



## Traditional wooden buildings and their damages during earthquakes in Turkey

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### Abstract

Wood is one of the oldest structural materials used in structures in many parts of the World. Woodframe buildings were also commonly constructed in Turkey until approximately 1960. After that, as reinforced concrete and masonry buildings have been preferred, wooden buildings have almost been forgotten. But, in 1999, Kocaeli and Duzce earthquakes reminded traditional buildings. Since reinforced concrete buildings presented high level of damage and traditional buildings relatively performed well during these earthquakes. In this study, types of traditional wooden buildings used in Turkey are mainly introduced and their damages in earthquakes are discussed. Damaged and undamaged wooden building photos are illustrated. Some structural weaknesses are highlighted by the earthquake damages including cracking and falling of plaster, failure of mortar, loosening or failing of connections, large lateral displacements, dislodgement of the masonry infill, loosening or failing of connections and failure of connections to foundation. © 2005 Elsevier Ltd. All rights reserved.

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### 1. Introduction

Three types of structural systems, *reinforced concrete*, *unreinforced masonry* and *woodframe* have been commonly constructed in Turkey. Modern buildings in the cities are generally built as reinforced concrete. Traditional wooden buildings were generally constructed in the ancient parts of city. Seismic resistance of these buildings became nearly universal in Istanbul from the 17th to the 19th centuries. But as safe as it may

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have been in earthquakes, wood construction was deadly in fires. Several huge fires swept the city in the early 19th century persuaded authorities to ban further wood construction unless protected by brick fire breaks [1]. By the late 19th century multiunit brick apartment buildings were replacing traditional timber framed buildings. But, woodframe construction is by far the most common housing type in Canada, the USA and New Zealand for single family and low-rise multi-family dwellings [2]. Over two million housing units are built annually in North America and Japan [3]. The general range of the fraction of wood structures to total structures seems to be between 80% and 90% in all regions of the USA [4].

In 1999, Kocaeli and Duzce earthquakes reminded traditional buildings to Turkish community. Although there were clusters of traditional buildings in the heart of earthquake areas, many of the ancient traditional timber framed houses remained intact, only a few were heavily damaged. However reinforced concrete buildings presented high level of damage [5]. This finding was confirmed by Turkish researchers such as Gülhan and Güney [6] who conducted a detailed statistical study in several areas of the damaged district. They found a wide difference in the percentage of modern reinforced concrete buildings that collapsed, compared to those of traditional construction. In one district in the hills above Gölcük where 60 of the 814 reinforced-concrete structures were heavily damaged or collapsed, only 4 of the 789 two-to-three-story traditional buildings collapsed or had been heavily damaged. The reinforced-concrete buildings accounted for 287 deaths against only 3 in the traditional structures. In the heart of the damage district in Adapazari, the research showed that 257 of the 930 reinforced concrete structures were heavily damaged or collapsed and 558 of moderately damaged. By comparison, none of the 400 traditional structures collapsed or were heavily damaged and only 95 of total were moderately damaged.

The widespread failure of reinforced concrete buildings in the 1999 Kocaeli and Duzce earthquakes not only forced Turkish academicians, engineers and architects to reassess reinforced concrete construction, but also pushed a few of them to reconsider a discarded technology, traditional timber framed systems. Figs. 1 and 2 show two views for traditional wooden houses survived both 1999 earthquakes without damage close to collapsed and heavily damaged reinforced concrete structures. There were relatively very few studies and information about earthquake damages of traditional wooden buildings in Turkey. But, investigations about the seismic behavior of traditional buildings are important due to two reasons. First one is, if possible, to reduce the loss of human lives and economic, building with traditional structural systems should be used in the earthquake regions. Second one is the fact that most of these wooden buildings constructed in 4000 various sites around seismic zones make important part of Turkish culture (there are almost 45,000



Fig. 1. View of traditional and reinforced concrete buildings after the 1999 Duzce earthquake.

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