APPLICATION OF NON-LINEAR FINITE ELEMENT DYNAMIC ANALYSIS FOR TRADITIONAL WOODEN STRUCTURE

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ABSTRACT: In this study, we performed the shaking table tests of traditional wooden structure such as temples and non-linear finite element dynamic analysis of the shaking table tests. In the experiment, the predominant frequency and amplification ratio in the case of large earthquake motion are lower than that in the case of small one because the slippage and uplift of columns were occurred in the case of large earthquake motion. In the analysis, there is a difference of predominant frequency compared with the experiments, however, the qualitative trend of experiments could be simulated.

KEYWORDS: Non-linear finite element analysis, Shaking table test, Anisotropy, Traditional wooden structure

1 INTRODUCTION

Traditional wooden architectural structures in Japan constructed with columns, Nuki (beams) and Kumimono are generally considered to have superior deformability and damping properties. However, very little study has been performed on the behaviour of traditional wooden architectures in earthquakes and so elucidation of the mechanisms involved in their dynamic behaviour remains incomplete. In this study, we conducted the shaking experiments of models based on the traditional wooden architectural frames and attempted the application of 3D finite element analysis for the simulation of the shaking experiments.

2 SHAKING TABLE TESTS

2.1 SPECIMENS AND TEST SETUP

Figure 1 shows the detail of specimens. A total of three specimens of one-fifth scale were tested. Test specimens were designed based on the traditional wooden architectural structures such as temples. The section size and the height of columns are 60x60mm and 600mm, respectively. All specimens consist of columns, beams (called Nuki as the traditional name) and Kumimono (traditional joint of eave-supporting assemblies). Only specimen C has the board wall. Table 1 shows the experimental parameters. The published wave of JMA Kobe (1995 NS) phase, shortened by half in times scale, was used as the input earthquake motion.

Figure 1: Configuration of specimens

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Table 1: The experimental parameter

<table>
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<th>Name</th>
<th>Specimen</th>
<th>restraint condition</th>
<th>weight (N)</th>
</tr>
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<tbody>
<tr>
<td>A-1</td>
<td>A</td>
<td>free</td>
<td>900</td>
</tr>
<tr>
<td>A-2</td>
<td>A</td>
<td>pin support</td>
<td>1500</td>
</tr>
<tr>
<td>A-3</td>
<td>A</td>
<td>free</td>
<td>900</td>
</tr>
<tr>
<td>A-4</td>
<td>A</td>
<td>pin support</td>
<td>1500</td>
</tr>
<tr>
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<td>B</td>
<td>free</td>
<td>1400</td>
</tr>
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<td>free</td>
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</tr>
<tr>
<td>C-2</td>
<td>C</td>
<td>pin support</td>
<td>1500</td>
</tr>
</tbody>
</table>

2.2 TEST RESULTS

Figure 2 shows the acceleration Fourier spectrum ratio between the top of specimen and the shaking table. The predominant frequency and amplification ratio of JMA_100% are lower than that of JMA_20%. This is because the slippage and uplift of columns were occurred in the case of JMA_100%.

![Graph showing acceleration Fourier spectrum ratio](image)

Figure 2: Acceleration Fourier spectrum ratio

3 NON-LINEAR FINITE ELEMENT DYNAMIC ANALYSIS

3.1 ANALYTICAL MODEL

Figure 3 shows the analytical model. Each element of the all members was individually modeled, their contact conditions were assigned, and the slippage and the separation were considered for all component material interfaces. Wood material model, taking anisotropy and material non-linearity into consideration, is used for material model.

![Analytical model](image)

Figure 3: Analytical model

3.2 ANALYTICAL RESULTS

Figure 4 shows the comparison between experimental results and analytical results in acceleration Fourier spectrum ratio. There is a difference of predominant frequency between experiment and analysis. In the analysis, however, the predominant frequency and amplification ratio of JMA_100% are lower that of JMA_20% as the same characteristic of experiments. Also the slippage and uplift of column are shown in the analysis (see in Fig.5).

![Comparison graph](image)

Figure 4: Comparison between experimental results and analytical results in acceleration Fourier spectrum ratio

![Uplift of column in analysis](image)

Figure 5: The uplift of column in analysis

4 CONCLUSIONS

In this study, we performed the shaking table tests of traditional wooden structure and non-linear finite element dynamic analysis of the tests. There is a difference of predominant frequency between experiment and analysis, however, we could simulate the qualitative trend of experiments.

ACKNOWLEDGEMENT

This study was supported by Kajima Foundation’s Research Grant. Special thanks to Harimashaji Koumuten Co., Ltd.