce, (2011), "New methodology for the application of vibration-based damage detection techniques" Structural Control and Health Monitoring, Volume -19, Pages 632-649.https://doi.org/10.1002/stc.456
18. MAIA.N, Silva.J, Almas.E and Sampaio. R, (2003), "Damage detection in structures: from mode shape to frequency response function methods", System and Signal Processing, Volume-17, Pages 489-498. https://doi.org/10.1006/mssp.2002.1506.
19. Chang Kai and Kim Chul, (2016), "Modal parameter identification and vibration-based damage detection of a damaged steel truss bridge", Journal of Engineering Structures, Volume-122, Pages156-173. https://doi.org/10.1016/j.engstruct.2016.04.057
20. Zhang Yao, Lie Seng, Xiang Zhihal and Lu Qiuhai,(2014), "A frequency shift curve-based damage detection method for cylindrical shell structure", Journal of Sound and Vibration, Volume -333, Pages 1671-1683.https://doi.org/10.1016/j.jsv.2013.11.026
21. Zhong.S and Oyadjii. S., (2008), "Analytical prediction of natural frequencies of cracked simply supported beams with a stationary roving mass", Journal of Mechanical System and Signal Processing, Volume-311, Pages 328-352. https://doi.org/10.1016/j.jsv.2007.09.009
22. Pandey, A., Biswas.M, and Samman, M., (1991), "Damage detection from changes in curvature mode shapes", Journal of Sound and Vibration, Volume-145, Pages 321-332. https://doi.org/10.1016/0022-460X(91)90595-B
23. Cawley, P.and Adams. R, (1979), "The location of defects in structure from measurement of natural frequencies", Journal of Stain Analysis, Volume-14.Pages 49-53. https://doi.org/10.1243%2F03093247V14204