Parameter Identification of Wooden Structures Based on Past Damage Data using DEM Simulation

University of Tokyo Student Member Muhammad Waheed SARWAR
University of Tokyo Fellow Yozo FUJINO

Introduction

Shaking of timber houses by previous earthquakes has yielded a significant amount of data on ground motions and building damage. However, most of available damage data is qualitative that has resulted in limited understanding of behavior of wooden structures under seismic loading. Understanding of wooden structure behavior requires thorough knowledge of structural properties. To interpret the structural properties, analytical and numerical models of wooden structures are critically needed. This paper presents the use of numerical simulation, Distinct Element Method (DEM), for identification of structural properties based on available damage data. A damage criterion is presented for classification of simulation results. Using proposed criterion, relationship between frequency of wooden structures and joint strength for different damage levels is established. Finally, joint strength distributions are identified using developed relations based on 1995 Hyogoken-Nanbu Earthquake damage data.

Theoretical background

Simulation of the collapse process is done using 3D distinct element method[1]. In DEM, a material is considered as an assembly of individual particles and the spring-dash pot assembly represents contact between particles. Since the breakage of the frame members is seen rarely in past earthquakes so the frame members are considered to be rigid elements for the analysis purposes. The joint model represents the connection between the structural elements. Joint is considered broken when fracture criterion is met. Once joint is broken, the contact between the elements is evaluated using the contact model. The time history of displacement and rotation of members is obtained step by step in the time domain by numerical integration of governing equations[1].

Structural Model and Analysis

A typical double story model frame structure is used to determine response of wooden houses with different structural properties. A 3D view of the model is shown in Figure 1.A series of analyses is performed for frequencies ranging from 2.2 Hz to 4.1 Hz with different joint strengths of model structure. Kobe earthquake is used as seismic input. Response of first story corner “a” is recorded. For each case, simulation results are analyzed to determine extent of damage using damage criterion[2] as shown in Figure 2 and then limiting values of joint strength for different damage levels are calculated.

Using threshold joint strength values at different frequencies; relations between frequency and joint strengths are developed[2] as shown in Figure 3. Being the linear relations, these can be easily extended to evaluate joint strengths at higher frequencies.

Identification of Joint Strength

Using damage survey data in Higashi-Nada Ward due to the 1995 Kobe Earthquake, wooden houses are divided into four groups based on construction age. The distribution of natural period of wooden buildings is modeled as standardized normal distributions and that of joint strength is modeled as lognormal distribution based on the damage survey data[3]. Knowing Frequency-Joint strength relations and natural period distribution, Monte Carlo method is used, for identification of joint strength distribution (μ,σ^2) so that the error between the simulated and actual damage levels is minimized. The identified values of the joint strength are summarized in Table 1 and comparison of simulated and surveyed results are shown in Figure 4 for first age group. A good agreement between simulated and actual damage to wooden houses is observed for identified joint strength values.

Keyword: Distinct Element Method, Kobe earthquake, Parametric Identification, Joint Strength, Wooden Structures
Address: Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8656, Japan; Tel: 03-5841-6099, Fax: 03-5841-7454
Email: sarwar@bridge.t.u-tokyo.ac.jp, fujino@bridge.t.u-tokyo.ac.jp

Conclusions

Distinct Element Method (DEM) is successfully employed to perform parametric studies on seismic performance of wooden structures. The numerical simulation results are used with the field data to determine one of the important structural properties, i.e., joint strength that otherwise would have not been possible. The joint strength distributions thus obtained are function of construction age group, and can be used, in future, for development of fragility curves numerically.

Acknowledgement

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References

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Figures and Table

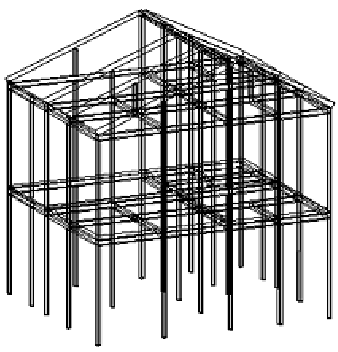

Fig. 1 3D view of Model Structure

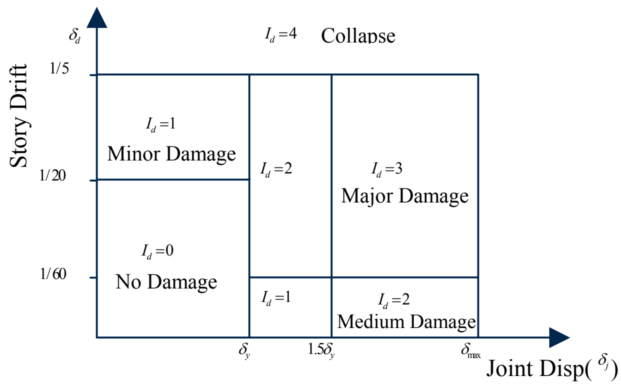

Fig. 2 Damage Criteria for Damage Classification

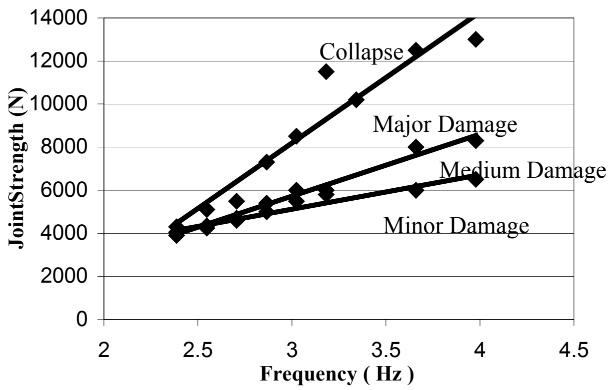

Fig. 3 Relationship between frequency and joint strength

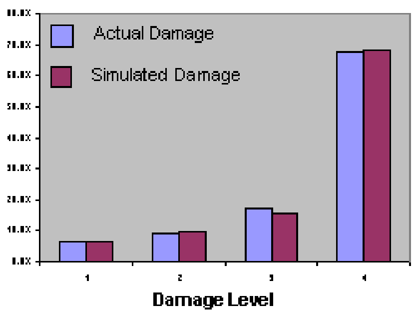

Fig. 4 Actual and simulated damage for construction period (~ 1948)

Period	Joint Strength Dist.	
	Mean (μ)	St. Dev. (σ^2)
~1948	5000	750
1949~1960	5000	850
1961~1974	5500	2000
1974~1985	6500	3200

Table 1 Identified joint strength parameters