Analysis of Crack Failure of RCC Beam Using Fem

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Abstract— The most common structural defect is the existence of a crack. Cracks are present in structures due to various reasons. The presence of a crack could not only cause a local variation in the stiffness but it could affect the mechanical behavior of the entire structure to a considerable extent. Cracks may be caused by fatigue under service conditions as a result of the limited fatigue strength. They may also occur due to mechanical defects. Another group of cracks are initiated during the manufacturing processes. Generally they are small in sizes. Such small cracks are known to propagate due to fluctuating stress conditions. If these propagating cracks remain undetected and reach their critical size, then a sudden structural failure may occur. Hence it is possible to use natural frequency measurements to detect cracks. In this paper work we are studying the effect of cracks generated at different lengths of beam and their effect on the structure also on mode shape and frequency of the structure. In this work we are also comparing abcus and ansys (analysis tool) for linear results and justify the effects of cracks with different depths of cracks at beams.

Keywords: Ansys, Beam, Failure, Cracks, Frequency, Mode Shape, Structural Analysis

I. INTRODUCTION

Beams are the critical structural members subjected to bending, torsion and shear in all type of structures. Similarly, columns are also used as various important elements subjected to axial load combined with/without bending and are used in all type of structures considering from building to bridge as piers or abutments. Therefore, extensive research works are being carried out throughout world on retrofitting of concrete beams and columns with externally bonded FRP composites. Several investigators took up concrete beams and columns retrofitted with carbon fiber reinforced polymer (CFRP)/ glass fiber reinforced polymer (GFRP) composites in order to study the enhancement of strength and ductility, durability, effect of confinement, preparation of design guidelines and experimental investigations of these members. The results obtained from different investigations regarding enhancement in basic parameters like strength/stiffness, ductility and durability of structural members retrofitted with externally bonded FRP composites, though quite encouraging, still suffers from many limitations. This needs further study in order to arrive at recognizing FRP composites as a potential full proof structural additive.

Composite structures are widely used in aerospace applications as well as civil engineering structure which made many researchers to study various aspects of their structural behavior. As these composite materials are subjected to various types of damage, mostly cracks and delamination which results in local change of the stiffness of element for such materials and also affects their dynamic characteristics. This problem has been a subject of many papers, but only few papers have been devoted to change in dynamic characteristics of composite structural elements. The reviews on cracked composite beam with respect to the present work are taken and studied for further work.

II. REVIEW ON VIBRATION OF CRACKED COMPOSITE BEAM

Prathamesh et. al. (2013) studies the vibration analysis of beam with an open edge crack. The vibration analysis is done for the simply supported beam with different crack location and crack depths the results of their analysis are compared with the previous studies. They have shown the variation of natural frequencies due to crack at various locations with varying crack depths. In addition they had done the vibration analysis of cantilever beam with different crack locations and crack depths. They performed the analysis by using ABAQUS software.

Mogal et. al. (2012) performs the vibration analysis of cantilever beam with two open transverse cracks. They have shown that the presence of cracks in the structure decreases the natural frequencies of vibration. They also show that the natural frequencies and the mode shapes changes are depend upon the crack locations and crack depths. The results the obtained numerically are compared with the results they obtained from simulation.

III. OBJECTIVES OF THE STUDY

The main objective of our study is to determine the following:

- To determine the effect of cracks generated at different lengths of beams.
- To determine the difference in analysis tool abacus and ansys.
- To determine the effect of cracks at modes and frequency of the beams.

IV. THE METHODOLOGY

The crack modeling has been important aspect because cracks in the beam create changes in their geometric properties. The analysis has been done by using finite element method. ANSYS is used to determine the important parameters of a structure which are natural frequencies and mode shapes for dynamic loading conditions. Modal analysis in ANSYS program is a linear analysis. The method of mode extraction includes block lanczo (default), Power Dynamics, sub space, reduced, unsymmetrical, and damped and QR damped.

The assumptions made in the analysis are:

1) The analysis is linear. That means the generalized Hooke"s law for the materials are linear.
2) The damping has not been considered in this study.
3) The crack is assume to be an open crack with uniform depth

A. Mathematical Model

The model chosen is a cantilever composite beam of uniform cross-section A, having an open edge traverse crack of depth

„a" at position „l1 ". The width, length and height of the beam are B, L and H respectively in figure.

Fig. 4.1: schematic diagram of cantilever beam with crack

Computational procedure for composite beam

For the analysis of composite beam a computer program is develop which is based on finite element method. In this procedure the material parameters like modulus of elasticity, modulus of rigidity, the Poisson ratio and the mass density of the composite beam material and geometric parameters like dimensions of the composite beam also the specifications of the damage like size of the crack and location of the crack are supplied as input data to the computer. The beam is then meshed and after that the support reactions are applied. After that the beam is taken under solution and the results are found out.

Steps for analysis of composite beam by ANSYS:

1) Preprocessing.
2) Solution.
3) Post processing.

For simply supported composite beam:

1) PREPROCESSING

1) Give job name and title in working directory and then RUN.
2) Set preference to structure.
   >Preferences > select structure > click OK.
3) Add SOLID 185 element.
   >Preprocessor > Element Type > Add > Solid > Brick 8 node 185 >click OK.
4) Give Elastic Modulus (EX) and Poisson"s Ratio (PRXY)
   >Preprocessor > Material Props > Material Models > Structural > Linear> Elastic > Isotropic >Young"s modulus of concrete, E_c2.17x10^4 N/mm^2, PRXY = 0.15> click OK
5) Provide density of the material.
   >Preprocessor > Material Props > Material Models >Structural
   >Density = 7650
6) Model a beam of Length = 3 m, Depth = 0.45m and Width = 0.3m.
   >Preprocessor > modeling > Create > Volumes > Block > By 2 Corners & Z > provide dimensions (width, height and depth) > click OK

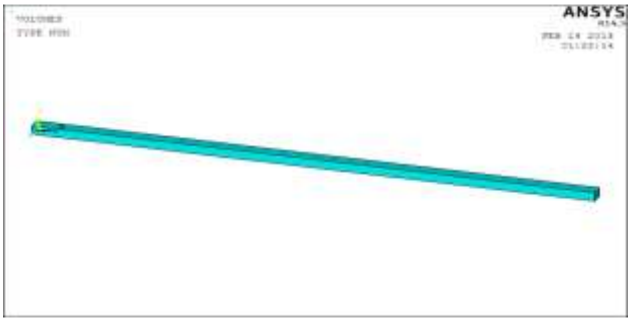

Fig. 4.2: Model of simply supported beam

7) Provide element edge length for meshing.
   >Preprocessor >Meshing > Mesh Tools > Size Control > Set to Global > give size of element edge length >click OK
8) Mesh the beam.
   >Preprocessor > Meshing > Mesh Tools > select Shape to Hex and Mapped > click on Mesh

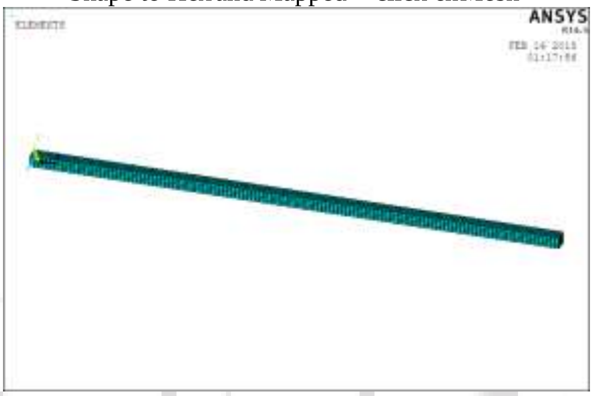

Fig. 4.3: Meshing of simply supported beam

Therefore in the first step of analysis that is preprocessing the modeling of simply supported beam is done and provided with required material properties. The required meshing is also done in the beam.

2) SOLUTION

1) Select the type of analysis that is modal analysis.
   Solution > Analysis Type > New Analysis > select to Modal > click Ok
2) Provide structural displacement for simply supported beam.
   Solution > Define Loads > Apply > Structural > Displacement > click OK
3) Solve the model.
   Solution > Solve > Current LS > click OK

3) POSTPROCESSING

1) Use the post processing tools to get the load value.
   >General Postproc> List Result > Detail Summary

In the second step of analysis that is solution the type of analysis is set and the required displacement for simply supported beam is provided to the model. After applying the displacement the solution of the beam is done.

B. For cantilever composite beam :

1) PREPROCESSING

1) Give job name and title in working directory and then RUN.
   Set preference to structure.
2) >Preferences > select structure > click OK.

3) Add SOLID 185 element.
   >Preprocessor > Element Type > Add > Solid > Brick 8 node 185 >click OK.
4) Give Elastic Modulus (EX) and Poisson‟s Ratio (PRXY).
   >Preprocessor > Material Props > Material Models > Structural > Linear > Elastic > Isotropic > EX = 30 e 9, PRXY = 0.17 > click OK
5) Provide density of the material.
   >Preprocessor > Material Props > Material Models >Structural>Density = 2400
6) Model a beam of Length = 3 m Depth = 0.45 m and Width = 0.30 m.
   >Preprocessor > modeling > Create > Volumes > Block > By 2 Corners & Z > provide dimensions (width, height and depth) > click OK

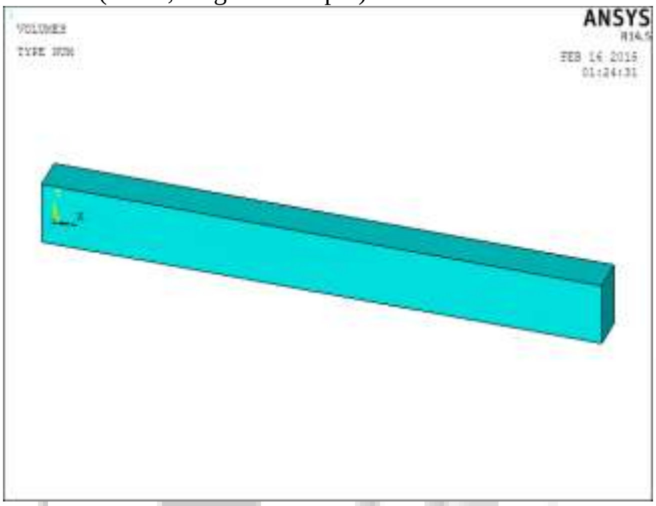

Fig. 4.4: Model of cantilever beam

7) Provide element edge length for meshing.
   >Preprocessor >Meshing > Mesh Tools > Size Control > Set to Global > give size of element edge length >click OK
8) Mesh the beam.
   >Preprocessor > Meshing > Mesh Tools > select Shape to Hex and Mapped > click on Mesh

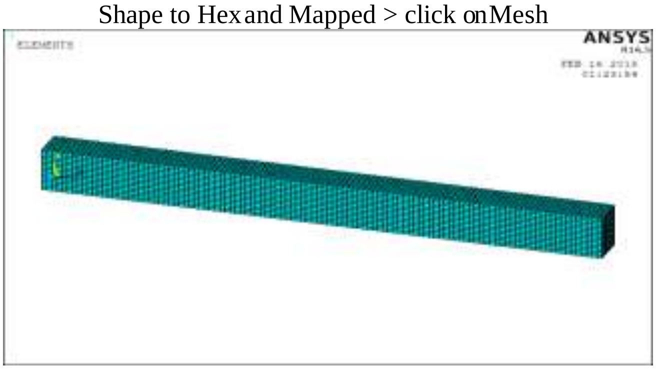

Fig. 4.5: Meshing of cantilever beam

Therefore in the first step of analysis that is preprocessing the modeling of cantilever beam is done and provided with required material properties. The required meshing is also done in the beam.

2) SOLUTION

1) Select the type of analysis that is modal analysis.
   Solution > Analysis Type > New Analysis > select to Modal > click Ok
2) Provide structural displacement for cantilever beam.
   Solution > Define Loads > Apply > Structural > Displacement > click OK
3) Solve the model.
   Solution > Solve > Current LS > click OK

3) POSTPROCESSING

1) Use the post processing tools to get the load value.
   >General Postproc> List Result > Detail Summary

In the second step of analysis that is solution the type of analysis is set and the required displacement for cantilever beam is provided to the model. After applying the displacement the solution of the beam is done.

V. ANALYSIS RESULTS

A. *Convergence Study*

The convergence study is carried out for a free vibation of composite beam and sufficient number of convergence test is obtained. Based on this study it is found that the element edge length is taken as 0.003 and 0.02 for simply supported and cantilever beam respectively, which is shown in table

Simply supported beam		Cantilever beam	
Edge length	Natural frequency	Edge length	Natural frequency
0.015	96.770	0.015	18.625
0.010	94.416	0.009	18.160
0.008	89.625	0.007	17.549
0.005	86.025	0.005	17.401

Table 5.1: Convergence of free vibration frequencies of cracked composite beam

B. *Validation*

The cracked concrete cantilever beam with a single crack has been considered for the free vibration analysis. The same beam has been solved previously with ABAQUS program and the results are compared with the present result which is obtained by using ANSYS program.

C. *Properties:*

Width of the beam = 0.3 m Depth of the beam = 0.45 m Length of the beam = 3 m Elastic modulus of the beam = 30 GPa Poisson‟s Ratio = 0.15
Density = 24 KN/m3 a = 5 mm
l_1= 1m

Mode No.	Natural Frequencies Obtained By:	
	ABAQUS CYCLES/TIME	ANSYS CYCLES/TIME
1.	4.51309	4.5388
2.	9.65376	9.6783
3.	27.6089	27.726
4.	43.2749	41.051
5.	54.6432	54.364

Table 5.2: Comparison of results obtained using ABAQUS and ANSYS software

Therefore the natural frequencies which are obtained by ANSYS are in good agreement with the previous studies. Hence we can solve further for other composite beams.

D. Comparison with Previous Studies

Results on the effect of various parameters on the vibration analysis of cracked composite are presented and the results of present analysis are compared with the previous studies.

E. Vibration Analysis Studies

The method of present analysis has been applied for the free vibration analysis of non-cracked and cracked simply supported beam.

Crack Position ξc = xc/L	Crack depth Cr =(a/H)	Natural Frequency ratio (ωc/ω)		Error%
		ABAQUS	ANSYS	
Un-cracked beam		1	1	0
0.2	0.1	0.997	0.999	
	0.3	0.987	0.994	
	0.5	0.956	0.985	
0.3	0.1	1.000	0.999	
	0.3	0.987	0.995	
	0.5	0.945	0.988	
0.5	0.1	0.997	0.999	
	0.3	0.994	0.998	
	0.5	0.988	0.994	

Table 5.3: Natural frequencies of a simply supported beam with a crack for first mode

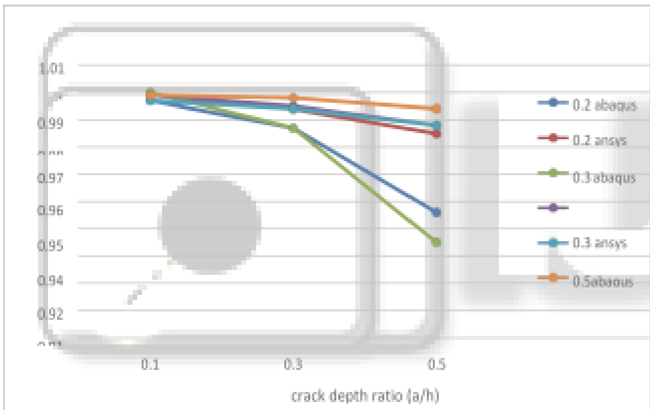

Fig. 5.1: frequancy ration of cantilever beam

Crack Position ξc = xc/L	Crack depth Cr =(a/H)	Natural Frequency ratio (ωc/ω)		Error%
		ABAQUS	ANSYS	
Un-cracked beam		1	1	0
0.2	0.1	1.000	0.999	
	0.3	0.999	0.998	
	0.5	0.974	0.993	
0.3	0.1	0.995	1.000	
	0.3	0.992	0.999	
	0.5	0.954	0.998	
0.5	0.1	0.990	0.996	
	0.3	0.981	0.989	
	0.5	0.931	0.961	

Table 5.4: Natural frequencies of a simply supported beam with a crack for second mode

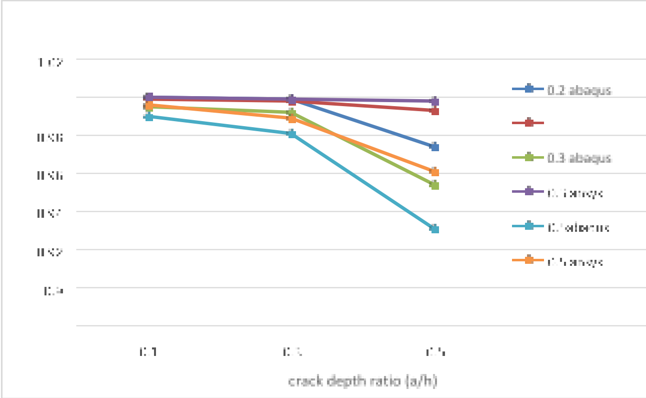

Fig. 5.2: natural frequency of second mode

VI. RESULTS

The comparison between the natural frequencies of the non-cracked and cracked composite beam with the previous studies is presented. As the changes of the first two natural frequencies is carried out for a free vibration of a composite beam with a single crack for various crack positions and crack depths. Similarly the first three natural frequencies is taken out for a cantilever beam with single crack for various crack positions and crack depths.

The geometrical characteristics and the material whichare chosen for the cantilever beam are Width of the beam = 0.30 m

Depth of the beam = 0.45 m Length of the beam = 3 m

Elastic modulus of the beam = 2x17^9 N/m^2 Poisson"s ratio = 0.15

Density = 2400 Kg/m^2

Crack position (ξc = xc/L) = 0.25, 0.33, 0.50 and 0.75

Relative crack depth (H= (a/h)) =0.1, 0.2 and 0.3

Crack position ξc = xc/L	Crack depth Cr=(a/H)	Present analysis Natural frequency ratio (ωc/ω)
Un-cracked beam		1
0.25	0.1	0.997
	0.2	0.990
	0.3	0.980
0.33	0.1	0.998
	0.2	0.993
	0.3	0.985
0.50	0.1	0.999
	0.2	0.997
	0.3	0.994
0.75	0.1	0.999
	0.2	0.999
	0.3	0.999

Table 5.5: Natural frequencies of a cantilever beam with a crack for the first mode

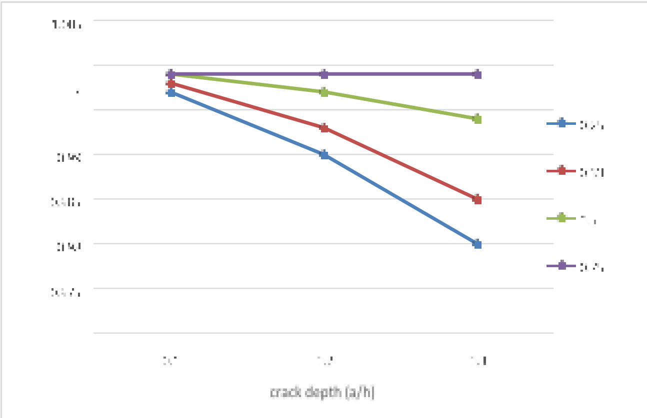

Fig. 5.3: natural frequency of a cantilever beam

Crack position ξc = xc/L	Crack depth Cr= (a/H)	Present analysis Natural frequency ratio (ωc/ω)
Un-cracked beam		1
0.25	0.1	0.992
	0.2	0.967
	0.3	0.890
0.33	0.1	0.994
	0.2	0.976
	0.3	0.945
0.50	0.1	0.997
	0.2	0.990
	0.3	0.978
0.75	0.1	0.999
	0.2	0.999
	0.3	0.998

Table 5.6: Natural frequencies of a cantilever beam with a crack for the second mode

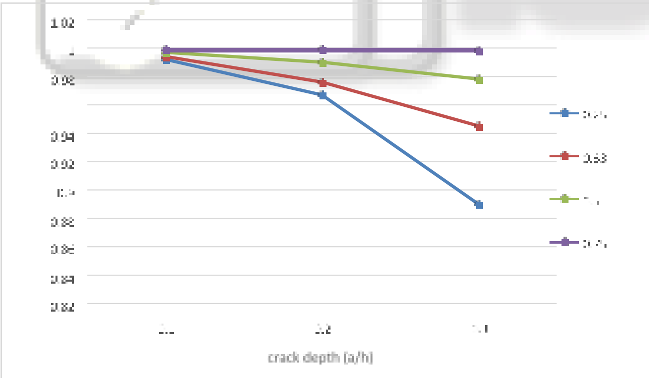

Fig. 5.4: frequency in second mode

Crack position ξc = xc/L	Crack depth Cr = (a/H)	Present analysis Natural frequency ratio (ωc/ω)
Un-cracked beam		1
0.25	0.1	0.999
	0.2	0.999
	0.3	0.998
0.33	0.1	0.998
	0.2	0.996
	0.3	0.991
0.50	0.1	0.997
	0.2	0.989
	0.3	0.977
0.75	0.1	0.997
	0.2	0.996
	0.3	0.991

Table 5.7: Natural frequencies of a cantilever beam with a crack for the third mode

VII. CONCLUSION

The conclusions which are made from the present investigation for the composite beam having transverse one edge open crack are

2) From the present investigation it has been observed that the natural frequencies of vibration of a cracked composite beam are not only the function of crack depth and crack location but also of the mode number.
3) It has been observed that the changes in the natural frequencies due to the presence of cracks is depend upon the location and the size of the cracks.
4) It can be concluded that as the location of a crack is constant, at that stage the natural frequencies are inversely proportional to the depth of crack.
5) The intensity of the reduction in the frequency increases with the increase in the crack depth ratio. This reduction in natural frequency along with the mode shapes of vibrations can be used to detect the crack location and its depth
6) The largest effects are observed at the centre of the simply supported beam and at the fixed end of the simply supported beam. Therefore from it has been concluded that decrease in frequencies is more for a crack located where the bending moment ishigher.
7) The effect of cracks is more pronounced near the fixed end than at far free end. It is concluded that the first, second and third natural frequencies are most affected when the cracks located at near of the fixed end, the middle of the beam and the free end, respectively

Here authors observed the analysis of beams and cracks generated over the beams due to load condition but none of the author presents the utilization of admixtures or frp technique to strengthen the beam.

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