DAMAGE ASSESSMENT BASED ON MODAL ANALYSIS OF PLATED STRUCTURE

Kyoto University Non Member ○Sakhiah Abdul Kudus
Kyoto University Regular Member Yasuo Suzuki
Kyoto University Regular Member Masahide Matsumura
Kyoto University Regular Member Kunitomo Sugiura

1. ABSTRACT

The degradation of steel structures, especially thickness reduction due to corrosion attack is very common issue for marine structures. Subjected to this matter, an urgent need to evaluate structural health condition of corroded steel structure is discussed in this paper in order to ensure the safety and reliability. This study focus on the effect of the thickness reduction on the dynamic behavior of steel structures. The influence of the severity of damage, position of damage on observed mode on the percentage reduction of natural frequencies and localization of mode shape of steel structure are depicted. Significant reduction of natural frequency and localization of mode shape in damage region can be observed in presence of severe damage. The vibration results summarize in this paper can serve benchmarks for researcher and as reference value for design engineer.

2. INTRODUCTION

The corrosion problem of marine structure is among the most harmful damaged that might give significant effect to stiffness, toughness and durability of the structure. With regard to this issue, serious attention should be given especially to an aged structure where possibilities of higher degradation might occur. A reliable evaluation method through SHM technique by utilizing modal analysis has been interest to a lot of researcher and engineer in order to monitor damage in structure and many studies have confirmed that modal parameter is one of promising tool for indicator of damage in structure (Haroun et al. 1993). Changes of natural frequency has shown prevalent method in modal analysis for structural damage assessment. The presence of damage in structure leads to decreasing of stiffness which consequently cause reduction of natural frequencies of the system. The utilization of mode shape as damage indicator in structure has received great attention due to characteristic of mode shape that provides local information which makes mode shape sensitive towards the presence of local damages.

This paper was aim to study the vibration characteristics of corroded steel plate where thickness profile is assumed based on steel pipe pile of jetty structure undergoing real corrosion and loss of thickness problem due to exposure of marine environment. The pipe structure was open up to represent plate structure and further assessment was conducted on this plate structure. The steel pipe pile is the main structure that supporting jetty where the thickness measurement was conducted on this pipe to obtain the information of thickness profile. The deviation of natural frequency and mode shape obtained from intact model towards damaged model was used as feature of damage identification.

3. METHODOLOGHY

A spiral steel pipe that has been exposed to the marine environment for 19 years is the object monitored, measuring at a total height of 10.5 m, outer diameter of 406.4 mm, and intact thickness of 9 mm (Tamura, 2005). The corroded steel pipe's surface profile has been measured using a laser displacement meter. The pipe is divided into four sections of interest, representing four important sections of marine environment as illustrated in Fig. 1, which are: splash zone, tidal zone, submerged zone 1, and submerged zone 2.

The plate model has been constructed using a three dimensional (3D) finite element analysis (FEA) with a programming language called Abaqus, version 6.14. To obtain natural frequencies and mode shapes, eigenvalue analysis has been performed, with the use of Lanczos eigensolver to solve the matrices. The material properties of the steel being considered are: density, ρ = 7850 kg/m^3; Poisson's ratio, v = 0.3; and Young's modulus, E = 210 GPa. Simply supported boundary condition was set for all edge of plate model.

4. RESULTS AND DISCUSSION

Detailed investigation into thickness reduction in steel plate has been conducted via FEA by substituting the corrosion distribution profile in the longitudinal and circumferential direction, as presented in Fig. 3. From the results obtained, high corrosion is seen in the splash zone, followed by tidal zone. Further, specimen No. 4 has shown less corrosion compared to specimen No. 3, indicating that the bottom part of the plate is less corroded compared to the upper part.

Fig. 2 show percentage deviation of natural frequency from intact model in the first 20 modes of plate model. Higher frequency deviation indicates more deterioration occurrences in the structure and it was observed that severe damage was occur in the splash zone compared to other zones. Submerged zone 1 and submerged zone 2 do not show large differences as per their thickness profile results. The results of frequency deviation have also shown good correlation with the results of the thickness profile as Fig. 3. Fig. 4 presenting the switch of mode shape. Global mode 1 and local mode 4, mode 11 and mode 20 have been extracted from modal analysis for further evaluation. At glance, the global mode which indicate the first mode of vibration show less changes towards local damage. A more clear changes in mode of vibration can be observed in local mode, where the selection of mode which is sensitive towards presence of damage is important. The localization was clearly occur in region which have higher loss of thickness as in splash zone and tidal zone.

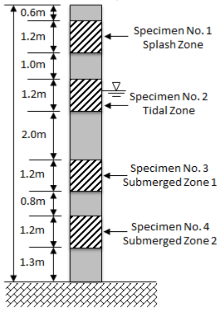


Fig. 1 Schematic diagram of steel pipe and the position of specimen number 1, 2, 3 and 4.

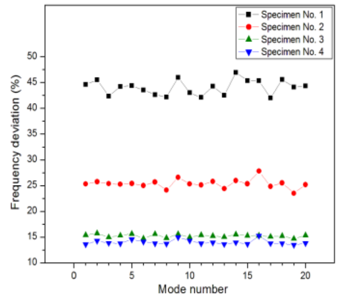
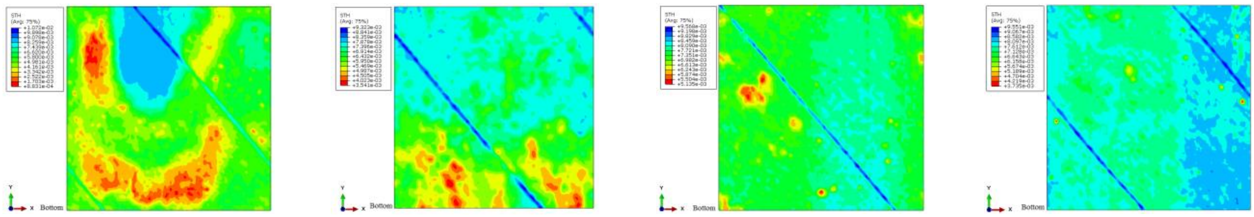


Fig. 2 Deviation of natural frequency in the first 20 modes of plate model.



(i) Specimen No. 1 (ii) Specimen No. 2 (iii) Specimen No. 3 (iv) Specimen No. 4

Fig. 3 The thickness profile of specimen number 1, 2, 3 and 4 representing the splash zone, tidal zone, submerged zone 1 and submerged zone 2 of the plate model.

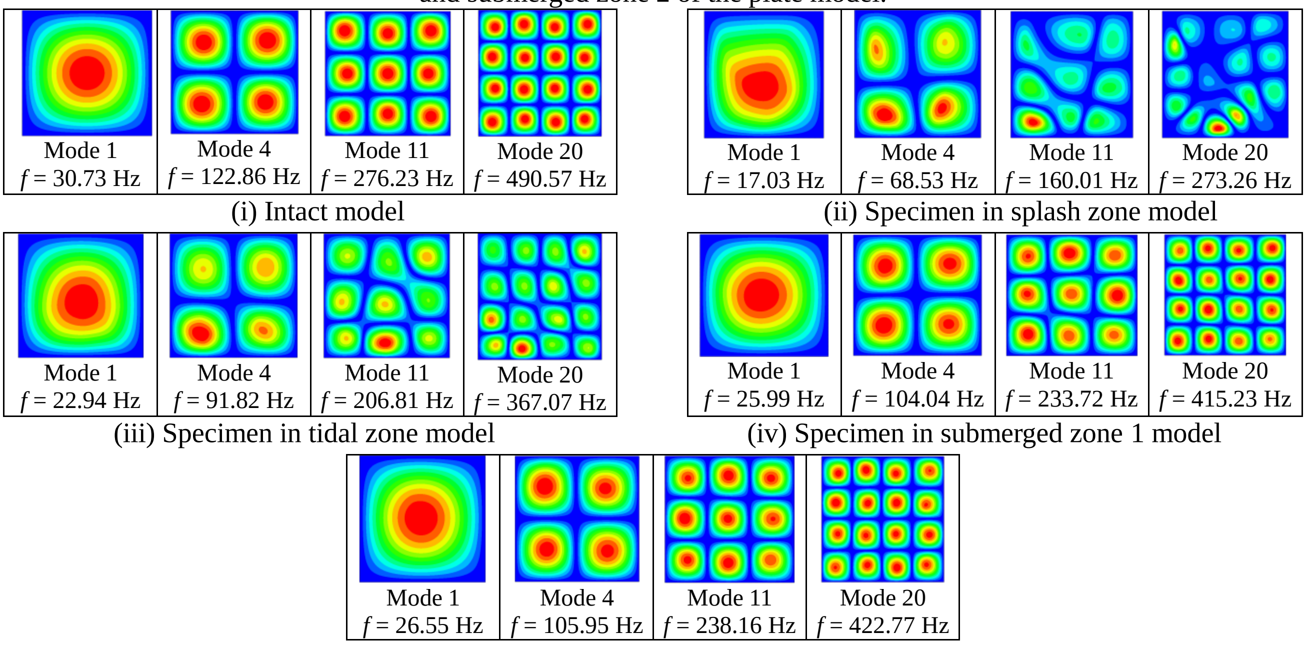


Fig. 4 Pattern switch of mode shape due to real corrosion damage profile in plate model.

5. CONCLUSIONS

In the present study, the sensitivity of vibration and its mode towards the presence of real corrosion profile was investigate. The observation from the results show that:

1. Higher corrosion rate can be seen in the upper part of the steel plate located in the splash zone. Corrosive occurrences are less in the upper part of the tidal zone, compared to its bottom part due to oxygen supply.
2. The changes of natural frequency from the intact model indicate the presence state of damage. Higher deviation of frequency was observed in splash zone specimen while contrasting lower frequency changes are in the submerged zone.
3. The localization of mode shape in damage region can provide information about the location and further size of damage.

REFERENCES

Haroun, M. A., Mourad, S. A., Flynn, N. H.: Modal Characteristics of Reinforced Concrete Pier Walls Before and After Cyclic Testing, Proceedings of the 11th International Modal Analysis Conference, Florida, 1993, pp. 1299-1302.
Tamura, I.: Corrosion Form and Dynamic Properties of the Steel Member in Corrosion Environment, Master Thesis , Kyoto University Graduate school of Engineering, Department of Civil and Earth Resources Engineering, 2005.

Keywords: Corroded steel, Finite element analysis, Modal analysis, Mode shape, Natural frequency
Contact address: Dept. of Civil & Earth Resources Eng., Bldg. C1, 615-8540, Kyoto, Japan. Tel: +81-75-383-3160