



FIGURE 25 THE WEST WALL OF THE HIGH SCHOOL BUILDING SHOWN IN FIGURES 23 AND 24. AGAIN, ALL LATERAL RESISTING ELEMENTS ARE SHATTERED.



FIGURE 26 SEVERAL BRICK CHIMNEYS FELL THROUGH THE ROOFS OF THE HIGH SCHOOL BUILDINGS.

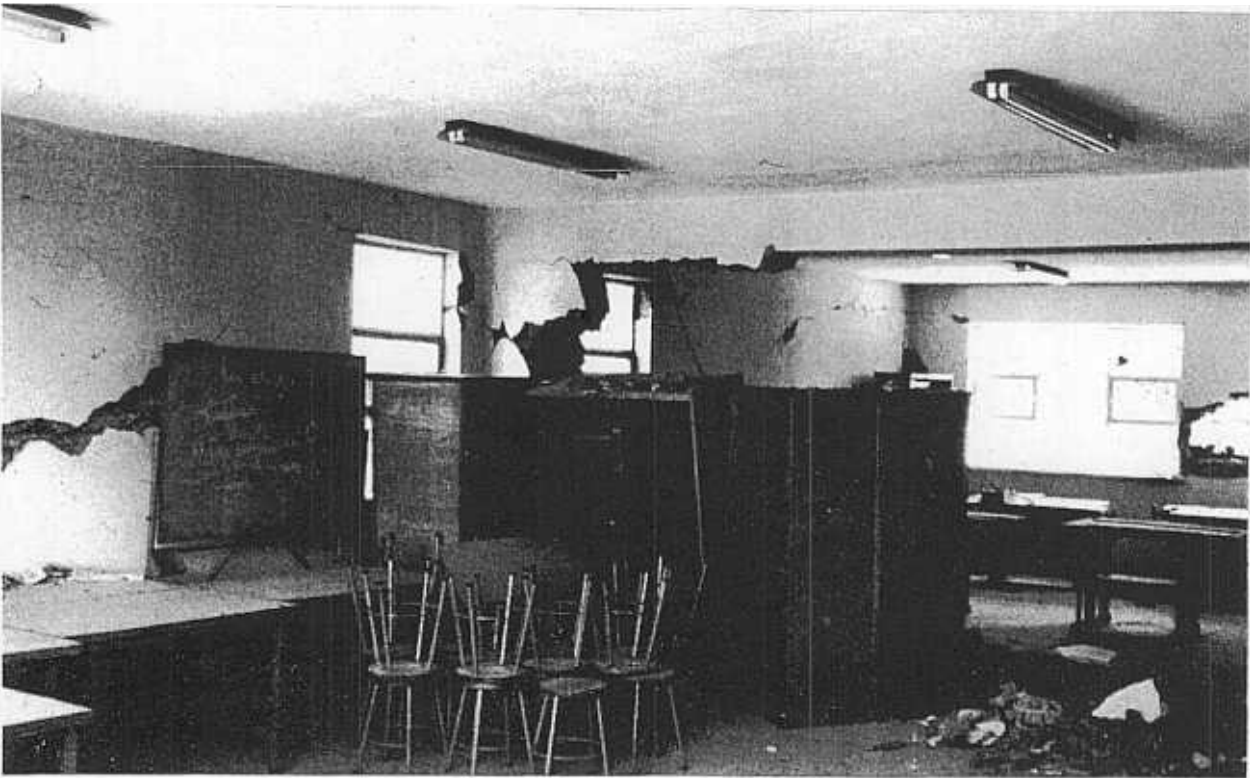


FIGURE 27 TYPICAL INTERIOR DAMAGE ALONG THE NORTH AND EAST WALLS OF THE HIGH SCHOOL BUILDING SHOWN IN FIGURES 23, 24, AND 25.



FIGURE 28 ANOTHER HIGH SCHOOL BUILDING THAT SUFFERED NEARLY TOTAL DAMAGE. NOTE THAT THE SECOND FLOOR WALLS ARE NOT AS SEVERELY DAMAGED.

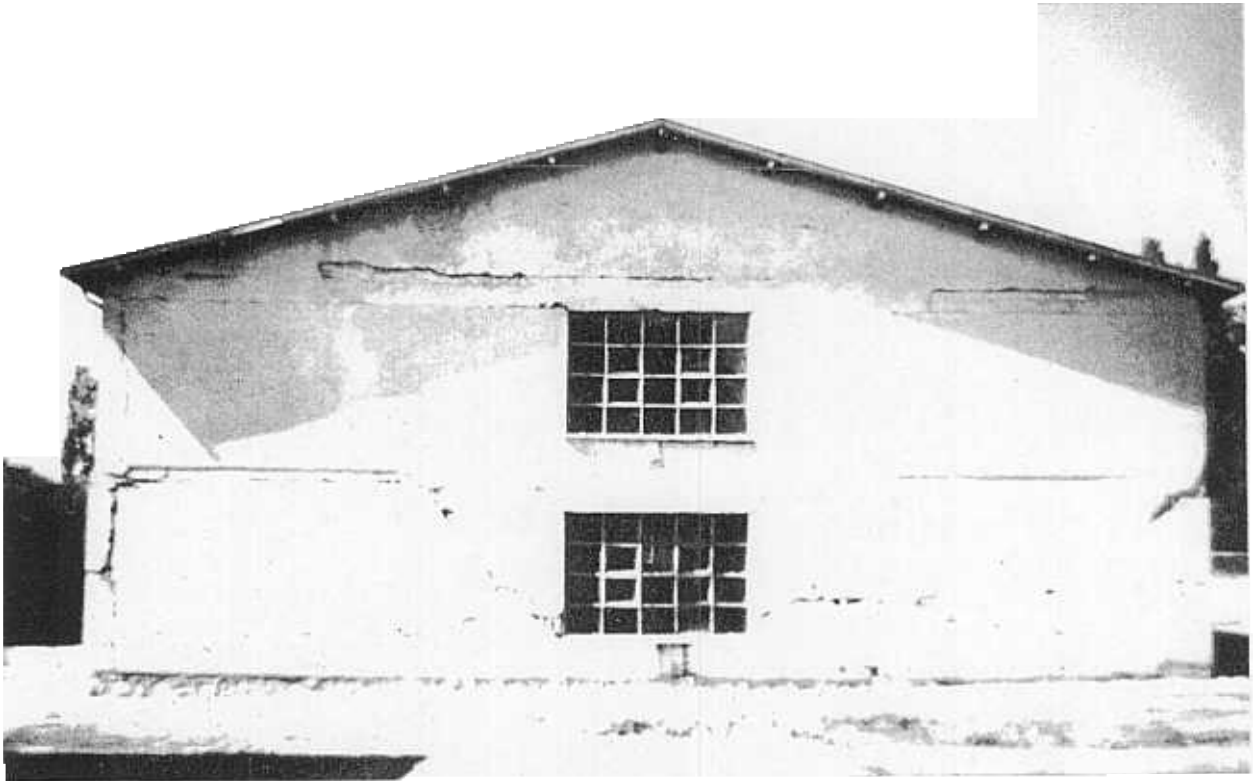


FIGURE 29 THE EAST END WALL OF THE HIGH SCHOOL BUILDING SHOWN IN FIGURE 28.



FIGURE 30 DAMAGE AND DEBRIS NEAR AN ENTRANCE TO THE HIGH SCHOOL BUILDING SHOWN IN FIGURES 28 AND 29.

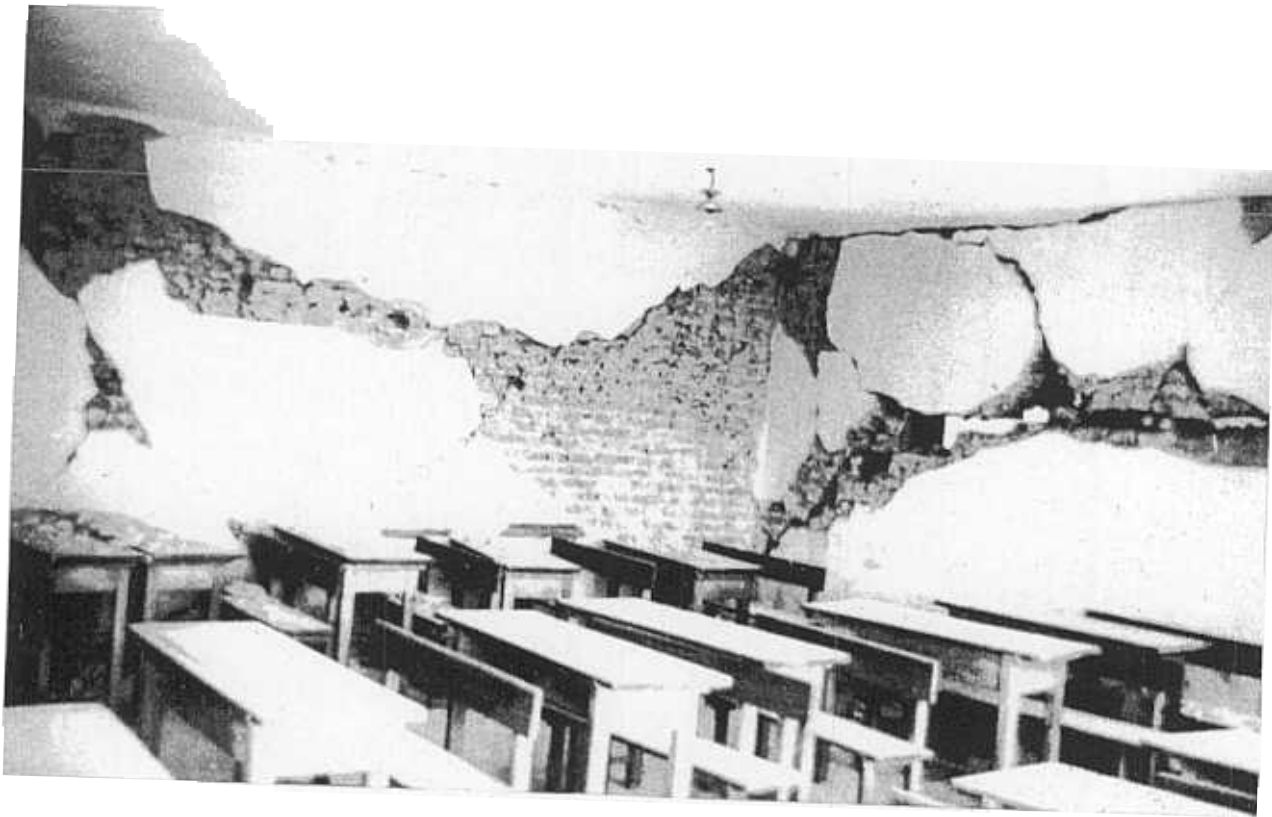


FIGURE 31 INTERIOR DAMAGE IN THE SECOND HIGH SCHOOL BUILDING

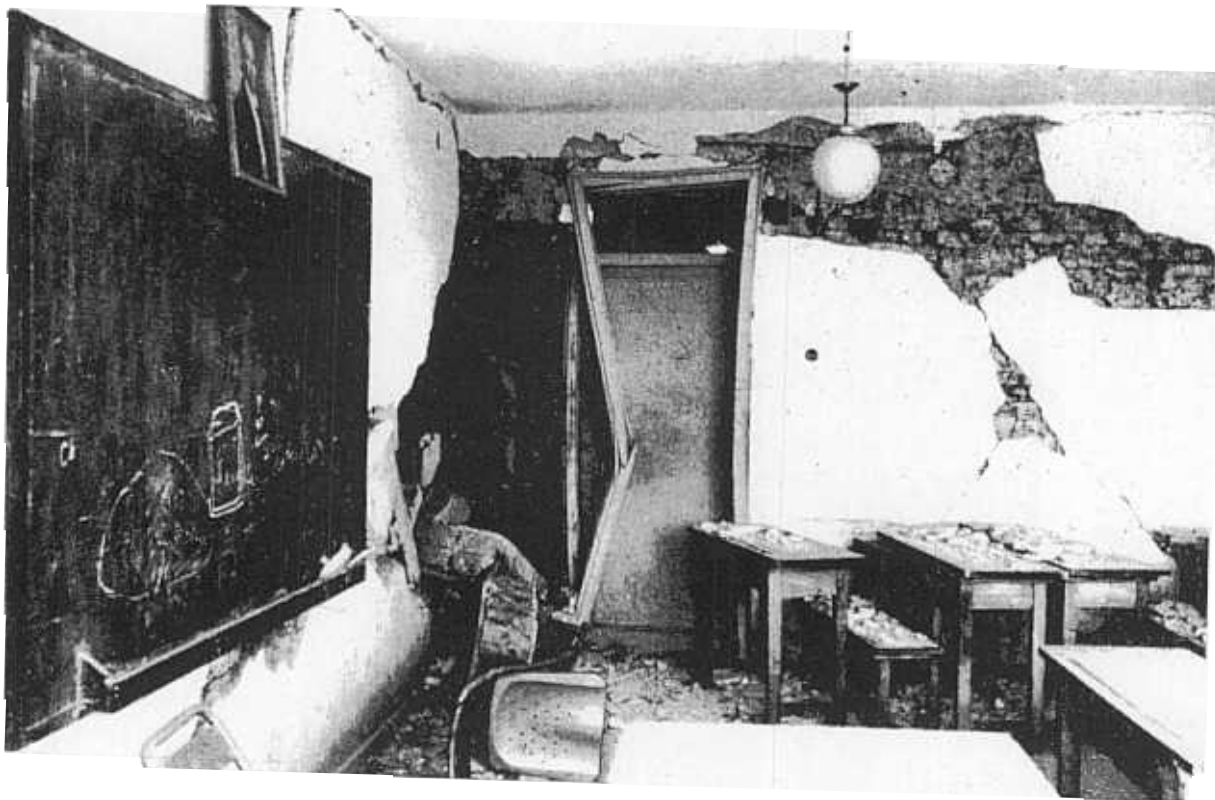


FIGURE 32 INTERIOR DAMAGE IN THE SECOND HIGH SCHOOL BUILDING



FIGURE 33 INTERIOR DAMAGE IN THE SECOND HIGH SCHOOL BUILDING.



FIGURE 34 DAMAGE CAUSED TO THE ROOFING TILES, APPARENTLY BY AMPLIFIED VERTICAL VIBRATION IN THE CENTRAL AREAS OF THE HORIZONTAL ROOF SPANS BETWEEN THE VERTICAL TRUSSES.



FIGURE VIEW THE SOUTH WAL THE ICE HOSPITAL

MINARETS

Several minarets in Lice failed, and at least one minaret in Hani survived, apparently undamaged. Two mosques, one in Lice and one in Hani, were completely destroyed, and there were no visible remains of their minarets. Two other minarets in Lice are shown in Figures 36 through 38. The first, located in the flat, newer area of the town, lost a few meters off the top, while the second and much shorter one, located in the hilly area near the hospital, was severely damaged. The unreinforced minaret (Figures 37 and 38), was built of grouted concrete blocks. The spiral separations between the blocks are particularly interesting.

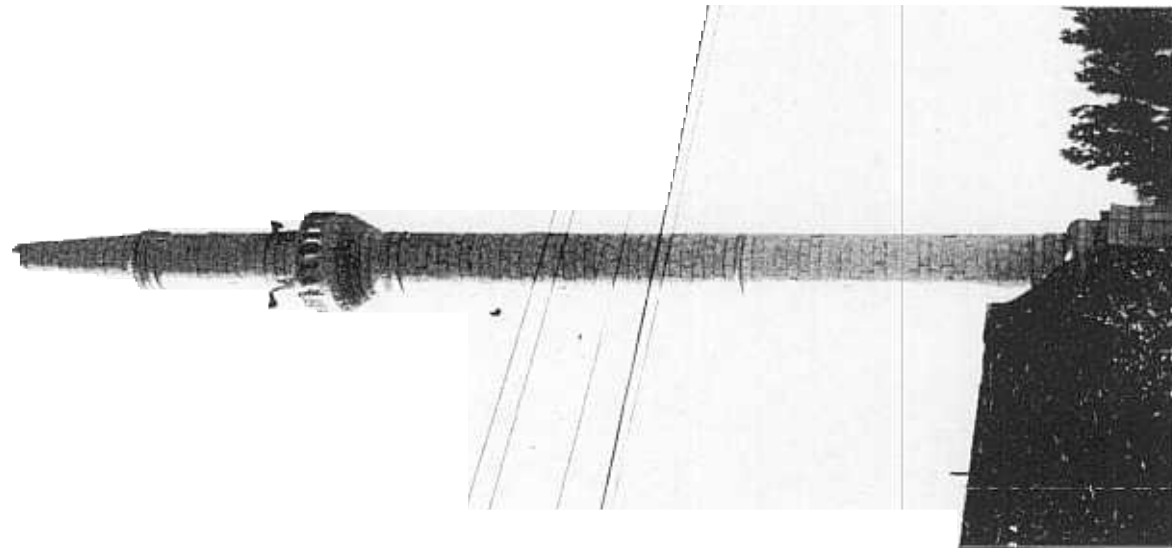


FIGURE 36 THE HIGHEST MINARET IN LICE LOST A FEW METERS FROM ITS TOP PORTION.

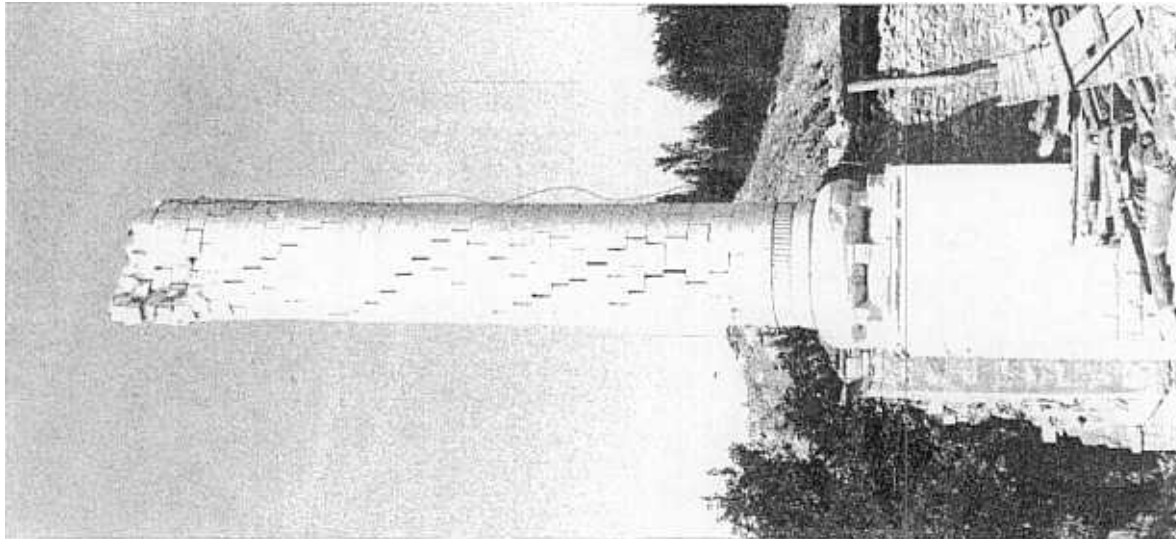


FIGURE 37 THE REMAINING PORTION OF ANOTHER MINARET IN LICE. THE SEPARATIONS BETWEEN THE BLOCKS FORM AN INTERESTING SPIRAL PATTERN.

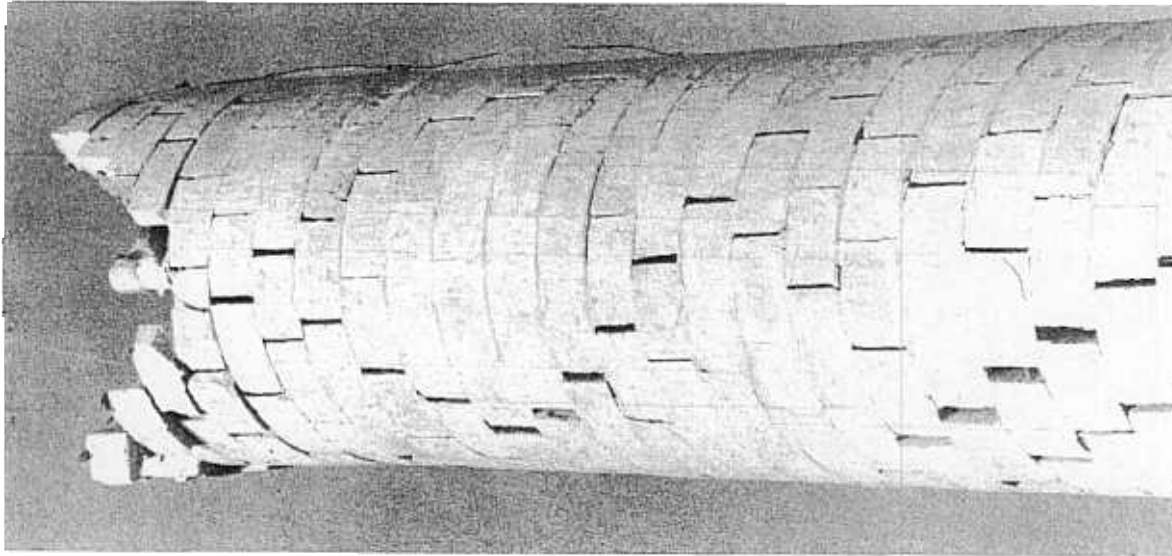


FIGURE 38 DETAIL OF THE DAMAGED MINARET SHOWN IN FIGURE 37.

RESIDENTIAL AND OTHER SMALL MASONRY BUILDINGS

Most of the buildings damaged by the Lice earthquake were masonry structures built in the rural Anatolian style of eastern Turkey. Although there are several variations of this style, the walls are typically of stone that is held together with mortar, sometimes containing cement.

Figure 39 illustrates typical Lice dwellings of the masonry style. In the hills, two buildings generally abut each other, as shown in the upper part of Figure 39, with narrow roads separating them from the buildings above and below. Figures 40 to 45 show general views and some details of the more typical houses. These undamaged buildings are in Hani. Their walls generally had more timber in them (Figure 43) than in walls of similar buildings in Lice.

In the Lice/Hani area, as reported by Keightley (1975) for the nearby Bingöl area, the walls of most village houses are made of broken pieces of stone set in mud mortar, often with small stones keyed in between larger ones. In Hani, and less often in Lice, horizontal wood bond strips about 10 centimeters in diameter and spaced 60 to 100 centimeters apart vertically are built into almost every wall. According to Keightley (1975):

These strips are set apart horizontally by short wood pieces so that there is one strip in each face of the wall at each level (walls are usually 50 to 60 centimeters thick). The bond strips in one wall are usually nailed to those in an intersecting wall, and are usually nailed at joints along the length of a strip. The nailed joints are weak, however, and the strips themselves often contain deep transverse saw cuts to permit straightening, so the tensile strength of the strips is low.

The functions of the bond strips would seem to be to break up long diagonal cracks in a wall, to act as tensile reinforcement when a wall bends in the horizontal plane, and to help tie walls together at a corner. It is difficult to estimate the effectiveness of construction with bond strips, the origin of which is unknown to the author, without tests performed on a shaking table. Certainly in the Bingöl region many stone

houses containing bond strips collapsed. Corners of houses fell out, joints between bond strips at the wall corners pulled apart, and walls collapsed, particularly walls parallel to roof beams, not tied together across the structure. Mud mortar in the Bingöl region was ineffective on the heavy stones except for initial dead-load compression so that there was almost no tensile strength in the wall and very little shear strength. It is believed that failure of most of these walls took place by successive collapses from the top.

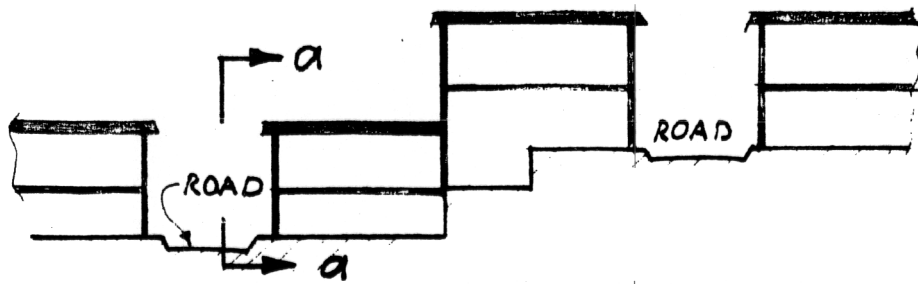
Most of the residential roofs in Lice and Hani are flat mud roofs. The roofs are supported by about 20 heavy poplar timbers spanning the length of the room, with 40 to 60 centimeters of mud packed on top. The flat mud roofs provide good insulation against the hot summers and cold winters of Anatolia, are watertight (with regular maintenance), and serve as a platform for the storage of firewood and hay. Such roofs may weigh as much as 1,000 kilograms/meter². The collapse of these roofs appears to have caused most of the casualties from the earthquake.

Figure 46 illustrates typical flat roof construction. The mud has been removed here, exposing the construction and showing the thickness of unremoved mud. Details of the roof-wall connections are shown in Figures 47 and 48. The usual failure mode of the roof was withdrawal of the timbers from the walls, which usually occurred at one end of the roof (Figure 49). In a few cases, the roofing timbers were encased in presumably reinforced concrete beams, as shown in Figures 50 and 51. In such cases the timbers generally remained in place. Other damage is shown in Figures 52 through 57.

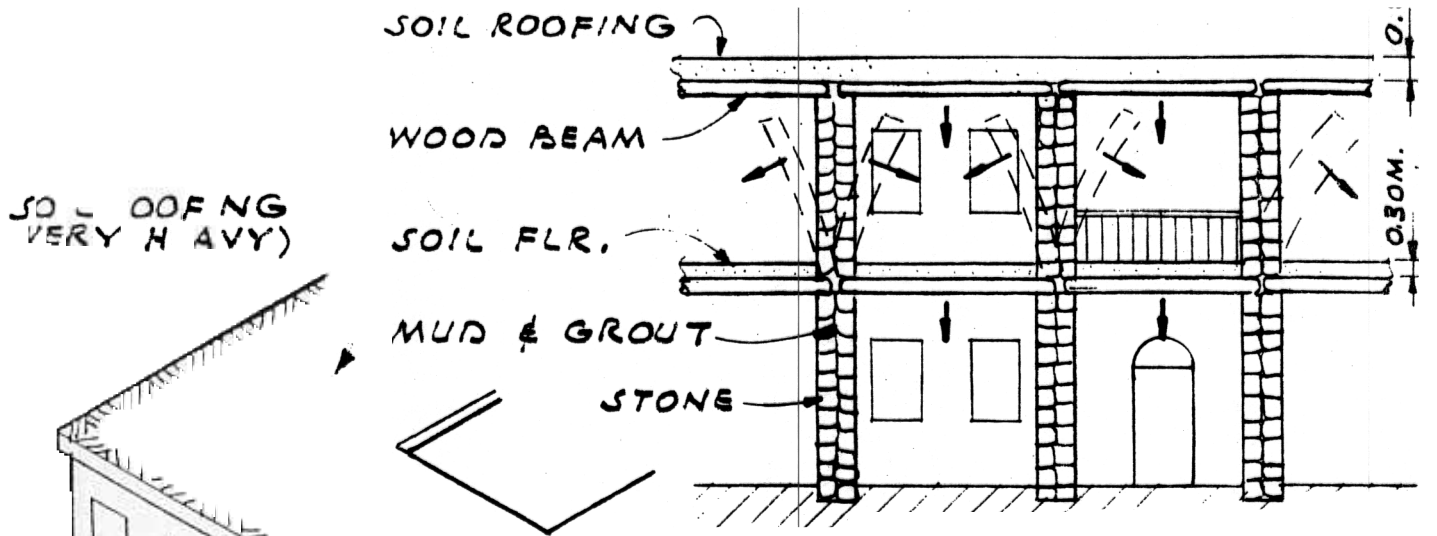
Many buildings, particularly smaller commercial buildings, had flat concrete slab roofs. As illustrated in Figures 58 and 59, these structures fared somewhat better; the load was carried into the walls, showing the importance of good diaphragm action. Often the wall damage consisted of substantial shear cracks and partial failure of the walls. There appeared to be fewer injuries from such failures.

As further illustrated in Figures 60 through 69, the performance of the local type of construction was extremely poor. Most buildings were total losses in the more heavily shaken areas. This fact is well known to the engineering

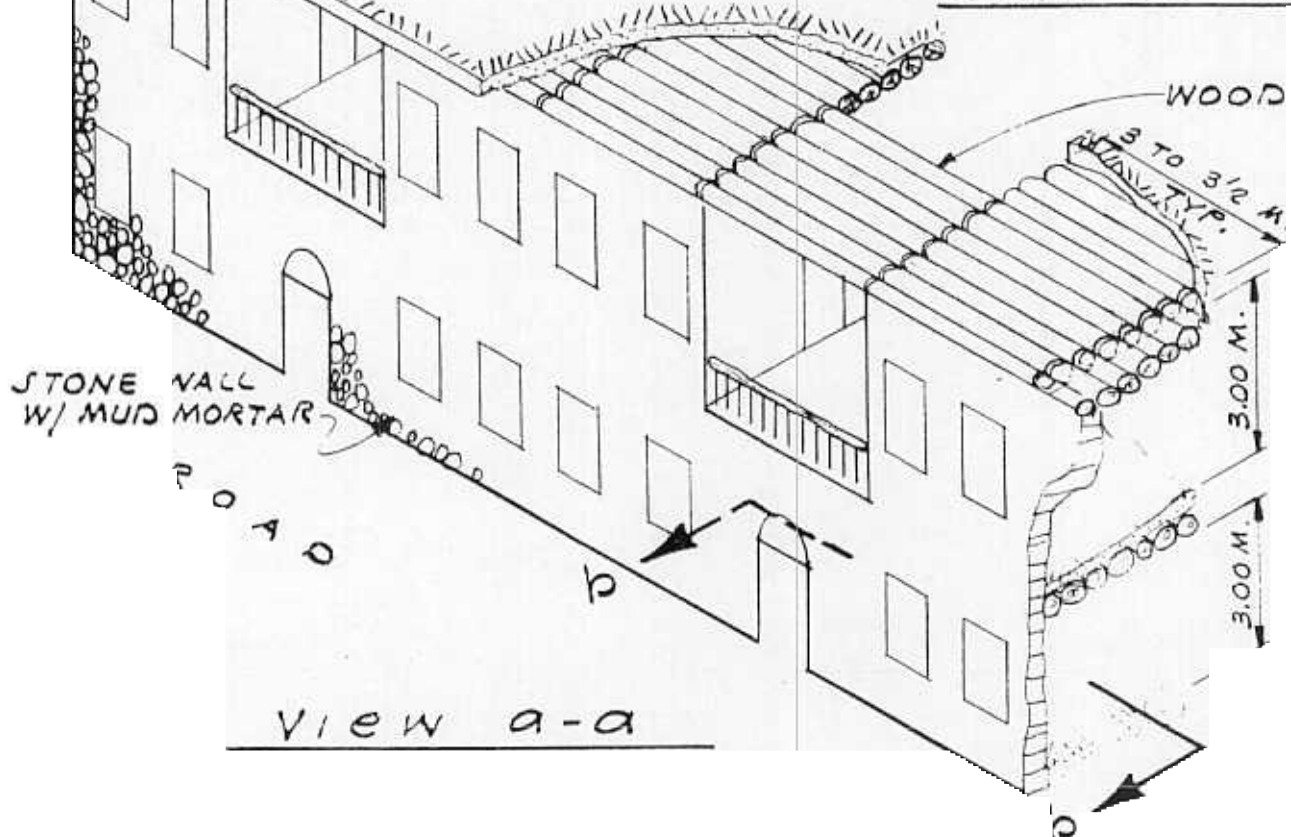
profession in Turkey, and measures are now being taken to alleviate this difficult problem.



TYPICAL CROSS SECTION
THROUGH RURAL DWELLINGS



Section b-b



View a-a



FIGURE 40 VIEW ACROSS MOSTLY UNDAMAGED DWELLING ROOFS IN HANI.



FIGURE 41 TYPICAL HOUSES IN HANI



FIGURE 42 TYPICAL HOUSES IN HANI.

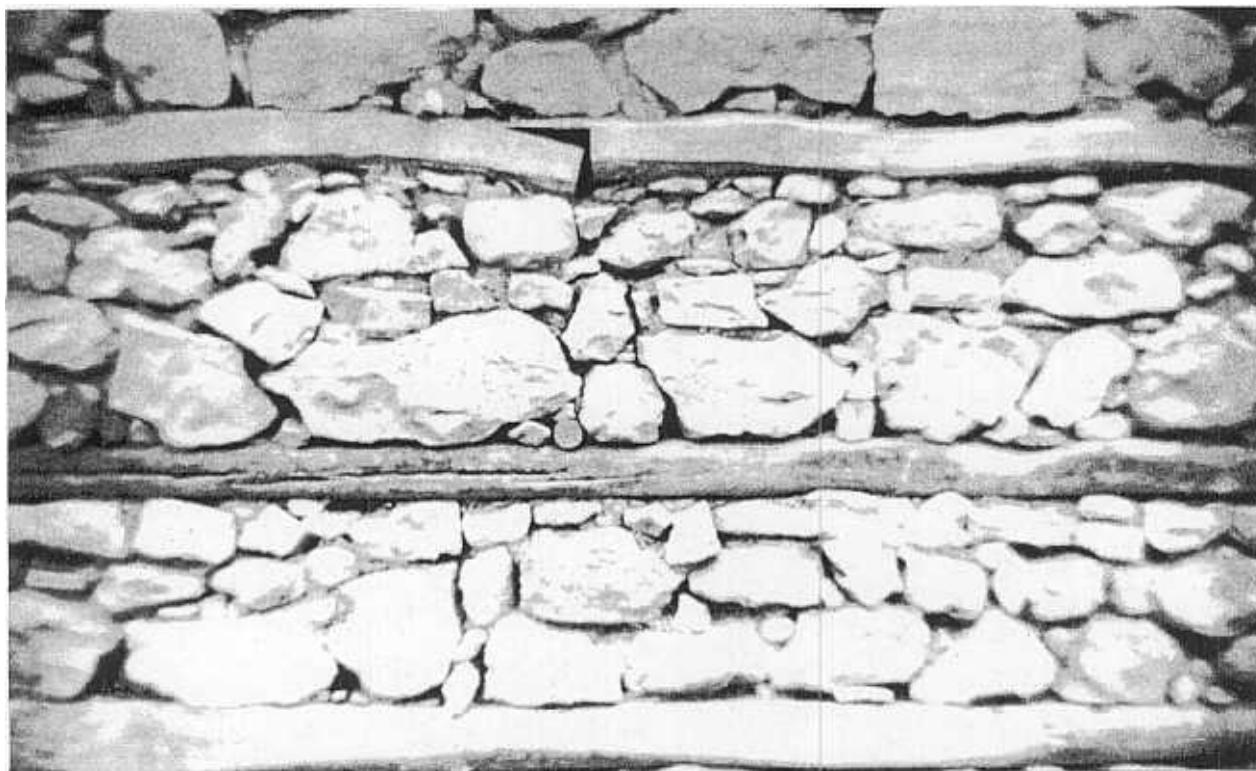


FIGURE 43 DETAIL OF THE EXTERIOR WALL OF A HOUSE IN HANI. THESE WOOD STRIPS WERE NOT AS ABUNDANT IN HOUSES IN LICE.

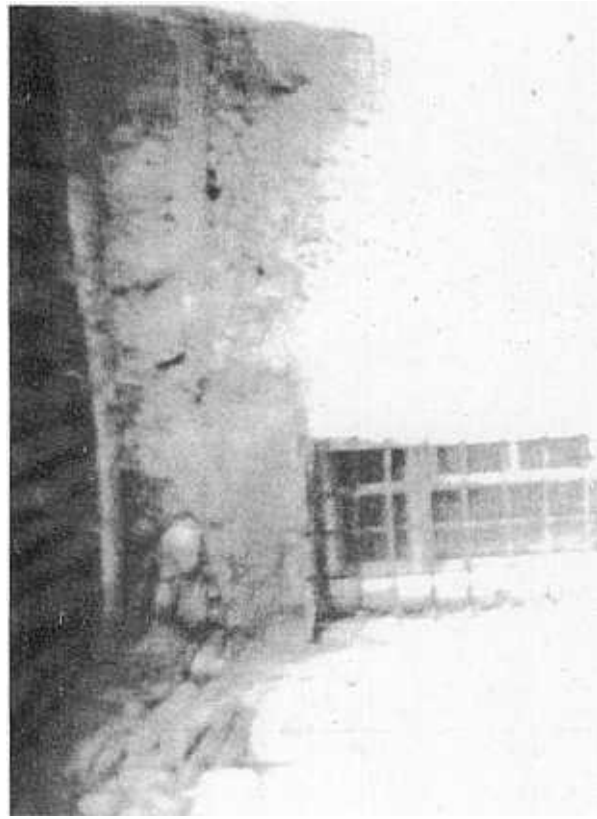


FIGURE
TYPICAL ENTRANCE
HANI
A DOWNHILL HOUSE



FIGURE
TYPICAL ENTRANCE
HANI
A DOWNHILL HOUSE

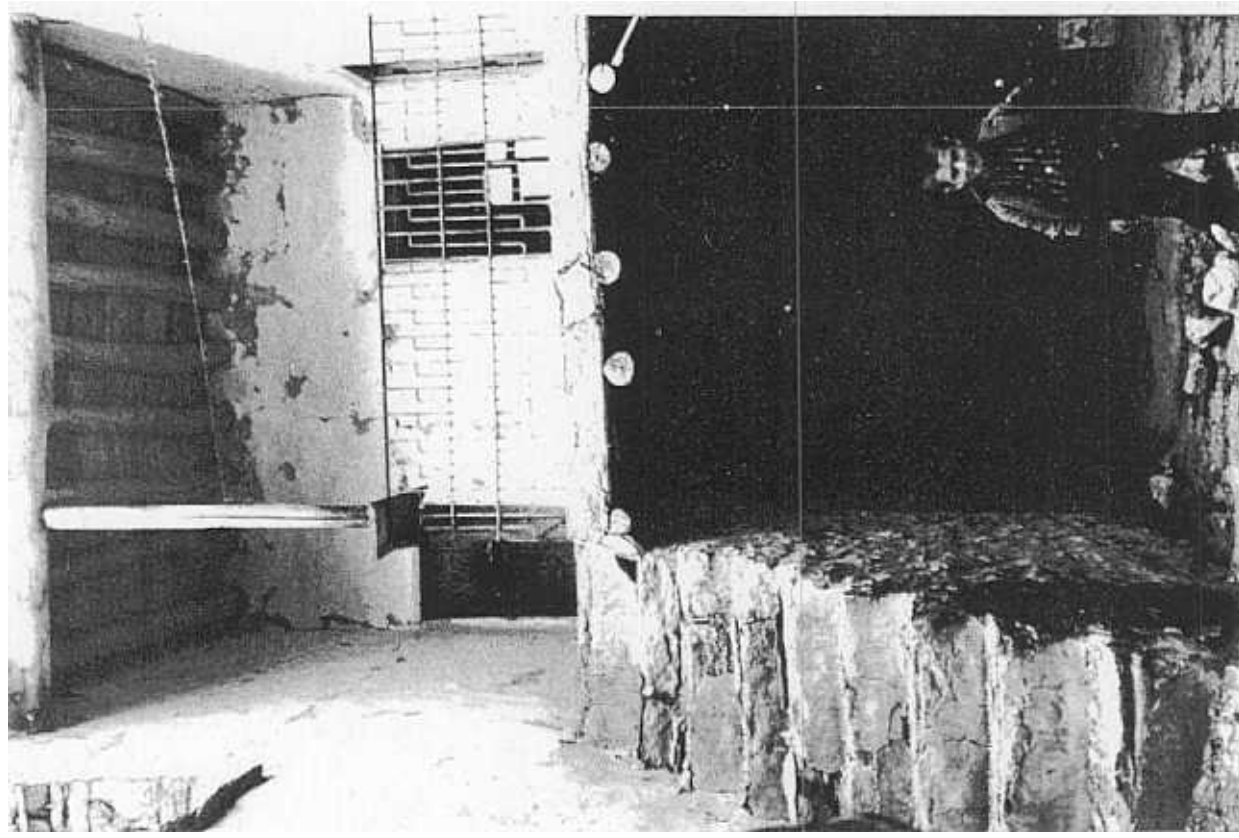


FIGURE
TYPICAL ENTRANCE
HANI
HOUSE THE FLATS
NOTE THE HEAVY FIRST FLOOR.

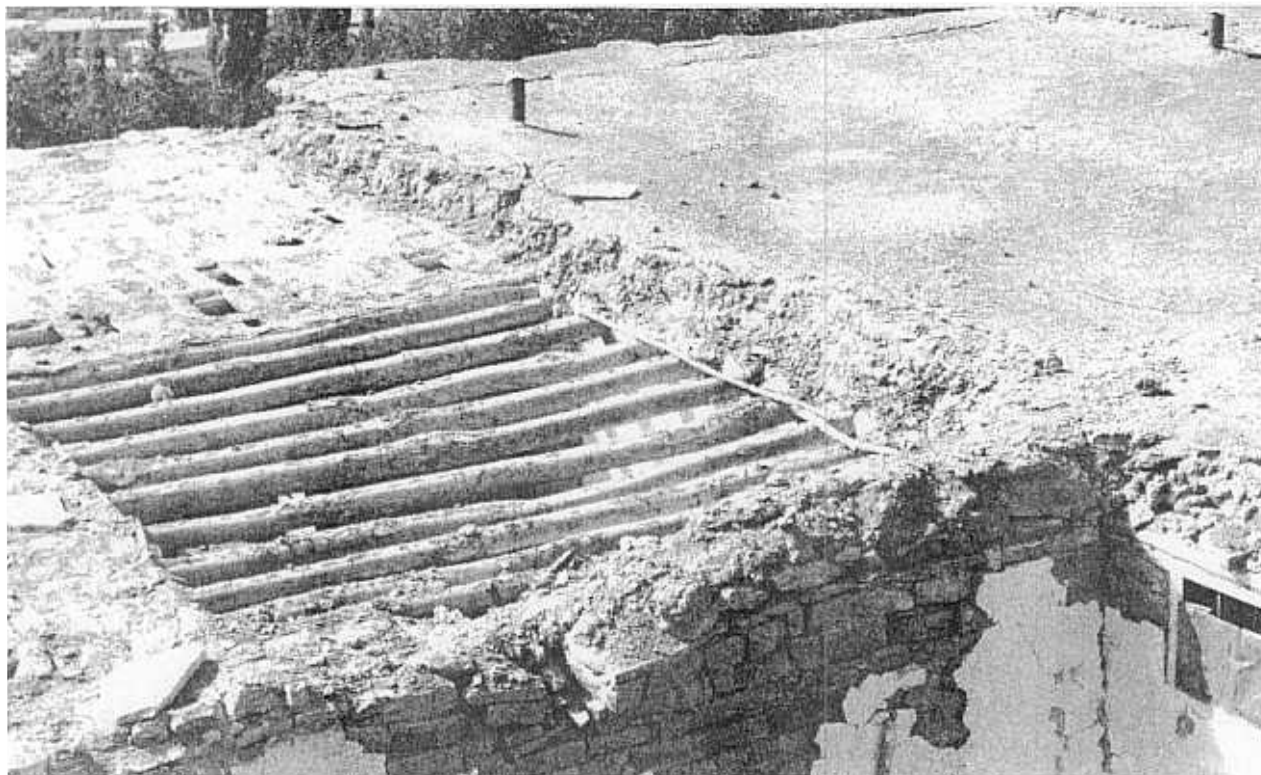


FIGURE 46 TYPICAL FLAT ROOF CONSTRUCTION IN LICE. THE THICKNESS OF THE MUD ROOF IS BETWEEN 40 AND 60 CENTIMETERS; THE ROOF MAY WEIGH AS MUCH AS 1,000 KILOGRAMS/METER².



FIGURE 47 DETAIL OF A CONNECTION BETWEEN THE ROOFING TIMBERS AND AN EXTERIOR WALL.

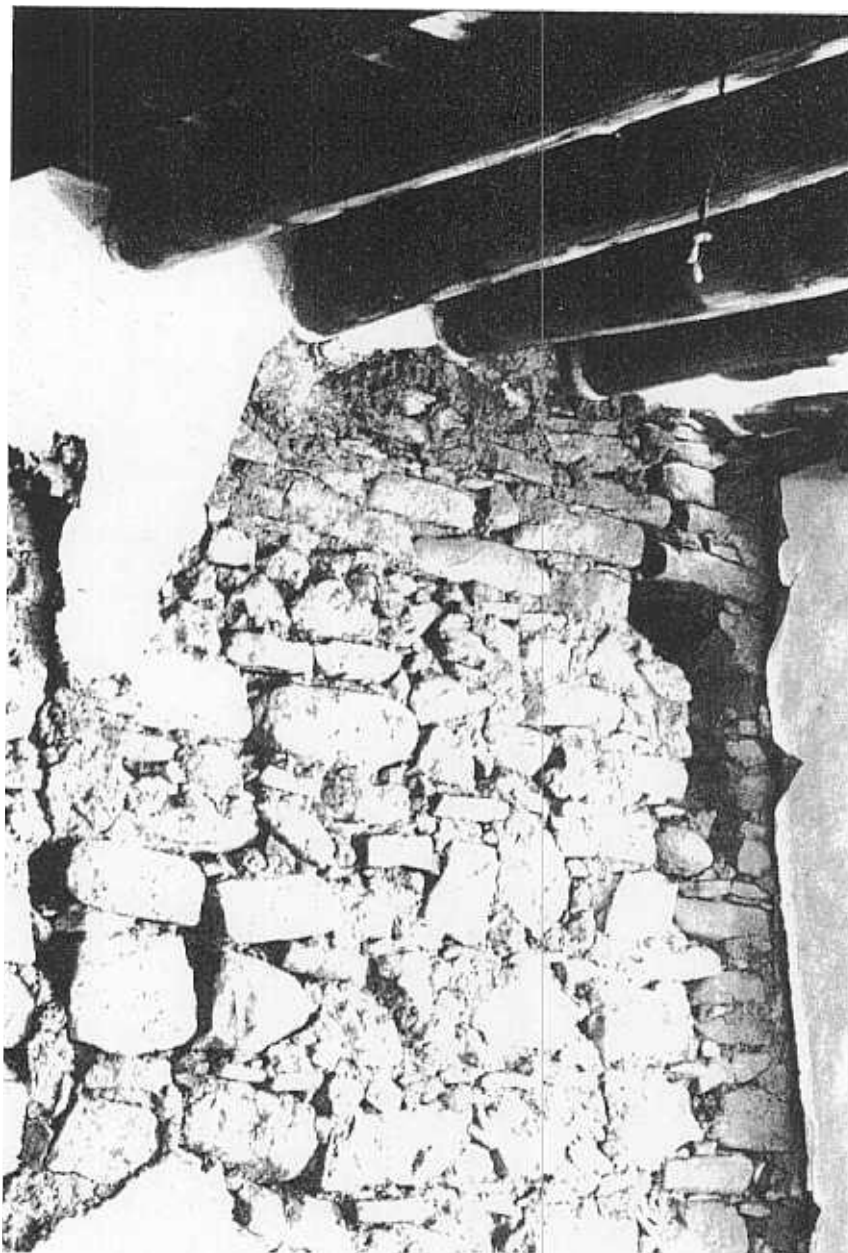


FIGURE 48 DETAIL OF AN INTERIOR ROOF-TO-WALL
CONNECTION IN LICE.



FIGURE 49 TYPICAL FAILURE OF A ROOF IN LICE.

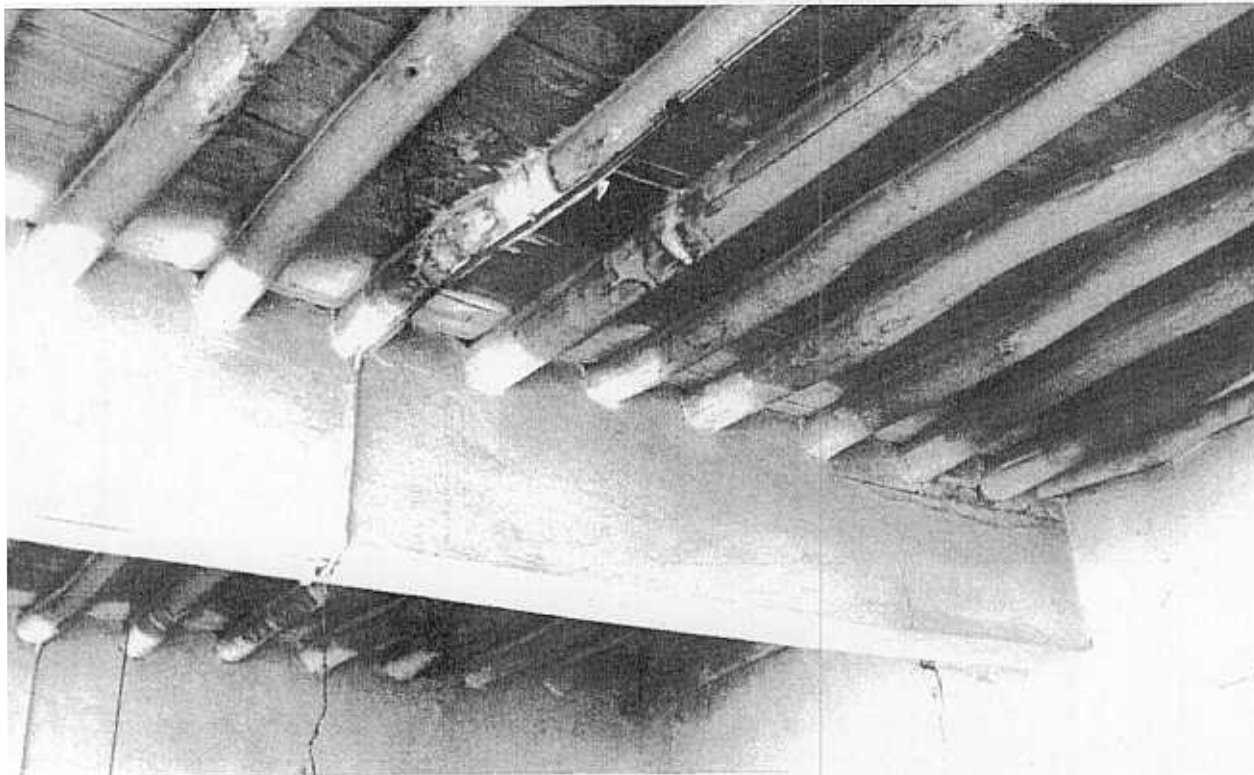


FIGURE 50 IN SOME STRUCTURES, THE ROOFS WERE SUPPORTED BY CONCRETE GIRDERS. IN SUCH CASES, THERE WAS SIGNIFICANTLY LESS DAMAGE TO THE ROOFS.

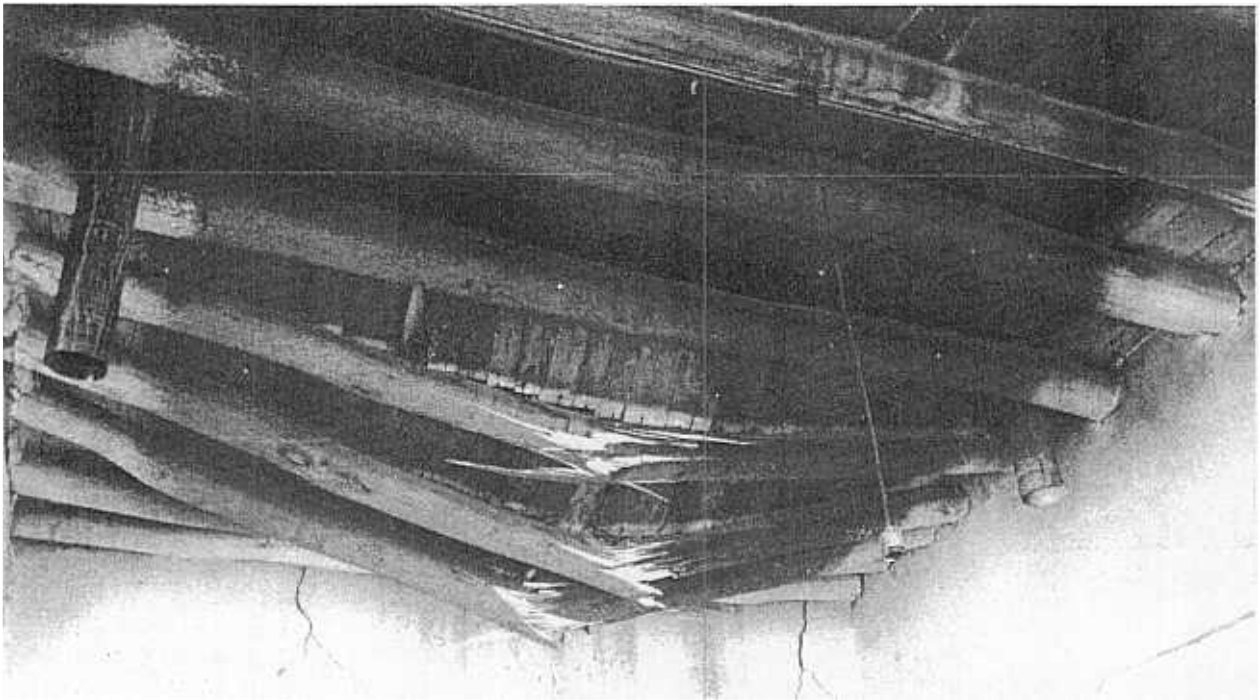


FIGURE 51 FAILURE OF THE ROOF TIMBERS IN A COMMERCIAL BUILDING WITH CEMENT MORTAR AND SOME CONCRETE FRAMING MEMBERS.

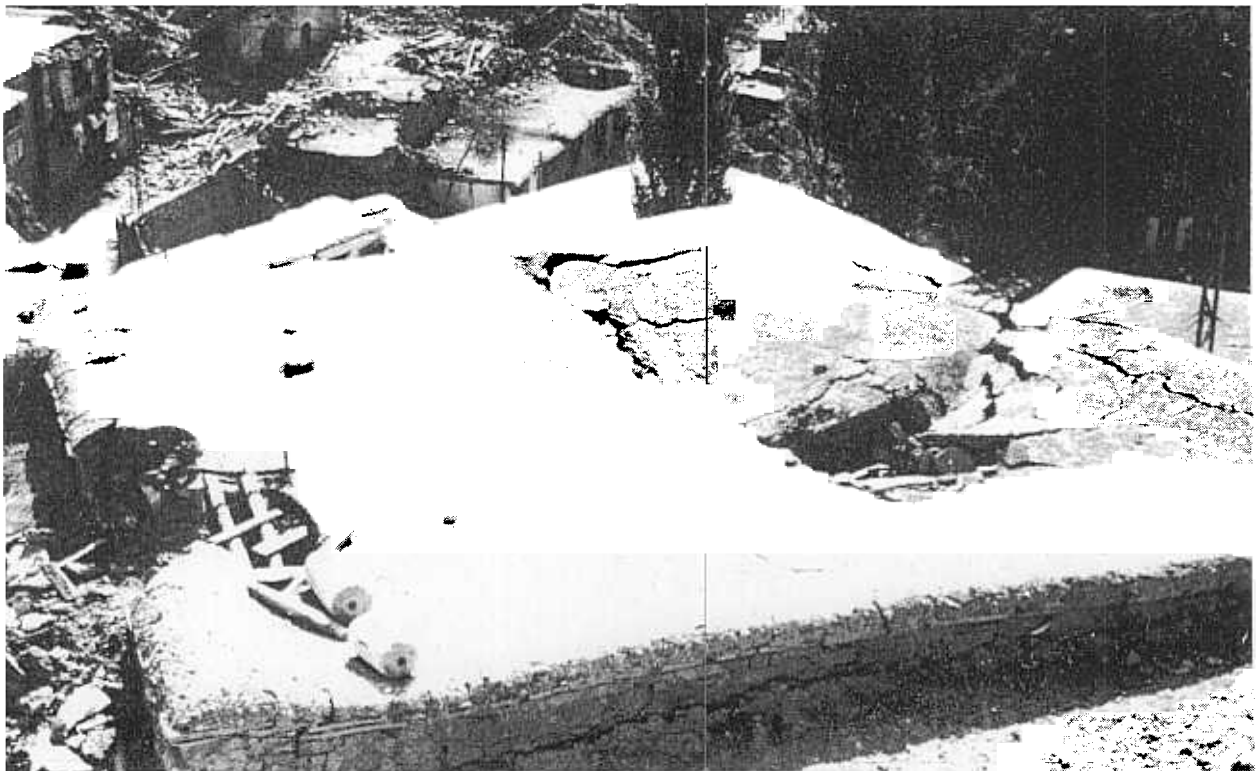


FIGURE 52 THE START OF THE DISINTEGRATION OF A FLAT MUD ROOF IN LICE.



FIGURE 53 THE FAILURE OF INTERIOR LOAD-BEARING ARCHES IN THIS MOSQUE IN HANI LED TO THE COLLAPSE OF ITS HEAVY MUD ROOF.



FIGURE 54 VIEW ACROSS SEVERAL PARTIALLY COLLAPSED ROOFS IN LICE.



FIGURE 55 THE INTERIOR OF A HOUSE WITH A COLLAPSED ROOF IN LICE.



FIGURE 56 GENERAL VIEW OF A SECTION OF LICE THAT SUFFERED LESS DAMAGE TO THE MUD ROOFS.



FIGURE 57 VIEW OF COLLAPSED ROOFS IN LICE. THE INTACT ROOFING TIMBERS HAVE BEEN PULLED OUT FROM THE RUINS, PRESUMABLY FOR RECONSTRUCTION.



FIGURE 58 A LIGHTLY DAMAGED MASONRY COMMERCIAL STRUCTURE IN LICE, WITH A CONCRETE FLAT SLAB ROOF. SOME OF THESE BUILDINGS HAD CEMENT MORTAR.

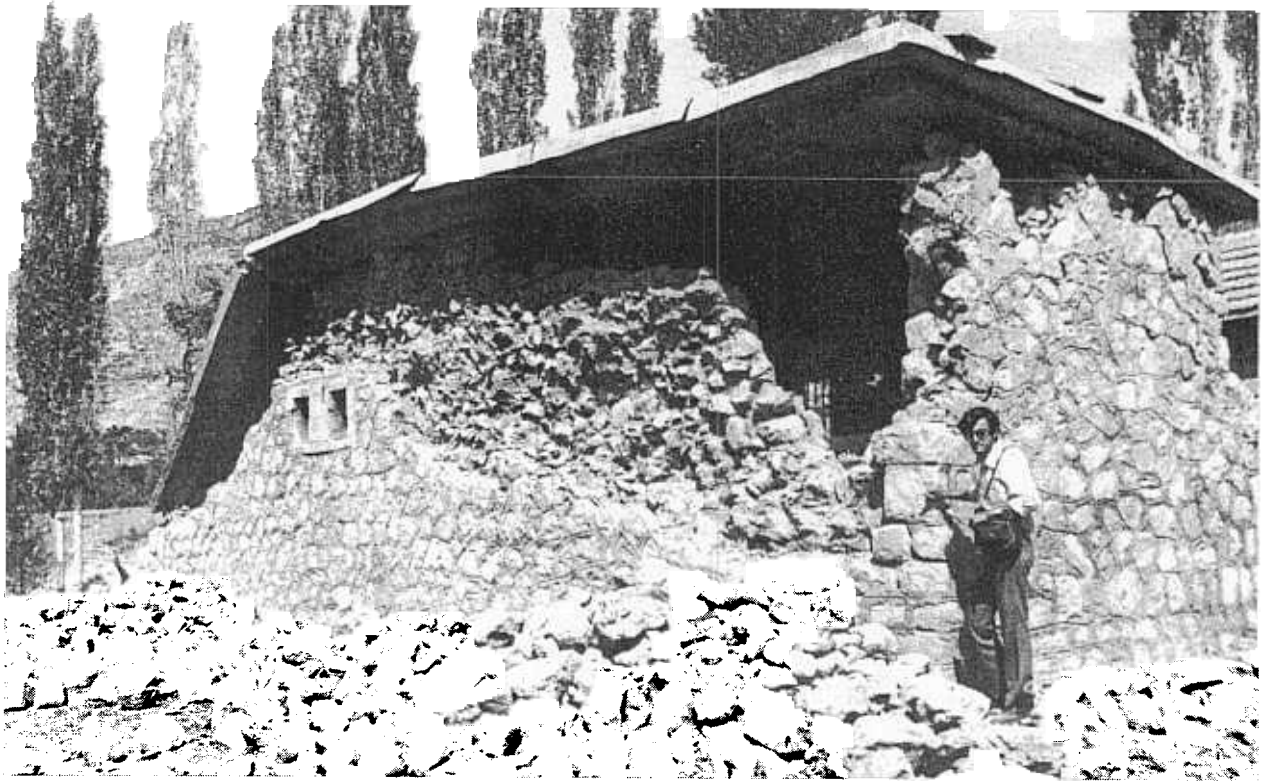


FIGURE 59 ONE OF THE MASONRY BUILDINGS OF THE JAIL IN LICE.



FIGURE 60 GENERAL VIEW ACROSS THE DEVASTATED EASTERN SECTION OF LICE.



RAL DE CT DN



TY' DAL RE UT' DAMAGED SEC CEMENT MORT RAL



FIGURE 6 PARTIAL COLLAPSE OF AN ANCIENT BUILDING



FIGURE 64 A PARTIAL COLLAPSE OF A MOSQUE



FIGURE TYPICAL VIEW OF TOTAL COLLAPSED HOUSE ICE



FIGURE THE START THE FAILURE WAL CEMENT MORTAR ICE

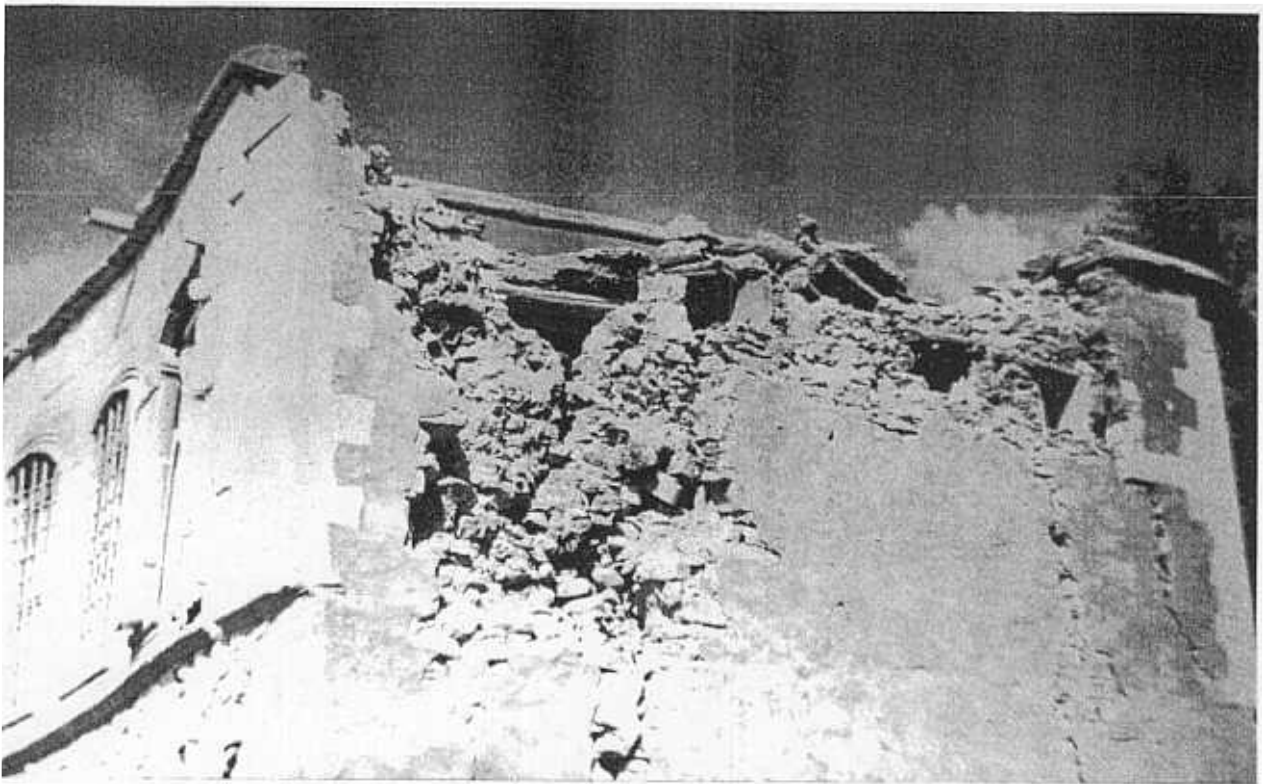


FIGURE 67 THE PARTIAL COLLAPSE OF A MUD MORTAR WALL FROM THE SAME BUILDING SHOWN IN FIGURE 66. IN GENERAL, BUILDINGS WITH CEMENT MORTAR FARED SIGNIFICANTLY BETTER.



FIGURE 68 EXTERIOR OF A SEVERELY DAMAGED HOUSE IN LICE.



FIGURE INTERIOR A SEVEREL DAMAGED HOUSE LICE

EARTHQUAKE-RESISTANT SINGLE-FAMILY DWELLINGS

On May 22, 1971, the town of Bingöl, some 50 kilometers north of Lice, was struck by an earthquake of Richter magnitude 7.0. About 755 people were killed out of a population of 17,000. Through the MRR, the government of Turkey, aided in the reconstruction and resettlement of the area. At that time some people were moved from Bingöl to the nearby towns of Lice and Hani, and new housing was provided for the refugees similar to housing near Bingöl described by Keightley (1975): the houses are of masonry, contain 55 meters² of gross area, and are on lots of 450 meters². They cost \$1,300 in 1971, which was payable over a 20-year period with no interest charge. Facilities for water to be piped to the houses initially cost \$35 extra, and facilities for electricity were initially \$40 extra. The chief complaint voiced by owners of these houses was their small size; each unit houses five or six persons. These houses, designed by the ERI to be earthquake resistant, received their first major test in Lice and Hani during the September 6, 1975, earthquake.

Figure 70 shows a row of these houses in the flat portion of Lice. None of the buildings seemed to be damaged severely although roofing tiles were shaken off and otherwise damaged. A number of similar homes were examined in the town of Hani (Figures 71 through 73). Here, the houses did not have tile roofs and experienced no noticeable damage. Our brief investigation indicated that these low-cost houses had survived a major shock without causing casualties. The MRR is now heavily committed to building about 3,000 similar houses in the stricken area. As of the beginning of October 1975, government plans called for the construction of 30 of these houses per day in Lice. Approximately 1,500 will be built in Lice, another 500 in Hani, and the rest throughout the area. All of these houses are prefabricated, as illustrated in Figures 74 through 77. About 440 of the homes are wood frame; they are purchased from Finland at approximately \$5,000 each, excluding utilities and construction but including shipping. The homes built by the MRR cost about \$3,300. Current plans call for the sale of these houses at approximately \$2,300 to those with higher incomes and at about \$1,200 to the poorer people. The loans are for 20 years, in-

terest free, and the debts will probably be cancelled after a few years as already done following previous disasters.

At the time of our visit, reconstruction planning for Lice and Hani was basically completed, and some construction had already begun. New city plans had been drawn for Lice and Hani, incorporating less geologically hazardous areas that are farther away from the rocky ridges with their many rockfalls.



FIGURE 70 A ROW OF LIGHTLY DAMAGED EARTHQUAKE-RESISTANT HOUSES BUILT BY THE MRR AND ERI FOLLOWING THE 1971 BINGÖL EARTHQUAKE.



FIGURE 71 UNDAMAGED EARTHQUAKE-RESISTANT HOUSES IN HANI.

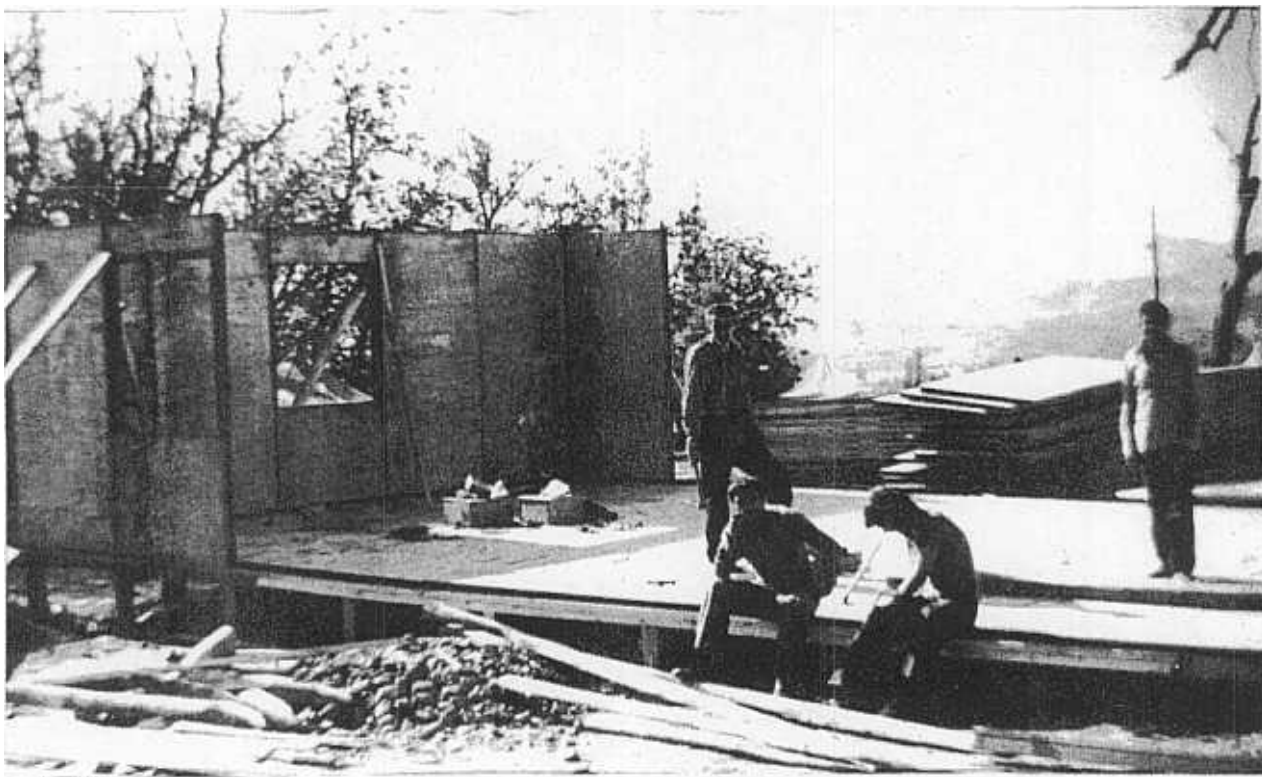


FIGURE 76 DETAILS OF EARTHQUAKE-RESISTANT HOUSES UNDER CONSTRUCTION IN LICE.



FIGURE 77 DETAIL OF A PREFABRICATED WALL PANEL SHOWING THE VERTICAL WOOD STUDS, THE EXTERIOR CEMENT BOARD, AND THE INTERIOR INSULATION.

EARTHQUAKE EDUCATION PROGRAM OF THE GOVERNMENT OF TURKEY

Under the direction of a minister appointed by the Prime Minister, the ERI of the MRR conducts research related to earthquakes and earthquake damage, prepares the earthquake zone map for Turkey, and has responsibility for revising the building regulations for the various earthquake risk zones. The ERI has also embarked on an ambitious and badly needed educational program particularly aimed at educating rural builders about the fundamentals of earthquake-resistant construction.

Appendix B is ERI's description of this program. The program consists of educational radio and television programs; preparation of free construction handbooks; preparation and wide distribution of large wall posters illustrating various earthquake engineering principles and methods of construction; organization of conferences, debates, informal discussions, and movie presentations on earthquakes; education of instructors, foremen, and laborers; and cooperation with the MRR for including necessary topics into the school curriculums.

The current government earthquake engineering education program is scheduled to continue until 1978. This program is also part of a larger earthquake engineering program that encompasses a more detailed microzonation study of all of Turkey and the installation of a country-wide strong motion accelerometer network.

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