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Testing and Seismic Capacity Evaluation of a Typical Traditional Ottoman Timber Frame

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Abstract In Turkey, as well as in Balkan countries, examples of an extant housing tradition namely hımış, which was formed during Ottoman period, can still be observed. In spite of minor local differences according to geographical locations, these Ottoman *hımış* houses are distinguished with a number of common architectural and technical peculiarities that is worth to preserve. They have similar timber frame construction system with different infill materials. There are numerous reports claiming that the hımış houses are seismically more resistant than other construction types such as reinforced concrete and/or masonry structures. However, nearly all such reports are based on observations made after historical or contemporary earthquakes and lack quantitative engineering approach. For these reasons, within the framework of an ongoing research project, supported by The Scientific and Technological Research Council of Turkey (TUBITAK), coded 106M499, the seismic resistance of traditional timber frame houses in Turkey was investigated. A number of timber frames were tested in the laboratory under cyclic and reverse lateral loading, with and without infill. The results were reproduced with pertinent analytical work. As a result, it was shown that connections that were traditionally made with the sole use of standard nails were always the location of failure. In this paper, the results obtained for one of these frames is presented together with its capacity curve analysis to see whether strengthening is needed or not from seismic design point of view.

Keywords: Timber frame house, hımış, seismic resistance, capacity curve

Introduction

The term "Ottoman house" is used to define traditional timber frame structures, developed on the Ottoman land and spread all over Ottoman geography from Anatolia up to Balkans between 17th and 19th centuries, having certain architectural and technical features that have profoundly been studied by many scholars (Cerasi 1998, Günay 1998, Kuban 1995, Eldem 1984, Kafesçioğlu 1955). A vast number of studies reporting the seismic resistance of such timber frame structures exist in the relevant literature, based mainly on visual investigations made in-situ after many historic and contemporary seismic events in Turkey and abroad (Şahin 2007, Gülkan and Langenbach 2004, Tobriner 2000, Gülhan and Özyörük 2000). In most of these observations, it is reported that the *hımış* structures had no or little damage. The most affected parts of the damaged timber structures were masonry sections, such as masonry ground floor walls, chimneys etc., and what's more, the timber frame remained intact, even in the case that loosening of infill materials occurred. On the other hand, there have been numerous collapsed hımış houses in Afyon earthquake (Feb. 3rd, 2002), which raised questions about much favored hımış houses. Lack of maintenance, material degradation, and improper nailing are believed to be some of the factors contributing to the occasional poor performances of timber structures under seismic loading.

The aim of this paper is to present a part of the preliminary results obtained from the ongoing TUBITAK (The Scientific and Technological Research Council of Turkey). Research Project, which

intended to investigate the seismic resistance of timber structures. Within this framework the data obtained at the end of one of the frame tests was used for the capacity evaluation according to ATC-40.

Frame Tests

Within the abovementioned framework, first of all, a number of timber frames of different geometrical configurations which are all representative for the settlement they belong were chosen from Safranbolu. Safranbolu is a town located in the northwest of Turkey, where hımış tradition has long been living and which is included in the World Heritage List since 1995.

Figure 1. A view from Safranbolu showing hımış houses

Then, a test-set-up was designed in the Structural Mechanics Laboratory in Middle East Technical University (METU), which is basically composed of a foundation part, horizontal and vertical masts to keep the frame to be tested in-plane, a hydraulic piston and a load-cell. The frames were tested under reverse - cyclic loading. During the experiments, top lateral displacement, diagonal displacement, foundation displacement (if, any) were all measured by means of a number of LVDT's. Load prisms were used to simulate horizontal laod, safely held during the experiments by means of crane.

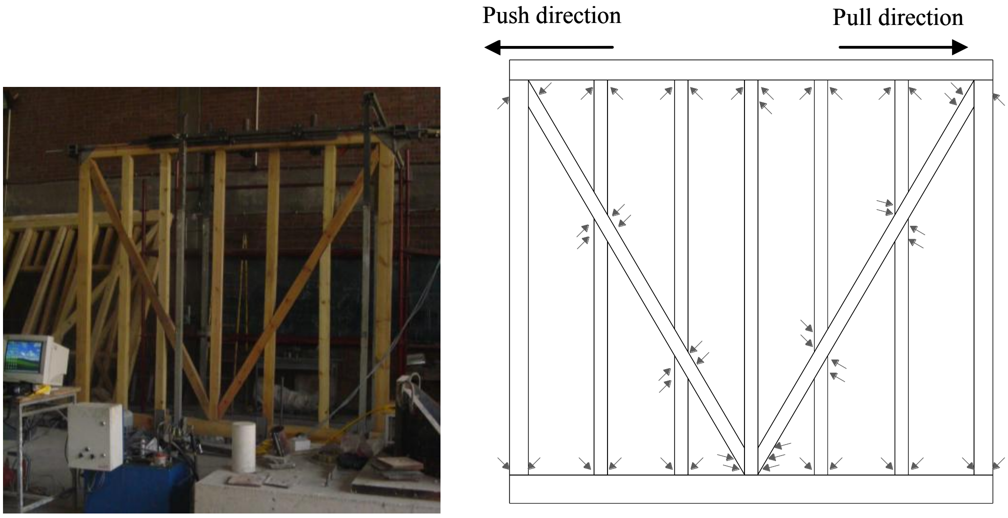

Figure 2: A typical timber frame taken from the case of Safranbolu (made of yellow pine and 360 cm x 330 cm [H x L]) (arrows represent nails at each connection)

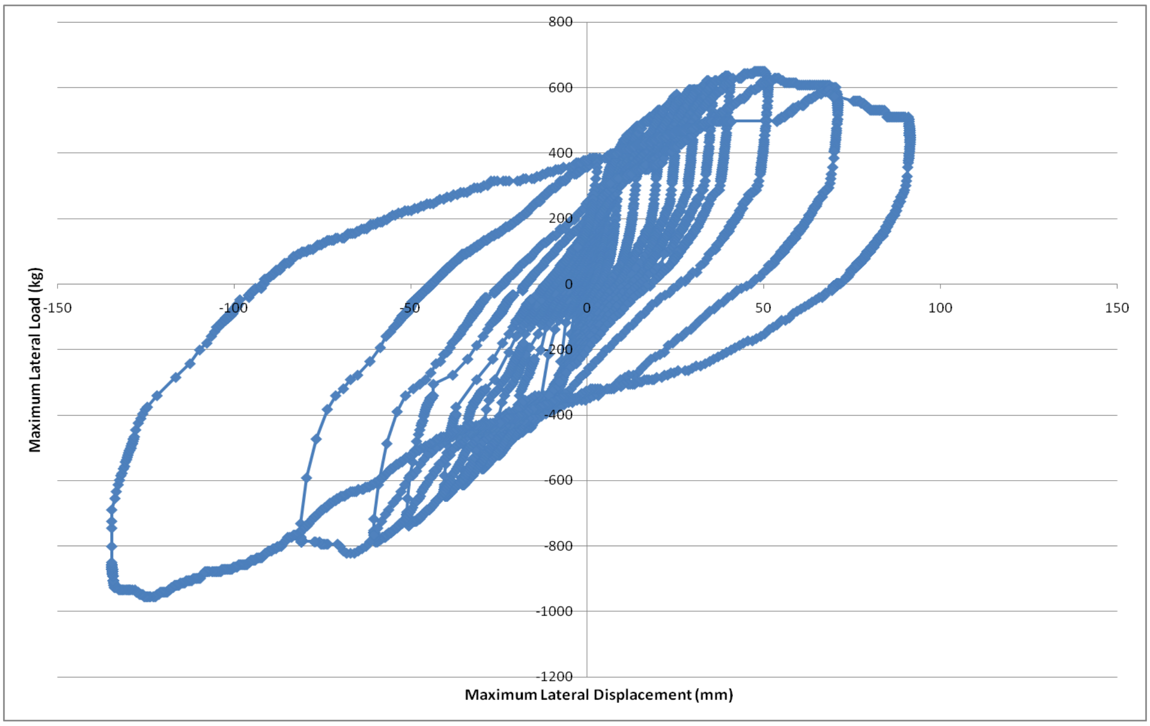

Figure 3: Lateral Displacement – Lateral Load relationship of the frame

Then, the load-displacement relation is used to evaluate the capacity of the frame in push and pull directions separately, by using the procedures proposed by ATC-40. According to this, the results obtained are represented as follows:

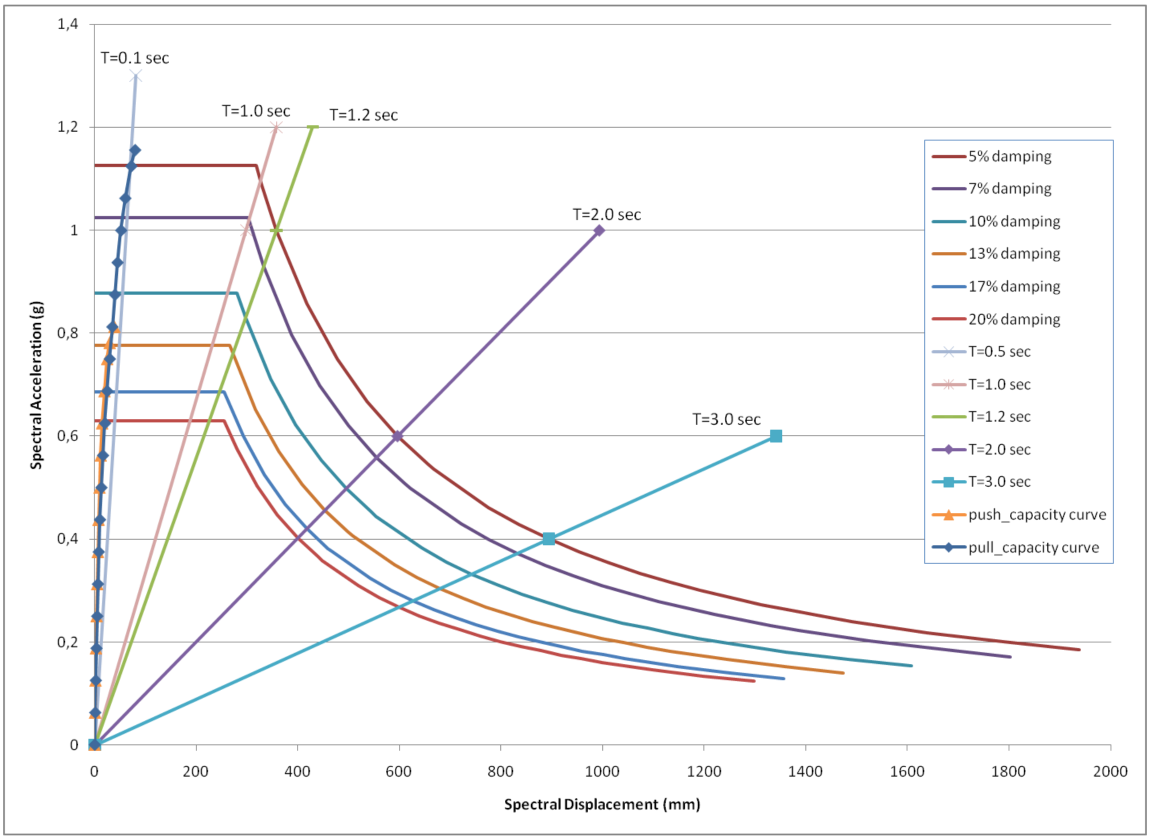

Figure 4: Family of demand spectra and capacity curves obtained for push and pull directions

As one can see from Fig. 4, the capacity curves obtained by using load-deflection behavior of the frame at both directions are placed very close to the vertical axis of spectral displacement – spectral

displacement graph, drawn for a variety of damping ratios. A closer view of capacity curves can be seen in Fig. 5.

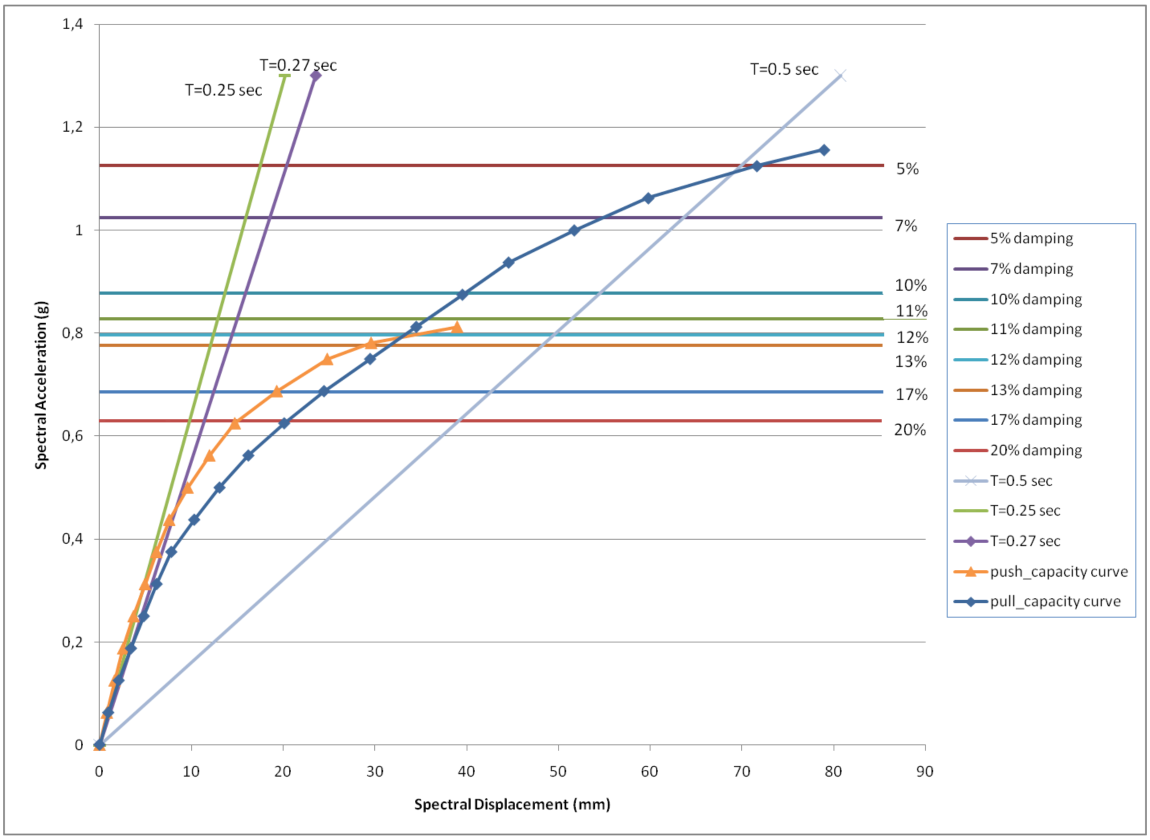

Figure 5: Close up of capacity spectra obtained for push and pull directions

Fig. 5 shows clearly that the frame had 0.25 sec and 0.27 sec initial periods for push and pull cycles, respectively.

At each iteration to find the performance point, the corresponding damping ratios were calculated by using the formulas (1) and (2) (ATC-40 1996)

$$\beta_0 = \frac{1}{4\pi}\frac{E_D}{E_{So}} \quad (1)$$

E_D : enery dissipated by damping

E_{So} : maximum strain energy

$$\beta_{eq} = \beta_0 + 0.05 \quad (2)$$

where 0.05 is the 5% viscous damping inherent in the structure, which is assumed to be constant.

At the end of a number of iterations, it was seen that the capacity curve obtained for the push cycles of the timber frame under investigation does not converge to any damping values.

For pull cycles, on the other hand, a performance point was obtained successfully, which corresponds to 6.7 % damping and a period of 0.465 sec. with a spectral displacement of 55 mm.

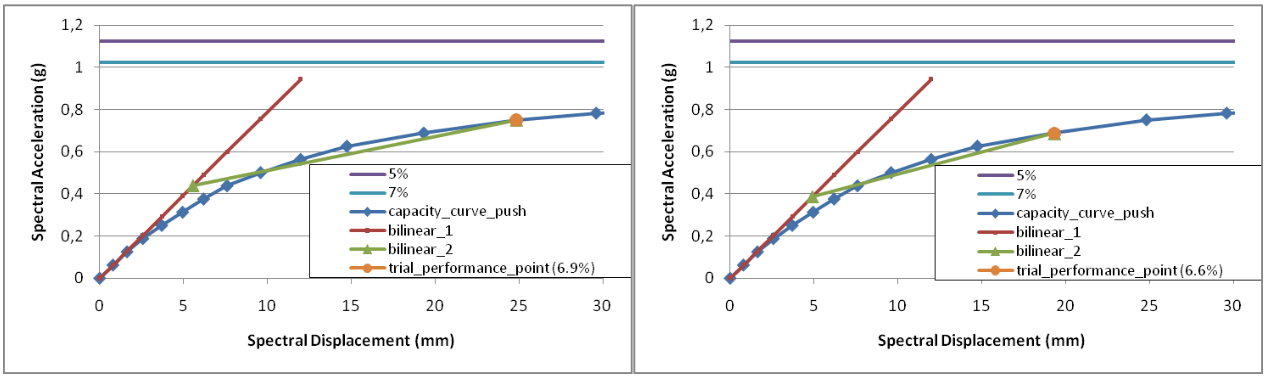

Figure 6: Examples to iterative steps belonging to push direction

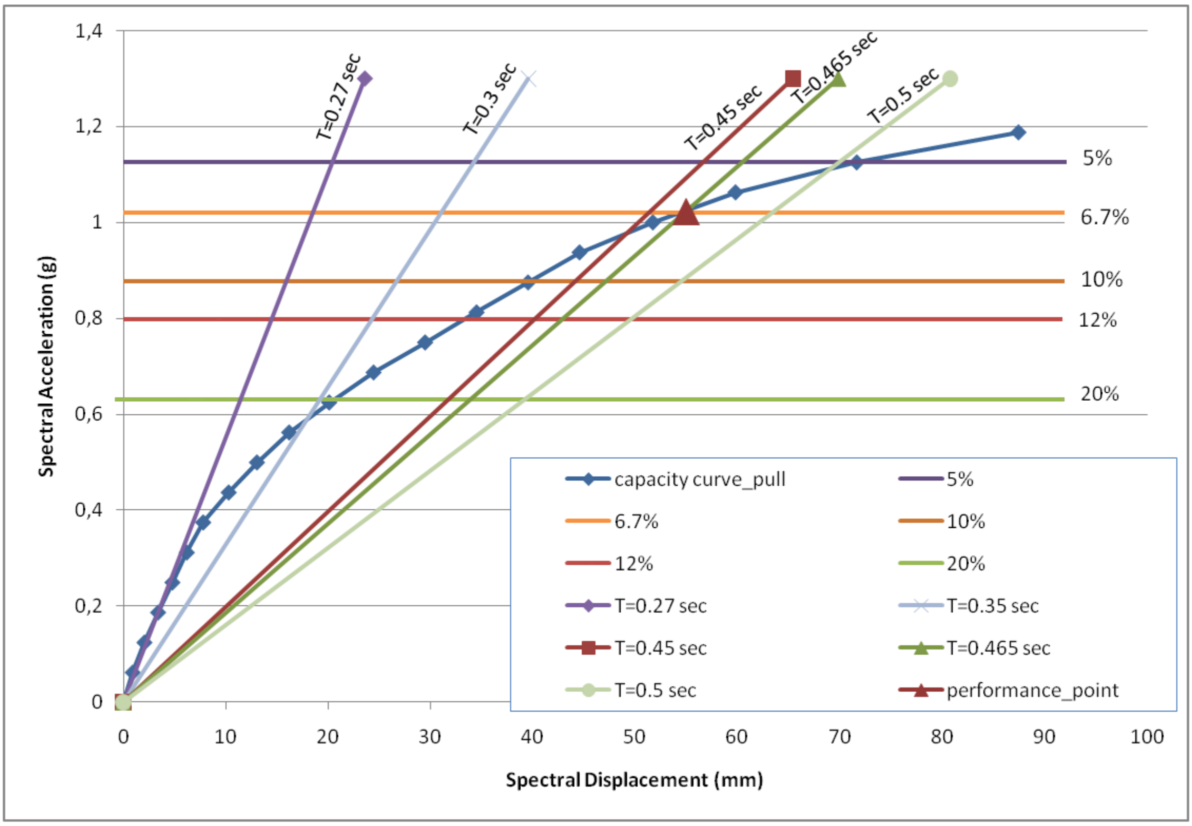

Figure 7: Performance point and period change of pull direction

Results and Conclusions

The basic conclusions that can be drawn at the end of the capacity analysis that has been conducted are explained briefly as follows:

1. The timber frame with nailed connections behaves nonlinearly starting from small deformations.
2. The frame behaved considerably different in the push and pull directions, which might indicate the importance of the number and driving angle of nails since the geometrical configuration is symmetrical in both sides of the frame. The order of loading direction (first pull or first push) can be studied as a parameter as well for future studies.
3. The frame does not have enough capacity in the push direction. Whereas, in the pull direction the capacity analysis converged in such a way that the frame had a period of 0.27 sec in the beginning, while the period is elongated to 0.465 sec when it was pushed to the performance point with a spectral displacement of approximately 55 mm, with a damping ratio of 6.7%.

4. ATC-40 evaluation procedure successfully applied to a wooden frame loading test results has shown that the frame can withstand the design load successfully in only pull direction.

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