UNITED NATIONS
CENTRE FOR REGIONAL DEVELOPMENT

DISASTER MANAGEMENT PLANNING
HYOGO OFFICE

Wooden Architecture and Earthquakes in Istanbul

A Reconnaissance Report and Commentary on the performance of wooden structures in the Turkish earthquakes of 17 August and 12 November 1999

国際連合地域開発センター
防災計画兵庫事務所

Wooden Architecture and Earthquakes in İstanbul

A Reconnaissance Report and Commentary on the performance of wooden structures in the Turkish earthquakes of 17 August and 12 November 1999[1]

Prepared for the United Nations Centre for Regional Development

Stephen Tobriner
Professor of Architectural History
University of California, Berkeley

April, 2000

The widespread failure of reinforced concrete buildings in the İzmit (Kocaeli) earthquake of 17 August 1999 and Düzce earthquake of 12 November 1999[2] not only forced Turkish architects and engineers to reassess reinforced concrete construction, but pushed a few of them to reconsider a discarded technology, traditional Turkish wood construction.[3] The damage caused by the two earthquakes shocked Turkish architects and engineers and the Turkish public. The thousands of reinforced concrete buildings that failed where typical of tens of thousands of yet undamaged buildings in the greater İstanbul metropolitan area.[4] While eastern Turkey has been subjected to several major earthquakes in the last forty years, İstanbul has not. Experts say İstanbul is overdue for a major earthquake.[5] Would increased use of wood construction help make İstanbul safer?

By the early 17th century timber frame construction for non-monumental buildings became popular in İstanbul replacing or being combined with earlier mud brick construction[6] While monumental buildings like mosques, külliyes, and palaces were constructed of stone and brick, vernacular houses were built using a stout wood frame, as Pietro della Valle describes circa 1614: "They first build a timber frame as in the ships and cover it by boards from the outside. The filling is of mud-brick or simple adobe."[7] Two devastating earthquakes shook İstanbul in the 16th century followed by two in the 17th century and three in the 18th century.[8] Perhaps one of the reasons wood frame construction became nearly universal in İstanbul from the 17th to the 19th centuries was its seismic resistance. But as safe as it may have been in earthquakes, wood construction was deadly in fires. Huge fires swept the city in the early 19th century causing authorities to bane further wood construction unless protected by brick fire breaks.[9] Further, the traditional single family wooden dwelling was increasingly regarded as a cultural liability as the Ottoman empire turned to western European urban prototypes like Haussmann's Paris for inspiration.[10] By the late 19th century multiunit brick apartment buildings were replacing traditional wooden houses. At the beginning of the 20th century reinforced concrete was introduced to İstanbul.[11] With each change in technology buildings grew in size. When reinforced concrete replaced wood as both the high style and vernacular architecture of İstanbul the advantage of wood construction in earthquakes was forgotten.

An active movement is afoot to reintroduce wooden Turkish buildings to the greater İstanbul metropolitan area. But no real wooden tradition survives in İstanbul today. How are the Turkish engineers and architects to revive a dead tradition? How can they effectively utilize traditional architecture and make it safe according to present-day standards? To appropriately evaluate the structural properties of the wooden buildings of Turkey we must understand them in context. While the so-called "Turkish house" or "Ottoman house" or *Hayat* has been extensively treated in relationship to its aesthetics, social configuration and even building parts, no one has as yet evaluated the design and construction of Turkish traditional wooden architecture in relationship to earthquakes.[12]

This paper aims to establish both a cultural and an engineering context in which to position historic wooden architecture in Turkey. It seeks to answer three questions: First, is there any evidence to suggest that these historic wooden structures were designed to resist earthquakes? We must turn to the historical record, look for coeval similarities around the world, and evaluate the surviving wooden buildings to propose an answer. Second, how well did wooden buildings perform in the recent Turkish earthquakes of 17 August and 12 November 1999? By evaluating the performance of Turkish wooden houses we can observe their strengths and weaknesses which will determine whether they are inherently safe in earthquakes. Third, combining the conclusions of the first and second parts of this paper, can strategies for retrofitting old buildings and constructing new ones be devised? Could wooden buildings again be built in parts of greater İstanbul? Would these new enclaves or districts be safer in earthquakes than the present city? This paper is meant to open the scholarly dialogue concerning Turkish wooden architecture and earthquakes. I cannot present a complete study of this vast subject here but it is my hope that this paper will provoke further debate and in so doing encourage future research.

Part One: The seismic resistance of the traditional Turkish wooden house

The history of antiseismic[13] wood construction in Turkey can only be discussed speculatively because so little has yet been published on the subject.[14] Did the people who lived in Turkish wooden houses during the 17th through 19th centuries believe they were safe in earthquakes? Was it the intention of the builders who constructed Turkish wooden houses to make them seismically resistant? It is disappointing that so few official reports or directives have been studied in relation to seismic safety. Written documents describing Turkish wooden houses in earthquakes are rare but the few that survive provide tantalizing clues. One document, a two page description of earthquake recovery, was mistakenly published by Zarif Ongun as a description of the 1509 İstanbul earthquake but convincingly attributed by Caroline Finkel to the İstanbul earthquake of 1766.[15] During the earthquake, the Topkapı Palace was slightly damaged. The unknown writer tells us that wooden buildings were constructed for the safety of the Sultan and his family in the Topkapı Palace gardens or perhaps at Edirne. He also writes that the government imported huge quantities of timber and nails. In another document published by Ambraseys and Finkel, Brother Tarillon reports that after the İzmir (Symrna) earthquake of 10 July 1688 masonry construction was used only in foundations and the lower parts of walls. The upper stories of buildings were constructed of timber frames with brick infill, "a technique that proved resistant in the earthquakes that followed. "[16] This same technique was used in Lima after the 1746 earthquake and in Lisbon after the 1755 earthquake.[17] Masonry was restricted to the ground floor, and lighter, more flexible wood construction was used above. In Lima the lighter upper stories were constructed by using the *quincha*, a wooden framework with waddle and daub, while in Lisbon military engineers invented an x-braced internal wooden frame called the *gaiola* to support the exterior masonry walls above the ground floor. Pietro della Valle's 17th century description of the construction of the Turkish house quoted by Kuban suggests that it too was constructed to be seismically resistant because it was a wooden skeleton. Della Valle writes "They first build a timber frame as in the ships and cover it by boards from the outside." The comparison to ships is telling. Several centuries later and half way around the world in San Francisco an advertisement for a seismically resistant wooden-frame hotel in 1870 describes it as having been built like a ship.[18] In the aftermath of the İstanbul earthquake of 1894 both experts and ordinary citizens were impressed by how well wooden buildings performed.[19] The Director of the Athens Observatory called to study the earthquake, concluded that timber structures outperformed masonry buildings even if they were old and poorly built. It was because İstanbul was a timber city, he wrote, that the damage was not more severe. Citizens from one district of the city petitioned to rebuild in wood rather than brick because they believed wood construction was safer in earthquakes.[20] The clues provided by these few written documents can be corroborated by the Turkish houses themselves.

Turkish houses have features which unite them with antiseismic construction elsewhere. The most obvious is that they are made of wood. The property of wood to be flexible without breaking and to return after bending to its former shape makes it an ideal construction material in earthquake country. If beams and columns are sufficiently strong and flexible, braced and tied together to work as units, wooden walls can resist the lateral forces induced by earthquakes. Although the spaces between the timber frame may be filled with adobe, brick or simply left vacant, the wooden skeleton of the Turkish house can stand on its own as a self-supporting system. The timbers are simply nailed together but the framework is stabilized by the use of diagonal braces.

According to Doğan Kuban, the timber frame in Turkish houses resists earthquakes well because it is tied together in boxes and panels:

> The main structural system in the *Hayat* houses was a timber skeleton used essentially over the masonry walls of the ground floor. This was neither a horizontal beam system nor a modern skeleton system. The connection between the horizontal and the vertical elements did not allow for continuity as in a modern structural skeleton. The continuity was not through the elements, thus linear, but it was like a box system where all the elements were integrated for the stability of the system. The primary and secondary uprights between the floors, horizontal elements, floor

> beams and diagonals, constituted panels and boxes. This system of continuous panels and boxes responds well under the stress of earthquakes.[21]

The panel system Kuban describes can only be expected to function in an earthquake if it meets several criteria. First, the wood members must be sufficiently strong and ductile to resist and dissipate forces acting on the plane of a wall. They have to be strong enough to restrain and hold the skeleton and infill when pushed sideways. For example, the framework of the derelict building which Kuban labels Apolyont Köyü in Bursa (fig. 1) must be sound enough to bend back and forth and carry its load without splitting. Second, the connections between the members must be strong enough to hold together without loosening or worse yet completely failing. It is extremely unlikely that a rectangular upright panel, like the second to the right bay with the blocked in window in the Bursa house, could ever effectively resist lateral movements. It would simply deform and collapse. To resist lateral movement the frame must have diagonal or x bracing. This building in Bursa has x bracing on the ground floor and four kinds of diagonal bracing on the first floor: the vertical diagonal at the corner a little higher than half the bay, the horizontal diagonal on which the corner brace rests which reaches across the corner bay, the smaller diagonals above the doorway and below the blocked up windows, and the diagonals above the doorway. We might also add the useless diagonals in the blocked up windows. How effectively these diagonals assist the vertical and horizontal members to resist lateral forces will decide whether the panels will function in an earthquake. The voids and solids within the panels, and the continuity between panel and panel, floor and floor, are crucial in the performance of the building as a whole. For example, the framing of the Hasan Aga house in Mudanya (fig. 2) lacks diagonals on the upper floors and the diagonals on the ground floor seem undersized. The builders are asking too much of the slender vertical timbers which support the upper two stories.

For the panels to work successfully as an antiseismic construction system they must be designed correctly, the more diagonal bracing the better. There is also an art to placing and designing diagonal bracing. The wider the base of the triangle in relation to its height the stronger it is. The diagonal should be connected to the vertical member as close to the joint with the horizontal member of the panel as possible. X braces are in general stronger than diagonal bracing alone. For all of these reasons the bottom floor of the house in Bursa has a far stronger frame than the upper floor.

Aesthetics and function have prejudiced the seismic stability of the Turkish house by limiting the locations of diagonals in the wall panel. Since corners are the most vulnerable to damage in lateral movement, builders have positioned the diagonals there. Even with changes in construction over the years these diagonals have been minimized to provide the maximum window area. This diminution of diagonal bracing can be seen in two diagrams Günay publishes illustrating versions of timber frame construction, the typical framing of the "old days" and "more recent date" (figs. 3 and 4). The controlling feature which will stabilize the facade or contribute to its failure in both cases is the diagonal at the corners. The problem with assessing the seismic vulnerability of these structures is that the diagonal bracing is inconsistent. It is not applied uniformly, nor is it the most prominent feature of these buildings.

Although we might argue about its effectiveness in resisting earthquakes the Turkish building system can be placed in the family of antiseismic wooden structures developing in the 18th and 19th centuries.[22] In Portugal the *gaiola*, mentioned earlier, utilized a wood frame to reinforce masonry buildings.[23] The system comprised a wooden framework of multiple x braces embedded in the cross walls of the interior of the buildings which stabilized an exterior rectilinear wooden skeleton attached to the masonry walls figs. 5 and 6). Masonry protected the exterior from fire while the wood compensated for the brittle masonry. After the Calabria earthquake of 1783 another system, the *casa baraccata*, was invented (fig. 7). Instead of x braces on the interior walls as in the *gaiola*, braces were now positioned on the exterior perimeter walls.[24]

Architectural theorists of the 18th century were convinced of the efficacy of using wooden construction in earthquake-prone areas. Wood construction technology was revolutionized in the early 19th century in the United States of America by the invention of balloon frame construction.[25] In this system of machine cut 2 x 4 or 2 x 6 inch vertical studs placed at 16 inch. intervals nailed to horizontal members with wire-cut nails (fig. 8) replaced heavy timber members secured by mortise and tenon joinery or spikes. Balloon frame construction was commonly considered to be seismically resistant in earthquake-prone 19th century San Francisco.[26] In general wood buildings were only wrecked in earthquakes when their brick chimneys collapsed, when they fell off their foundations, or when basement half-stories constructed with unbaced "cripple" walls, collapsed (fig. 9).[27]

Although Turkish houses do share traits with seismically resistant wooden buildings the question is still open as to the intent of their builders. The balloon frame was the simplest, cheapest, and fastest method of building in San Francisco. Its seismic performance was secondary. Such may have been the case in İstanbul. Reha Günay, in his *Tradition of the Turkish House and Safranbolu Houses*, concludes its simple nailed connections are indications of its ephemeral nature.

> The broad-sectioned timber elements and carefully designed details seen in German, British or Japanese communities do not exist in the Turkish house. It is not just a coincidence that the same simple construction details can be traced in America, which throughout their history...people have been on the move towards the west. This construction method also facilitated the reconstruction, within a short time when whole quarters were destroyed instantenously [sic] by fire. The way in which people view life also plays a role in the selection of timber frame construction: Human life is temporary; it is only natural that houses are also built to last for a temporary period. [28]

Further, it is important to remember that braced timber frames were popular in areas where earthquakes rarely struck like England, France and Germany.[29] When the timber frame is intentionally left uncovered on the facades of structures they are it is called half-timbered. Treatises on the aesthetics and construction of half-timbered building like Pierre Le Muet's *Maniere de bastir pour touttes sortes de personnes* (Paris, 1623) were not uncommon. In post-medieval England half timber originally buried in plaster was uncovered for aesthetic reasons.[30] Fake half timbering became popular in 19th century England and can even been seen copied in plastic in buildings in the United States today.

Although we cannot positively answer the question of whether their builders and owners intended Turkish wooden houses to be safe in earthquakes, we can evaluate the seismic performance of remaining buildings. Are surviving Turkish wooden houses safe in earthquakes? We can propose an answer to this question by examining individual buildings still surviving today. One of the greatest concentrations of 19th century Turkish wooden houses is in Safranbolu, a city designated as a UNESCO world heritage site because of its inventory of more than 800 houses. Safranbolu is in the Black Sea region of Turkey, north-east of İstanbul and by road about 150 kilometers from Düzce. Safranbolu suffered no damage from the two earthquakes in 1999. While it has been shaken in previous earthquakes which have affected the northern Anatolian seismic zone, according to Günay it has suffered no "serious harm".[31] Safranbolu has been studied extensively by a number of prominent scholars, including the dean of Turkish house studies, Sedad Eldem.[32] I have relied most heavily on the work of Doğan Kuban and especially Reha Günay. I also visited Safranbolu and examined many of the features I discuss.

What, in general, can be said about the seismic safety of the buildings in Safranbolu? Of course, they incorporate the elements of the braced frame discussed above, which is an advantage, but they also have serious design weaknesses. We might best examine them by analyzing their plans and elevations in relation to the concept of building configuration. The architectural form of a building influences its performance in earthquakes. For the purposes of this paper building configuration can be defined as "building size and shape, the size and location of structural elements, and the nature, size and location of nonstructural elements that may affect structural performance."[33] In general the more regular the configuration of a structure, the better. For example, a symmetrical, square building more evenly distributes forces and than an irregular L-shaped building. When irregularities occur they can create torsion and stress accumulation. Obviously, many irregular buildings are constructed in earthquake country, but when they are engineers must carefully calculate how these irregularities affect their performance. Regular configurations have several characteristics which optimize their performance: low height to base ratio, equal floor heights, symmetrical plan, uniform section and elevations, maximum torsional resistance, balanced resistance, short spans and redundancies, and direct load paths.

Let us first consider a symmetrical configuration in plan. The şehir house of Arap Hacilar has an excellent configuration in plan (fig. 10). It is almost square with evenly distributed, vertically continuous interior and exterior walls. Whereas the Saraçlar şehir house (fig. 11), while having a more or less regular, rectangular plan, incorporates a *hayat*, or open porch on one side. Doğan Kuban, in his book *The Turkish Hayat House*, believes this open gallery was the original core of the Turkish house in the 16th century which slowly became internalized as time went on. If so, this hallmark of the Turkish house would have presented a hazard in earthquake country because it is more flexible with no infill walls and less diagonal braces than the other perimeter walls. The fact that it continues around the corner of the building on the middle floor (around the storage chest) would help to create torsion—a twisting---in the building under seismic loads. The tendency to twist under torsional forces would be increased by the thick masonry wall across from the *hayat*.

Further, the *hayat* in Saraçlar şehir house creates a void disrupting vertical continuity because it is two stories high and supports a *eyvan* (hall) on the third story (fig. 12). The middle story is particularly vulnerable. For example, in another Safranbolu house the boarded up *hayat* illustrates the problem in elevation (fig. 13). The *hayat* with its long support columns may not be able to support the floor above it. In that case the *hayat* supports constitute a so-called soft story which might collapse in an earthquake. Note too that the walls of the Saraçlar şehir house present another vertical discontinuity. The middle floor is cantilevered over the ground floor. These cantilevers create a more complicated load path has the walls might rock back and forth in plane (in the direction of the wall) or out of plane (at right angles to the wall). The cantilever projections would tend to "wag" back and forth in an earthquake, stressing their connections to the main wall. These connections, called reentrant angles, might be stressed to the point of collapse. The şehir house of Haci Kadılar illustrates another problem with these projections (fig. 14). Imagine the walls of this house being pushed in plane and out of plane. Because they are discontinuous with the stone foundation their weight comes down on the diagonal braces embedded in the wall. This uneven load could push the wall inward, collapsing it. Where multiple cantilevers occur, as in the Antepler house (fig. 15), danger of discontinuity increases.

Another important consideration is how the elements resisting sideways movement, or shear (a force which acts by attempting to cause planes of an object to slide over one another) are arrayed within the building. This is particularly hard to judge because the construction of bracing in the interior walls, and sometimes the exterior as well, is impossible to know. But again considering the şehir house of Arap Hacılar (fig. 10) note the proportion and placement of solid walls to voids. This house would be more resistant to lateral forces than the Kaymakamlar şehir house(fig. 16) with more voids and less interior and exterior walls.

The masonry ground floors of the houses of Safranbolu present two problems. Some ground floors are exceptionally high because houses are sited on steep slopes (fig. 17) which means that the structure has a high height to base ratio. This creates an inherent instability in the structure as a whole as it increases the probability of rocking. But even more difficult to judge and potentially more dangerous is the masonry construction of the ground floor. In an earthquake will the masonry be able to function as a unit or will it shatter in pieces? Masonry is brittle and composed of a myriad of individual rocks, commonly rubble, held together by weak mortar. Sometimes strips of wood run through the courses of masonry (fig. 18). When I first saw them I thought they might be bond beams, tying the building together. But they may have been used to simply level the courses of stone at given intervals. Their insertion in the wall probably further weakens it. In the United States the construction of the masonry ground floor would be called "unreinforced masonry." Under California law older brick buildings of this type of construction must be reinforced and the usual method is with concrete or steel. Engineers in the United States would consider the masonry walls of Safranbolu extremely hazardous in a strong earthquake.[34]

It is also important to ascertain how the forces are counteracted from story to story. Are the floor planes strong and stiff enough to act as diaphragms distributing the load to the walls? Are the connections between the individual members strong enough to hold the building together as it moves? The heavy tile roofs and stone infill in the timber frame create enormous weight and increased mass. Are the wooden connections strong enough to resist it? Turgut Cansever, the most famous living Turkish architect, is convinced the nailing system can resist seismic forces. He has seen extra-long nails and drew a sketch of them for me (fig. 19).[35] But whether these nails are as common as he thinks, and how effectively they work is still open to question.

Exquisite Safranbolu is at risk in a strong earthquake and the uniqueness of its buildings makes this risk harder to gauge. Each patron and builder had a slightly different idea of what was beautiful, useful and strong. Some houses are built symmetrically with many well positioned diagonals, others are not. Each house must be evaluated separately in relation to its seismic safety for us to understand how it will perform in an earthquake. Every aspect of the building must be considered. A "recent" Safranbolu house illustrates this point. It is symmetrically planed with a beautifully articulated frame (fig. 20). The bracing system for the two story facade includes twelve diagonals, three of which are deeper than most in Safranbolu. But the framed upper stories rest on an exceptionally high rubble masonry ground floor which is very vulnerable to earthquake damage. So its prospect for surviving an earthquake is mixed. In order to understand the risks at Safranbolu houses like the one illustrated in figure 20 must be modeled on computer simulation programs like finite element analysis SAP 2000 to judge how they might perform in an earthquake.

Part Two: The performance of traditional wooden Turkish houses in the İzmit (Kocaeli) earthquake of 17 August and Düzce earthquake of 12 November, 1999.

The Turkish earthquakes of August and November 1999 were important tests for the durability of traditional wooden Turkish houses in earthquakes. The buildings shaken were not as old nor as beautiful as those at Safranbolu, but they were of the same timber-frame family. The comments which follow are based on my observation of wooden buildings during a reconnaissance trip to Turkey in December, 1999. Thus far no detailed evaluation of the performance of Turkish wooden architecture has appeared to augment my own. I focus on four sites, Kaynaslı and Düzce shaken in both earthquakes, but most badly on 12 November, and Ulaşlı and Degirmendere which were damaged on 17 August.

Kaynaslı

This small village north of Düzce was the epicenter of the so-called Düzce earthquake of 12 November, 1999. It is an agricultural village in a mountain valley bisected by the main east-west highway between İzmit and Bolu. The downtown area is located on a stream which runs south to east less than a city block south of the highway. The town follows the banks of the stream up a small valley rising south to the mountains. I visited the town less than two weeks after the second earthquake to strike it. People were salvaging what they could from the ruins. Some were removing roof tiles, others timbers, and still more furniture and household goods. They were living in a newly erected tent city south west of the former downtown.

Although damage was considerable on both sides of the highway, with about 20 per cent of the buildings collapsed, the most spectacular damage was concentrated along the stream banks to the south. Here the reinforced concrete buildings of four to five stories failed at the ground floor causing many to settle one story (fig. 21). Citizens told of many people dying in these first stories because they were watching a soccer match in small ground floor bars and restaurants. But many of the failures were in structures that were as yet incomplete. The lack of concrete shear walls combined with weak columns in both the incomplete and complete structures was the cause of collapse. The upper stories of the reinforced concrete buildings were for the most part still intact although obviously askew.

Because Kaynaslı is a poor farming village it retained many wooden buildings in its housing stock and a dozen of these ascended the picturesque stream south up a hillside (fig. 22). Because they were on alluvial soil the shaking must have been intense. However they seemed to be excellent candidates for surviving an earthquake of considerable magnitude. These wooden buildings were very similar in design. They were one or two stories structures with square or rectangular ground plans, hip roofs and a moderate ratio of apertures to walls of 1.5 to 3. The were far smaller than the houses in Safranbolu and in every way more modest. They had none of irregular or discontinuous features (like cantilevered upper stories or *hayats*) that characterized older Turkish wooden houses. These were regular blocks, probably with westernized floor plans, some so modern-looking that they appeared to be reinforced concrete apartment blocks. Their states of repair varied from excellent to extremely poor. All were of frame construction with heavy timber members and at least two diagonal timbers on each side, one was sheathed in wood. Some had an x brace or two on each side (fig. 23). In addition the interior walls were braced with diagonals. The infill was mostly brick sometimes stone and mud often artfully arranged in the wooden frame. Their responses varied but in general were no better than the reinforced concrete buildings. Most two story buildings lost their ground floors (fig. 24), some lost the diagonals or x braced shear panels (fig. 25) while others slipped off their foundations. In at least three cases reinforced concrete structures hit or pounded against the timber frame buildings collapsing them (fig. 26). There were some notable successes: In one case a concrete building lost its first story sending heavy debris into a derelict timber frame house which in turn collapsed against another timber frame house shoving the second story sideways. Although the last building lost plaster it remained standing. Where the buildings were well built, one story, and had foundations that did not fail, they had a chance. The patterns of damage (broken plaster, lost panels) clearly show the diagonal panels taking the lateral load (fig. 27). Sometimes, even in failure they dissipated enough energy to save the rest of the wall.

Düzce

Düzce was still recovering from the August earthquake when it was struck by the November 12 temblor. Downtown, a score of concrete buildings pancaked in the November 12 earthquake. In the central district whole blocks were badly damaged, others evacuated, and still others already demolished. Strikingly, next to several collapsed reinforced concrete buildings stood poorly maintained wooden buildings still intact.

The wooden buildings in Düzce included a type which can also be seen along the road to Kaynaslı. These were square or rectangular apartment buildings of two stories with multiple entrances invariably painted green (fig. 28). There are hundreds on the outskirts of the Düzce, perhaps built as some form of public housing dating from the period of the 1920s and 1930s when, in order to contain foreign debt, the Union and the Progress Committee under the government of Atatürk encouraged a renewal of native building techniques and materials.[36] These buildings are quite different from the houses of Safranbolu in plan and elevation. As in Kaynaslı, these buildings are quite simple and unassuming. But note that their windows are placed well in from the corners and at wide intervals, making it possible to load the walls with x braces and diagonals which helps to make these buildings much more likely to resist earthquakes than the historic structures at Safranbolu. Several of these buildings survived in the downtown section of town near the river, sitting damaged but still standing among the ruins of collapsed reinforced concrete apartment buildings. Concrete buildings on three sides of the building illustrated in fig. 29 collapsed. Its neighbor (fig. 28) also survived, with its broken plaster finish exposing where the braced frame took the forces. Another strange contrast could be seen just next to the river where many reinforced concrete buildings pancaked. In back of the ruins of a pancaked reinforced concrete apartment building stands intact an elaborate but today derelict wood frame building (fig. 30, 31).

Ulaşlı

Ulaşlı is a small village near the sea about 15 kilometers west of Gölcük where major losses had occurred in the first earthquake. It is a village of low-rise reinforced concrete buildings and several dozen timber framed buildings on flat, well drained countryside. The ground-shaking here was not nearly as severe as in Kaynaslı judging from the damage. The ground-floor columns of the reinforced concrete buildings are cracked but structures still remain standing. But the citizens of the town insist that the timber framed buildings saved their lives. The little town is a treasure-trove of timber buildings.

Two structures, both with concrete additions, illustrate the pre-collapse damage patterns of timber framed buildings. The first is a two story rectangular building, wood framed with brick infill in a herringbone pattern in the front, probably brick and reinforced concrete in the rear (fig. 32). Cantilevered over the doorway is a timbered porch corresponding to the *eyvan* or hall. One enters the ground floor (fig.33) (perhaps a version of the *hayat*) and finds steps and a raised platform to the left. The center of the floor-joists is supported by a rough-hewn beam in turn supported by a single post with braces. On the right against the outside wall is the kitchen (fig. 34). The working of the diagonals in the earthquake dislodged the plaster as the house oscillated. A similar pattern can be seen in the back bedroom on the left hand side. In the front bedroom the vertical timbers on the exterior wall began to rotate. In the second, slightly larger house (fig. 35), the entire second story front facade with its wooden porch, is cantilevered over the ground floor as in older traditional buildings in Safranbolu and İstanbul. Diagonal bracing appears at the corners and in the center side elevation of the building. The ground plan and structure resemble the first house. Here the main cracking seems to be along the front facade and rear of the building with diagonal cracks at corners, probably where diagonal timbers are located. While some plaster fell and the buildings obviously moved they are not collapse hazards.

Degirmendere

The downtown of Degirmendere, a seaside city not far from İzmit, was badly damaged in the August earthquake. Like Düzce, wooden buildings stood alone in areas where they had been surrounded by failed concrete buildings, now abandoned or demolished. In one downtown area a collection of buildings survives (fig. 36), some obviously lower class, others more sumptuous, two stories tall with central cantilevered porches probably corresponding to *eyvans* under gable roofs. The latter probably date from the art nouveau period of the late 19th century. They appear undamaged from the earthquakes, but a group of reinforced concrete buildings beside them also fared well enough to be re-inhabited. In Degirmendere the wood frame is infilled with wattle and daub, making it far lighter than the brick and rubble infill walls seen in other locations.

Conclusions

The conclusion of this brief survey is that Turkish timber frame construction can be designed to be seismically resistant. In general this ancient system did as well as reinforced concrete structures nearby and sometimes markedly better. Granted there was a difference in scale which may have accounted for more failures in concrete. But nevertheless the performance of the wood frame houses was impressive. Unfortunately I did not have a team of investigators at my disposal with maps of the affected areas to make complete surveys. In an article published in 1989, M. Hasan Boduroğlu surveyed damage caused by sixty earthquakes between 1925 and 1984 to rural buildings in Turkey. Eighteen percent of rural buildings at that time were timber framed. He felt that timber framed buildings with hollow walls (*Bağdadi*) outperformed infilled timber frames (*Hımış*) and both were substantially safer than adobe or rubble stone masonry structures. He observes "The traditional construction techniques used in timber frame buildings have been very successful. In contrast to stone masonry buildings, they my adequately resist

...earthquake forces."[37] But only by studying each building extremely thoroughly, calculating ground motion, and then finally modeling it using infinite element analysis in computer programs like SAP2000 or a pushover analysis will we be able to be sure of our judgments.[38]

Part Three: Retrofit and revival of the traditional wooden Turkish house.

Contemporary living traditions which might be a basis for the revival of Turkish wooden buildings are hard to find. A search of İstanbul yields few new buildings which employ the timber frame construction technology of the Turkish house. Instead, reinforced concrete buildings are being built with wooden facades which are supposed to evoke the wooden architecture of the past. For example, a corporation building in the Beyoğlu district has a reinforced concrete frame but the building is massed as if it were wooden and clad with wood. In Sultanahmet, where tourists want to stay in traditional wooden buildings, there are very few to be found. The new Blue House is another example of a reinforced concrete building being clad in wood (fig. 37). Here, the nod to the past is just that. Never could this building be mistaken for a traditional wooden structure. But even older hotels like the Obelisk are brick buildings with reinforced concrete additions clad in wood. In spite of the enthusiasm of national architects like Eldem and Cansever for traditional Turkish architecture, contemporary wooden versions of the classic Turkish houses or stores are not being built. Similarly, in the historic city of Safranbolu reinforced concrete buildings which attempt to respect their wooden neighbors by incorporating cantilevers and roof brackets are encroaching on the town while rows of reinforced concrete flats crest the hill behind it. No new wooden buildings appear to have been constructed.

As derelict Turkish wooden buildings decay and collapse in İstanbul they pose a question about traditional architecture and earthquakes which bears on any attempt to revive wooden construction. These collapsing buildings present us with one of the two last variants of the traditional Turkish house, neither included in Eldem's discussion of the three periods Turkish wooden architecture. One of the last variants was the version sponsored by Atatürk's administration which was discussed in relation to Düzce. It is possible that many of the derelict buildings in İstanbul date from this same period. Diana Barillari and Ezio Godoli describe some of the mansions and townhouses from around 1900 which they place as late as the 1920s or 1930s.[39] Perhaps it was during this period that Turkish builders modified the traditional panel construction by using smaller, more uniform members and continuous diagonals in a version of balloon frame (discussed earlier). The exterior walls of two derelict buildings in Sultanahmet illustrate this variant (figs. 38 and 39). Note that the diagonals closest to the corner are inverted in relation to the system in practice at Safranbolu. Instead of placing the hypotenuse of the triangle at the corner it is farther in the interior wall plane. This practice is contrary to the earlier ones in Turkey and also contrary to balloon framing in the United States. It is a Turkish variant. This system, a westernized version of traditional Turkish construction, must also be included in our concept of what is Turkish and worth emulating.

In the area struck by the earthquakes of August 17 and November 12 traditional construction is still being practiced, if marginally. A professional carpenter repairing a building in Ulaşli explained the slightly bent diagonals of Chestnut which are common in the town are intentionally selected to put spring into the wall (fig. 40). Nearby several temporary one story timber framed buildings with Styrofoam infill covered with plastic repeated the tradition configuration of diagonal bracing found in Turkish houses. It was instructive to see the pattern because it indicated that traditional construction techniques were alive and well (figs. 41 and 42). Similarly as a temporary building in Kaynaslı of traditional Turkish timber frame construction was being erected. In Degirmendere within the last year an exhibition hall was erected using traditional design and methodology (fig. 43). It was clearly meant to be a modern traditional structure which incorporates both the pattern of diagonal half-timber and the waddle and daub infill particular to Degirmendere.

By observing the present construction practices and the design of Turkish wooden architecture of the past the following guidelines can be proposed for seismic retrofit and revival:

Retrofit of old construction

- Make sure foundation is firm. Stone foundations perhaps stabilized with concrete and steel or reinforced concrete frame.
- Attach mudsill (bottom sill in figure 8a "c" in figure 4) to foundation with bolts
- Make sure all wood connections are as sound as possible, strap or tie together where possible.

Revival of timber frame technology

Planning

- Analyze the performance of the structure before it is built.
- Use two structural engineers, one to propose the design, another to check it. Peer review is mandatory.
- Evaluate performance in relation to code prescriptions.

Construction

- Investigate light infill material for walls.
- Investigate composite frames of steel or laminated wood.
- Investigate appropriate material for light roofs.
- Institute a two story limit.
- Tie and strap all beams, posts and diagonals with metal bolts and a culturally friendly form of metal brackets.
- Use tiedowns from floor to floor.
- Insure the floor and roof act as diaphragms.
- Tie mudsill, or bottom of wooden frame to the foundations.
- Beware of rot, termites.
- Have a fire-extinguishing method in place.

Conclusion

Could wooden buildings again be built in Turkey? The answer must be that wooden buildings could again become popular as an alternative to reinforced concrete. Would they be safer than reinforced concrete buildings? They would certainly be safer than a vast majority of present-day concrete buildings in the İstanbul metropolitan area. But reinforced concrete can be designed to be seismically resistant as well. Wood in itself does not guarantee safety. Antiseismic design makes a structure safe. The use of wood as the dominant structural material raises many questions. Can it be used effectively in relation to the tremendous growth of the city? Because wooden structures will be smaller than standard reinforced concrete buildings, will they exacerbate urban sprawl? Will the use of wood degrade the remaining forest cover in Turkey and create a host of environmental problems? While these questions must be answered before large scale operations are undertaken, for the present it is possible to endorse correctly built wooden structures as a viable, intelligent option.

[1] I would like to express my thanks those people who helped me with my research: Professor İhsan Mungan, Mimar Sinan University, Prof. Sami Kilic, Boğaziçi University, Prof. Mete Sözen, Purdue University, , Prof. Frederick Krimgold, Virginia Polytechnic Institute, Prof. Zeynep Ahunbay, İstanbul Technical University, Prof. Mustafa Erdik, Kandilli Observatory and Earthquake Engineering Institute, İstanbul, Prof. Fikret Yegul, University of California, Santa Barbara, Dr. Caroline Finkel, Arch. Turgut Cansever, Arch. Suphi Saatçi, Arch. Çelik Erengezgin, Orhan Esen, İnsan Yerleşimleri Derneği. I could never have completed my research without the help and companionship of Emre Özkan and Meltem Şahin, Research Assistants, Structural Engineering, Mimar Sinan University. Halil Sezen, at the Pacific Earthquake Engineering Research Center, UC Berkeley, and Sibel Zandi-Sayek, PhD candidate, Architecture UC Berkeley, helped in translating and finding contacts. Prof. Filip Filippou, Dept. of Civil Engineering, UC Berkeley, kindly looked over the manuscript. Last I would like to thank Mr. and Mrs. Cengiz Demirtaş for an unforgettable dinner in a tent in the ruins of Düzce on the first evening of Ramadan.

[2] For reports on the earthquakes see the Kandilli Observatory web site, http://www.koeri.boun.edu.tr/earthqk/earthqk.html, "The İzmit (Kocaeli), Turkey Earthquake of August 17, 1999," EERI Special Earthquake Report, *EERI Newsletter*, 33:10, October, 1999, *Perspectives*, Degenkolb, November, 1999, *Newsletter*, Mid-America Earthquake Center, 2:2, October, 1999. Also see *Deprem Özel Sayısı, Cogito*, İstanbul, 1999, for commentary and discussion of the earthquakes.

[3] Turgut Cansever has begun to plan a new neighborhood of wooden houses on the outskirts of İstanbul. Mr. Cansever believes in an integrated strategy of low-rise wooden structures, as well as steel, reinforced concrete, brick and stone structures. Mr. Çelik Erengezgin of Bursa advocates traditional Turkish wooden architecture as well, however he endorses a wider use of wood for all types of buildings. Prof. Sadettin Ökten of Mimar Sinan University is simulating seismic loading of wooden members. Architects and engineers in İstanbul, considering the scope of the problem of poor reinforced concrete construction, are interested in solutions utilizing wood.

[4] It was obvious from surveying the damage in the earthquake zones that many of İstanbul's buildings shared the same deficiencies. In particular "soft" first stories or ground floors and discontinues between stories are the rule. Emre and Sibel Özkan's apartment building in İstanbul is a case in point. The ground floor without shear walls is occupied a retail tire store. Above the store are the apartments. The columns of the building are discontinuous and because one had cracked Emre saw that it has four reinforcement bars tied at more than 50 cm., just the same construction detail that had failed in Düzce and elsewhere. Everyone I talked to in İstanbul was concerned. Prof. Mustafa Erdik discussed the tremendous magnitude of the problem with me.

[5]In December, 1999, newspapers reported that seismologists were predicting an earthquake would strike İstanbul. Major earthquakes do strike İstanbul, but at varying intervals from as little as eleven years to around one hundred and twenty years: 1509, 1556, 1648, 1659, 1719, 1754, 1766, 1894, 1912. See N.N. Ambraseys and C.F. Finkel, *The Seismicity of Turkey and Adjacent Areas, A Historical Review, 1500-1800,* İstanbul,

1995, N. Pinar and E. Lahn, *Türkiye Depremeleri İzahlı Kataloğu*, İstanbul, 1952. For the earthquakes of 1894 and 1912 see note 14 below.

[6] D.Kuban, *The Turkish Hayat House*, İstanbul, 1995, p. 238

[7] Kuban *Ibid.*

[8] For earthquakes that struck İstanbul from the 16th through 18th centuries see Ambraseys and Finkel, *The Seismicity of Turkey*

[9] For destructive fires and attitudes towards them see D. Barilari and E Godoli, *Istanbul 1900, Art Nouveau Architecture and Interiors*, New York, 1996, p.79-82. Z. Çelik,*The Remaking of Istanbul, Portrait of an Ottoman City in the Nineteenth Century*, Berkeley, 1986, pp. 49-81

[10] Z. Çelik,*Ibid.* and Barilari and Godoli, p. 13

[11] For example see Çelik, p. 76.

[12] I have not yet read all the available books on timber-framed construction in Turkey. Yet the authors I have read, while alluding to the strength of the timber-framed Ottoman house or Turkish house in earthquakes, have not analyzed either a single representative example or a group of these structures as a type. For example, Sedad Eldem (*Türk Evi Osmanlı Dönemi/Turkish Houses of the Ottoman Period*, İstanbul, 1984, I, P. 41) writes "construction techniques and limitations were not without their effect on the form of domestic architecture. After the first great fires, attempts were made to assure that houses were built "of brick as before" or the "less timber be employed" in their construction, but such efforts were reserved by the dominant fear of earthquakes. This duality of approach remained evident until the 18th century, by which time timber framed buildings were indisputably in the majority." Eldem does not make clear here or elsewhere exactly how the buildings resist earthquakes. Önder Köçükerman, in his *Kendi Mekânının Arayışı İçinde Türk Evi/Turkish House, In Search of Spatial Identity*, does not mention earthquakes in relation to timber-framed construction in Turkey (although he does include it in a discussion of Japanese architecture (p. 32). Reha Günay mentions earthquakes as a causal factor in the popularity of the Turkish house: "All the geographic areas where the Turkish House has spread are within seismic zones. It may be due to this fact that the timber frame construction system was devised and widely used. This method is resistant to horizontal forces and is also safer due to its lightness. It can be seen that this method was improved within time"(p.30). The fullest discussion and analysis is supplied by Kuban (*The Turkish Hayat House*, p. 241) which I quote in the text of the paper and attempt to examine.

[13] The word "antiseismic," a translation of the Italian "antisismico," is used here to mean a structure which is designed to be seismically resistant.

[14] Although scholars are increasingly investigating historical earthquakes (as in H. Dursun, "İstanbul 'u seven katlanir depremine," Osman Köker, "Sansüre Uğramış, Bir Deprem, İstanbul, Adapazarı, İzmit, Yalova, 10 Temmuz 1894,"*Toplumsal Tarih*, 69, Eylül 1999, pp. 4-7, F. Ürekli, *İstanbul'da 1894 Depremi*, İstanbul, 1999, N. N. Ambraseys and C. F. Finkel, "The Saros-Marmara Earthquake of 9 August, 1912" *Earthquake Engineering and Structural Dynamics*, 15, 1987, pp. 189-211) there needs to be more emphasis on the history of antiseismic design (if it occurred). Extensive studies have been carried out on famous structures in Istanbul (as for example the work

of R. J. Mainstone, "The Süleymaniye Mosque and Hagia Sophia ," *IASS Symposium on public assembly structures, Mimar Sinan University*, İstanbul, 1993, E. Mark, A.S. Çakmak, K. Hill, R. Davidson, "Structural Analysis of Hagia Sophia: a historical Perspective," A. S. Çakmak, R. Davidson, C.L. Mullen, M. Erdik, "Dynamic analysis and earthquake response of Hagia Sophia," and M. Erdik, E. Dururkal, Ö. Yüzügüllü, K. Byen, U. Kadakal "Strong-motion instrumentation of Aya Sofya and the analysis of response to an earthquake of 4.8 magnitude," *Structural Repair and Maintenance of Historical Buildings III*, Bath, England, 1993, pp. 33-46, 67-84, 99-114) but everyday buildings need to be studied as well. Using contemporary observations and data Ambraseys and Finkel ("The Saros-Marmara Earthquake") discuss the performance of building types and the intensity of the earthquake in relation to future seismic threat. They are primarily interested in seismology, not engineering or building construction. Mustafa Armagan's *Alev ve Baton* (İstanbul, 2000) represents a promising new direction in research. It traces the history of the condemnation of the wooden house in the 1920s from a political standpoint. In San Francisco I have been attempting to create a context for understanding why and how antiseismic design was used. See my "A History of Reinforced Masonry Construction Designed to Resist Earthquakes: 1755-1907," *Earthquake Spectra*, Vol. 1, No. 1, November 1984, pp. 125-150. "Bond Iron and the Birth of Anti-Seismic Reinforced Masonry Construction in San Francisco, "*The Masonry Society Journal,* Vol. 5, No. 1, January-June 1986, pp. 12-18.. "Construzione anti-sismiche in muratura nella storia di San Francisco," *Costruire in Laterizio*, no. 15, May-June, 1990, pp. 191-196 Chapter 5, "How has architecture responded to earthquake challenges over time?" *Past, Present and Future Issues in Earthquake Engineering; Proceedings of the fiftieth annual meeting of the EERI*, 1998, pp. 9-12. pp. 13-23.

[15] Ambraseys and Finkel, *The Seismicity of Turkey,* p. 144; document of 1766 in Zarif Ongun, "1509 (Hicrî) senesinde İstanbulu baştanbaşa harab eden zelzelede şehri tamir için alınan tedbirler," *Arkitekt*, 1940, pp. 164-167.

[16] Ambraseys and Finkel, *The Seismicity of Turkey,* p. 93; İzmir continued to be a city of wooden houses until 1922 when it was burned during a battle between Greek and Turkish forces.

[17] On Lima and Lisbon see Charles Davis, "Shaking the Unstable Empire: The Lima, Quito, and Arequipa Earthquakes, 1746, 1783, and 1797" and Tobriner, "Safety and Reconstruction after the Sicilian Earthquake of 1693---the 18th century context," in *Dreadful Visitations, Confronting Natural Catastrophe in the Age of Enlightenment*, ed. Alessa Johns, New York and London, 1999, pp. 113-144 and 49-77.

[18] The building in question was the Grand Hotel in San Francisco. See "South Hall and Seismic Safety at the University of California in 1870," *Chronicle of the University of California*, 1: 1, 1998, p. 16.

[19] Köker, p. 6, Ürekli, pp. 40-54.

[20] Yet when newspapers published the opinions of the experts, architects wrote that the reason masonry had failed was that it was constructed by non-architects who knew nothing about good construction. Western-style masonry construction had survived, they argued, and begin a discussion of the best way of building masonry walls. Ürekli, *Ibid.*

[21] Kuban, p. 241

[22] Tobriner, "Safety and Reconstruction after the Sicilian Earthquake of 1693---the 18th century context," in *Dreadful Visitations, Confronting Natural Catastrophe in the Age of Enlightenment*, ed. Alessa Johns, New York and London, 1999, pp. 49-77.
[23] V. Cóias e Silva, "Um Novo modelo (e uma Nova Visão) do Edificado Pombalino," *Monumentos, Revista semestral de edificios e monumentos*, 6, March, 1997, 80-85.
[24] "La Casa Baraccata: Earthquake-resistant Construction in 18th Century Calabria," *Journal of Architectural Historians*, May 1983, XLII, No. 2, pp. 131-138. "La casa baraccata: un sistema antisimico nella Calabria del xviii secolo," *Per Costruire in Laterizio, antologia di saggii dalla rivista ufficiale*, ed. C. Latina, Rimini, 1999, pp. 203-209.
[25] See D. Upton, *Architecture in the United States*, Oxford, 1998, pp. 152-155 and pp. 307-309.
[26] For statements that wood was seismically resistant see: Tobriner, "South Hall and Seismic Safety at the University of California in 1870," *Chronicle of the University of California*, 1; 1, 1998.
[27] See P. I. Yanev, *Peace of Mind in Earthquake Country: How to Save Your Home and your Life*, San Francisco, 1974 and later editions.
[28] Günay, *Tradition of the Turkish House and Safranbolu Houses*, İstanbul, 1998, p. 66
[29] Although earthquakes do occur in Central Europe the cheapness of wood as opposed to masonry probably explains the popularity of timber framed buildings constructed in Germany in the late 16th through the 18th centuries. The half-timbered motifs of St. Andrew's cross, the Swabian wife, the Husband and the Half-husband can be seen in half-timbered churches especially in the area of Vogelsberg in Hesse, Germany. The intricacy of the exposed timber frames was extremely refined and contrasts markedly with the more casual timber frames of Turkish houses. See Förderkreis Alte Kirchen eds., *Fachenwerkkirchen in Hessen*, Königstein/Taurnus, 1987.
[30] For an introduction to English timber-framed buildings see R. Harris, *Discovering Timber-Framed Buildings*, Bucks (UK), 1978; also see bibliography in Upton, *Architecture in the United States, pp. 307-309*
[31] Günay, p. 93
[32] Sedad Eldem's series on the Turkish house (*Türk Evi Osmanlı Dönemi/Turkish Houses of the Ottoman Period*, İstanbul, I, 1984, II, 1986, III, 1987) is an indispensable source for Safronbolu. The best study of the city is Reha Günay's *Tradition of the Turkish House and Safranbolu Houses*, İstanbul, 1998.
[33] My comments on configuration and buildings as well as hazards specific to wooden buildings are derived from many sources, among them *Buildings at Risk: Seismic Design Basics for Practicing Architects*, AIA/ACSA Council on Architectural Research, Washington, DC, 1994; C. Arnold and R. Reitherman, *Building Configuration and Seismic Design*, NY, 1982, and Yanev, *Peace of Mind in Earthquake Country.*
[34] Mr. Turgut Cansever believes that the negative assessment of masonry ground floors is too sweeping. These masonry walls can be antiseismic. He cites the example of the Muharrem Nuri Birgi house in Salacak, İstanbul, an 18th century wooden structure he restored in the 1970s which suffered no damage in the last two earthquakes.

[35] I interviewed Mr. Turgut Cansever in his office in December, 1999. At that time he drew the sketch illustrated here. Whether the nails were actually strong enough to provide a "moment" connection is still unclear. These nails or spikes are mentioned---disparagingly---in one 19th century document: "The frame, which is of very small dimension for the size of the building, is clumsily fastened together be large spikes" (J. De Kay, *Sketches of Turkey*,1831 and 1832, New York: 1833, quoted by Kuban, p. 239.)

[36] Barilari and Godoli, p.182

[37] M. H. Boduroglu, "Rural buildings in Turkey that have suffered damages in recent earthquakes and their main causes," *Bulletin of the International Institute of Seismology and Earthquake Engineering*, 23, 1989, p. 369.

[38] See E. Toby Morris, R. Gary Black, and Stephen Tobriner, "Report on the Application of Finite Element Analysis to historic Structures, Westminster Hall, London," *Journal of the Society of Architectural Historians* 54:3, September 1995, pp. 336-347.

[39] Barilari and Godoli, p.182.

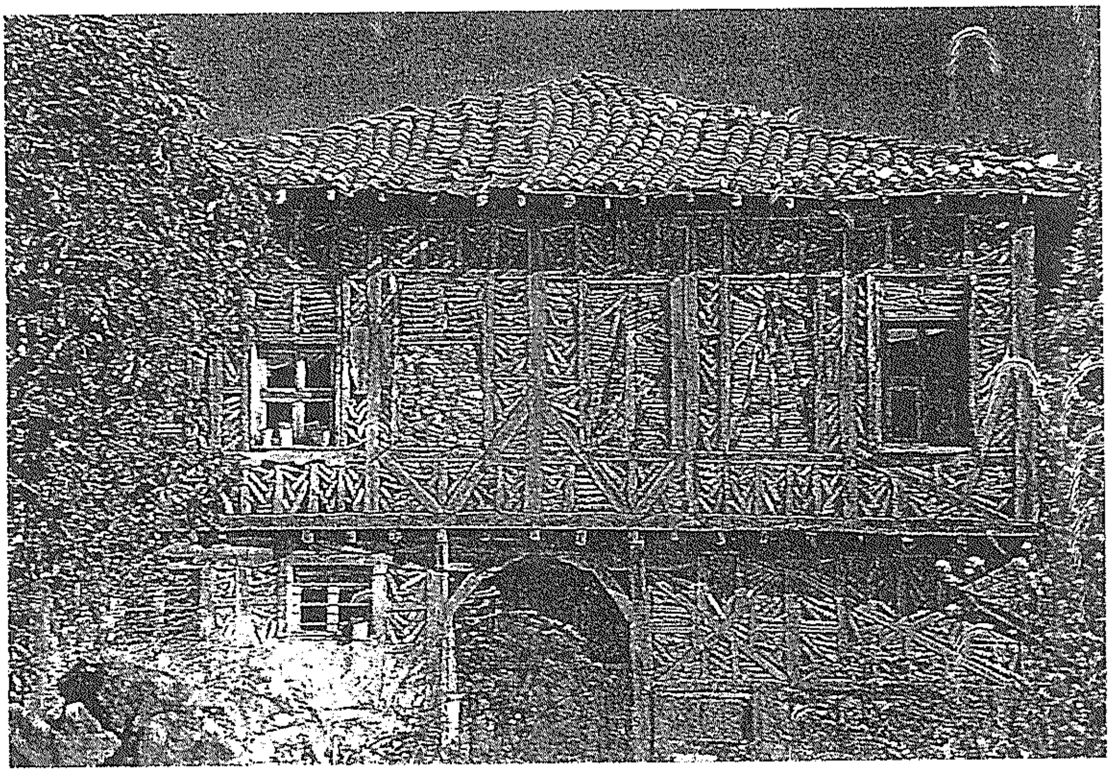
Figures*

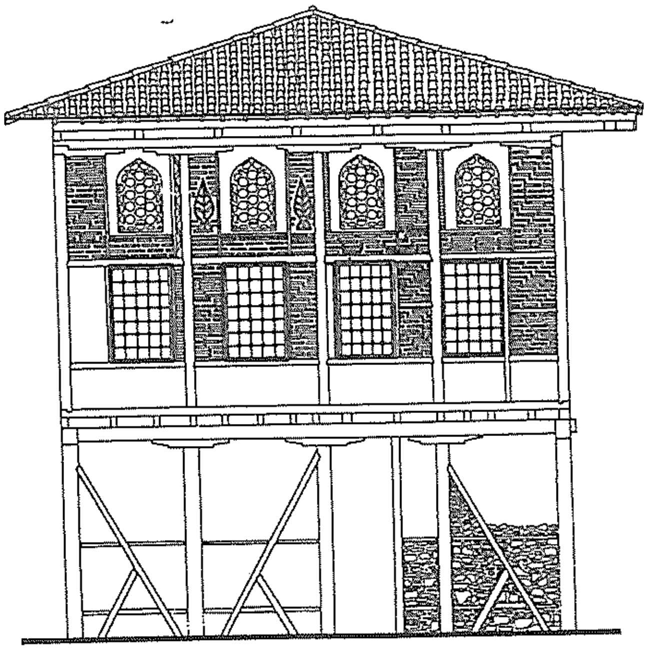
Wooden Architecture and Earthquakes in Istanbul

1. Apolyont Köyü, Bursa (after D. Kuban, *The Turkish Hayat House*, Istanbul, 1995, p.241)
2. Hasan Aga house, Mudanya (after Kuban, p. 240)
3. Typical timber framing in "old days" (after R. Günay, *Tradition of the Turkish House and Safranbolu houses*, Istanbul, 1998, p. 302)
4. Typical timber framing of "more recent date" (after Günay, p. 303)
5. *Gaiola* system, Portugal (after V. Cóias e Silva, office drawings, 1995)
6. *Gaiola* system, Portugal (after V. Cóias e Silva, office drawings, 1995)
7. *Casa baraccata*, Calabria (after Tobriner, "La casa baraccata: un sistema antisimico nella Calabria del xviii secolo," *Per Costruire in Laterizio, antologia di saggii dalla rivista ufficiale*, ed. C. Latina, Rimini, 1999, p. 205.)
8. (a.) An example of modern balloon frame construction (after A. G. H. Dietz, *Dwelling House Construction*, Cambridge, Mass., 1977, fig. 5.12) The sheathing (plywood in this illustration) resists shear forces, hence the lack of diagonal bracing in the frame. This kind of balloon frame is rarely used in the United States today because of the lack of lumber long enough for two story studs. More common is platform frame construction (b.) in which each story is framed separately and braced with diagonals as well as sheathed. The illustrated in figure 8b. is a two-story platform-framed house in construction. The first floor has been framed and sheathed and its joists provide the platform for the second floor, which is partially framed.. (after E. Allen, *Fundamentals of Building construction, Materials and Methods*, N.Y., 1985, fig. 5.41)
9. An example of the flexibility of balloon frame construction after the 1906 earthquake (W. Bronson, *The Earth Shook, the Sky Burned*, San Francisco, 1959 p. 27)
10. Arap Hacilar house, Şehir district, Safranbolu (after Günay, p. 212)
11. Saraçlar house, Şehir district, Safranbolu (after Günay, p. 214)
12. *Hayat*, Saraçlar house, Şehir district, Safranbolu (Günay, p. 159)
13. Timber frame house, Safranbolu (Günay, p. 147)
14. Haci Kadilar house, Şehir district, Safranbolu (Günay, p. 223)
15. Antepler house, Safranbolu (Günay, p. 226)
16. Kayamakamlar house, Şehir district, Safranbolu (Günay, p. 213)
17. Timber frame houses, Safranbolu (Günay, p. 121)
18. Timber frame house, Safranbolu (Günay, p. 222)
19. Turgut Cansever, Sketch of nail connections, drawn Dec. 1999
20. Timber frame house, Safranbolu (Günay, p. 123)

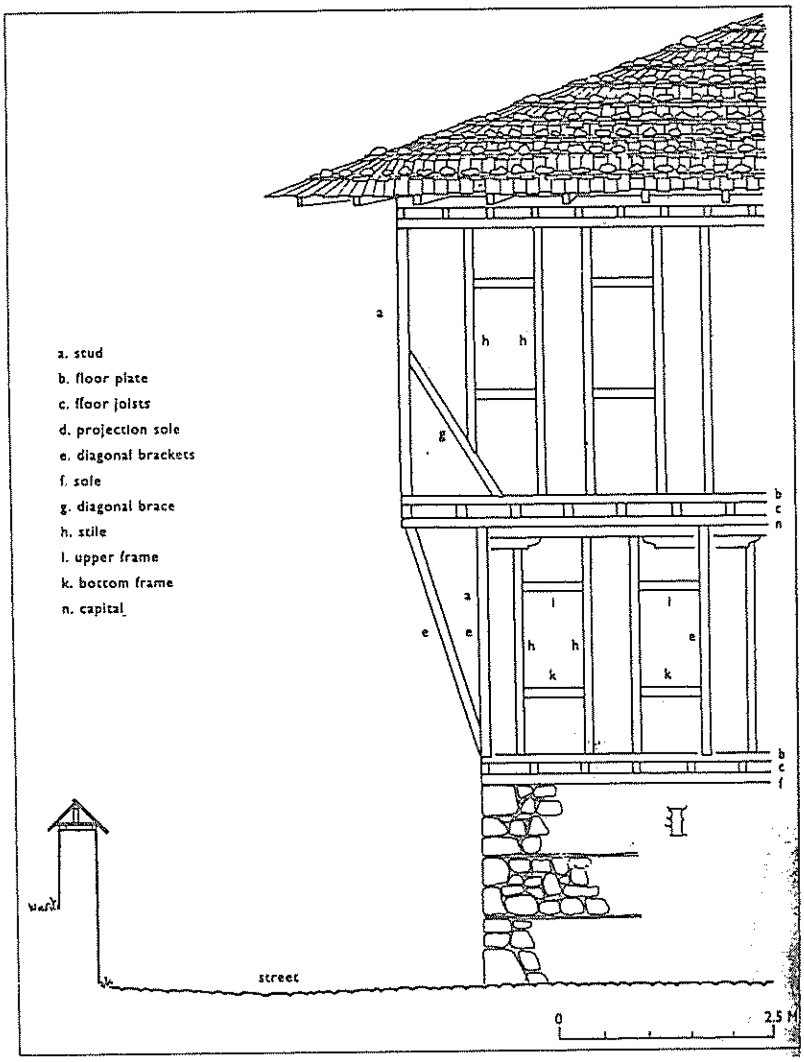
* Unless otherwise indicated photographs are by the author.

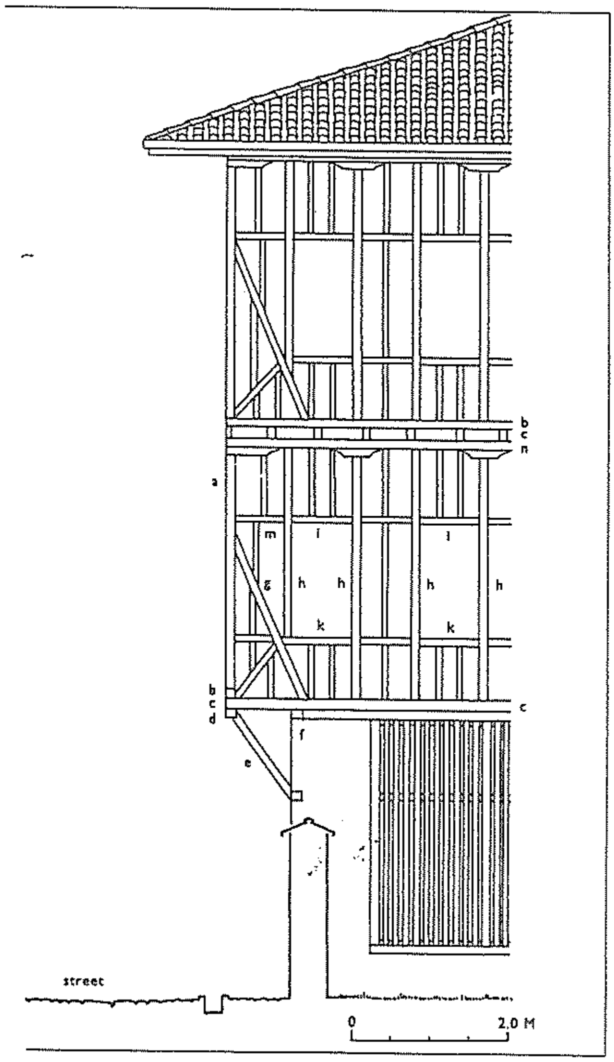
21. Reinforced concrete buildings, Kaynaslı
22. Timber frame buildings on hillside, Kaynaslı
23. Timber frame house, Kaynaslı
24. Timber frame house, Kaynaslı
25. Timber frame house, Kaynaslı
26. Timber frame house, Kaynaslı
27. Timber frame house, Kaynaslı
28. Timber frame house, Düzce
29. Timber frame house, Düzce
30. Timber frame house, Düzce
31. Detail, timber frame house, Düzce
32. Timber frame house, Ulaşlı
33. Interior, timber frame house, Ulaşlı
34. Interior, timber frame house, Ulaşlı
35. Timber frame house, Ulaşlı
36. Timber frame house,Degirmendere
37. Blue House, İstanbul
38. Derelict wooden building, İstanbul
39. Derelict wooden building, İstanbul
40. Carpenter and diagonal of timber frame, Ulaşlı
41. Temporary timber housing, Ulaşlı
42. Temporary timber housing, Ulaşlı
43. Newly erected timber frame building, Degirmendere



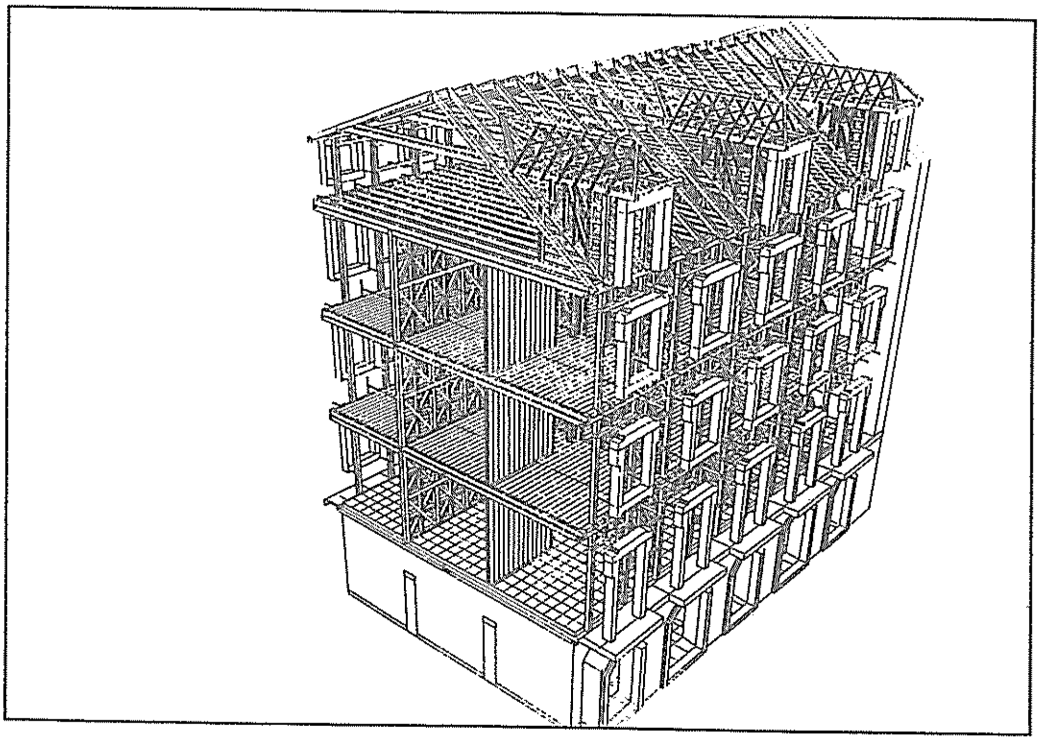


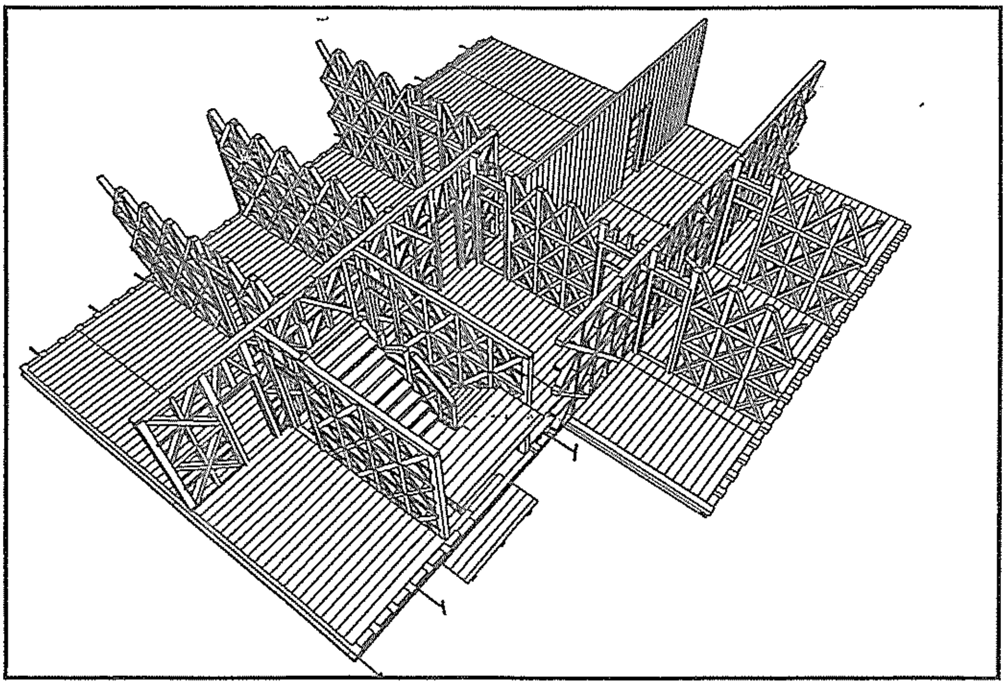
1. Apolyont Köyü, Bursa (after D. Kuban, *The Turkish Hayat House*, Istanbul, 1995, p.241)
2. Hasan Aga house, Mudanya (after Kuban, p. 240)





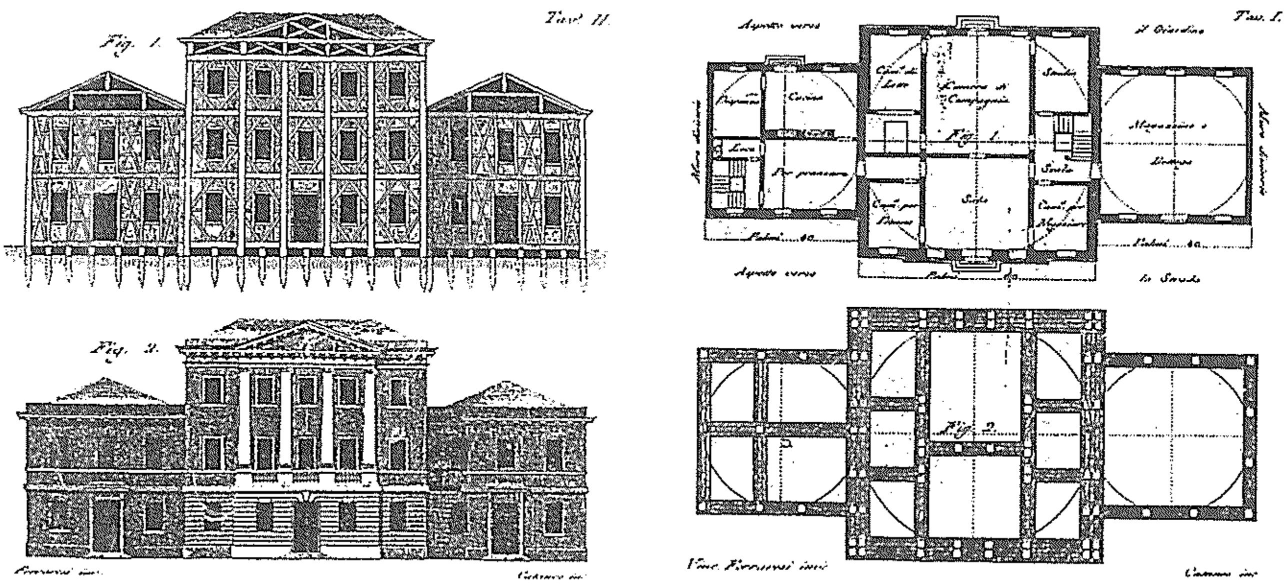
3. Typical timber framing in "old days" (after R. Günay, *Tradition of the Turkish House and Safranbolu houses*, Istanbul, 1998, p. 302)
4. Typical timber framing of "more recent date" (after Günay, p. 303)



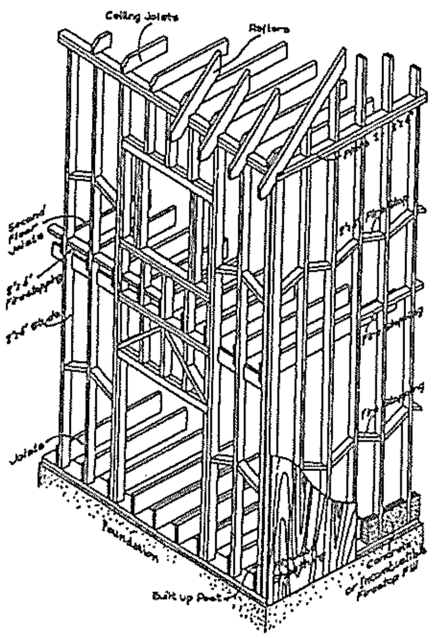


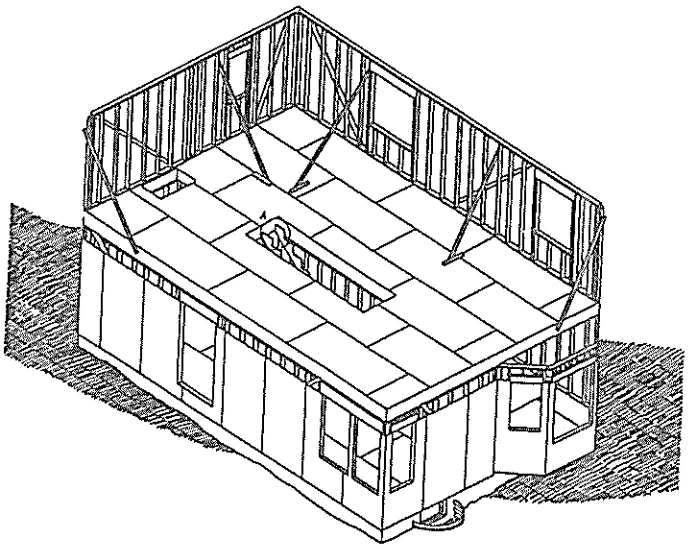
5. *Gaiola* system, Portugal (after V. Cóias e Silva, office drawings, 1995)
6. *Gaiola* system, Portugal (after V. Cóias e Silva, office drawings, 1995)

2

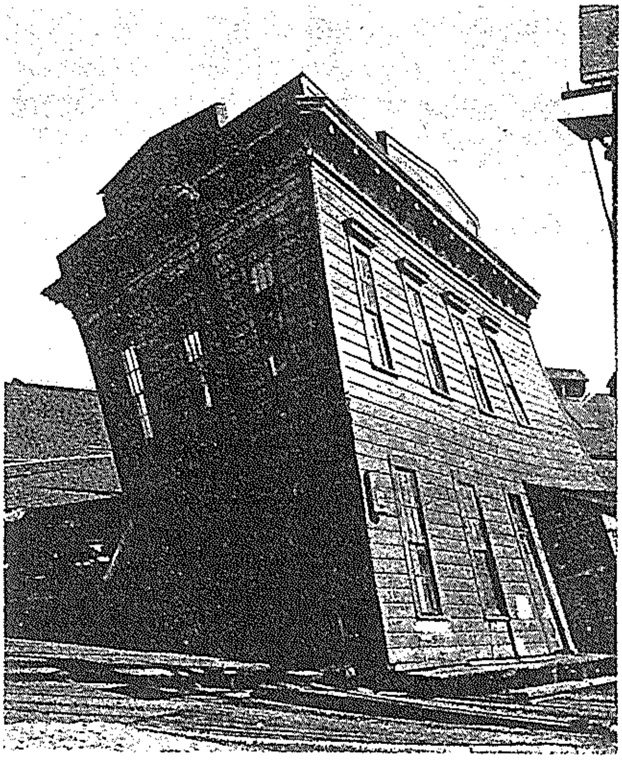


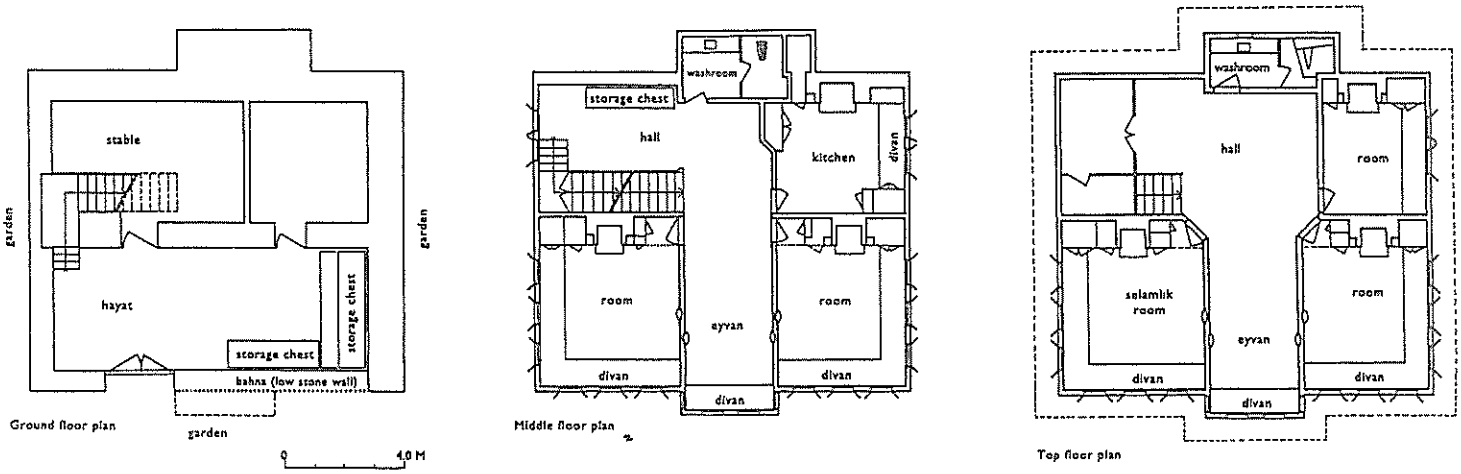
7. *Casa baraccata*, Calabria (after Tobriner, "La casa baraccata: un sistema antisimico nella Calabria del xviii secolo," *Per Costruire in Laterizio, antologia di saggii dalla rivista ufficiale*, ed. C. Latina, Rimini, 1999, p. 205.)



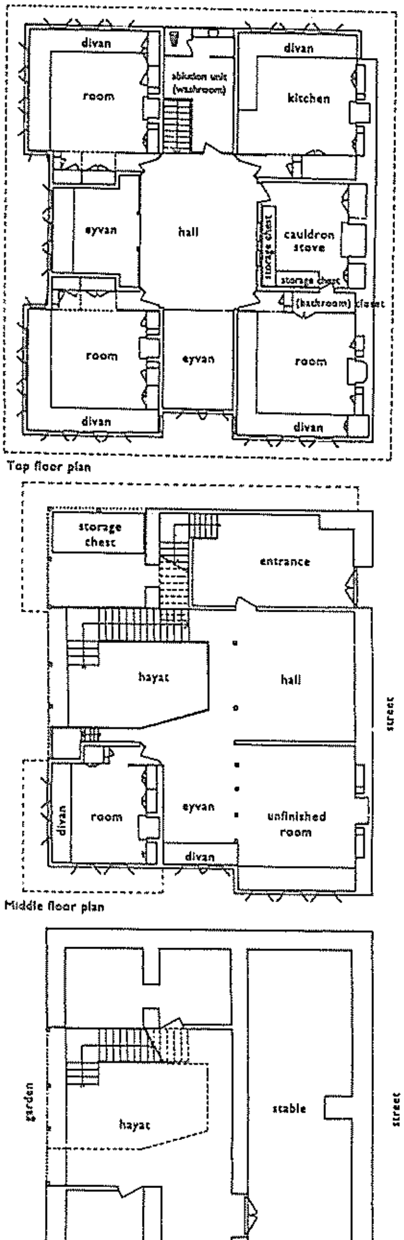


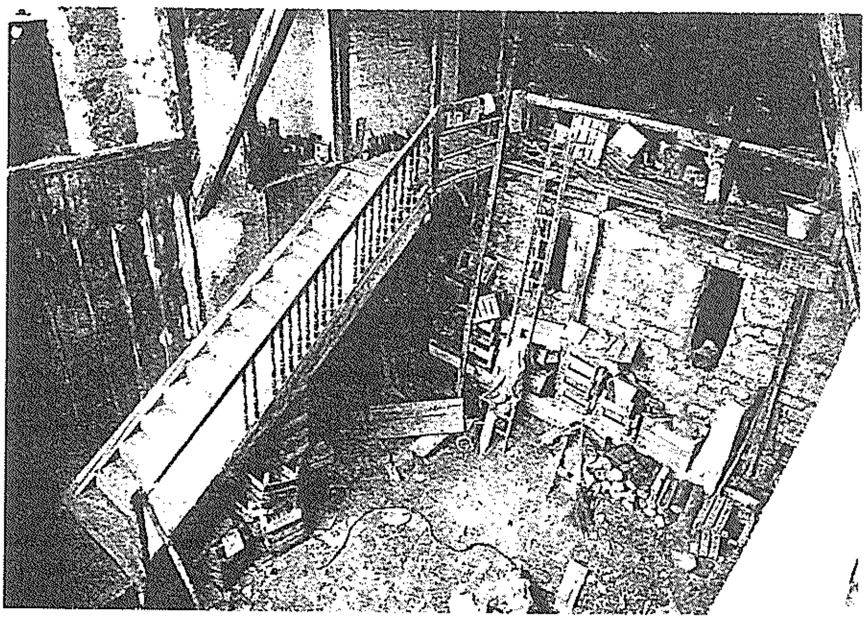
8. (a.) An example of modern balloon frame construction (after A. G. H. Dietz, *Dwelling House Construction*, Cambridge, Mass., 1977, fig. 5.12) The sheathing (plywood in this illustration) resists shear forces, hence the lack of diagonal bracing in the frame. This kind of balloon frame is rarely used in the United States today because of the lack of lumber long enough for two story studs. More common is platform frame construction (b.) in which each story is framed separately and braced with diagonals as well as sheathed. The illustrated in figure 8b. is a two-story platform-framed house in construction. The first floor has been framed and sheathed and its joists provide the platform for the second floor, which is partially framed.. (after E. Allen, *Fundamentals of Building construction, Materials and Methods*, N.Y., 1985, fig. 5.41)



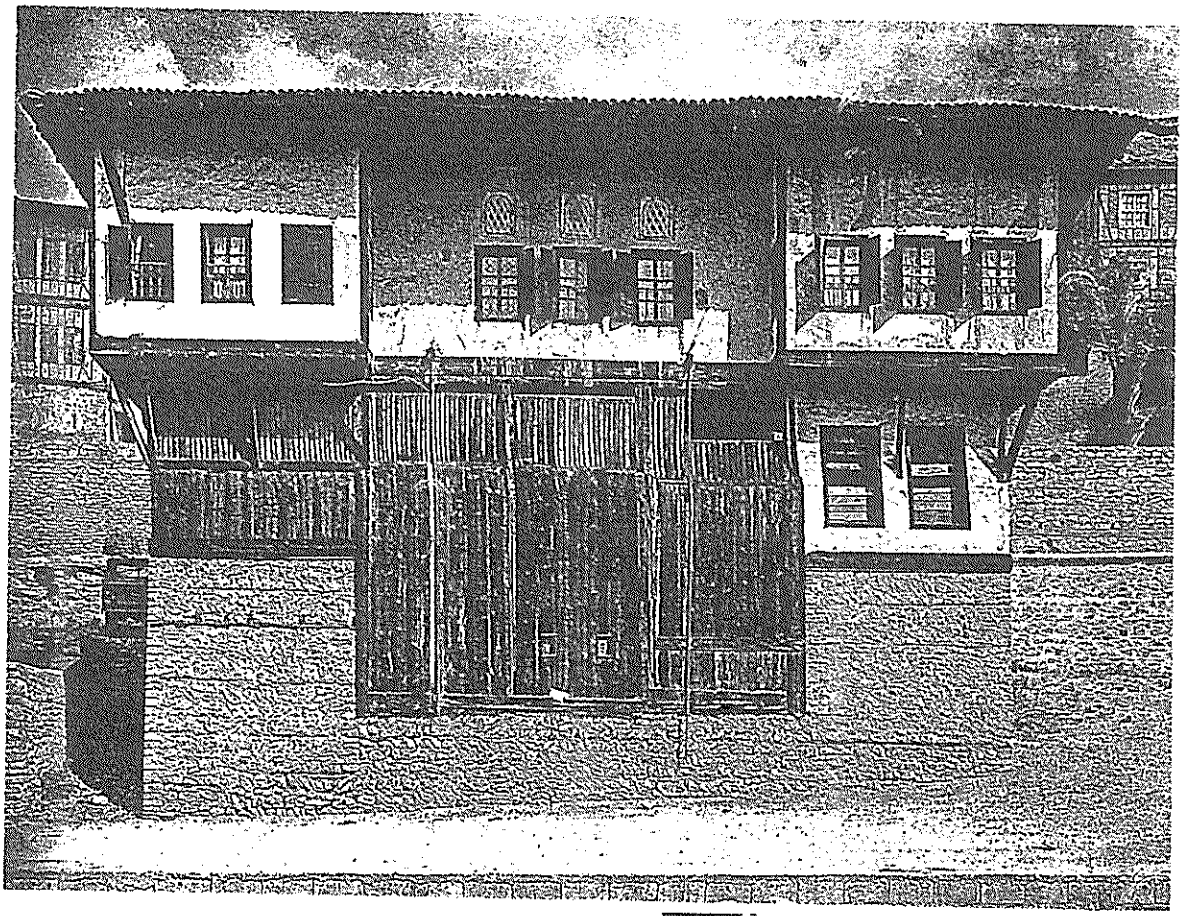


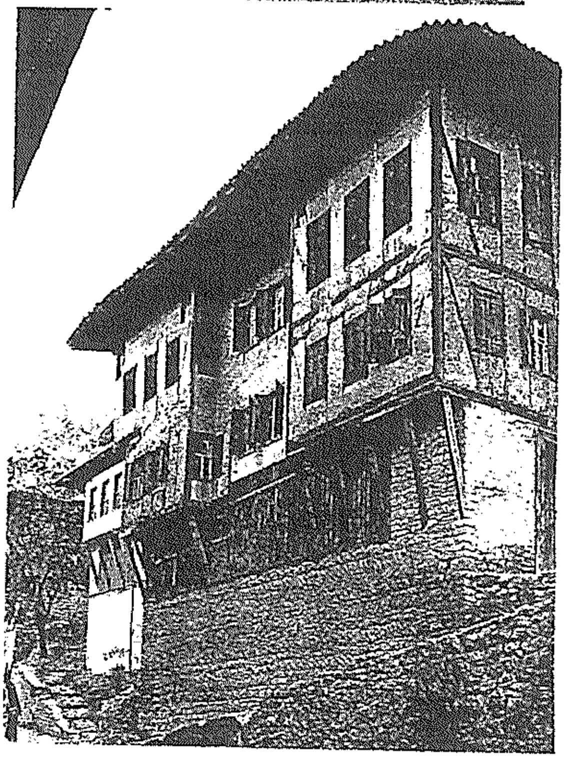
9. An example of the flexibility of balloon frame construction after the 1906 earthquake (W. Bronson, *The Earth Shook, the Sky Burned*, San Francisco, 1959 p. 27)
10. Arap Hacilar house, Şehir district, Safranbolu (after Günay, p. 212)



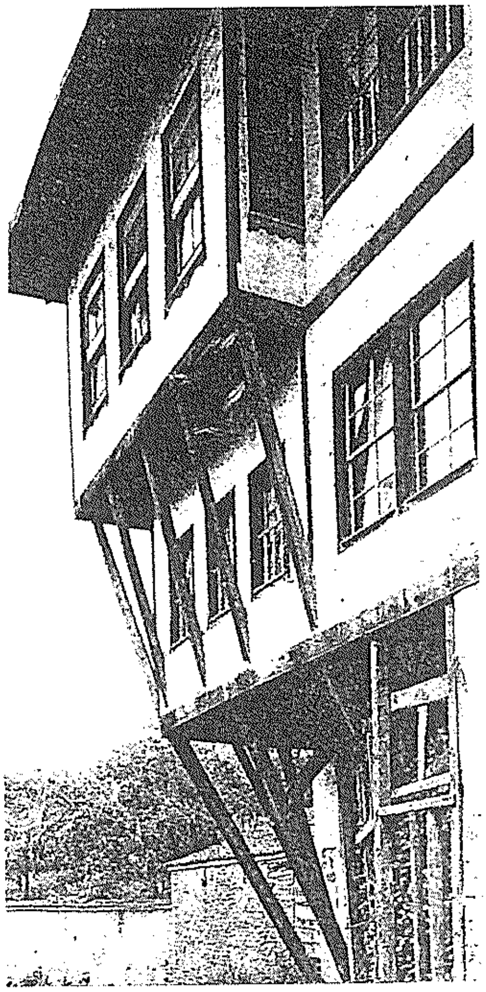


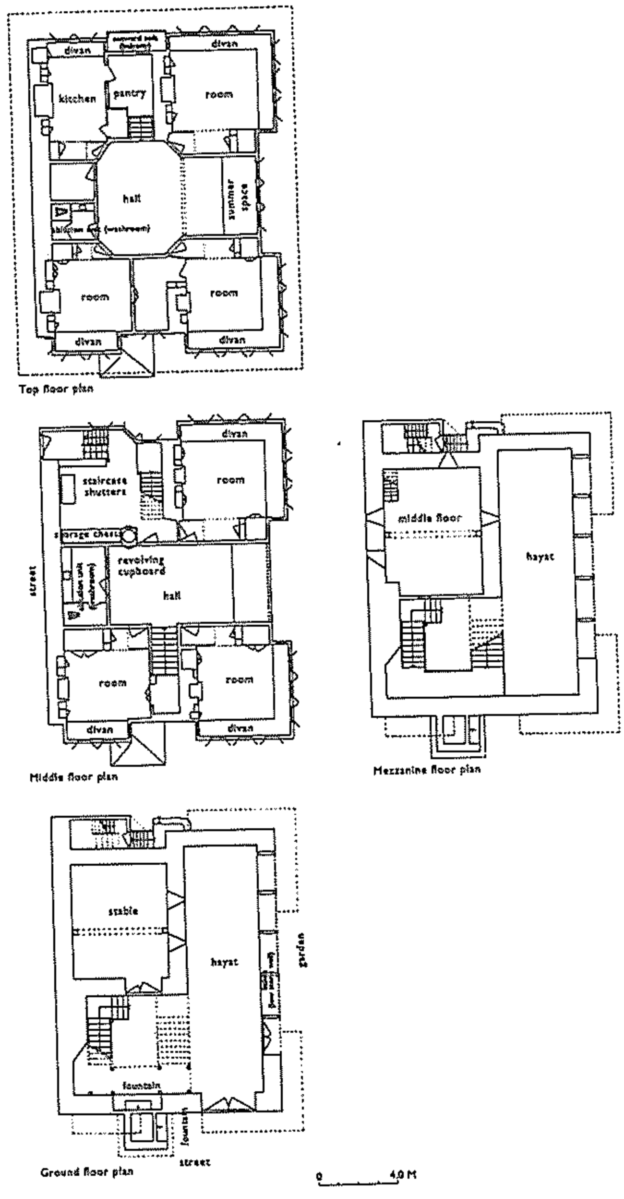
11. Saraçlar house, Şehir district, Safranbolu (after Günay, p. 214)
12. *Hayat*, Saraclar house, Şehir district, Safranbolu (Günay, p. 159)



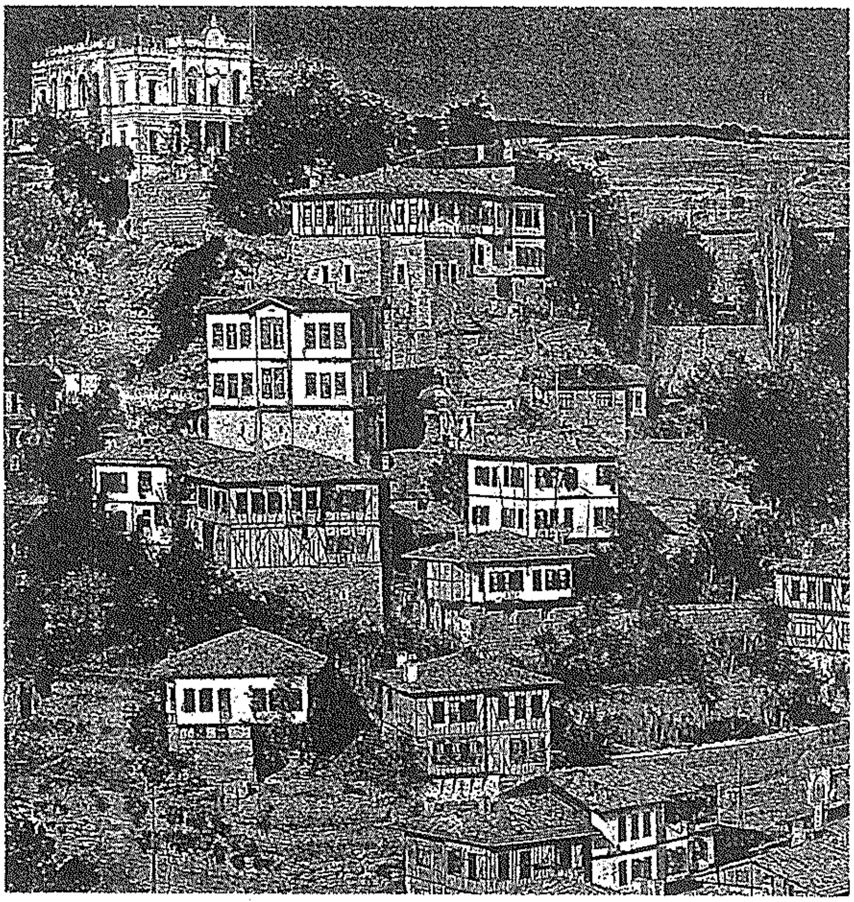


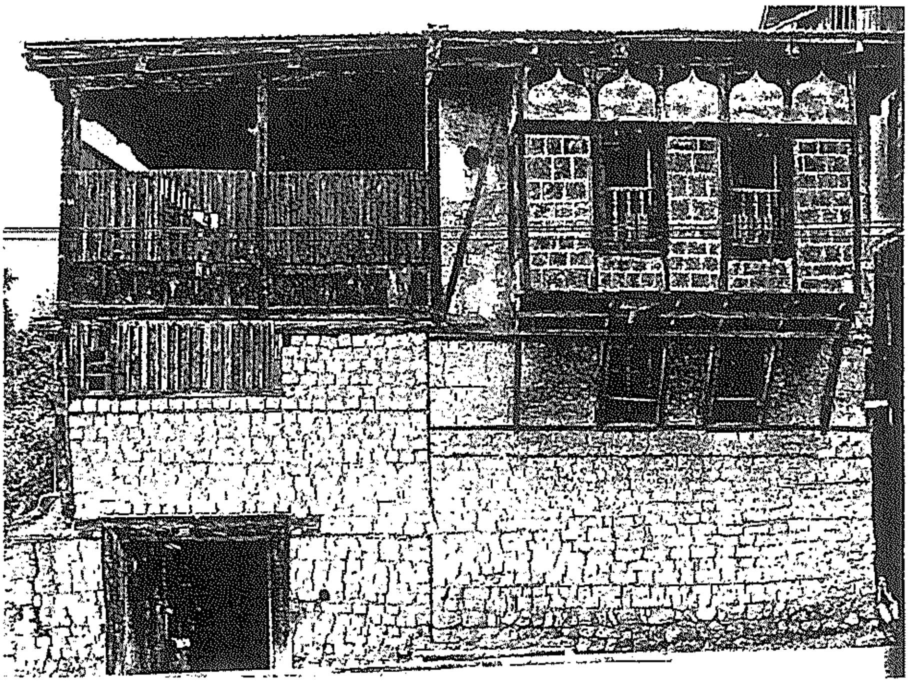
13. Timber frame house, Safranbolu (Günay, p. 147)
14. Haci Kadilar house, Şehir district, Safranbolu (Günay, p. 223)



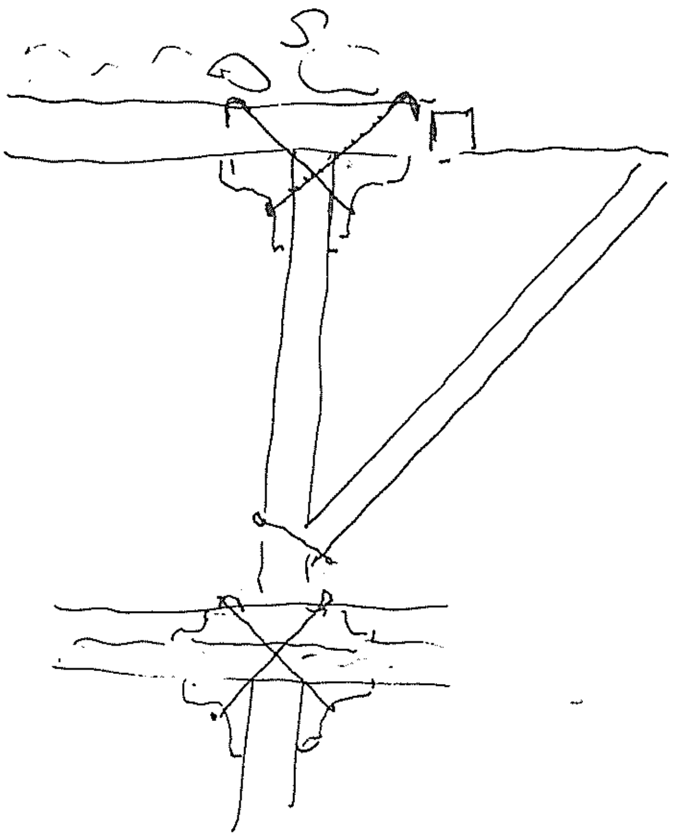


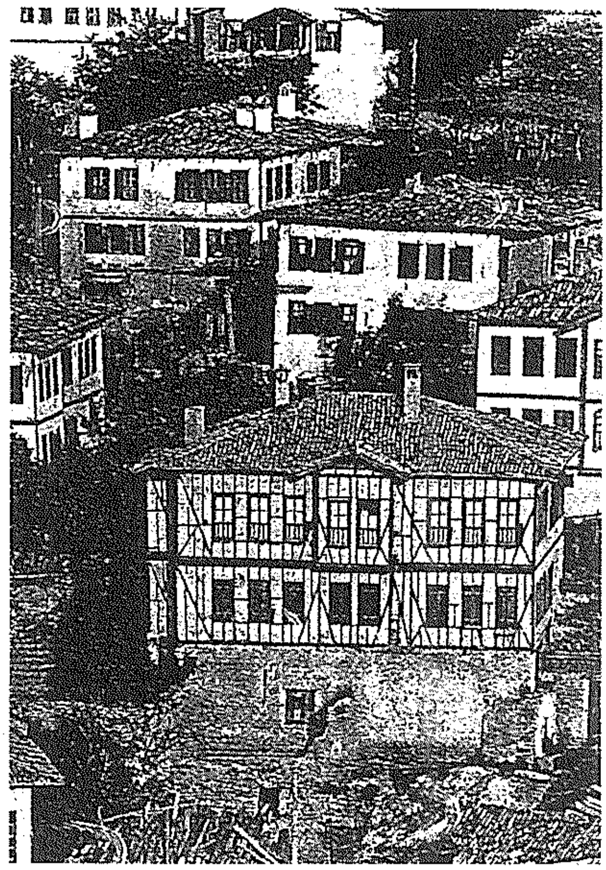
15. Antepler house, Safranbolu (Günay, p. 226)
16. Kayamakamlar house, Şehir Safranbolu (Günay, p. 213)



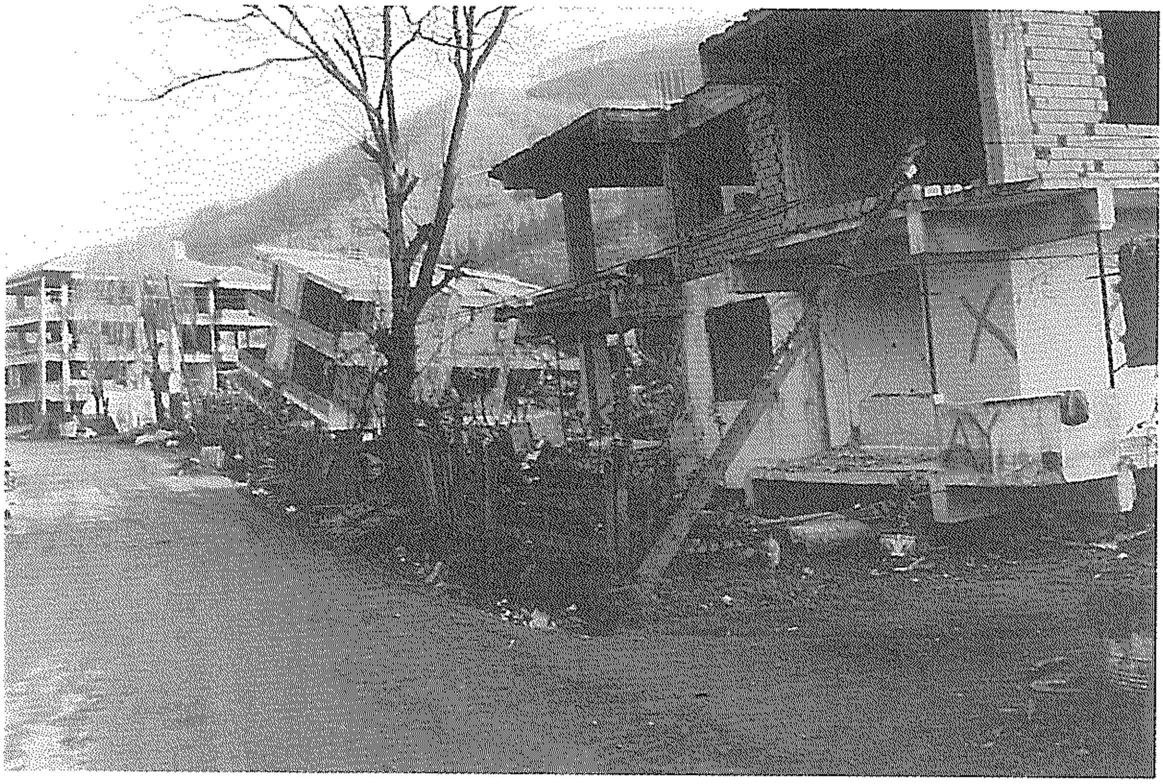


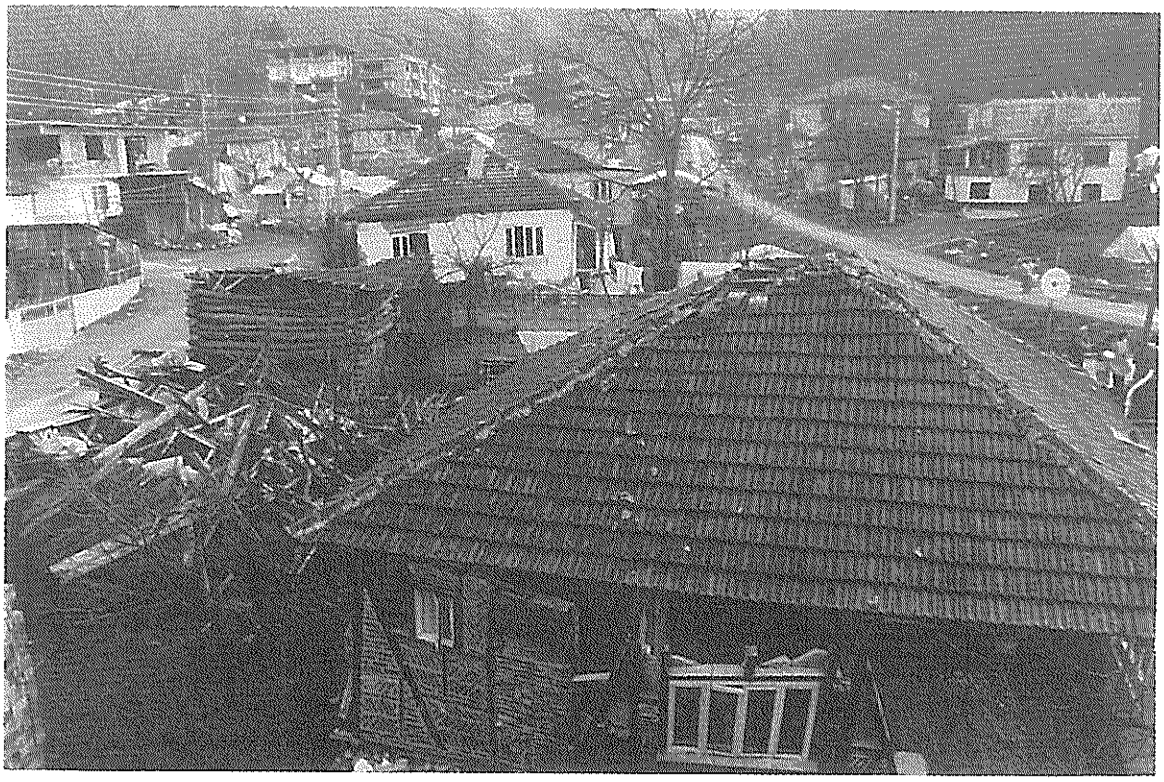
17. Timber frame houses, Safranbolu (Günay, p. 121)
18. Timber frame house, Safranbolu (Günay, p. 222)





19. Turgut Cansever, Sketch of nail connections, drawn Dec. 1999
20. Timber frame house, Safranbolu (Günay, p. 123)





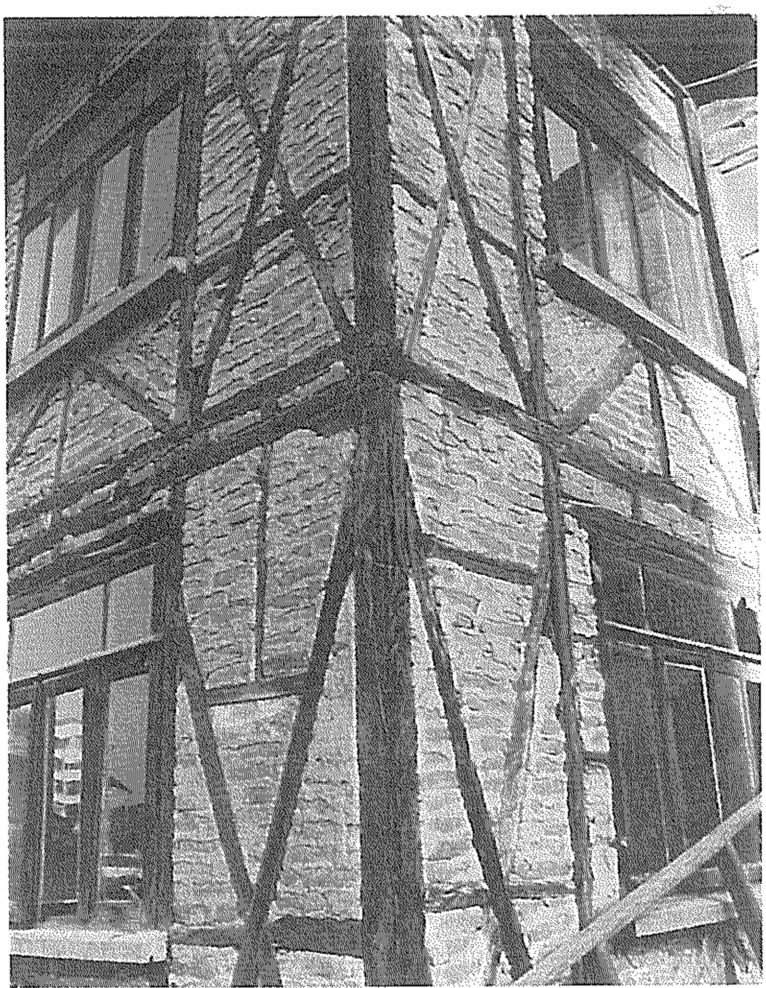
21. Reinforced concrete buildings, Kaynaslı
22. Timber frame buildings on hillside, Kaynaslı

23. Timber frame house, Kaynaslı
24. Timber frame house, Kaynaslı

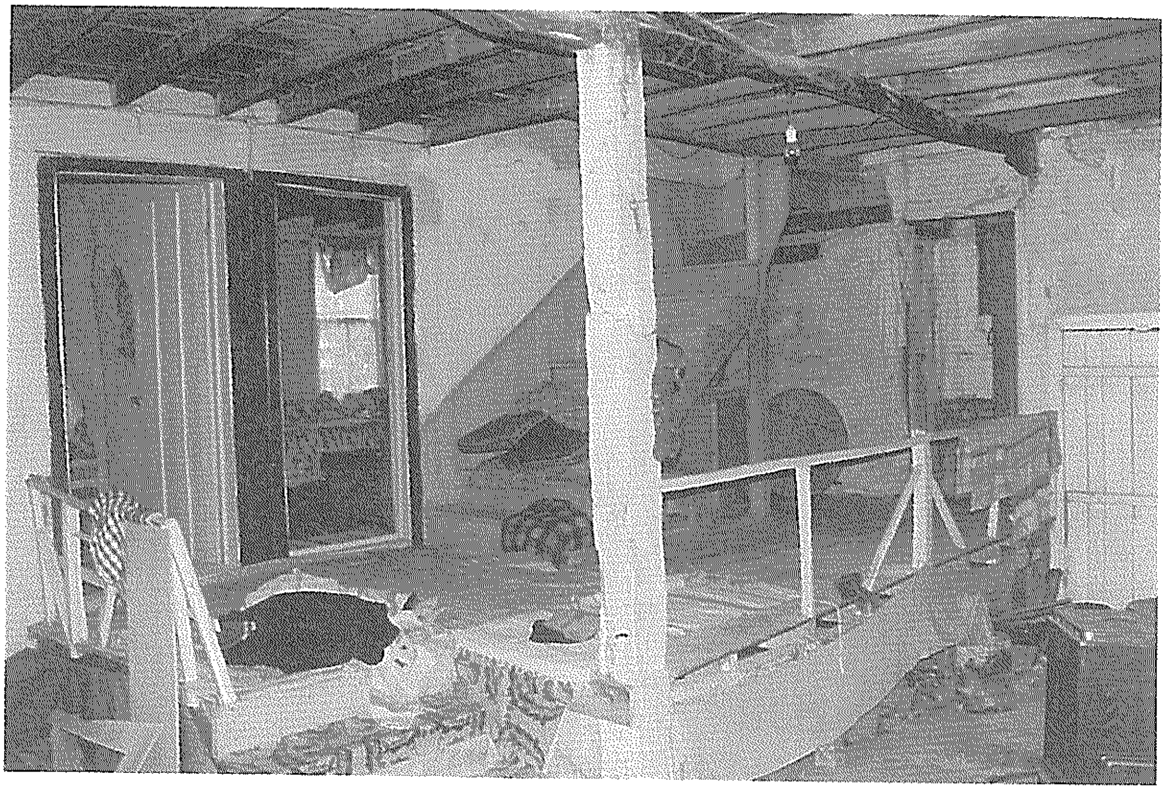
25. Timber frame house, Kaynaslı
26. Timber frame house, Kaynaslı

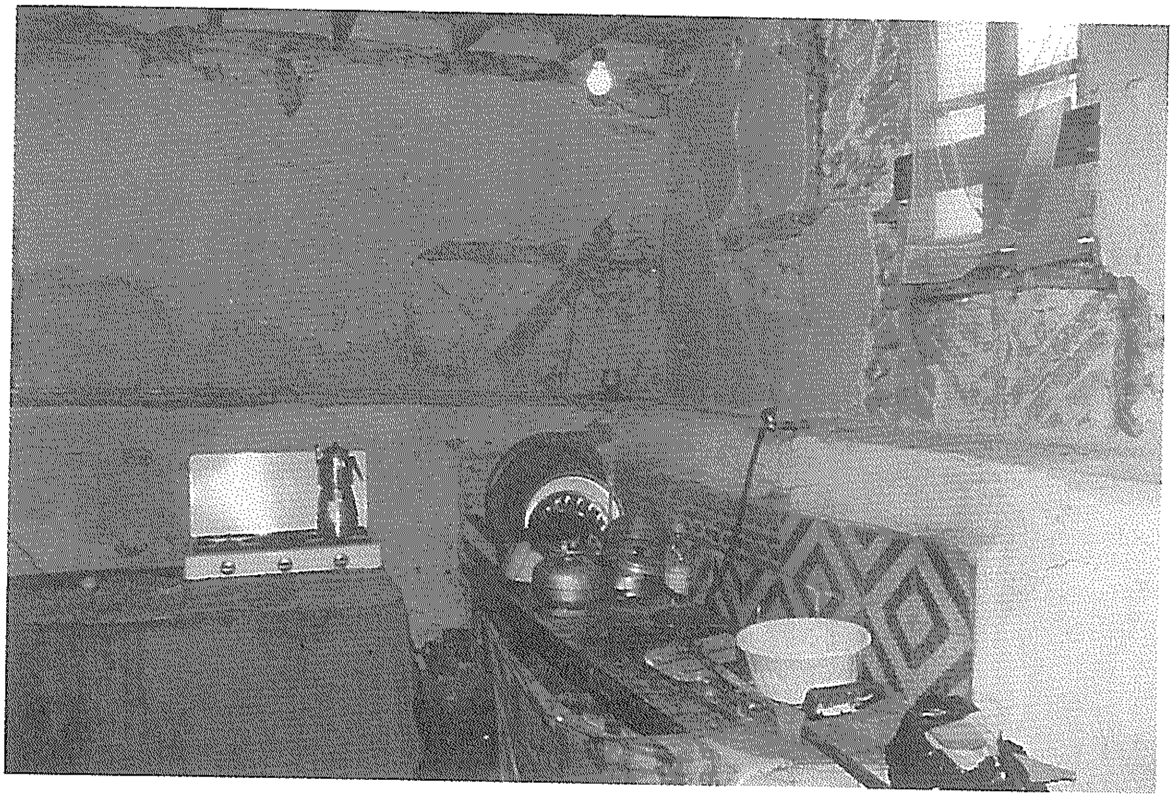
27. Timber frame house, Kaynaslı
28. Timber frame house, Düzce

29. Timber frame house, Düzce
30. Timber frame house, Düzce

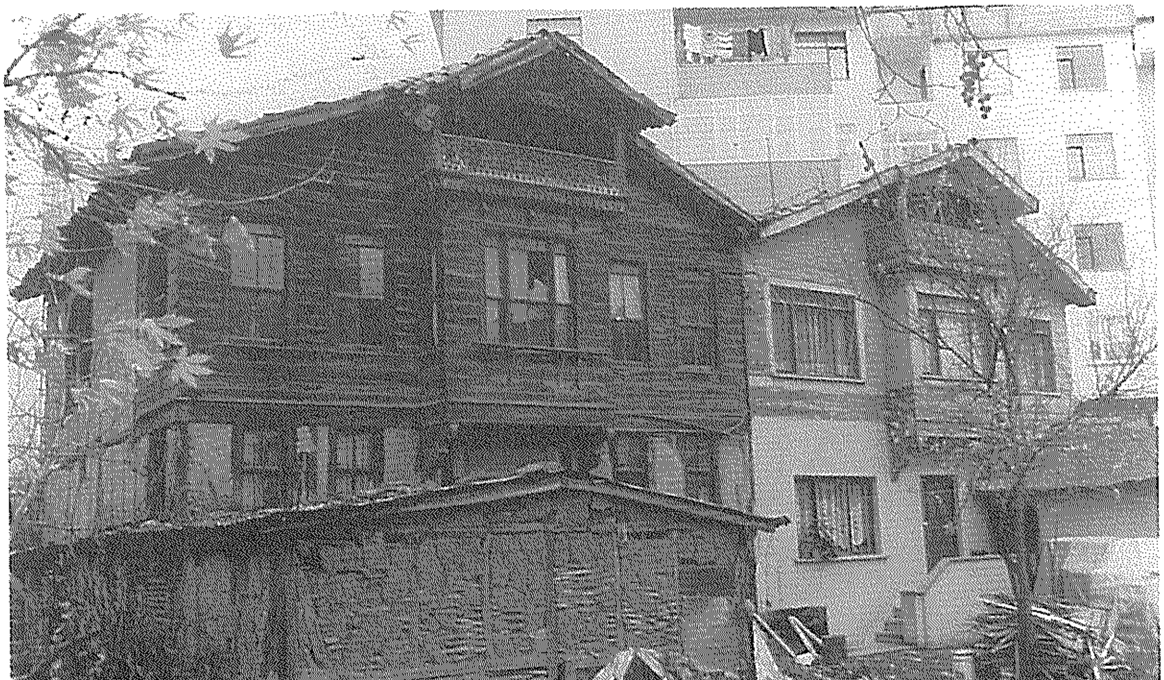


31. Detail, timber frame house, Düzce
32. Timber frame house, Ulaşlı

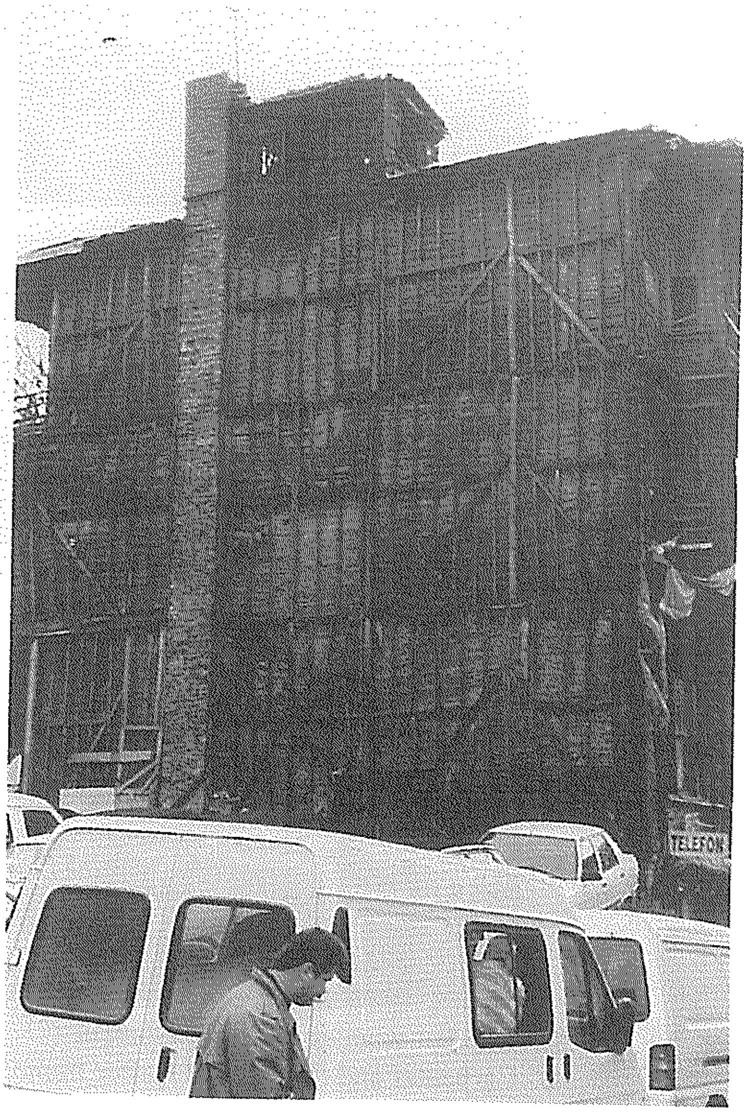




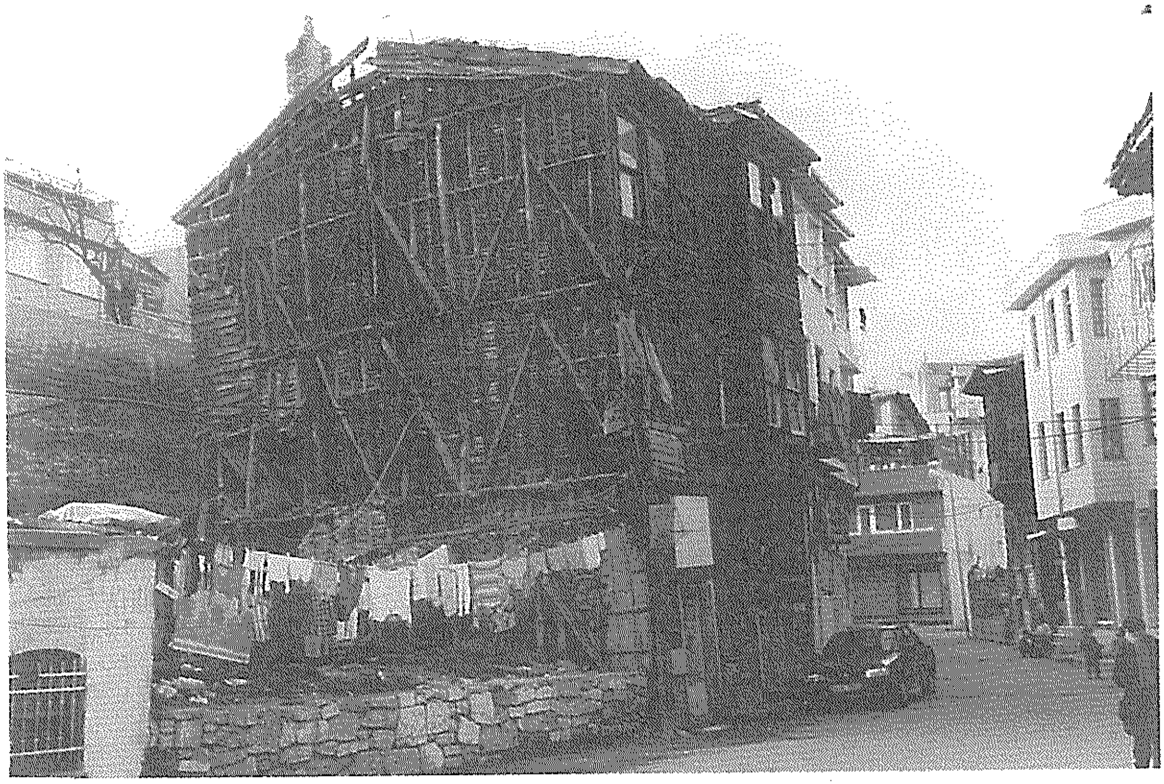
33. Interior, timber frame house, Ulaşlı
34. Interior, timber frame house, Ulaşlı

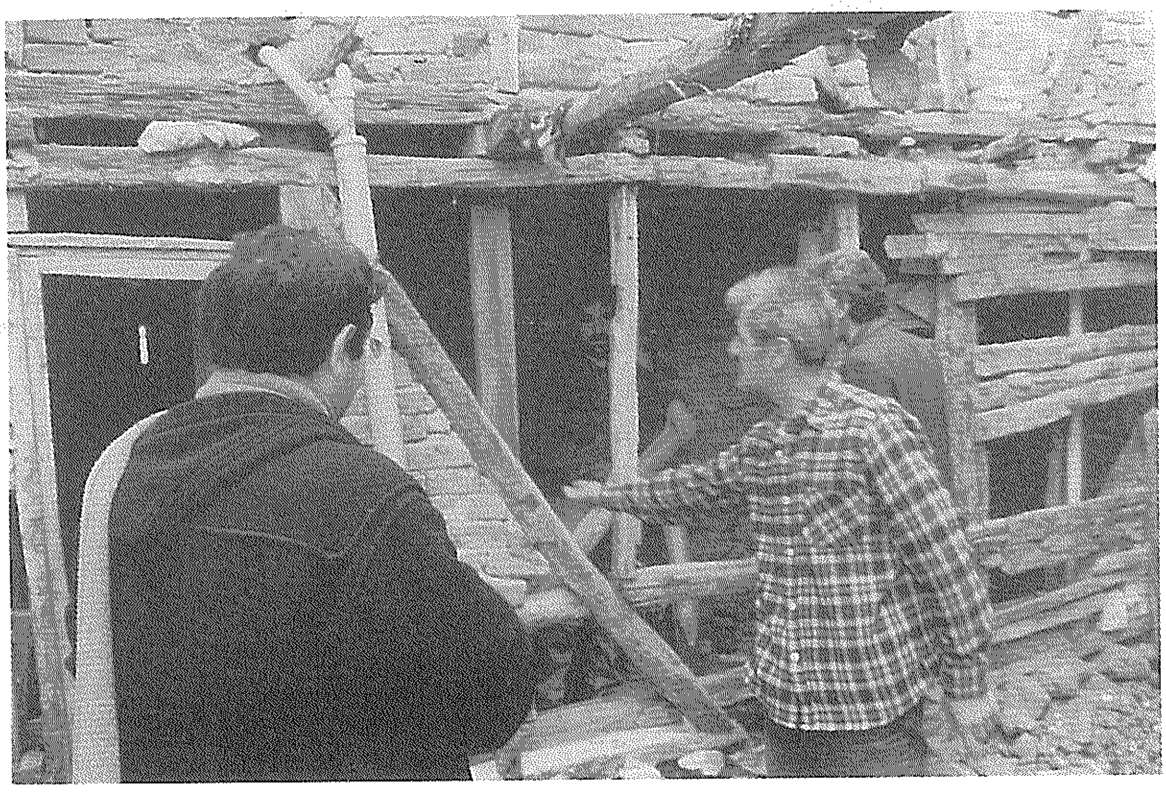


35. Timber frame house, Ulaşlı
36. Timber frame house,Degirmendere

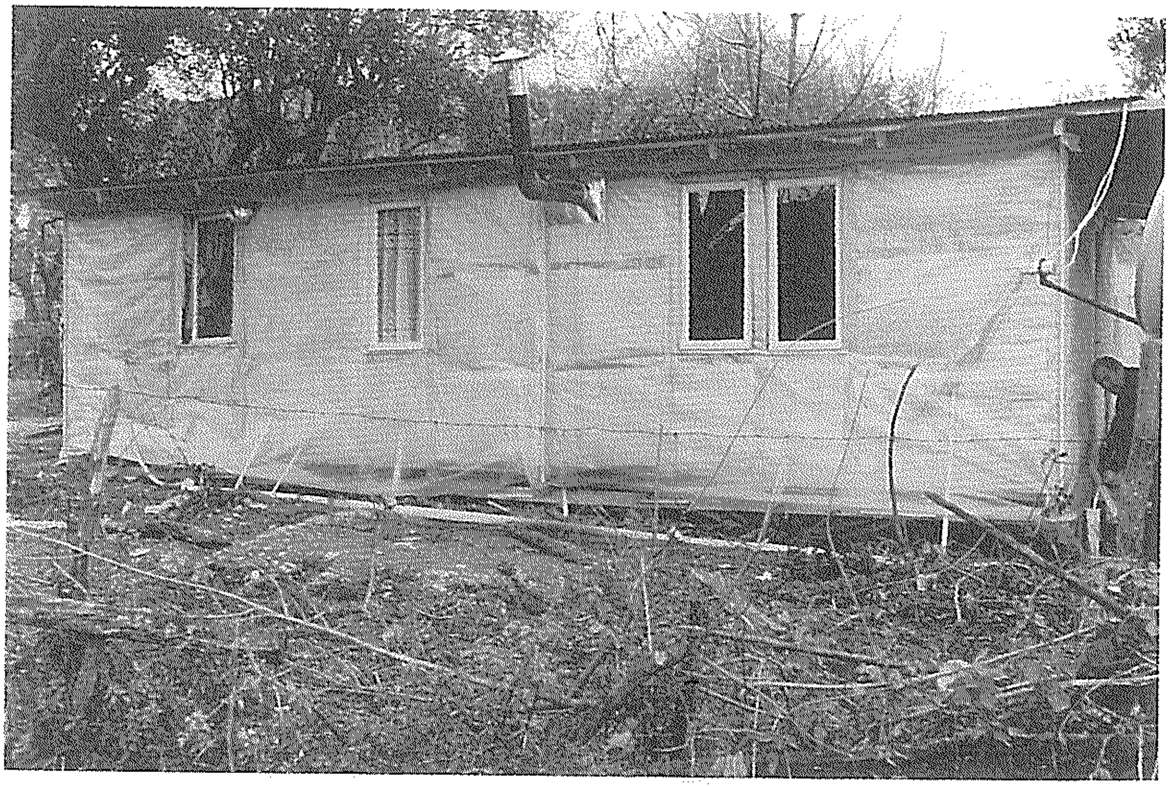


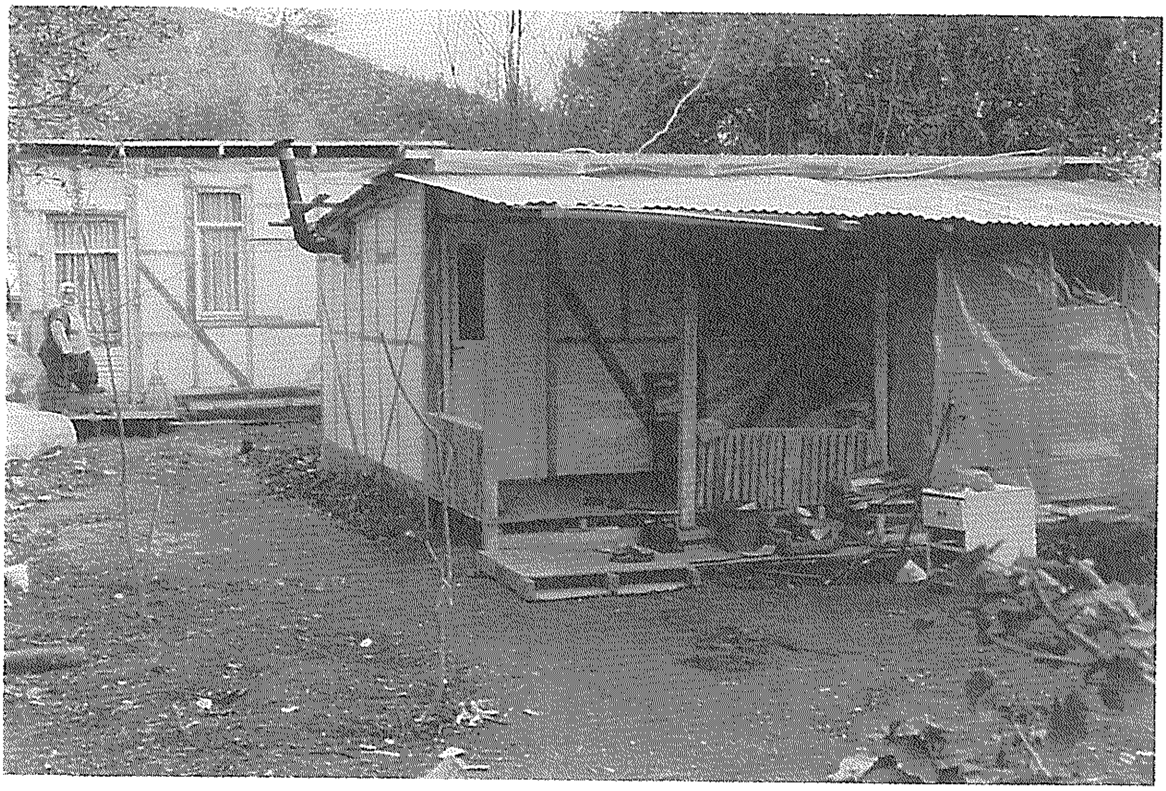
37. Blue House, İstanbul
38. Derelict wooden building, İstanbul



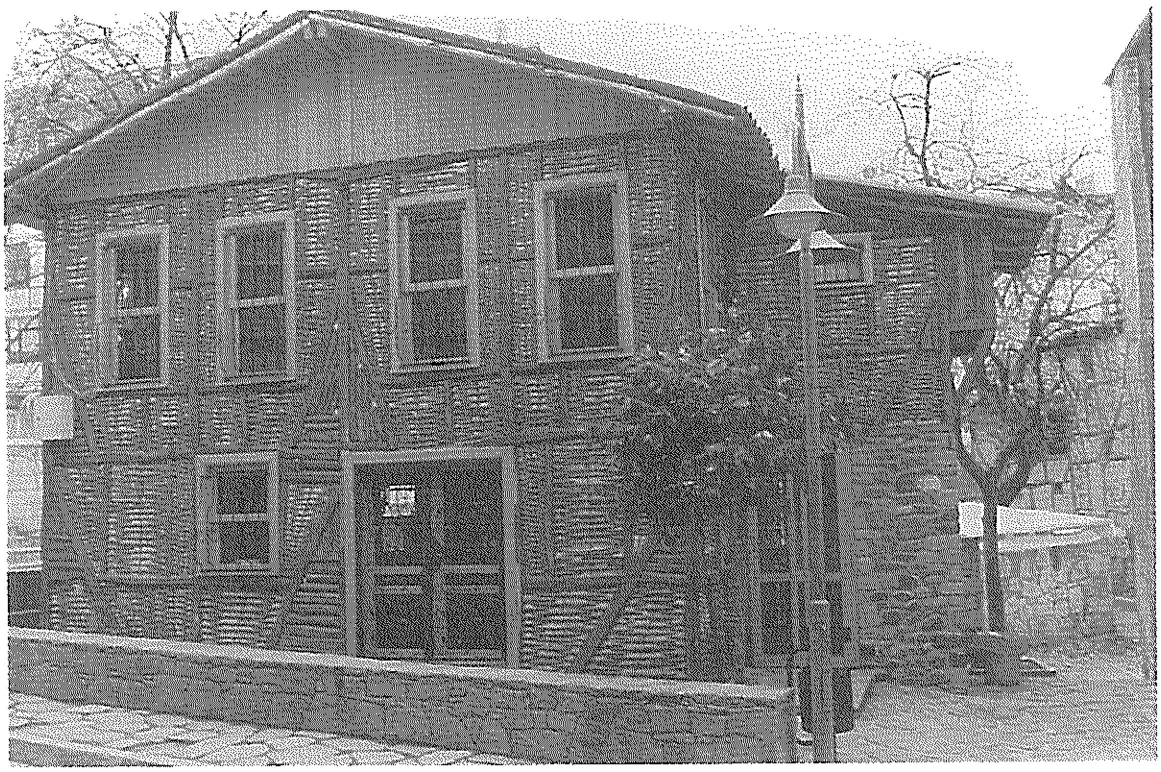


39. Derelict wooden building, İstanbul
40. Carpenter and diagonal of timber frame, Ulaşlı





41. Temporary timber housing, Ulaşlı
42. Temporary timber housing, Ulaşlı



43. Newly erected timber frame building, Degirmendere

United Nations
Centre for Regional Development

Disaster Management Planning Hyogo Office

CONTACT INFORMATION
For further information on the Disaster Management Planning Hyogo Office and its activities, contact:

Masami Kobayashi
Tel: +81-78-230-7561
Fax: +81-78-230-7565
Email: rep@hyogo.uncrd.or.jp
Web site: http//www.hyogo.uncrd.or.jp

Mailing address:
UNCRD Disaster Management Planning Hyogo Office
IHD Centre Building, 4th Floor
1-5-1 Wakihama-kaigan-dori, Chuo-ku
Kobe 651-0073, JAPAN

国際連合地域開発センター
防災計画兵庫事務所

所長　小林 正美

〒651-0073 神戸市中央区脇浜海岸通 1-5-1
IHD センタービル 4 階
電話（078）230-7561
ファックス（078）230-7565
E メール rep@hyogo.uncrd.or.jp
ホームページ http//www.hyogo.uncrd.or.jp