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Finite element model calibration of steel frame buildings with and without brace

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ABSTRACT

This paper focuses on both the monitoring of the dynamic response of steel buildings with and without brace elements and the importance of model calibration on the steel buildings. The study involves the application of modal testing techniques to collect data from a three-story steel frame building model tested at the Civil Engineering Department of Karadeniz Technical University. The experimental measurements are performed under randomly generated loads. Dynamic characteristics (natural frequencies, mode shapes and modal damping ratios) obtained from bare and braced steel frame models are compared with each other. The initial analytical models of the steel model for bare and braced cases are developed and calibrated according to the experimental measurement results. The calibration process aims to minimize the differences between experimental and analytical natural frequencies. The connection rigidities of the beam-to-column are selected as a calibrating parameter in the model calibration process. It is observed that the brace elements cause an increase in the natural frequencies due to the increasing stiffness as well as the changes in the modal behavior. Static analyses of the steel frame model for bare and braced cases are carried out to emphasize the importance of the model calibration by comparing maximum lateral displacements. The calibrated analytical models produce larger lateral displacements than the initial models. The results reveal that the dynamic behavior of steel structures should be evaluated considering the calibrated models for safety of these structures.

1. Introduction

The actual dynamic behavior of structures may differ from the designed case. This arises from not only idealizations in the design stage but also some inevitable errors in the construction stages. In recent years, the vibration monitoring of structural systems has emerged as an active field in civil engineering. This provides engineers the opportunity to estimate the actual behavior of structures and take action on undesired cases by calibrating and updating analytical models.

Steel structures are preferred for light weight and construction speed. The steel frame buildings are generally strengthened by brace elements to increase stiffness. In many cases, it may be difficult to predict the actual behavior of steel structures because of the fact that there are many connections on the beam-to-column joints and brace elements. The connection rigidity of frame elements affects the static and dynamic behavior of steel structures. The steel structures are generally designed to be pinned or fully rigid connections. However, the connections can't behave as designed [1]. In reality, connections in steel frames are mostly semi-rigid [2]. Research into the testing of various types of common connections as well as on the numerical techniques of completing an analysis of flexibly connected steel frames were developed by Pogg [3].

Kohoutek [4] tested semi-rigid connections using the dynamic non-destructive investigation of connection rigidity. It was presented by Dyke et al. [5] the second phase of the activities of the Structural Health Monitoring Task Group, involving the application of structural health monitoring techniques to data obtained from a four-story steel frame structure tested. The study also involves damage detection which was simulated by removing brace elements within the structure. The natural frequencies and corresponding mode shapes were identified for different damage scenarios. The dynamic response of semi-rigid frames was modeled by linear elastic rotational springs in the study of Ozturk and Catal [6] which reduced coefficients and lateral rigidity values to represent the real behavior of frames and determined the values for each frame, individually. Comparison of response characteristics of five different multi-story frames with reference to their modal attributes resulted in an indication that connection flexibility tends to increase vibration periods, especially in lower modes. A study in determination of the quality of the semi-rigid connections by considering changes in dynamic characteristics of steel structures was presented by Türker et al. [7]. The investigations involve three scaled models: columns with box cross-sections, columns with rectangular cross-sections, and a 2D frame. The investigations consist of experimental measurements,

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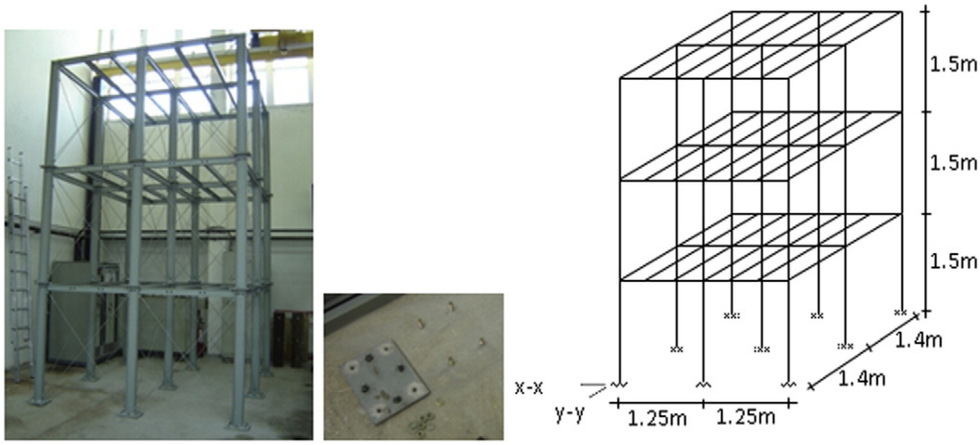

Fig. 1. Some views of the steel building model.

analytical modeling and comparison of the results to get connection rigidity. It was concluded in this study that creating a fully rigid connection is very difficult. It is very effective to evaluate the connection rigidities on the steel structures by considering the changes in the natural frequencies.

The presented study aims to evaluate the effects of model calibration on the dynamic characteristics of steel frame buildings with and without brace elements. The investigations are carried out on a three-story frame building model in the laboratory of the Civil Engineering Department of Karadeniz Technical University. It is observed from measurements on the frame building model that the braces cause an increase in the natural frequencies by stiffening the model. The experimental and analytical behaviors of the steel frame models with and without braces are not identical. The model calibration process by minimizing the difference between the natural frequencies is applied to the initial analytical models. By this way, the realistic analytical models of the steel building model are attained for bare and braced cases.

2. Modal testing

Modal testing is a form of vibration testing of an object where the natural frequencies, modal damping ratios and mode shapes of the object under test are determined. A modal test consists of not only an acquisition phase, but also of an analysis phase as well. The complete process is often referred to as experimental or operational modal analysis depending on the source of vibration used in the test [8,9].

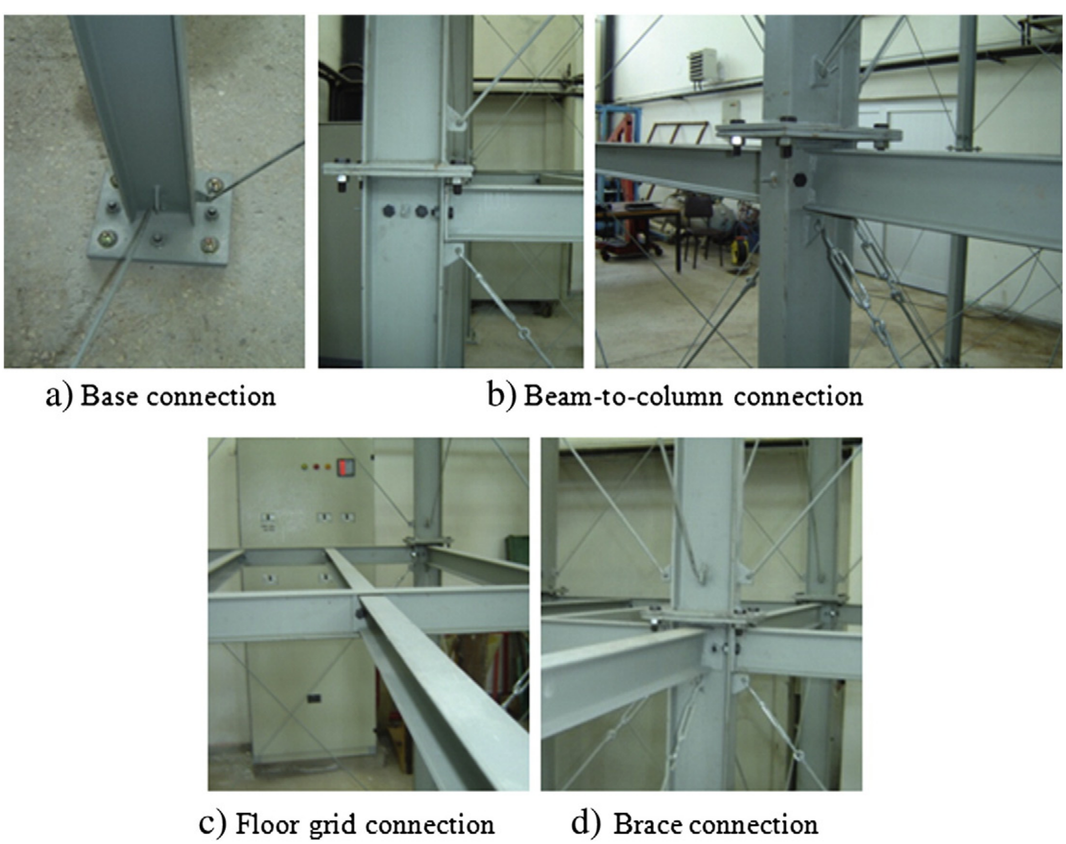

Fig. 2. Some views of connections on the steel model.