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## Modal System Identification Technique in Structural Damage Assessment

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## Summary

A modal damage detection and assessment technique of multi-story, multi-bay framework is presented. The fundamental natural frequency and mode shape of the structure are the only modal information necessary in this approach. The *equivalent relative lateral story stiffness* ( $R_{i,i+1}$ ) is chosen as a physical damage predictor parameter, which seems to be sensitive enough to offer the best information for occurrence, localisation and extent of the structural damage. It is assumed that the baseline parameter values are known. A data perturbation scheme is used both for the baseline and for the damaged structure, to establish the threshold above which damage can be confidently discerned from noise. To examine and illustrate the proposed damaged assessment technique, a numerical simulation study is performed and different damage types were considered.

**Keywords:** System identification theory, damage assessment, modal damage detection..

## 1. Introduction

One of the most challenging task for modern day structural engineer is to control the behaviour of the structure during its life time and, from time to time, to evaluate the structural damage, in order to ensure the safety of the construction. The system identification (SI) method seems to be the best tool to accomplish this task [1-3]. A variety of techniques for evaluating damage in structural systems have emerged and evolved in recent years. In this paper, a modal system identification technique is presented. The fundamental natural frequency and mode shape of vibration are the only modal measured information necessary to identify the occurrence, location and extent of the damage. The damage is defined as any change in the performance of the structure. For a structural system, such change means a reduction in its carrying capacity, which can be expressed by the reduction in flexural rigidity  $EI$  of the structural members. With this definition of damage, one must look for changes in certain physical parameters of the structure, between two time-separated moments. The choice of physical parameters, which have to be related to the measured modal characteristics of the structure, is of major importance. The *equivalent relative lateral story stiffness* ( $R_{i,i+1}$ ) is chosen as physical damage predictor parameter, which seems to be sensitive enough to offer the best information for occurrence, localisation and extent of the structural damage. It is assumed that the baseline parameter values

are known. The accuracy of such a model is generally impaired by the presence of random noises such as modelling errors, unmeasurable disturbances, and measurement errors. A data perturbation scheme is used both for the baseline and for the damaged structure, to establish the threshold above which damage can be confidently discerned from noise. To examine and illustrate the proposed damaged assessment technique, a numerical simulation study on a three-story three-bay frame and a five-story two-bay frame is performed and different damage types were considered. We chose a simulation study over a real case study because our aim is to quantify the performance of the proposed technique, not simply to illustrate its use. Simulation is a method of controlled experimentation that allows such a quantification.

## 2. Conclusion

A new damage detection and assessment technique is presented. This study has shown that the chosen structural parameters, i.e. the equivalent relative lateral story stiffness, are sensitive even to not very large damage, and allows to localise the damaged stories. The damage localisation is based on an output-error parameter estimation procedure. The constitutive parameters of the structural system are estimated using a frame analysis model with known topology and geometry. The measured fundamental modal parameters, frequency and shape mode vector, are the only data necessary for damage detection and assessment, and the number of necessary measurement points is equal to the level number. The procedure was illustrated and tested using Monte Carlo simulation on two examples. The procedure of using noise perturbation on baseline structure proved to be a reliable method for assessing whether damage is detectable above the noise in the measurements. In all of the cases studied, the most severely damaged stories were always identified with great certainty.

Although the feasibility of the proposed procedure for structural damage assessment of multi-story multi-bay structure based on the measured modal data has been demonstrated, many related issues have not yet been addressed and additional research will be required.

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