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Damage Detection on Structural Elements

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Abstract: Early damage detection in aerospace, mechanical, and civil engineering structures for the purpose of structural health monitoring has been considered more attention in the last two decades. In order to monitor the existence condition of structures, some researchers attempted to develop vibration-based damage detection methods for the localization and quantification of damages. The basic idea of the vibration-based methods is that modal parameters are functions of the physical properties of structure such as mass, stiffness, and damping. Some researchers utilized only natural vibration frequencies for damage identification. The advantages of these approaches are that the test of a structure is relatively easy which can be done by only few sensors and has relatively higher precision than those based on other parameters; because the natural frequencies have least statistical variation from random error sources than other modal data. The major objectives of Structural health monitoring are to enhance the performance of an existing structure, to monitor the structures which are affected by external forces, improve towards the design based on the feedback, Post-earthquake structural integrity can be assessed. And to enhance the performance-based design philosophy
Keywords: Natural Frequencies, Mode shapes, Static Analysis, Displacement.

I. INTRODUCTION

Structural health monitoring (SHM) is tool for providing an assessment for the present condition of the building. SHM technique allow the experimental models of the structure, using vibrations. Over the years, SHM -Structural Health Monitoring of buildings has received increased attention for implementing a strategy called - damage detection. It includes observation of a building system over a time using an arrangement of sensors & obtaining of structural responses, damages sensitivity & statistical analysis in the building. A time series model is used to detect the damage sensitive features from SHM data to identify and recognize the damages. While considering time series model approximate vibration response of a structure are obtained with a residual error, deviations found in the co-efficient can be further inferred in the structure.

Many of the important structure like Dams, bridges, towers, &tall buildings require regular monitored for detection of damages considering SHM. Generally, damages may be due to poor workmanship & also wrong interpretation while analysing the design and drawing There are many other parameters which may cause/ reduce the quality of the work due to temperature variation, quality of materials, segregation, settlement which can leads to deterioration of the structural members.

SHM & Damage Assessment (DA) based data measurement is one of the most significant issues related to reliability and safety structures. It not only prevents catastrophic failure but also to delay the service life of structure. The Primary objective for SHM is to identify the state of the structure, which may be either healthy or damaged. Further it also provides the information about location & damage severity.

II. OBJECTIVES AND METHODOLOGY

A. Objectives

1) To study and analyse the influence of structural damage on vibrational characteristics of structure
2) To modelling and analysing simple 2-Dimensional steel frame in ANSYS-Work bench version 17.0 without the introduction of damages
3) To understand the behaviour of steel frame with the introduction of damage at supports and at mid span and different severities.
4) To understand the behaviour of steel moment resisting frame with the different level of damage
5) Response characteristics are compared before and after the introduction of cracks.

B. Methodology

In this study A 2-Dimensiona steel moment resisting frame having two bay three storeys is modelled in ANSYS Work bench version 17.0.The damage in the form of crack width of 60mm is introduced at support and midspan of steel moment resisting frame. Damage is introduced at different severities i.e., depth of cut is taken as 25% and 50% of I-beam depth. Modal analysis, Static analysis, is carried out to find modal frequencies, displacement and responses of steel frame respectively.

III. RESULT AND DISCUSSION

A. Static Analysis

Static Analysis– 25% Damage

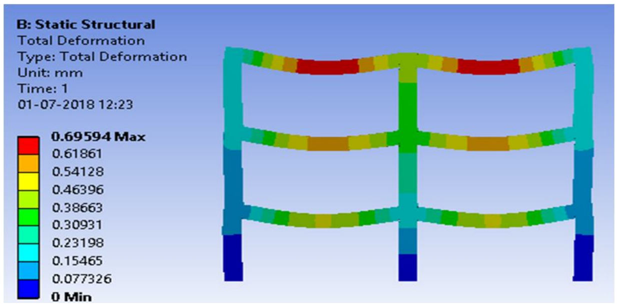


Fig 1- Static Deformation – Model 1

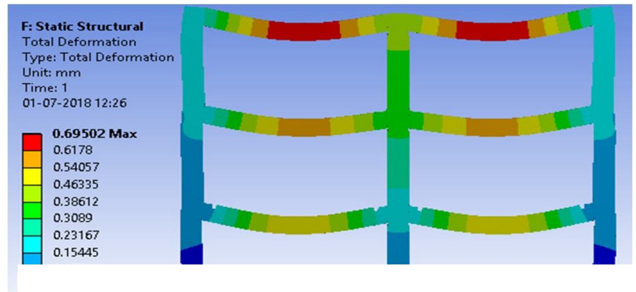


Fig 2: Static Deformation (25% Damage) Model 2

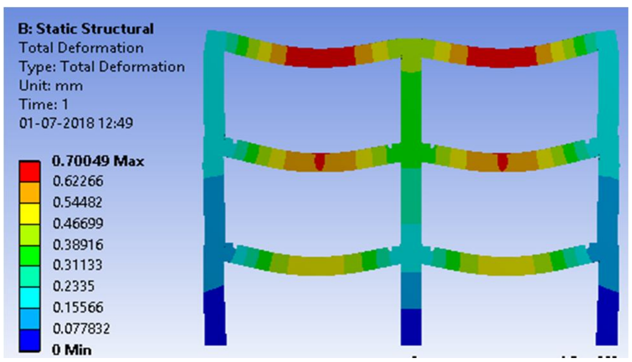


Fig 3: Static Deformation (25% Damage) Model 3

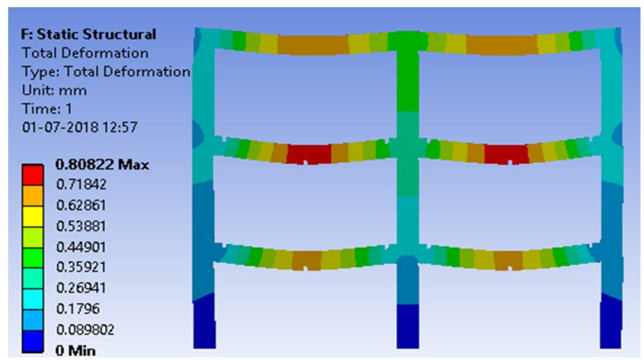


Figure 4: Static Deformation (25% Damage) Model 4

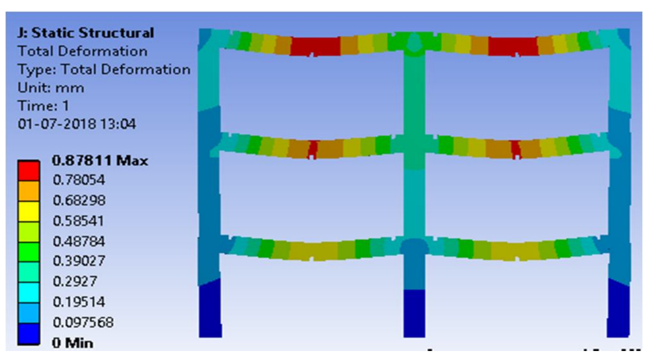


Figure 5: Static Deformation (25% Damage) Model 5

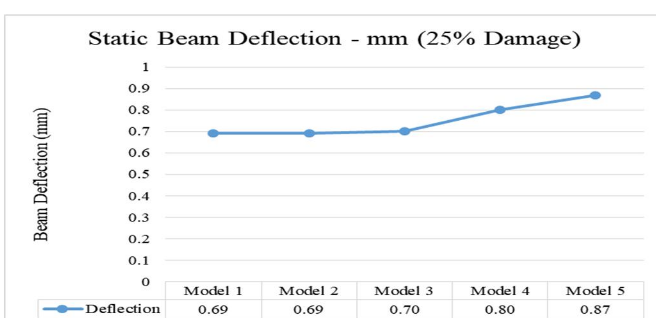


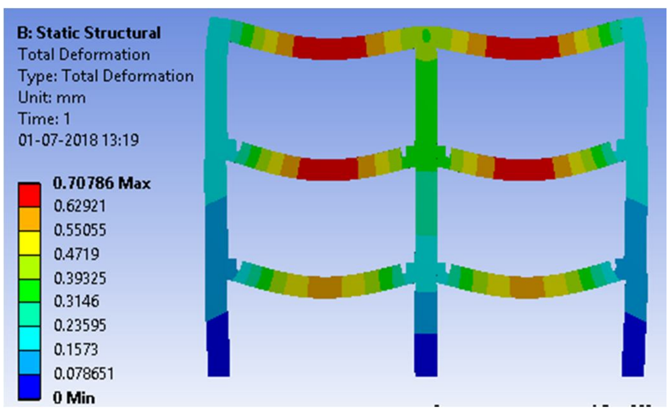
Figure 6: Static Deformation (25% Damage)

Table 1: Summary of Beam deflection for 25% Damage

Maximum Beam Deflection (25% Damage)		
Model No.	Type	Beam Deflection (mm)
Model 1	No damage	0.69
Model 2	Damage at supports (S 1)	0.69
Model 3	Damage at supports (S1&S2)	0.70
Model 4	Damage at supports & Mid Span (S1&S2)	0.80
Model 5	Damage at supports & Mid Span (S1,2 &3)	0.87

The above figure shows the variation of maximum vertical deformation observed in beam for 25% damage case. It is clear from the above Figure 5.6 that maximum deformation is found to be 0.87 mm for model 5 at level 2 and level 3 (where damage is at supports and mid span at all the three levels) which is 26.1% higher than the frame without any damage.

B. Static Analysis -50% Damage



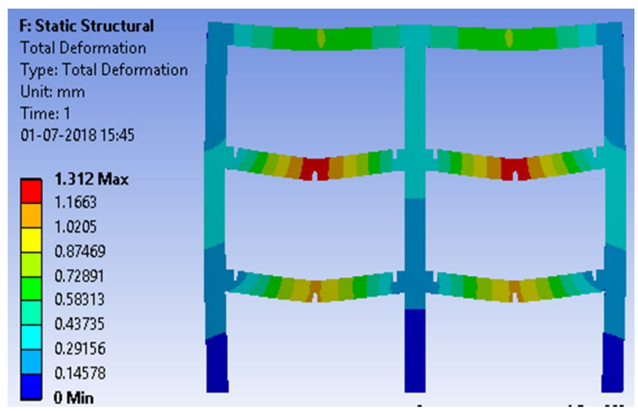


Figure 7: Static Deformation (50% Damage) Model 6 Figure 8: Static Deformation (50% Damage) Model 7

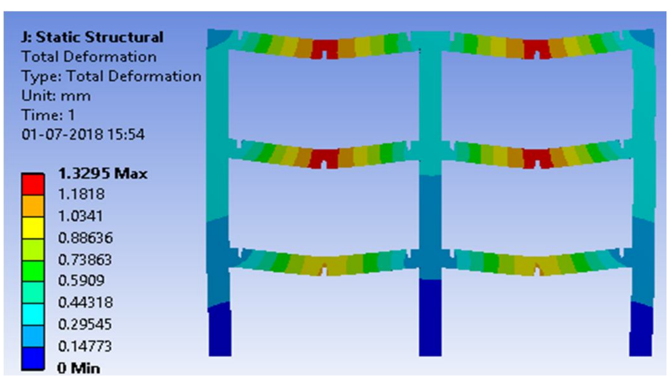


Figure 9: Static Deformation (50% Damage) Model 8

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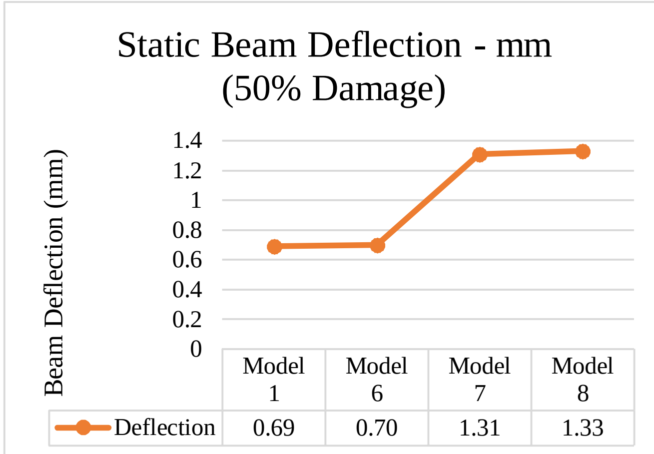


Figure 10: Static Deformation (50% Damage)

Table 2: Summary of Beam deflection for 50% Damage

Beam Deflection (50% Damage)		
Model No.	Type	Beam Deflection (mm)
Model 5	No damage	0.69
Model 6	Damage at supports (Storey 1&2)	0.70
Model 7	Damage at supports & Mid Span (Storey 1&2)	1.31
Model 8	Damage at supports & Mid Span (Storey 1,2 & 3)	1.33

With the increase in percentage of damage it is observed that, deformation in the beam has increase to 0.87 mm (in 25% damage) to 1.33 mm which is found to be 53% high. Also form Table 5.2 in comparison with undamaged beam, deflection is found to be 93% high.

C. Modal Analysis

Modal Analysis – 25% Damage

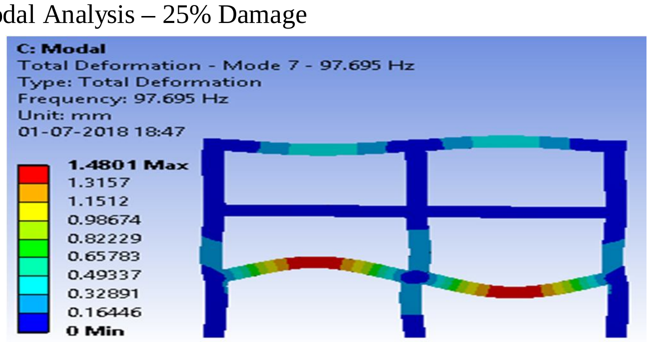
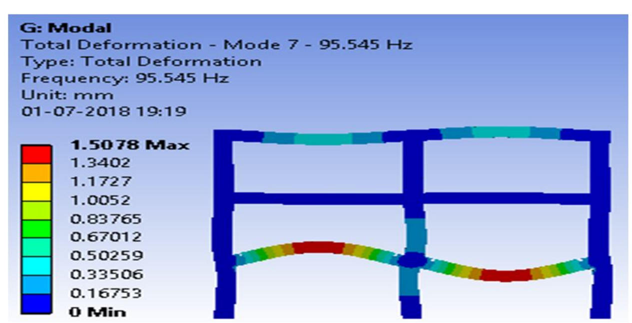


Fig 11: M Frequency and Deformation (Mode 7) – Model 1



Figu12: Modal Frequency and Deformation (Mode 7) – Model 2

(25% Damage)

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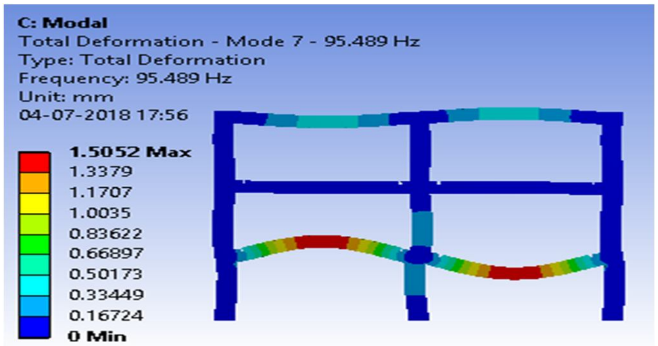


Fig13: Modal Frequency and Deformation (Mode 7) – Model 3 (25% Damage)

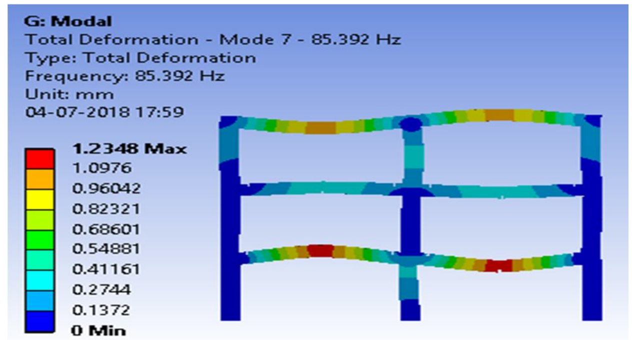


Fig14: Modal Frequency and Deformation (Mode 7) – Model 4 (25% Damage)

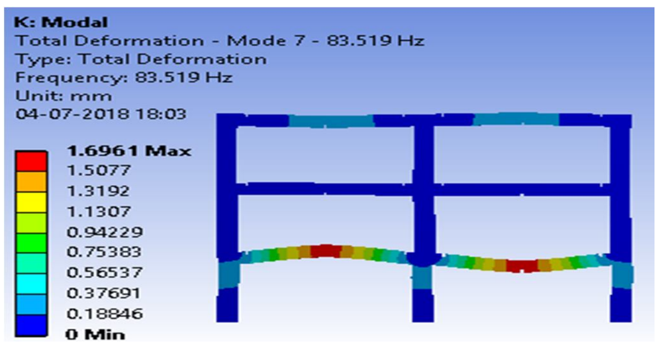


Fig15: Modal Frequency and Deformation (Mode 7) – Model 5 (25% Damage)

Table 3: Mode vs. Frequency (25% Damage)

Modal Analysis Frequency (Hz.) (25% Damage)					
Mode No.	Model 1	Model 2	Model 3	Model 4	Model 5
1	12.78	11.96	11.32	11.32	11.17
2	43.29	42.97	41.45	41.48	40.15
3	74.92	74.63	73.74	70.96	68.86
4	79.67	79.37	79.40	78.57	72.96
5	82.76	82.65	82.19	79.25	78.39
6	91.19	91.02	89.91	82.15	80.43
7	97.70	95.55	95.49	85.39	83.52

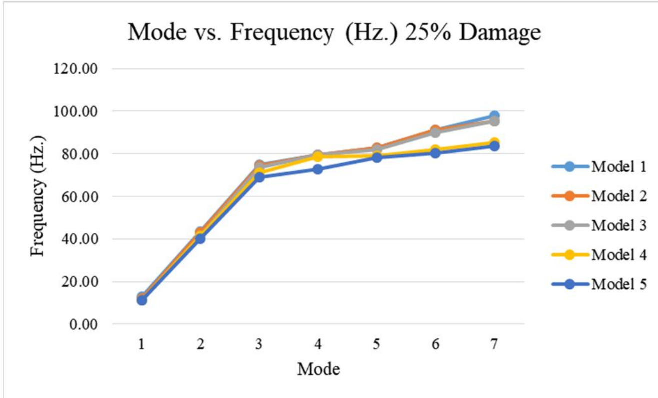


Fig16: Mode vs. Frequency (25% Damage)

From the Fig.16 it can be observed that, frequency of the damaged framed is found to be reduced from 12.78 Hz. to 11.96 Hz. in mode 1, which is found to be 7% compared to undamaged frame. But subsequent introduction of damage at supports and at different levels, a further reduction in frequency is observed about 12.6% compare to undamaged frame steel moment resisting frame.

Table 4:Mode vs. Deformation (25% Damage)

Max. Displacement (mm) (25% Damage)					
Mode No.	Model 1	Model 2	Model 3	Model 4	Model 5
1	0.69	0.68	0.70	0.70	0.71
2	0.63	0.65	0.61	0.62	0.65
3	1.00	0.98	0.95	1.01	1.11
4	0.75	0.70	0.74	1.35	1.55
5	1.20	1.23	1.18	0.91	1.31
6	1.41	1.41	1.43	1.31	1.21
7	1.48	1.50	1.50	1.23	1.69

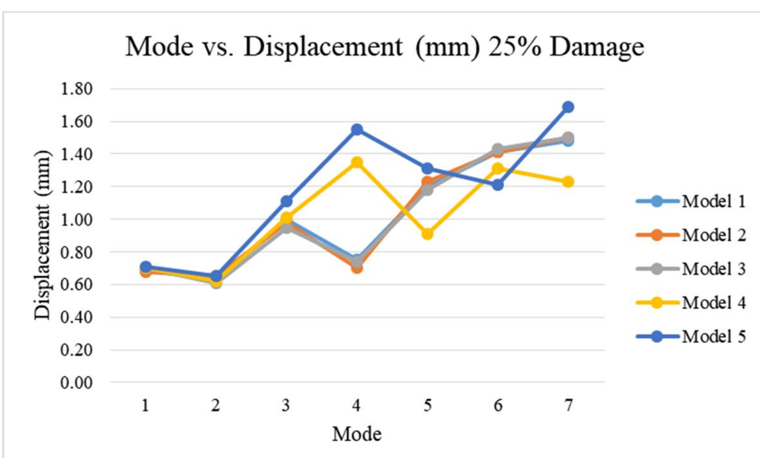
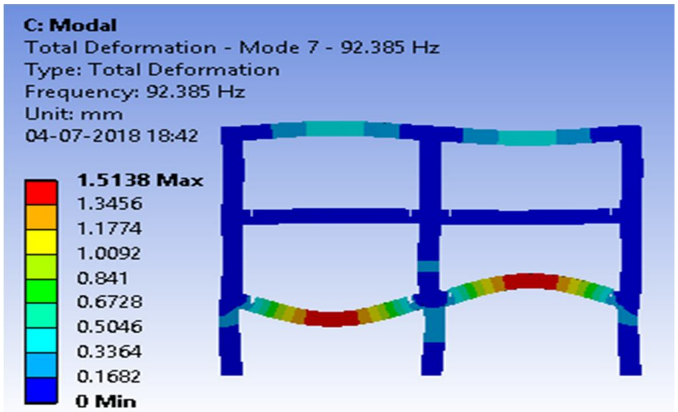


Fig17: Mode vs. Deformation (25% Damage

D. Modal Analysis-50% Damage



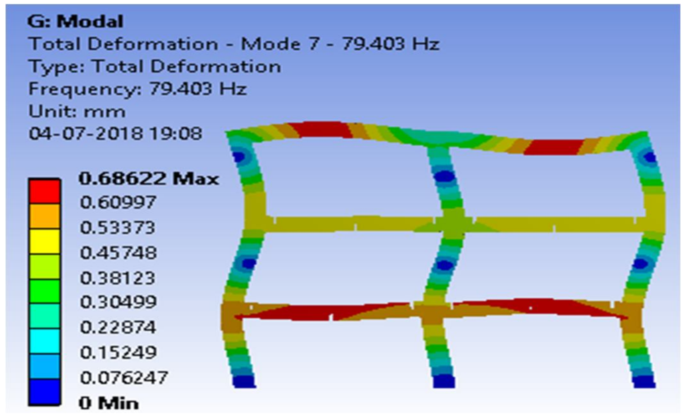


Fig18: Modal Frequency and Deformation (Mode 7) – Model 6 (50% Damage) Fig 19: Modal Frequency and Deformation (Mode 7) – Model 7 (50% Damage)

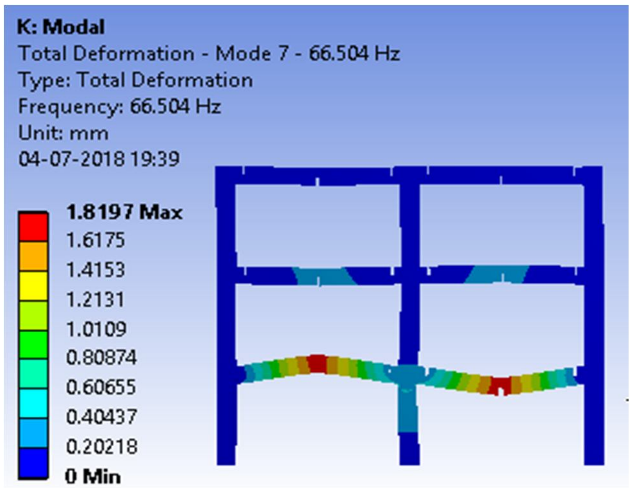


Fig 20: Modal Frequency and Deformation (Mode 7) – Model 8 (50% Damage)

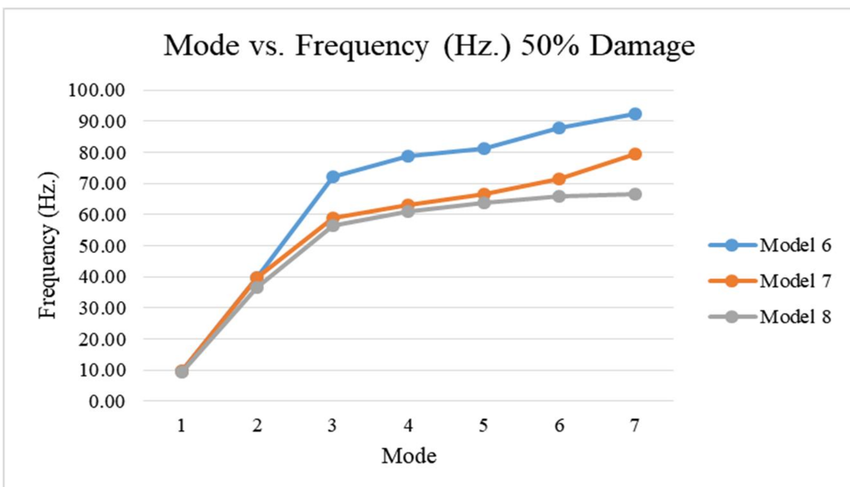


Fig 21: Modal Frequency (50% Damage)

Table: 1 Mode vs. Frequency (50% Damage)

Modal Analysis Frequency (Hz.) (50% Damage)			
Mode No.	Model 6	Model 7	Model 8
1	9.85	9.86	9.39
2	39.56	39.58	36.56
3	72.26	59.00	56.45
4	78.88	63.14	60.86
5	81.25	66.53	63.74
6	87.95	71.33	65.75
7	92.39	79.40	66.50

Table: 6 Mode vs. Displacement (50% Damage)

Max. Displacement (mm) (50% Damage)			
Mode No.	Model 6	Model 7	Model 8
1	0.70	0.70	0.74
2	0.61	0.62	0.66
3	0.89	1.44	1.14
4	0.71	1.76	1.61
5	1.13	1.80	1.65
6	1.40	1.65	1.27
7	1.51	0.68	1.81

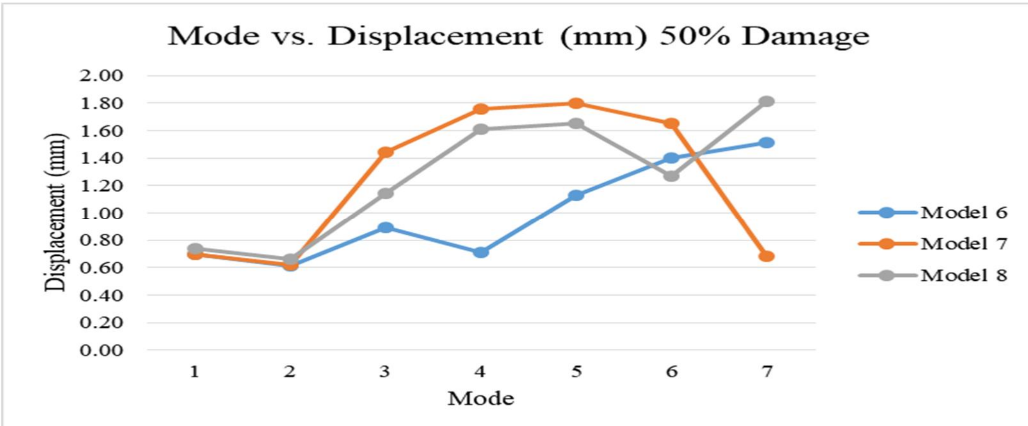


Fig 22: Mode vs. Displacement (50% Damage)

IV. CONCLUSIONS

A. From the static analysis it can be concluded that, vertical deformation depends on the level of damage, crack location in beam and development of cracks at different heights in the structure.

B. With the increase in damage percentage static deformation has be found to increase 93% compared to undamaged state.

C. From the modal analysis, it can be conclude that, the maximum modal deformation occurred at mode 7 in all the cases and frequency of the system is dependent on the level of damage and damage location.

D. With the increase in damage percentage from 25% to 50% frequency is found to be reduced with increase in modal displacements up to 23%.

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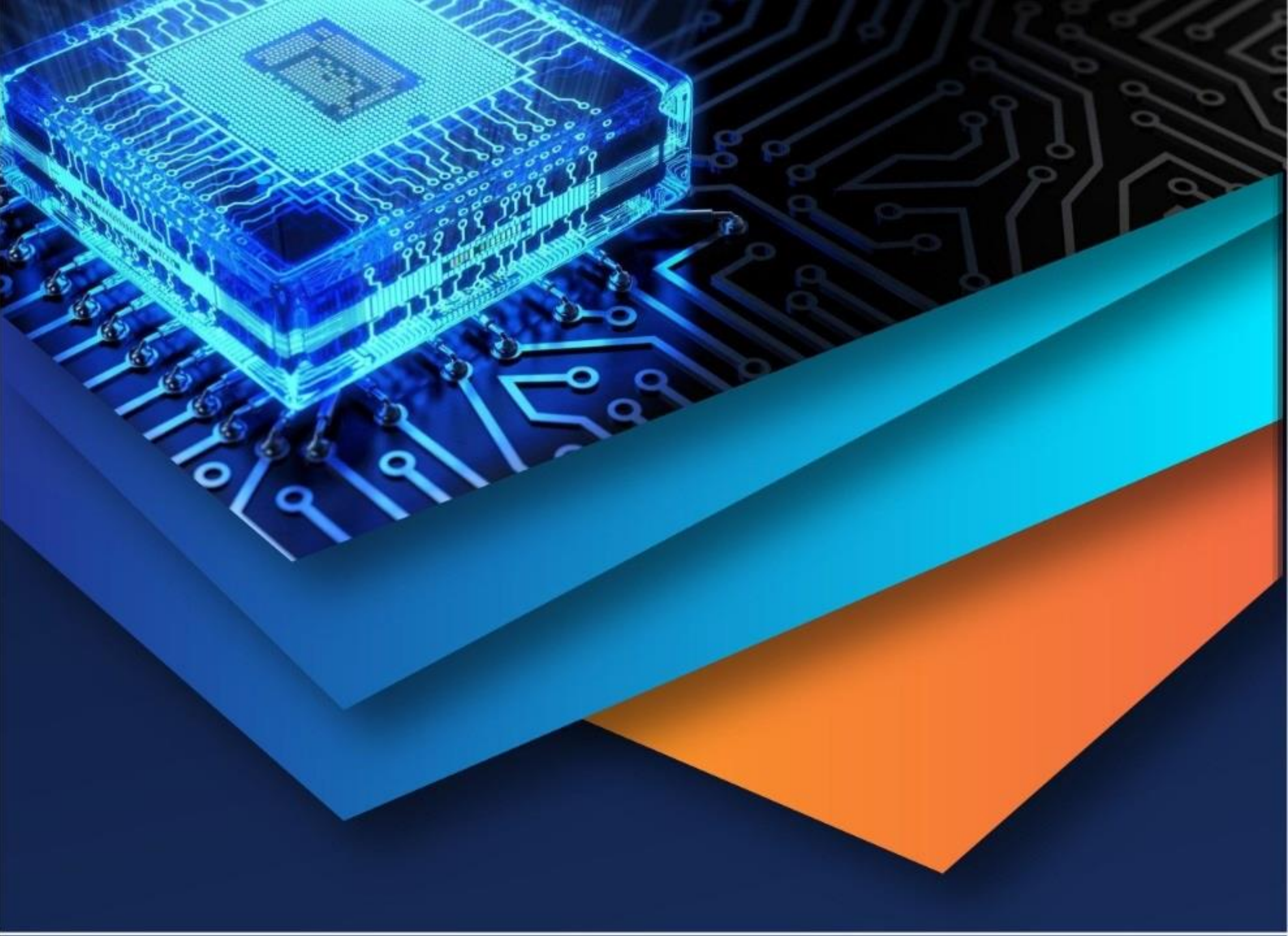

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