FREE VIBRATIONAL ANALYSIS OF CRACKED RC BEAM- A REVIEW

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Abstract - *Identification of faults in dynamic structures and components are a significant aspect in judgment creating about their overhaul and retirement. Failure to identify the damages has various significances, and they change based on the use, and significance of the vibrating structures and elements. Premature identification of faults in engineering structure during their service period is the great challenge to the engineers. Though dynamic based fault diagnosis has been advanced for last three decades and there is large number of literatures, still there are so many problems avoid doing it from application. Cracks in vibrating system can lead to a sudden and total failure from which recovery is impossible. This results in change in the physical characteristics of a structure and thus the dynamic response also varies. Depth of the crack and its location from fixed are the main parameters for the vibration analysis.*
It becomes very important to know the changes in these parameters of the structure in order to access its reliability, performance and safety & to study the effect of the parameters on the natural frequency of beams. In this paper, the effect of crack parameters (relative crack location & crack depth, and crack inclination) on the modal parameters of a cracked fixed and simply supported RC beam are examined by finite element analysis using ANSYS 17. In future this analysis can be extended by considering different cross sections of the beam such as circular, trapezoidal etc. with different materials.

Key Words: Vibrational analysis, simply supported beam, fixed beam, crack, natural frequency ,mode shape

1.INTRODUCTION

Vibrations are time dependent displacements of a particle or a system of particles with respect to an equilibrium position. One of the most important parameters associated with vibration of structure is the natural frequency. Each structure has its own natural frequency for a series of different modes which control its dynamic behaviour. All the structure which have some mass and elasticity is said to vibrate. When the amplitude of these vibrations exceeds the permissible limit, failure of the structure occurs. To avoid such failure, one must know the operating frequencies of the materials under various boundary conditions like simply supported, fixed or when in cantilever conditions. The presence of cracks in a structural member, such as an RC beam, causes variations in stiffness, the magnitude of which depends on the location, inclination and depth of the cracks. The monitoring of the changes in the response parameters of a structure has been used for the assessment of structural integrity, performance and safety. A crack in the dynamic structures can lead to untimely failure if it is not identified in early time. Modal parameters like modal frequencies, mode shapes are the functions of the structural properties like stiffness and mass of the structure. So, the variation of structural properties will cause the variation in the modal properties.

The main objective of this paper is to study the variation in the modal parameters (natural frequency an mode shape) of an RC beam as the crack depth and crack inclination varies by conducting the free vibrational analysis in ANSYS 17.

2. THEORETICAL BACKGROUND

The natural frequencies of a cracked system can easily be obtained through many of the structural testing methods. When any two natural frequencies of a cracked simply supported reinforced concrete beam are obtained from measurements, the location, inclination and the depth of the crack can then be determined.

2.1 Classification of vibration

Vibration can be classified as:

- Free and forced vibration: If a system, after an internal disturbance, is left to vibrate on its own, then the vibration is known as free vibration. Here no external force acts on the system. If the system is subjected to an external force, then the resulting vibration is known as forced vibration. If the frequency of the external force coincides with one of the natural frequencies of the system, resonance occurs and the system undergoes dangerously large oscillations.

- Undamped and damped vibration: If no energy is dissipated in the friction or other resistance during oscillation, the vibration is called undamped vibration. If any energy is lost in this way, it is called the damped vibration. The consideration of damping becomes important in analysing the vibratory system near resonance.

- Linear and nonlinear vibration: If all the basic components of vibratory system—the spring, the mass and the damper—behave linearly, the resulting vibration is known as linear vibration. If any of the basic components behave non-linearly, the vibration is called nonlinear vibration.

2.2 Crack

A crack in a structural member introduces local flexibility that would affect vibration response of the structure. This property may be used to detect existence of a crack together its location, inclination and depth in the structural member. The presence of a crack in a structural member alters the local compliance that would affect the vibration response under external loads.

- Based on geometries, cracks are classified as follows:
  (1) Transverse crack: These are cracks perpendicular to beam axis. These are the most common and most serious as they reduce the cross section as by weakens the beam. They introduce a local flexibility in the stiffness of the beam due to strain energy concentration in the vicinity or crack tip.
  (2) Longitudinal cracks: These cracks parallel to beam axis. They are not that common but they pose danger when the tensile load is applied at right angles to the crack direction i.e. perpendicular to beam axis.
  (3) Open cracks: The cracks always remain open. They are more correctly called "notches". Open cracks are easy to do in laboratory environment and most experimental works are focused on this type of crack.
  (4) Breathing crack: These cracks open when the affected part of material is subjected to tensile stress and close when the stress is reversed. The component is most influenced under tension condition. The breathing of crack results in non-linearity in the vibration behaviour of the beam. The "transverse breathing" cracks have direct practical relevance and most theoretical research efforts are concentrated on this.
  (5) Slant cracks: These are cracks at an angle to the beam axis.
  (6) Surface cracks: These are the cracks that open on the surface. These are normally detected by dye-penetrates or visual inspection.
  (7) Subsurface cracks: Cracks that are developed inside surface and not on the surface are called subsurface cracks. Special techniques such as ultrasonic, magnetic particle etc. are needed to detect them.

3. LITERATURE REVIEW

3.1 General

Before embarking on the analysis, it is considered useful to review the works carried out by others in the past. A number of journals and proceedings which deals with the vibrational analysis and damage detection of beam have been referred and are presented below.

3.2 Review of past works

O. S. Salawu (1997), discussed the use of natural frequency as a diagnostic parameter in structural assessment procedures using vibration monitoring. The relationships between frequency changes and structural damage are discussed. Various methods proposed for detecting damage using natural frequencies are reviewed. Factors which limit successful application of vibration monitoring to damage detection and structural assessment are also discussed.

Keiichi inoue , Masaru kikuchi , Masaiki ueda , and Takeaki koshikawa (2004), analysed the vibration problem of reinforced concrete beam members including bond-slip of the reinforcements. In this paper, virtual work is used to derive equations based on the finite element method. For free vibration analysis the effect of bond-slip on the characteristics of vibration depends on the different bond moduli assumed, whereas, for sinusoidal dynamic analysis, the effect of bond-slip on the response depends on the different bond moduli assumed, as well as, the bond-slip damping and period of the input.

N. Poovarodom and K. Charoenpong (2004), presents a study on dynamic testing and numerical analysis of a 6-story RC building to develop more understanding and add more informative results for the problem in this area. The influence of masonry walls and foundation flexibility on the natural frequencies, damping ratios and mode shapes were examined through ambient vibration measurements in conjunction with numerical modelling. The increases in natural frequencies of the building with the amount of partition masonry wall are discussed.

Tayfun Dede, Yusuf Ayvaz and Yaprak I O ¨ zdemir (2010), done the materially nonlinear free vibration analysis of a beam by using the finite element method. Here, two approaches are used. In the first approach, the material matrices of concrete and reinforcement are constructed separately, then superimposed to obtain the element stiffness matrix. In the second approach, the reinforcement is uniformly distributed throughout the beam. So, the beam is modelled as a single composite element with increasing the modulus of elasticity of concrete considering the reinforcement ratio. It is concluded that the approaches and the model considered in this study can effectively be used in the materially nonlinear free vibration analysis of reinforced concrete (RC) beams and the effects of the change in the stiffness matrix from initial to yield on the nonlinear frequency parameters of the beam are always larger than those of the change from yield to failure.

Gawali a.l and Sanjay c. kumawat (2011), have made vibrational analysis of beam.It is found that the frequencies of vibration of cracked beams decrease with increase in crack depth for crack at any particular location due to reduction of stiffness. The effect of crack is more pronounced near the fixed end than at far free end. The first natural frequency of free vibration decreases with increase in number of cracks. The natural frequency decreases with increase in relative crack depth.

V. Srinivas,C. Antony Jeyasehar ,K. Ramanjaneyulu , Saptarshi Sasmal (2012), done an experimental investigations on effect of damage on vibration characteristics of a reinforced concrete beam. Forced vibration testing of a reinforced concrete beam has carried out using an electro-dynamic shaker under sweep sine and random loadings to identify the changes in vibration characteristics under different damaged conditions. Along with the dynamic characteristics, the static response of the beam during application of the loading is also obtained to evaluate the damage state. Two distinct cases ,i.e, during initiation of crack and after yielding of main reinforcement of the beam are studied. Dynamic characteristics (frequencies and mode shapes) was evaluated from the FRF matrices based on the responses measured through accelerometers. It is observed that the damage causes the changes in flexural rigidity of the beam which is clearly observed by the shift in natural frequency at different levels of damage.

Prathamesh M. Jagdale, Dr. M. A. Chakrabarti (2013), presented a model for free vibration analysis of a beam with an open edge crack. Variations of natural frequencies due to crack at various locations and with varying crack depths have been studied. When the crack positions are constant i.e, at specific crack location, the natural frequencies of a cracked beam are inversely proportional to the crack depth. It has been observed that the change in frequencies is not only a function of crack depth, and crack location, but also of the mode number.

Saidi abdelkrim, Hamouine abdelmadjid and Abdellatif megnounif (2014), studied the effect of crack depth and location on modal properties of the beam. When the location of the crack increases starting from the clamped end of the beam, natural frequencies of the beam and the amplitude of high frequency vibration also increase, but the amplitude of low frequency vibration decreases. It was shown that as the depth of the crack increases, the amplitude of vibration also increases at high frequencies but the natural frequencies decrease as expected.

Ali Ahmed (2014), done the modelling of a reinforced concrete beam subjected to impact vibration. In this study, thirty analyses have been executed changing different parameters, like damping, tension and compression stiffness recovery, damage parameter-strain, displacement relations and friction coefficient,to choose the best performing FE model.

Malay Quila, Prof. Samar Ch. Mondal, Prof. Susenjit Sarkar (2014), worked on the theoretical analysis of transverse vibration of a fixed beam and investigates the mode shape frequency. Also in this paper, a model for free vibration analysis of a beam with an open edge crack has been presented. Variations of natural frequencies due to crack at various locations and with varying crack depths have been studied. Natural frequency changes drastically when crack is on that point where amplitude of vibration is maximum. It is observed that natural frequency of the cracked beam decreases with increase in crack distance and crack depth due to reduction in stiffness. It appears therefore that the change in frequencies is not only a function of crack depth and crack location but also of the mode number.

Neha S. Badiger (2014), carried out the four point bending analysis using reinforced concrete beam. The results of the beam with respect to mesh density, use of steel cushions for support and loading points, effect of shear reinforcement on flexure behaviour, impact of tension reinforcement on behaviour of the beam are analysed. It is observed that by varying the tension steel, the initial cracking behaviour is not affected. But it has more impact in the post cracking stage of the beam. The ultimate capacity of beam could be varied by varying the steel percentage. By removing steel plate at support and loading point, stress concentration takes place. The beam without steel plate show more cracks than beam with steel plate. For more accurate analysis, steel cushion has to be included in modelling.

Mr. Gade Ganesh G, Prof. Mhaske M. S (2015), done the vibration analysis of a cantilever cracked beam using various techniques. It has been observed that the changes in natural frequencies are the important parameter that determine crack size and crack location respectively.

Preethy Dharanya.Y1, Dr. Srinivas.V2, Dr. Anand.N3 (2015), made an investigation into the possibility of using non-linear vibration characteristics to detect damage in reinforced concrete beams under simply supported and free free conditions. Modelling of reinforced concrete beam was carried out using Ansys12.1 software and simulations results were obtained for linear, nonlinear, modal analysis and transient dynamic analysis. Dynamic characteristics (frequencies and mode shapes) have been evaluated from the FRF matrices based on the responses measured through accelerometers. It was observed that the damage causes the changes in flexural rigidity of the beam ,clearly observed by the shift in natural frequency at different levels of damage. From vibration testing, it is observed that there is a decrease in frequency of 10–15% for the first three modes from undamaged to cracking and failure conditions of the beam. It was observed that there is clear shift in natural frequencies with the increase in damage level.

Arjun S. Menon and Glory Joseph (2015), studied the dynamics of composite beam with transverse non-propagating open crack. By using the models of the cantilever cracked composite beam the influence of depth of a crack in a cracked composite beam on stress, the changes of the natural frequencies of the cracked composite beam as function of the angle of fibres, the effect on cracks due to harmonic loads, effect of boundary conditions are found.

Pramod Kumar, S. Bhaduri (2015), discusses the detection and prediction of cracks in structures.In this paper a review is conducted on the prediction and detection of crack in structures. Different methods of crack analysis are discussed in this paper.

A.I. Deokar, S.D. Katekar (2015), evaluated natural frequencies and mode shapes by FEA Software ANSYS 11. A simple elastic simply supported beam with crack at the different locations and crack depth is considered for the modal analysis. The frequency of beam when the crack is in the middle is less than the frequency with crack near the end position and the natural frequency of beam decrease with increase in crack depth due to decreasing of beam stiffness at any location of crack in beam.

Ms. P. P. Gangurde, R.S.Pawar (2016),done the vibration analysis of cracked simply supported beam subjected to free excitation at the base. The effect of non-linearity's on the natural frequency and mode shapes of cracked simply supported beam is done by theoretical, numerical and experimental methods. Numerical verification of vibration analysis of cracked simply supported beam having non-linear parameters and evaluation of natural frequency and mode shapes with ANSYS software for free vibration are done.

4. CONCLUSIONS

This chapter dealt with the numerous numbers of papers and journals that has been found helpful for carrying out the work. A brief review of the presented literatures shows that the natural frequency changes substantially due to the presence of cracks depending upon the depth and inclination of cracks. Many non-destructive methodologies for crack detection have been in use worldwide. However the vibration based method is fast and inexpensive for crack/damage identification.

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