SEISMIC BEHAVIOR OF CYLINDRICAL WOODEN WATER TANK IN VIBRATION TEST

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ABSTRACT: Wooden tanks are used to preserve important parts of public facilities, such as hospitals. Ensuring the safety of these public facilities during earthquakes is important; there has been insufficient research on the seismic resistance of wooden water tanks. We performed vibration experiments using ground motions greater than 1g, and analyzed displacement response. The strain results and acceleration response were analyzed with the yield limit strain. The experiment results confirmed the safety of wooden tanks during earthquakes; the strain was about one-thirds the maximum yield limit strain.

KEYWORDS: Wooden tank, Vibration test, Strain, Earthquake, Sloshing

1 INTRODUCTION

1.1 HISTORY OF WOODEN TANKS IN JAPAN

In Japan, wooden barrels have a long history as tanks used for fermentation. Since the early 1900’s, tanks have been used for chemical industries, and individual content weights presently exceed 300t. While reservoirs of medium- and large-scale tanks have increased, damage to steel water tanks due to sloshing was reported after the 1964 Niigata earthquake [1]. Sloshing was also reported to have occurred during the 1995 Kobe earthquake and 2011 Tohoku earthquake. However, there have been almost no reports of earthquake damage to wooden tanks. A survey of the literature showed few experimental results on the behaviour of large scale earthquakes.

1.2 HISTORY OF WOODEN TANK STUDY

Fujiwara and Kitahara [2] of Japan Architectural Institute, conducted vibration tests with the 1940 NS EL Centro wave, and were only ones to measure the acceleration of a wooden tank, dynamic characteristics (particularly the vibration number and critical damping ratio), and a variety of effects of initial band tensions according to different wooden tank shapes.

1.3 NOVELTY AND CONTRIBUTION OF THIS RESEARCH

In this study, the numerical values observed from the wooden tank demonstrated vibrations and confirmed the tank’s safety during earthquakes. The safety was guaranteed based on the behavior of the wooden tank.

2 EXPERIMENT

2.1 STRUCTURE OF WOODEN TANK

For the structure of the wooden tank, hagi junctions were used to connect the side uneven boards on the side.

Figure 1: Connection method

Figure 2: Test wooden tank

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With ozone and mezane, steel bands are tightened, without the use of an adhesive binding. The rigidity of the structure was confirmed by the introduction of an initial stress. The wooden tank used hagi junctions to connect the uneven side boards, which called ozane and mezane.

2.2 OVERVIEW OF EXPERIMENT

Using the 10t vibration units owned by Kanazawa Institute of Technology, we conducted an oscillation experiment on a wooden tank with content weight of 3t that was designed and manufactured following the traditional method using natural dried domestic cedar. We performed a free vibration test, sweep test and strong motion test, to measure the displacements, accelerations, strains and water pressures of parts (wood and steel) of the wooden tank.

2.3 INPUT SEISMIC MOTION

Two input seismic motions were selected from recent major earthquakes: JMA KOBE 1995 NS motion from the 1995 Southern Hyogo Prefecture earthquake and MYG013110311446NS motion from the 2011 Tohoku earthquake. The time response of a tank-model installed on the top of a 15-story reinforced concrete (RC) building was simulated and the time response of a test tank during a motion experiment was observed.

3 RESULTS

3.1 EFFECTS ON WOODEN SIDE BOARDS

![Figure 5: Strain of sides boards](image)

At the bottom, the strain tended to increase as the fluctuating water pressure increased toward the bottom of the tank. The strain was found to be less than the strain at which the wooden boards would break.

3.2 EFFECTS ON STEEL BANDS AND BOLTS

![Figure 6: Band strain](image)

The strain on the bands tended to increase, especially for the bottom band, but it was small compared to the yield strain of the steel plate. A large strain occurred for the side plate, but the band could sustain the long-term allowable stress as it was about 1/3 of the maximum stress for the yield strain of the bolts.

4 CONCLUSIONS

This study reviewed the behavior of a wooden tank. We analyzed the displacement response, strain response and acceleration response. The impact on each member confirmed the safety of wooden tank. The strain was small compared with the yield strains for ground motions over 1g.

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