EERI

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

NEWSLETTER



ISSN 0270-8337



Earthquake Engineering Research Institute
499 14th Street, Suite 320
Oakland, California 94612-1934
Phone:(510)451-0905 Fax:(510)451-5411

Learning From Earthquakes

## Earthquake Strikes in Guerrero, Mexico

On September 14, at 8:04 am local time an earthquake of $M_s = 7.2$ ($M_w = 7.3$) occurred along the Pacific coast of the State of Guerrero, Mexico, close to the town of Copala. The shallow focal depth (17.5 km), the focal mechanism (thrust), and the low dip angle indicate that it was a typical earthquake of the Mexican subduction zone in the interface between the North American and Cocos plates.

The earthquake produced high intensities in the epicentral area where it caused considerable damage in some villages in South Guerrero and Southwest Oaxaca. The region is sparsely populated so only six people died, although 2,000 people remained homeless and more than 5,000 houses were affected with a distinct level of damage. Typical adobe houses are made of walls without any type of horizontal or vertical reinforcement for continuity and confinement, and of light roofs of palms and logs. Failures recorded are similar to those observed in other earthquakes in Mexico and include diagonal tension cracking, out-of-plane wall failures, and roof collapses.

Among the population of Mexico City this earthquake produced distress and interest disproportionate to its actual intensity and consequences, perhaps because the date brought back memories of the tragedy of September 19, 1985. However, the intensity in the city was moderate, similar to that caused by the event of April 25, 1989.

With the exception of about 10 buildings with structural damage, mostly nonstructural elements were distressed. Typical nonstructural damage observed included inclined cracking of masonry and gypsum partition walls, cracks along the wall-frame element joints, distorted window and door frames, and cracks along construction joints. In most instances, distress was attributed to excessive lateral flexibility of the structural system. Most damaged structures exhibited tilting; flexural and shear cracking in reinforced concrete beams, columns and walls; and minor inclined cracking in beam-to-column and slab-column connections.

It is encouraging that severe damage in buildings and infrastructure did not occur within the city. The fact that three days after the earthquake outstanding structural damage had not been detected indicates the effectiveness of measures adopted to reduce the seismic vulnerability there (more stringent building code requirements, better quality control procedures during construction, repair/strengthening of damaged and weak structures). However, structures must survive more severe motions than those inflicted by this latest event. Therefore authorities and engineers must carefully evaluate the effects produced by this earthquake and detect evidences of inadequate response. Particularly, buildings which exhibited some nonstructural damage or important foundation movements must be examined. Among the buildings that were distressed are some that were rehabilitated after 1985. Their behavior in this earthquake may indicate that a successful upgrade has not yet been accomplished.

*The information for the above report was compiled by Sergio M. Alcocer, Roberto Meli, Mario G. Ordaz, and Roberto Quaas from the National Center for Disaster Prevention (CENAPRED) in Mexico City.* *The publication and distribution of the report was funded by NSF Grant #BCS-9215158, EERI's Learning From Earthquakes project.* *For information on the early warning system which was tripped before this earthquake, see page 5.*

Learning From Earthquakes

## Magnitude 7.6 Quake Hits Manzanillo, Mexico

A Richter magnitude 7.6 earthquake hit the west coast of Mexico on October 9 close to the coastal town of Manzanillo, approximately 220 km southwest of Guadalajara and 550 km west of Mexico City. Early reports indicated that 30-40 people were killed in the earthquake which caused the most damage in the central states of Jalisco and Colima. The quake lasted one minute and 40 seconds and collapsed numerous buildings. In the seaside resort of Manzanillo the 12-story Costa Real Hotel collapsed, killing at least 12 people. The Jalisco State Judicial Police headquarters in Manzanillo also fell to the ground, killing eight people. A more detailed report of this earthquake will be an insert in the December Newsletter.

# The Dinar, Turkey, Earthquake of October 1, 1995

*The following report is a combination of information compiled from three separate teams which investigated this earthquake and submitted reports summarizing their reconnaissance efforts. These teams were made up of the following people: Pan. G. Carydis, Professor of Earthquake Engineering, NTUA, and Efth. L. Lekkas, Geologist, Assistant Professor, Athens University; U. Ersoy, S. M. Uzumeri, G. Ozcebe, and U. Polat from the Middle East Technical University in Ankara, and T. Tankut from the Scientific and Technical Research Council of Turkey; and Professor Mustafu Erdik from the Bogazici University in Istanbul.*

## Introduction

On Sunday, October 1, 1995, at 5:57 pm local time, a strong earthquake measuring 6.1 on the Richter scale hit the city of Dinar, Turkey, causing casualties and extensive damage to buildings in Dinar as well as nearby towns and villages including Dazkiri, Yuregil, Basmakci, and Evciler. Dinar is located in southwestern Anatolia, 360 km from Ankara, and has a population of 40,000. The epicenter of the quake has coordinates 38°00'N and 30°10'E and is a few kilometers

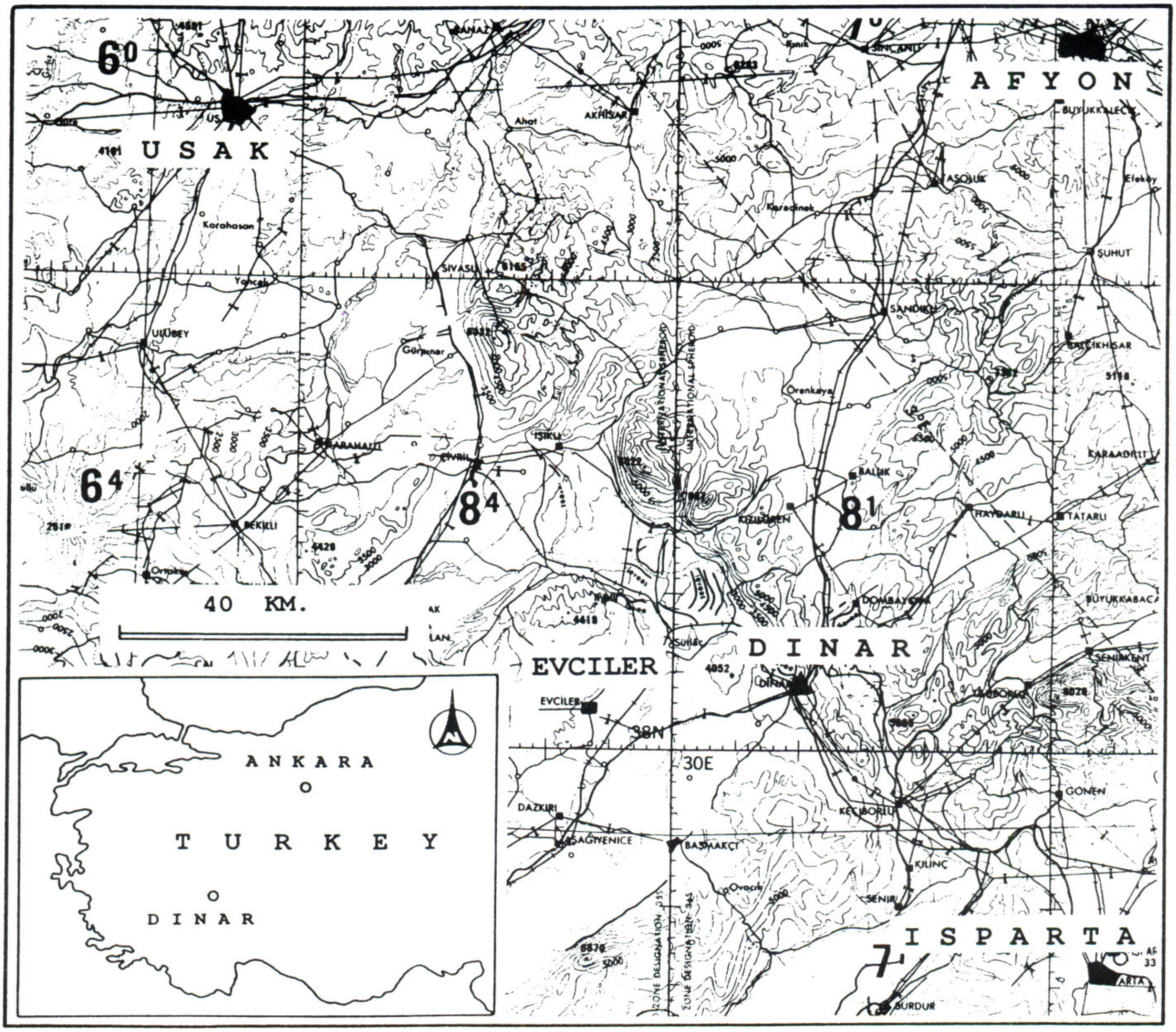


***Figure 1*** *- General topographic map of the Dinar area.*

***Figure 2*** *- Typical case of the total collapse of a four-story R/C building.*

southwest of Dinar.

Starting on September 26, six days prior to the earthquake a number of preshocks were observed with magnitudes varying from 3.4 to 4.8. This earlier seismic activity alerted people in the town and many had left town or had moved outside of their houses when the main shock struck. This is believed to have decreased the number of casualties. It is estimated that only 10,000 of the permanent residents were in the Dinar area at the time of the earthquake.

According to official reports, the deaths are between 90 and 100, while the wounded are between 230 and 270 persons. According to the first investigations that were made, about 40-50% of the houses were destroyed. More specifically, 2,043 buildings were totally destroyed, including several government buildings, while about 4,500 buildings were heavily damaged.

## History and Geography

Dinar has a history going back to about 1200 BC. In the eighth century King Midas made Dinar (then Meandros) the capital of his kingdom. Dinar lost its importance during the Byzantium era. Dinar survived as a small town in Selcuk and Ottoman times, becoming a county center of the Afyon Province under the Turkish Republic.

Geographically Dinar lies in the so-called "Region of Lakes" of southwestern Anatolia. Dinar is situated between the provincial centers of Afyon and Burdur on the main highway to Antalya in the south. The elevation of Dinar varies between 860 and 950 meters.

The town center is located partly on the hills extending in the northwest-southeast direction. However, the bulk of the residential, commercial, and government buildings are situated in a flat zone extending in the southwest direction below the hills. This zone is located on an N-S trending alluvial plateau with several levees to guide the main tributary of the Buyuk Menderes River.

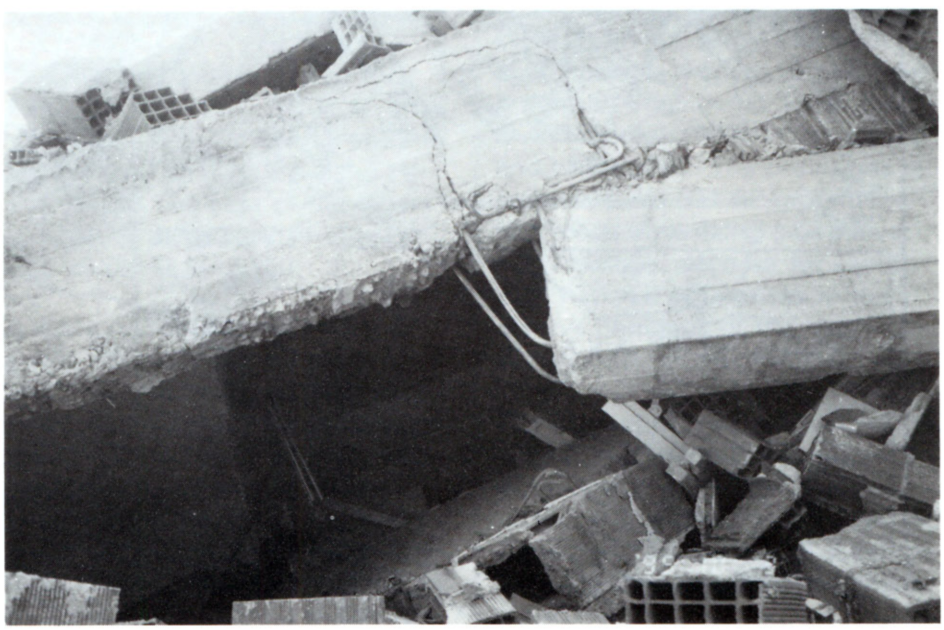

***Figure 3*** *- Typical detail of a beam-to-column joint.*

## Geology

As far as the neo-tectonic provinces of Turkey are concerned, Dinar is located in the transition zone between the central Anatolian "Ova" provinces and the western Anatolian extensional provinces. The meeting point of the Cretan (Hellexnic) Arc and the Cyprus Arc, to the south of the Adana/Cilicia basin, is in the Region of the Lakes. This region is dissected by a multitude of NE-SW trending faults of normal and possibly strike-slip motion.

The surficial geology of the hills to the east of town consists of Eocene and Cretaceous limestones, marl, and schist. The plateau is covered with Quaternary alluvium containing sand, gravel, and clay. The transition areas at the foot of the hills are covered by continental deposits. Reports indicate that NW-SE trending fault ruptures have been observed at about 5 km northeast of Dinar following the earthquake.

***Figure 4*** *- Collapse of a weak upper story.*

## Seismicity

Dinar is in the First Degree Hazard Zone of the official earthquake hazard zonation map of Turkey. Over the course of two millenia, at least 20 earthquakes of intensities of VIII and above have affected the region. Earthquakes of this century that have caused damage in Dinar occurred on October 3, 1914 (Ms = 7.0), August 7, 1925 (Ms = 6.0), and May 12, 1971 (Ms = 6.2). All of these events had normal faulting mechanisms.

The 1914 earthquake, associated with a 23-km fault rupture along the southeast coast of the Burdur Lake, approximately 60 km south of Dinar, destroyed about 17,000 houses and killed 4,000 people. The 1925 earthquake destroyed about 2,500 houses and killed 330 people. In the 1971 earthquake, 1,487 houses were destroyed at Burdur, killing 57 people.

***Figure 5*** *- Most R/C buildings in the downtown area collapsed or were severely damaged.*

## Ground Motion

As reported by the Earthquake Research Division of the general Directorate of Disaster Affairs the main shock of the earthquake has been recorded by seven stations of the national strong ground motion network. The records obtained at Dinar Health Center for the September 26 (ML=4.6) preshock have peak accelerations of 0.09g, 0.16g, and 0.04g respectively in NS, EW, and S directions. The main shock record obtained at Dinar Meteorology Station indicates horizontal PGA levels of 0.28g in both horizontal directions and 0.11 in the vertical direction.

The horizontal components sustained 0.15g level for about 14 sec and indicate a second s-wave arrival about 10 sec after the first arrival. From an s- and p- wave arrival time difference of about 3 sec, an approximate hypocentral distance of 18 km can be estimated.

The pseudo-acceleration response spectra, for 5% damping, reaches an average level of about 0.9g between 2 and 5Hz, which covers the fundamental frequency of vibration for most 2- to 5-story structures.

## Damage

Buildings—Soil conditions played an important role in the performance of buildings. The city of Dinar is fairly compact and takes up only a small area. It is built, though, on every type of ground. The city towards the northeast is built on hard ground which outcrops at the highest, in terms of altitude, points of Dinar. On the other hand, the western part of the city, which is the lowest in terms of altitude, is built on soft ground material, which has a small depth (almost zero at the eastern part) in some areas to a large depth (deep alluvial deposits) in others.

Most of the engineered buildings in Dinar were located on the flat part on river-born sediments. The rest were located toward the hills where the buildings rested on better soil.

***Figure 6*** *- Damage to an adobe building.*

The damage in Dinar is estimated to be very great for such a small area. In the higher parts of Dinar, where the foundations were on the bedrock, the effects of the earthquake on the buildings were small or non-existent. Here the buildings, their chimneys, and the minarets were untouched. The damage starts gradually (fractures in chimneys, breaking off of top part of minarets, damage to buildings), as one proceeds towards the lower

***Figure 7*** *- Damage to soft story columns.*

***Figure 8*** *- Short column failure.*

parts of the city. Damage reaches a peak in the center of the city and then starts to decrease. The last phenomena occur on thick alluvial deposits.

Although the major damage was confined to the town of Dinar, there was some damage in the villages and small towns in the surrounding area. However, this damage was mostly light to medium and it rapidly attenuates with distance from Dinar.

The building structures in Dinar range from one to five stories. There is no industrial facility in the town. Along the main streets, first stories of buildings are generally occupied for commercial purposes. Buildings with more than three stories are almost all reinforced concrete construction. Buildings with a lower number of stories tend to be partly reinforced concrete and mostly brick masonry. Stone masonry and adobe buildings are very few.

Almost all reinforced concrete buildings are moment resisting frames with hollow brick and occasionally solid brick infill walls. Reinforced concrete shear wall construction is rare. In masonry buildings, load bearing walls are generally made of solid brick.

Most of the buildings located in the downtown area (the sediments) suffered damage. Even the series of preshocks prior to the main event caused light structural and mostly non-structural damage in some buildings in the southwestern part of town.

Most of the four- and five-story reinforced concrete apartment buildings were either heavily damaged or totally collapsed. Some three-story buildings suffered similar damage. One- or two-story building collapses were rare.

Initial estimates based on preliminary walking surveys indicate that approximately 30 buildings totally collapsed and around 50 to 60 buildings experienced first-story and occasionally an intermediate story failure.

As an initial rough estimate, approximately 30% of all other buildings suffered heavy damage


***Figure 9*** *- Failure of middle story due to pounding.*

***Figure 10*** *- Inadequate lateral stiffness due to slender columns.*

in the form of severe deterioration in columns and beam-column joints of reinforced concrete buildings and severe cracks and separations in load bearing walls of masonry buildings. Moderate damage is estimated at about 40% of the total building stock.

According to preliminary statistics by the local government as of October 7, around 1,000 buildings suffered heavy damage or collapsed in the town center.

Most of the government buildings located on alluvial soil in the flat southwestern zone of the town center suffered significant damage. City government buildings, town hall (municipality building—an old building of stone masonry), and telecommunications (PTT) building did not collapse but suffered moderate to heavy damage. The three-story police center totally collapsed. The judiciary court building, a high school, and six apartment buildings used as residences of government officials had severe damage and two other similar apartment buildings collapsed.

The majority of the 47 government buildings were reinforced concrete. The damage to reinforced concrete buildings in general seemed to be more intensive than would be expected from an earthquake of this size. It should be noted that some of the private and government buildings were designed and built before 1975 and therefore did not comply with the requirements of a modern building code (such as confinement requirements).

The 1975 Turkish Seismic Code is similar in many respects to the Uniform Building Code of the same period. In the Turkish code, ductile framing is emphasized and current revisions are underway and almost complete. However, most of the buildings in Dinar were designed and built after 1975 and they still suffered damage. The percentage of reinforced concrete buildings that totally collapsed was greater than the percentage of those that just had slight damage. This means that the structures with reinforced concrete construction had very little ductility.

The main causes of damage to reinforced concrete buildings included soft story collapse,


***Figure 11*** *- Chimneys were chopped off in the downtown area.*

short columns, irregular framing, and a hammering effect from adjacent buildings. In general, no structural walls were used in Dinar buildings. The column sections were usually rectangular, being very slender in one direction. Therefore, a great number of buildings did not have adequate stiffness.

The code provisions and good detailing practice were not followed. Ends of columns were not properly confined. Ends of ties were not anchored into the core. The frames in Dinar could not be classified as ductile frames.

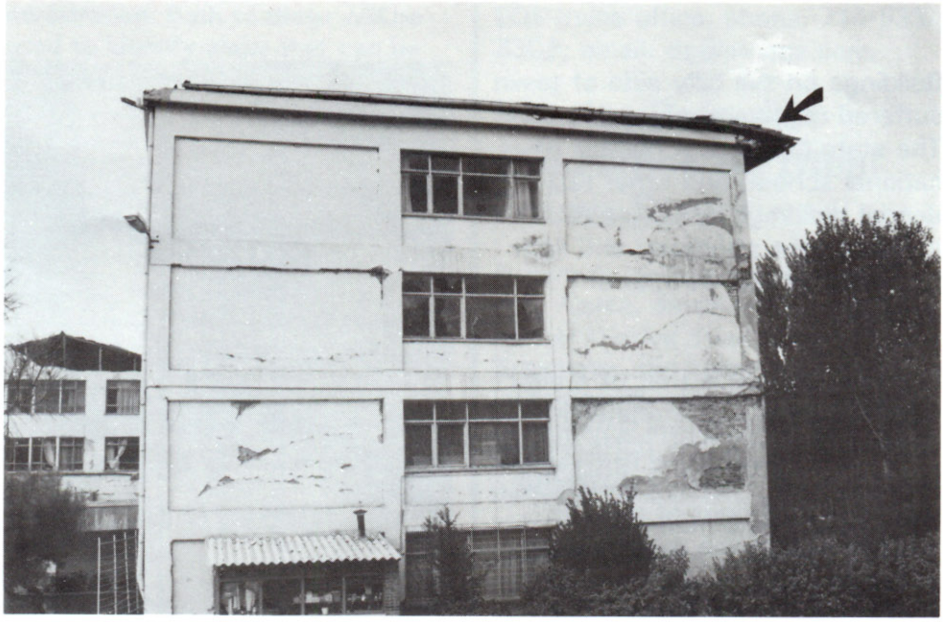

***Figure 12*** *- Many roofs were damaged - this one moved about 1 meter N-E.*

In a great majority of buildings inspected, the concrete quality was poor. Concrete was of low strength and did not appear to be properly proportioned and compacted. Another main cause of damage was a lack of inspection. Had there been effective inspection, most of the damages due to detailing and material quality could have been avoided. Some adobe buildings had braced timber frames and some had no framing. Adobe buildings with timber frames suffered little or no damage. Plain adobe buildings suffered medium to heavy damage.

Most of the brick masonry buildings were two to three stories high and were residential. A great majority of the structures with brick load-bearing walls suffered medium to heavy damage. Shear failure of walls with diagonal cracks between the windows was very common. In the walls of some of these buildings, hollow clay tile was used. Bearing failures, under gravity loads enhanced by vertical acceleration, were observed in the walls of such buildings.

***Figure 13*** *- Ground fracture near Dinar.*

There were also buildings with thick (500 mm) stone load-bearing walls, which were one or two stories high. No significant damage was observed in this type of building. One is impressed by the sight of 4- and 5-story reinforced concrete buildings which have collapsed while next to them there are 2- and 3-story masonry buildings that have not been damaged at all.

There was only one steel framed industrial building located 35 km from the epicenter. This building suffered no damage.

Buildings on the hilly side of town suffered relatively minor damage. The state hospital, a nearby vocational school, and other residential buildings in this area suffered light structural and light to moderate non-structural damage.

The final picture is that of a near field earthquake at a relatively small depth. In a few parts of the town one can detect a powerful vertical component of motion, while in others the motion comprises all components quite intensively. Also, the collapses are in all directions, their majority, though, being along the northeast-southwest direction.

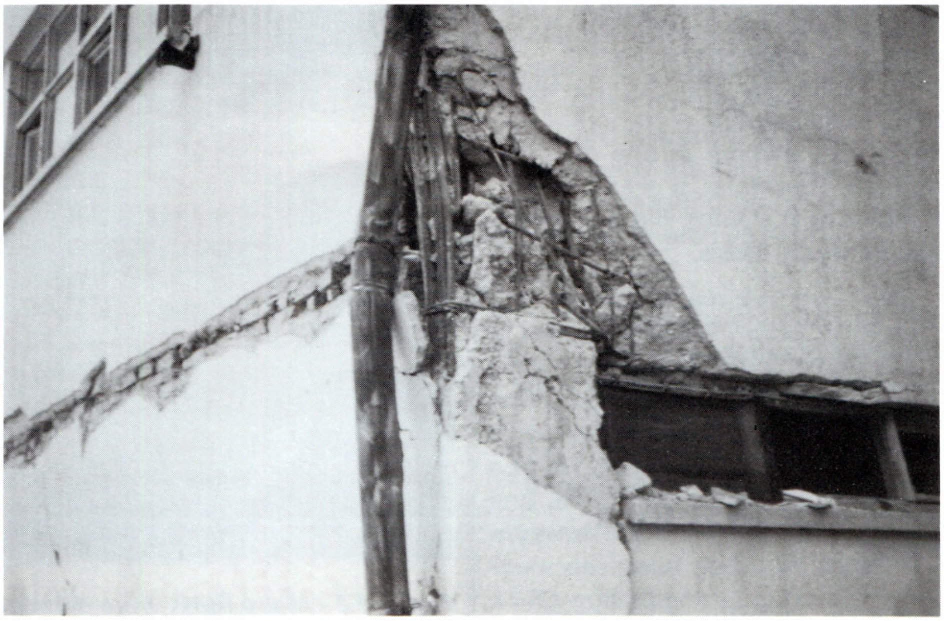

***Figure 14*** *- Inadequate confinement at the joints and at column ends.*

Lifelines—The main shock of October 1, 1995, caused the failure of electric power, water, and telephones in the city of Dinar and surrounding areas. These services were not repaired and restored until the 5th of October. It was reported that about 30% of the transformers in the town were damaged. Although the underground water system was undamaged, because of breaks resulting from collapsed buildings, the water supply had to be cut off. Telephone lines and the main switch building were also damaged and no connection could be made for a few hours after the main shock.

There were two bridges in the area and they were not damaged. There was no damage reported to highway and railroad bridges in the vicinity.

Because of the collapse of many structures in the city of Dinar, many roads in the city were cut off. The clearing of the debris and the opening of the roads took place in stages, starting on October 4th. The most important airport of the region, Afyon, remained operational.

## Conclusions

The majority of the buildings in Dinar were considered to be engineered buildings and were designed and built after the adoption of the 1975 Turkish Code. Still, the level of damage was considerable. It is interesting to note that more than 20% of the government buildings and about 30% of the private buildings either collapsed or suffered heavy damage.

It should be noted that the damage observed was not considered to be due to the inadequacy of the code. The problem was that the code requirements were not followed. The causes of failure were obvious and could be eliminated if the code was followed at design and construction stages. Buildings which were designed and built with some care did not suffer damage.

*The publication and distribution of this report were funded by National Science Foundation Grant #BCS-9215158, EERI's Learning From Earthquakes Project.*

***Figure 15*** *- The unusual collapse of a five-story building.*