Effectiveness of different Crack Depth at various Locations of Steel Frame Structure

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Abstract - *The cracks in the building can cause severe damage to the structures serviceability. The cracks is in the structure are caused due the poor construction, improper structural design which leads to the collapse of the member or in some cases partial or entire collapse of the structure. So the study of the cracks and its behavior is very essential in the design of the structure. The cracks in the structures at different location and at different depth varies the frequency, time period and displacement. The current study involves the analysis of a steel frame structure using SAP-2000 software tool. The crack depth of 5mm and 10mm are introduced into the structure at various level and the parameters such as frequency, time period and displacement are studied. Then multiple cracks of 5mm and 10mm are introduced. The study shows that cracks at lower storey near to support causes more displacement when compared to cracks at higher storey.*

Key Words: Crack depth, Natural Frequency, Mode Shape, Harmonic analysis, SAP, Steel frame etc...

1. INTRODUCTION

In current days, with the headway in innovations, multistoried structures are being worked at a quick rate. Because of quick development rehearses, there might be flaw in development which may make harm the structure after a specific time frame. Auxiliary harm is characterized as the adjustment in the basic parameters of structures that may influence its present or future exhibitions. Damage is defined as the deviation in original material or geometric properties of a structure due to cracks, corrosion, fatigue which causes displacements, vibrations. For the safety of proper purposes, persistent upkeep and fix works for the structures are required. There were two physical based method such as mode shapes and natural frequency as these methods were widely adopted in the detection of damage procedures for the detection of single and multiple cracks and these methods are the vibration-the adjustment in modular curvatures and common frequencies to characterize the damage likelihood

based structural health monitoring system which manages capacities.

The parameters such as natural frequencies and mode shapes can be obtained from the vibration-based damage detection methods i.e., Experimental studies or through analytical studies. The natural frequencies and modal shapes are called as modal parameters or eigen parameters. Natural frequencies provide the stiffness properties whereas modal parameters due to vibration give the deformed shape of the structure. And these modal parameters don't give the location of the damage directly in any damaged structures. These modal parameters serve as a basis for finite element model updating, structural damage detection, structural safety evaluation. Hence suitable algorithms are necessary for the detection of local damage and its quantification in various structures.

In general, any damage detection techniques involve a forward problem and an inverse problem. The modal parameters provide solution for the forward problem. The inverse problem consists of determination of damage parameters like crack length or location from the measured structural response.

1.1 Objectives

The main objective of the present study is to analyse the simple harmonic response of the steel frame with and without cracks at different locations.

1. To study the simple harmonic response of the healthy steel frame structure.
2. To study the response of the steel frame structure for 5mm crack width at various locations.
3. To study the response of the steel frame structure for 10mm crack width at various locations.
4. To study the response of the steel frame structure for multiple cracks

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1.2 Methodology

Simple harmonic analysis is carried out on a healthy steel frame and a frame with cracks at different locations and depths and for multiple cracks using SAP-2019 software. From modal analysis first three i.e., 1st, 2nd, 3rd natural frequencies and mode shapes are obtained.

Table-1: Properties of the steel frame

Steel Frame

Length of the frame	3m
Width of the frame	3m
Total height of the frame	9m
No. of bays	Single bay
Steel section	200x10mm
Each storey height	3m
Modulus of elasticity	210 GPa
Crack depth	5mm,10mm

2. Modal Analysis

The essential accessory in vibration analysis is modal analysis. To figure out the Eigen frequencies and mode shapes of structures and its structural element is the main purpose of the modal analysis. Natural frequencies and mode shapes of both cracked and un-cracked frames by using SAP software has been obtained.

For harmonic analysis following steps considered are as follows:

- Developing the model (steel frame) and defining material properties and section properties.

- Meshing and assigning the boundary condition.

- Harmonic aid is utilized to measure outcome for displacement, natural frequency.

- Set harmonic analysis and analyze the model.

- Evaluate the outcome in the fashion of pictorial representation.

2.1 Equation of motion

$M\ddot{X} + C\dot{X} + KX = F(t)$ - For Damped system.............. (1)

$M\ddot{X} + KX = F(t)$ - For Un-damped system............. (2)

$M\ddot{X} + KX = 0$ – Free vibration..................................... (3)

Harmonic Analysis

If load is harmonic the response is also harmonic

$F(t) = F_0 e^{iwt}$ .... (4)

Where,

$e^{iwt} = \cos\omega t + i\sin\omega t$

ω – Excitation frequency

t – Time period; K – Stiffness matrix; M – Mass matrix;

$C = \alpha M + \beta K$ – Damping matrix

Excitation Force $F(t) = F_0 e^{iwt}$

Corresponding response is expressed as

$X(t) = X_0 e^{iwt}$ .... (5)

$\dot{X}(t) = X_0 iw e^{iwt}$ .... (6)

$\ddot{X}(t) = X_0 i^2 w^2 e^{iwt}$

$= -X_0 w^2 e^{iwt}$ .... (7)

Substituting equations (5), (6), (7) in (1)

$M\ddot{X} + C\dot{X} + KX = F(t)$

$\{M \times (-X_0 w^2 e^{iwt}) + C \times (X_0 iw e^{iwt}) + K \times (X_0 e^{iwt})\} = F_0 e^{iwt}$

$X_0 \times (-M \times w^2 + C \times iw + K) = F_0$

$$X_0 = \frac{F_0}{(-M \times w^2 + C \times iw + K)}$$

$(X_0 = X_0(\omega)$ For $F_0 = 1)$

$$X_0(\omega) = \frac{1}{(-M \times w^2 + C \times iw + K)}$$

The progressed strength and weight matrix due to destructions are demonstrated as

$(K) = (K_0) \pm (\Delta K); \qquad (M) = (M_0) \pm (\Delta M)$

Where,

(ΔK) = Alternate in strength due to harm

(ΔM) = Alternate weight due to harm

(K_0) = Unique strength matrix of size n x n

(M_0) = Unique regular weight matrix of size n x n

As a result damping matrix can be acquired as
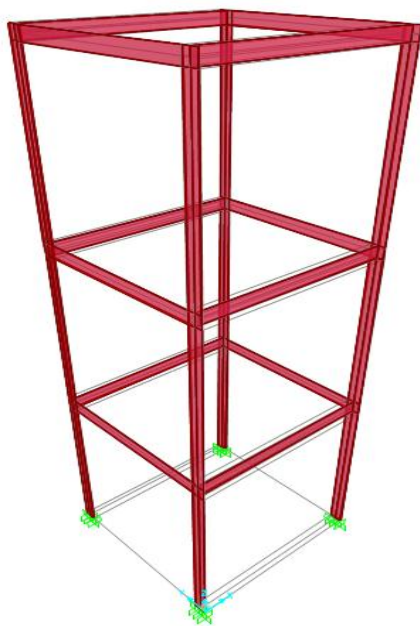$(C_0) = \alpha(M_0) + \beta(K_0)$

Fig -1: 3D view of Healthy Steel Frame

3. Results and Discussion

In the present study steel frame with, without cracks and multiple cracks are developed as shown in fig in the above chapter. Natural frequencies, mode shapes and displacement of cracked and un-cracked frames is gained by performing modal analysis using SAP2000 software. The crack locations are considered for the frame models as 0.5, 1.5, 2.3, 3.5, 4.5, 5.3, 6.5, 7.5, 8.3m from the support for steel. For these crack locations crack depth considered are 5, 10mm.The comparison for displacement v/s frequency of healthy and cracked beams at different locations graphs has been plotted below.
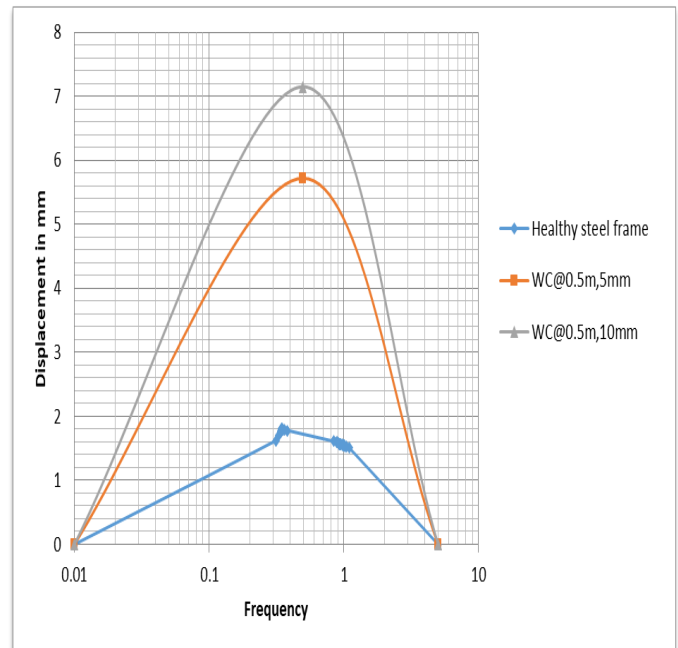

Fig -2: The comparison graph of Frequency v/s Displacement of Healthy steel frame and frame with cracks of (5,10mm) depths at location 0.5m

3.1 It has been observed that the maximum time period is for healthy frame structure of 3 mode shapes. As the crack depth increases the time period of the structure decrease. The percentage reduction for 10mm crack at 0.5m is 27.78% compared of healthy frame.
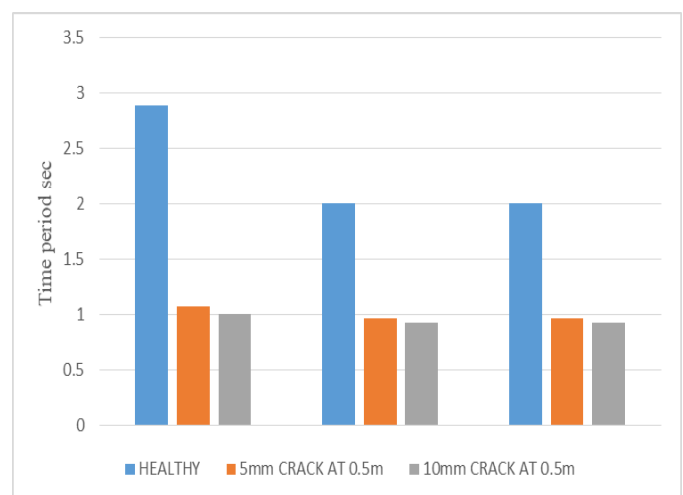

Fig- 3: Comparative graph for Variation of Time period of un-cracked and cracked steel frame for 3 mode shapes at identical crack locations of different depths

4. Conclusions

Based on the results obtained the variations of Eigen frequency and Eigen vectors because of presence of crack on steel frame structure, following conclusions are done:

- Variations in natural frequencies and mode shapes are due to variation in crack specifications such as crack location and crack depth.
- Crack existing near to the fixed end support of the steel frame have greater increase in natural frequency and displacement than compared to crack existing away from the fixed support.
- With increase in depth of the crack at constant location there is slight increase in displacement, frequency and decrease in time period.
- With increase in number of cracks the natural frequency, displacement increases and time period decreases.

4.1 Scope of future work:

- The effect of cracks can be studied by implementing cracks in beam element.
- The effect of multiple cracks can be studied by implementing cracks in columns and beam elements simultaneously.

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