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A Review on "Damage Assessment of Laterally Restrained Steel Beams Using Elemental Strain Energy"

Rushikesh Gurpude[1] | Sanjay Denge[2]

[1]Department of Civil Engineering, V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India
[2]Assistant Professor, Department of Civil Engineering, V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India
Corresponding author Email ID: gurpuderishi@gmail.com

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ABSTRACT

This paper presents the analytical investigation of laterally restrained built up steel beam under dynamic response using finite element software ABAQUS. The main objective of this study was to estimate the mode shapes and mode shape curvature of the laterally restrained built up steel beam. The three parameters such as modal frequencies, mode shapes and mode shape curvature are suggested for identifying the damages in built up steel beam. Damage assessment is done by linear perturbation free vibration study using finite element software ABAQUS. The frequency extraction methods for built up steel beam was done in ABAQUS to get the dynamic response. The Lanczos eigen solver was used for finding the mode shapes. Eigen value extraction, the natural frequencies and the corresponding mode shapes of a system were studied.Structural steel is used in load bearing frames in buildings , and as members in trusses, bridges, and space frames. It requires a fire resistance and corrosion protection. The main advantage of structural steel are strength, speed of erection, prefabrication and demountability. Damage accumulated in the structures due to its environmental loadings such as wind, snow, and ice. Structural Health Monitoring refers to the process of implementing damage detection and characterization strategy for engineering structures.

Keywords-ABAQUS, Laterally restrained steel beams, Strain Energy, Damage Assessment, Finite Element

1. INTRODUCTION

Damage is defined as any internal change in a system that may prevent the system to perform the way it was intended to. It is undesirable and should be detected in its earlier stage itself to prevent catastrophic failure. Thus the process of identifying the presence of damage and its characterization are collectively known as damage assessment. Structural Health Monitoring (SHM) is the process of implementing a damage detection and characterization strategy for engineering structures, which is of most important concern now-a-days.Structural steel is used in load bearing frames in buildings, and as members in trusses, bridges, and space frames. It requires a fire resistance and corrosion protection. The main advantage of structural steel are strength, speed of erection, prefabrication and demountability. Damage accumulated in the structures due to its environmental loadings such as wind, snow, and ice. Structural Health Monitoring refers to the process of implementing damage detection and characterization strategy for engineering structures. Here damage is defined as the changes to the material and geometric properties of a structural systems, including changes to boundary conditions and system connectivity, which adversely affect the system performance. The process of implementing damage detection and characterization strategy for engineering structures is known as structural health monitoring. Here damage is defined as the changes to the material and geometric properties of a structural systems, including changes to boundary conditions and system connectivity, which adversely affect the system performance. Here, the dynamic response of the steel beam are identified by using finite element software. This research was to derive an innovative method to assess structural damage in steel truss bridges. First, it proposed a new damage indicator that relies on optimising the correlation between theoretical and measured modal strain energy. Second, in order to support the proposed damage indicator, the research studied the applications of two state of the art modal identifications techniques.Structural steel is used in load bearing frames in buildings , and as members in trusses, bridges, and space frames. It requires a fire resistance and corrosion protection. The main advantage of structural steel are strength, speed of erection, prefabrication and demountability. Damage accumulated in the structures due to its environmental loadings such as wind, snow, and ice. Structural Health Monitoring refers to the process of implementing damage detection and characterization strategy for engineering structures. 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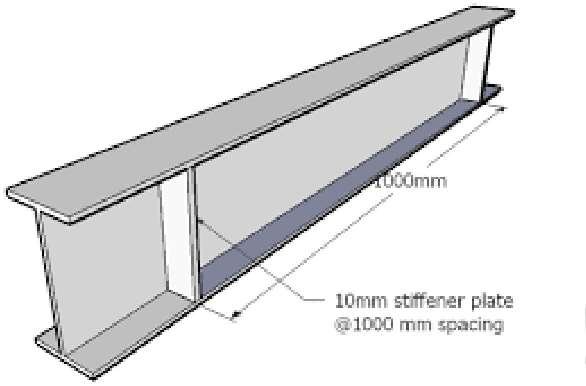
(C.Zang et al.,2007) reduced frequency domain correlation criteria by means of Revised Manuscript Received on April 12, 2019. Sangeetha K, PG student, Department of Civil Engineering, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India. Vimala S, Professor, Department of Civil Engineering, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India. window averaging. Damaged indicators are calculated from a set of window averaged integration of GSC and GAC functions over the measurement of frequency range to establish the performance of correlation measures using damage identification. (Ahmed A.Elshafey et al.,2011) conducted an experimental study using hinged-fixed beam to illustrate to use and the feasibility of the technique is used for identifying the location of the damage and the Frequency Response Function is used to identify the existence of damage and location of damage. (Miroslav Pastor et al., 2012) they compared the quantitative correlation between the dynamic response of the modal test data. (V.Srinivas et al., 2013) Damage identification studies are carried out based on the dynamic properties of the structures such as frequencies and mode shapes using advanced techniques ANN and GA. And also by using combined objective function of frequencies and mode shapes ,GA is used to locate and quantify the damages. (Resmi G et al.,) presents multi criteria damage approach is based on modal parameters extracted from the free vibration responses for laterally restrained steel beam. Finite Element Method ABAQUS to quantify local damages using extracted mode shapes and curvature mode shapes, damage quantification using MAC and CAC is found to predict the intensity of damages in the structures to detect the damages. (Richard Frans et al.,2017) focuses on the identification and location of the damage of structures using two techniques, i.e., mode shapes and damage locating vector methods. Both the methods are applied to shear building and plane truss structures.



OBJECTIVES

- Damage assessment is done using linear perturbation free vibration study in ABAQUS, a Finite Element software, by introducing damage in the form of localised cross section reduction.
- Single and multiple damage conditions are analysed using dynamic response parameters such as modal frequencies, mode shapes and mode shape curvature.
- Treat the main loading bearing elements of structures, viz beam and plate, and complete bridge structures for damage assessment under different damage scenarios.
- Demonstrate the feasibility and capability of the proposed procedure through numerical examples.

2. LITERATURE REVIEW

Sr. No	Paper Title	Findings
1	Damage Assessment of Laterally Restrained Steel Beams using Dynamic Response [ResmiG. and Baskar K.]	This paper uses the same correlation criterion for correlating the changes in displacement mode shapes of baseline and damaged beam, thereby quantifying the damage globally. A new correlation method is introduced for curvature mode shape, Curvature Assurance Criteria (CAC), to quantify the change of curvature mode shape curve from baseline undamaged one, to show the effect of all localised damages in the structure. MAC and CAC together provide an overall idea of total damage in the beam.
2	Behaviour of restrained steel beam at elevated temperature – parametric studies [Ahmed Allam and Ali Nadjai]	This paper aims to investigate computationally and analytically how different levels of restraint from surrounding structure, via catenary action in beams, affect the survival of steel framed structures in fire. This study focuses on examining the mid-span deflection and the tensile axial force of a non-composite heated steel beam at large deflection that is induced by the catenary action during exposure to fires.
3	Research on Laterally Restrained Built Up Steel Beam Under Dynamic Response [Sangeetha K, Vimala S]	This paper presents the analytical investigation of laterally restrained built up steel beam under dynamic response using finite element software ABAQUS. The main objective of this study was to estimate the mode shapes and mode shape curvature of the laterally restrained built up steel beam.

Dynamic response-

Dynamic response is response of the structure to dynamic load. Dynamic loads induce acceleration and the resisting forces and whereas the static loads induce only resisting forces. The dynamic response of the system gives an idea, that how the system will behave under the particular type of dynamic force. This is very essential in designing to resist the earthquake vibrations. The vibration will respond to dynamic force of particular frequency. This response are investigated at the different strain rates. It also subjected to cyclic loading. Here, to find the Mode shapes, Curvature mode shape, Modal assurance criteria and Curvature assurance of the built up steel beam.

3. PROPOSED METHODOLOGY

This research was to derive an innovative method to assess structural damage in steel truss bridges.

1. First, it proposed a new damage indicator that relies on optimising the correlation between theoretical and measured modal strain energy.

2. Second, in order to support the proposed damage indicator, the research studied the applications of two state of the art modal identifications techniques.

- Fast computers and sophisticated finite element techniques have enabled the possibility of analysing hitherto intractable problems in structural engineering while simplifying the analyses of other problems.
- This research study uses dynamic computer simulation techniques to develop and apply a procedure using non-destructive vibration based methods for damage identification in the chosen structures.
- Limited experimental testing is carried out to establish the hypothesis and validate the computer model.

1. Model both baseline and damaged laterally restrained beams in FE software ABAQUS.
2. ii. Conduct a linear perturbation free vibration analysis in ABAQUS for built up steel beam to get the dynamic response.
3. iii. Extract modal parameters such as frequency and mode shape using Lanczos eigen solver of ABAQUS.
4. iv. Export the mode shape thus obtained to MS Excel to calculate the mode shape curvature.
5. v. Identify the intensity of change in structural response using Modal Assurance Criteria (MAC) and CurvatureAssurance Criteria (CAC).

VERIFICATION OF ABAQUS MODEL-

The ABAQUS model is verified by using the classical solution of free vibration of continuous system. The Euler Bernoulli's beam theory is one of the basic assumptions used in the differential equation of continuous system. The standard result of continuous system are derived for the beam. The fundamental frequency of a beam is obtained as

$$f = \frac{\pi}{2L^2}\sqrt{\frac{EI}{A\rho}}$$

where,
f-fundamental frequency,
L-Length of beam,
E-Young's Modulus of material,
I-Moment of Inertia,
A-Area of cross section and
ρ-Density of material.
ISMC 350 section is considered with 2m length of beam,
$E=210\times10^9$ N/m^2,
$I=10008\times10^4$ mm^4
$A= 5366 \times 10^4$ m^2. From equation, the fundamental frequency is obtained as 277.385 Hz.

FE modelling-

The baseline and damaged laterally restrained steel beams are modelled in FE software ABAQUS, as a 3D conventional shell element with six degrees of freedom per node. The damage is provided in such a way to simulate corrosion by reducing the cross sectional area, the details of which are given in succeeding sections.

4. CONCLUSION

In this paper, the damage identification is based on modal parameters which were extracted from linear perturbation free vibration response for laterally restrained built-up steel beam. This method is used to develop an accurate beam using ABAQUS, and to quantify the damage using the extracted mode shapes and curvature mode shapes. The important conclusions of the steel beam are as follows, Damage quantification using MAC and CAC is found to predict the intensity of damage in the structure. MAC is a global damage quantifying parameter which entirely depends on mode shape, while CAC is a local damage quantifying parameter which entirely depends on curvature mode shape graphs. CAC can be used as a tool for quantifying the change in curvature mode shape graph due to all localised cross sectional damages. The proposed method is able to identify damage in laterally restrained built up steel beam under dynamic response.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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