Quindío, Colombia Earthquake of January 25, 1999: Reconnaissance Report

by

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16. Abstract (limit 200 Words)

The report documents damage caused by the January 1999 earthquake that struck the region around Quindio in western Colombia. It begins with a brief summary of the seismological characteristics and statistics on deaths, injuries, number of buildings damaged, and economic losses. The region's tectonic setting is discussed, including a fault map and an epicenter map. The strong motion records are also examined. Brief descriptions and illustrations of damage to the following types of structures are provided: unreinforced masonry; concrete frames; residential buildings; guadua frames; and churches. Descriptions are given of damage to electric power systems, telecommunication facilities, water supply systems, roads, bridges, airports, industrial facilities, hospitals, fire stations, and police stations. An evaluation of the emergency response and temporary shelter is followed by a discussion of disaster recovery and reconstruction. The report concludes with an outline of the rebuilding strategies that have been adopted by the Fondo de Reconstruccion del Eje Cafetero (FREC).

17. Document Analysis a. Descriptors

Earthquake Engineering. Quindio, Colombia earthquake, January 25, 1999. Damage. Regional tectonics. Strong motion records. Armenia, Colombia. Unreinforced masonry buildings. Concrete frame buildings. Unreinforced infill panels. Failure modes. Guadua frame buildings. Churches. Residential structures. Houses. Apartment buildings. Multistory buildings. Lifelines. Electric power distribution systems. Telecommuncation equipment. Water supply systems. Roads. Highway bridges. Airports. Industrial facilities. Hospitals. Fire stations. Emergency response. Disaster recovery. Temporary shelter. Reconstruction. Intraplate fault system.

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Abstract

At 13:19 local time (18:19 GMT), on Monday, January 25th, 1999 an earthquake with magnitude 6.2 on the Richter scale occurred in the western part of Colombia. The earthquake caused approximately 1,200 deaths and 5,000 injuries, damaged or destroyed 50,000 structures, and displaced more than 200,000 persons from their homes throughout an area extending some 50 kilometers from the epicenter. Economic losses are estimated to exceed $2 billion. This report describes the types and causes of damage resulting from the earthquake and the resulting social and economic impacts.

Reconnaissance Team and Acknowledgements

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Paul Flores and Alejandro Asfura of EQE International, the authors of this report, visited the area most affected by the January 25, 1999 Quindío, Colombia earthquake during the week of February 1-7, as part of a team sent by Earthquake Engineering Research Institute (EERI). This reconnaissance trip was part of EERI's "Learning from Earthquakes Program." The other members of the reconnaissance team were:

- Eduardo Fierro, Wiss Janney Elstner Associates, Inc.
- Mauricio Ciudad-Real, Kinemetrics, Inc.
- Patricia Guerrero, Universidad del Valle, Cali, Colombia
- Maria Del Mar Lopez, University of Michigan
- Walter Marin, Universidad del Valle, Cali, Colombia
- Kimberly Schoaf, UCLA School of Public Health

The authors wish to thank all of the members of the EERI team for sharing their information and professional perspectives on the affects of the earthquake. We would also like to thank the staff of the Universidad del Valle, in particularly Professor Peter Thomson, for facilitating the team's visit, and the many Colombian government officials who took the time from their emergency and recovery activities to provide the team with data and information.

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Section 1
Introduction

At 13:19 local time (18:19 GMT), on Monday, January 25th, 1999 an earthquake with magnitude 6.2 in the Richter scale occurred in the western part of Colombia. The earthquake caused serious damage throughout an area extending some 50 kilometers from the epicenter. At 17:44 local time (22:44 GMT) of the same day, a strong aftershock, with magnitude 5.8, occurred causing additional damage. The affected area is within Colombia's coffee-growing region making it one of the country's most important economic centers.

Source: MAGELLAN Geographix

Figure 1-1 Map of Colombia and the Affected Area

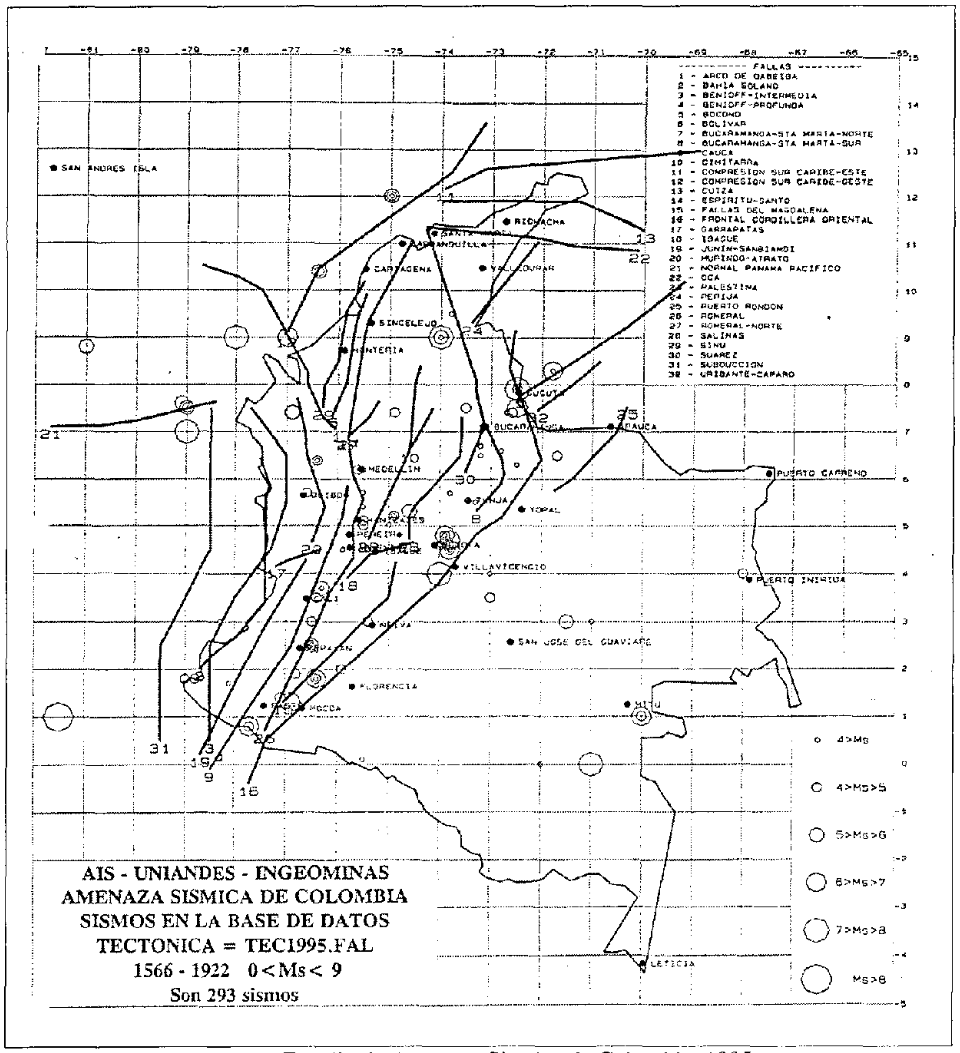
Seven Departments (equivalent to a U.S. state or county) and 28 municipalities were affected. The area contained within the Quindío Department was the most affected with catastrophic levels of destruction in the department's capital, the City of Armenia, and the towns of Calarcá, Circasia, Montenegro, Córdoba, La Tebaida, Filandia, Pijao, and Quimbaya (see figure 1-1). It is estimated that 80% of the total damage occurred in Quindío. Pereira, the capital city of the Risaralda Department, also suffered damage.

According to official information dated March 3, 1999, it is estimated that the earthquake caused approximately 1,200 deaths and 5,000 injuries, damaged or destroyed 50,000 structures, and displaced more than 200,000 persons from their homes. Also, approximately 1,200 rural installations that process coffee beans (*Beneficiaderos*) were destroyed. The Comisión Económica Para América Latina (CEPAL) estimates economic losses at over $2 billion.

Section 2
Tectonic Setting

Earthquakes in Colombia are generated by the subduction of the Nazca tectonic plate beneath the South American plate along the Colombia-Ecuador trench, and by the complex array of intraplate seismic faults in the central-western part of the country (see figure 2-1). These intraplate seismic faults can generate strong shallow earthquakes that can cause widespread destruction.

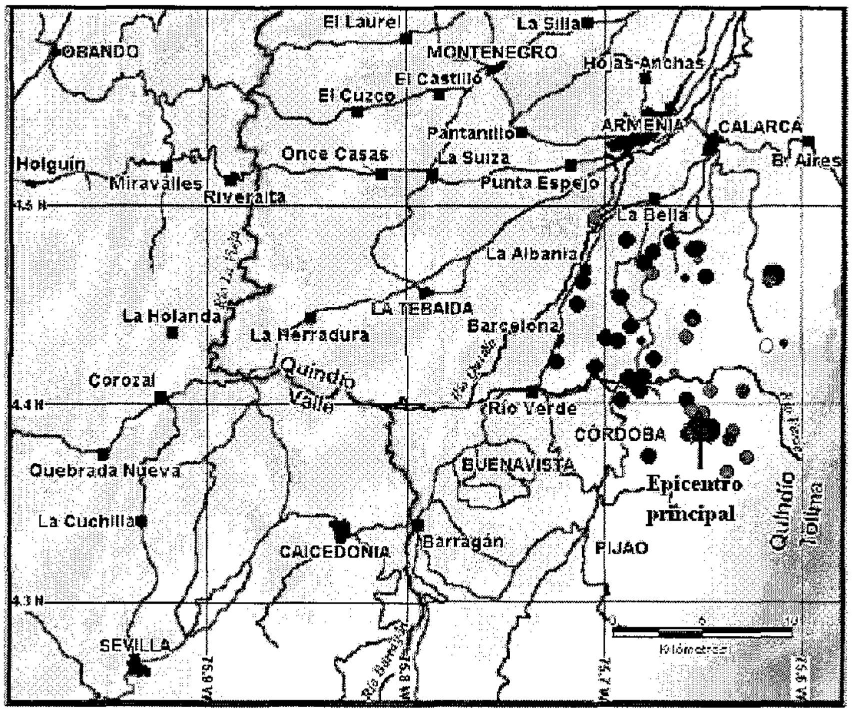
The January 25th, 1999 earthquake occurred in the system of intraplate faults that runs parallel to the Andes Mountains with a trend toward the northeast. This fault system is characterized by a strike slip type of movement. The fault involved in this earthquake had a left-lateral strike slip movement.



Source: Estudio de Amenaza Sismica de Colombia, 1995

Figure 2-1 Map of Faults

The location of the epicenter was estimated at latitude 4.41 degree North, and longitude 75.72 degree West, in the western side of the Central Range of the Colombian Andes Mountains. The focus was estimated at a depth of approximately 10 kilometers. The strongest aftershock location was estimated at 4.39 degree North and 75.72 degree West with a depth of 10 kilometers (see figure 2-2). The soils of the affected area are characterized by deep layers (larger than 100 meters in some areas) of volcanic ash and volcanic sedimentary deposits. These soil conditions were the main factor in the amplification of the seismic waves and the large number of landslides. The soil characteristics correlate well with the distribution of structural damage observed.



Source: O.S.S.O., Universidad del Valle, Colombia

Figure 2-2 Epicenter Map and Aftershocks

2.1 Affected Region

The earthquake primarily affected the departments of Quindío, Risaralda (southern part), Valle del Cauca (northern part), Tolima (western part), and Caldas (southern part). This region is in the western part of Colombia on the Central Range of the Colombian Andes Mountains. Quindío, the most affected department, is on the foot of the western side of this Central Range. It is a hilly region with unstable soils.

The region is basically an agricultural area that produces coffee, bananas, yuca, citric fruits, and some cattle. This area is called *eje cafetero* since it is the main coffee region of Colombia and thus, one of the most important economic centers of the country.

Fortunately, the earthquake was not strong enough to cause any damage in Cali, the most important city of the region, located 130 kilometers southwest of the epicenter.

The City of Armenia has a population of 223,000 (1993 census) and is located 17 kilometers north of the epicenter. According to preliminary information dated January 31, 1999, 60% of the structures in the city suffered some level of damage. The Quindío towns of Calarcá, Circasia, Montenegro, Córdoba, La Tebaida, Filandia, Pijao, and Quimbaya, were also severely damaged.

The City of Pereira, with a population of about 380,000, is located approximately 48 kilometers north of the epicenter. According to preliminary information dated January 31, 1999, 385 structures collapsed and 522 will need to be demolished. Pereira also suffered damage during the February 8, 1995 earthquake.

2.2 Strong Ground Motion

Colombia's National Accelerographic Network administrated by Ingeominas consists of several strong motion instruments that are owned by Ingeominas, Observatorio Sismológico del Sur Occidente (OSSO), Universidad del Quindío, and Corporación Autónoma Regional de Risaralda (CARDER). Many of the network's stations, installed on rock and soft soils, were able to record the main shock and aftershocks.

Table 2-1 Stations and Maximum Accelerations

City	Station		Station Coordinates		Peak Ground Acceleration (cm/sec^2)			Epicentral Distance (km)
	Code	*Classifi-cation*	*LAT N*	*LON W*	*E-W*	*VERT*	*N-S*	
Armenia	CARME*	Soil	4.50	75.80	530.0	465.0	589.0	17
Filandia	CFLAN**	Soil	4.69	75.62	567.0	198.0	480.0	19
Pereira	CLROS***	Soil	4.84	75.68	180.6	73.6	188.5	48
Pereira	CMAZP***	Soil	4.81	75.69	253.2	99.1	290.7	48
Pereira	CSTRC***	Soil	4.88	75.63	181.3	63.3	259.3	48
Pereira	CPER2*	Soil	4.84	75.75	210.3	97.4	145.8	48
Pereira	CPER1*	Rock	4.78	75.64	77.7	25.5	49.8	48

Source: Ingeominas

All of the stations are subscribed to the National Accelerographic Network administrated by INGEOMINAS, but are owned by different organizations, as follows:

* INGEOMINAS

** Universidad del Quindío

*** Corporación Autónoma Regional de Risaralda (CARDER)

Table 2-1 gives a list of maximum ground acceleration of the main shock recorded in several stations in the area affected by the earthquake. The maximum ground accelerations recorded on rock at 48 kilometers of the epicenter are approximately 0.08g in the horizontal direction and 0.03g in the vertical direction. The maximum horizontal ground accelerations recorded on soil vary from about 0.60g, at 17 kilometers from the epicenter, to 0.30g, at 48 kilometers from the epicenter. The maximum vertical ground accelerations recorded on soil vary from about 0.47g, at 17 kilometers from the epicenter, to 0.10g, at 48 kilometers from the epicenter. The ratios between the maximum accelerations recorded on soil and the accelerations recorded on rock were in the approximate range of 2.5 to 4.

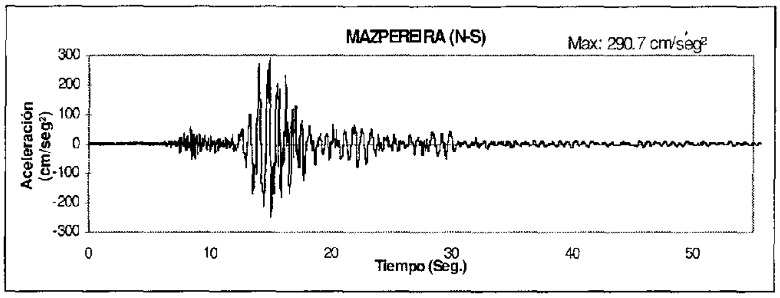
Figures 2-3 through 2-6 show the acceleration records for two stations and their corresponding response spectra. The response spectra corresponding to the motions recorded on soil clearly show the effect of the soft soil layers in the frequency content of the surface motions. Figure 2-7 shows the distribution of maximum ground acceleration recorded in the affected area.

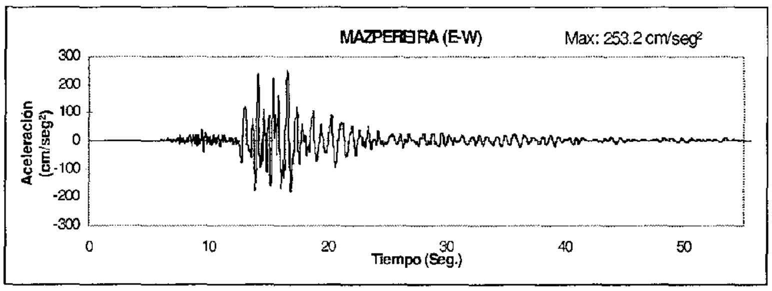
Strong Ground Motion Records

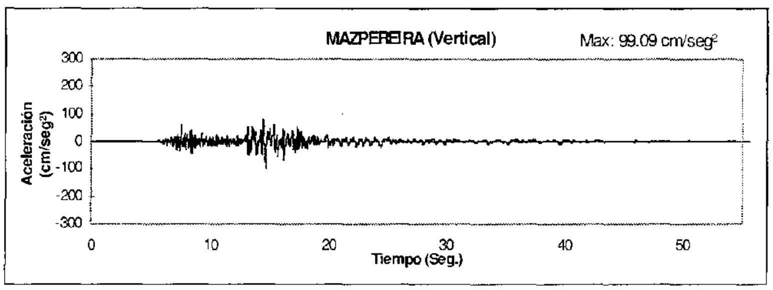
Station: CMAZP
Instrument: K2 S/N 959
Resolution: 18 bits

Classification: Soil
G Level: 1G

N-S	E-W	VERT
290.7	253.2	99.09







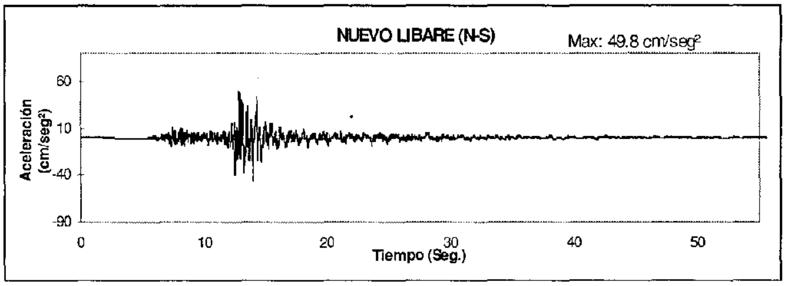
Source: CARDER - Corporación Autónoma Regional de Risaralda Pereira, Colombia

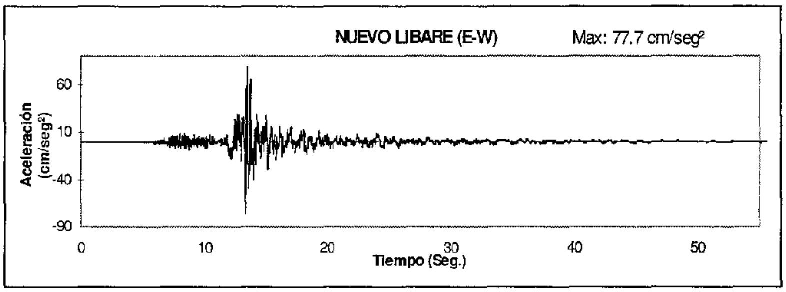
Figure 2-3 Strong Ground Motion Records, Station CMAZP

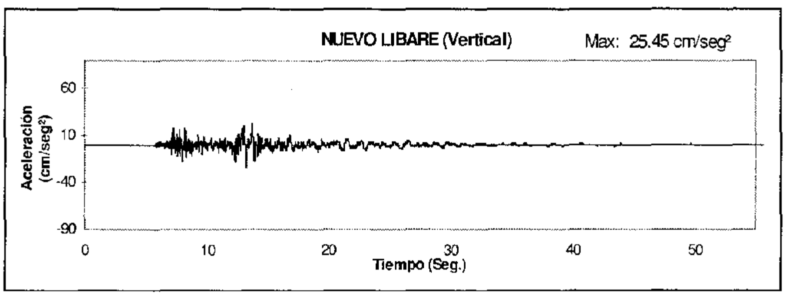
Strong Ground Motion Records

Station: CPER1 Classification: Rock
Instrument: K2 S/N 646 G Level: 1G
Resolution: 18 bits

N-S	E-W	VERT
49.8	77.7	25.5

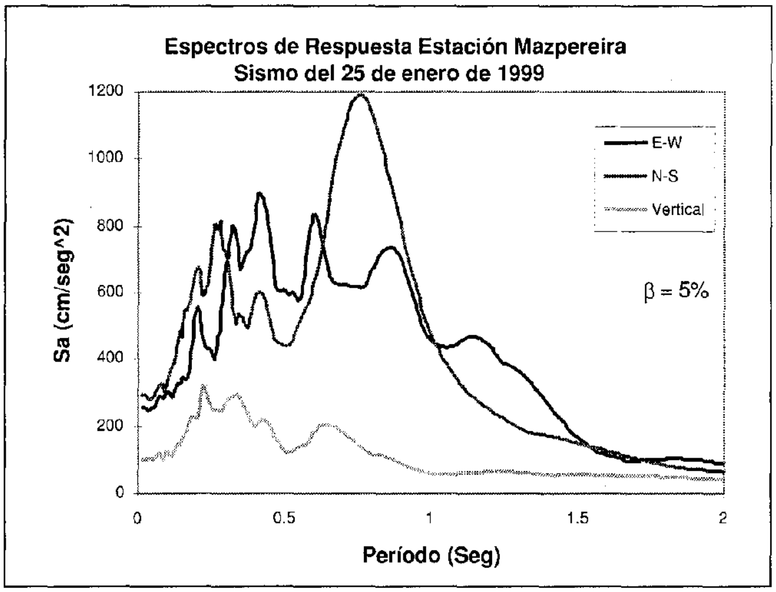






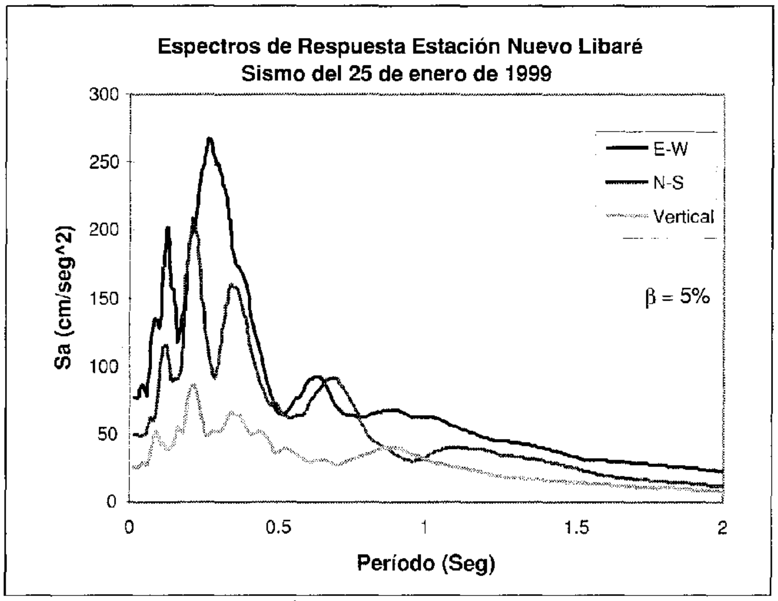
Source: CARDER - Corporación Autónoma Regional de Risaralda Pereira, Colombia

Figure 2-4 Strong Ground Motion Records, Station CPER1



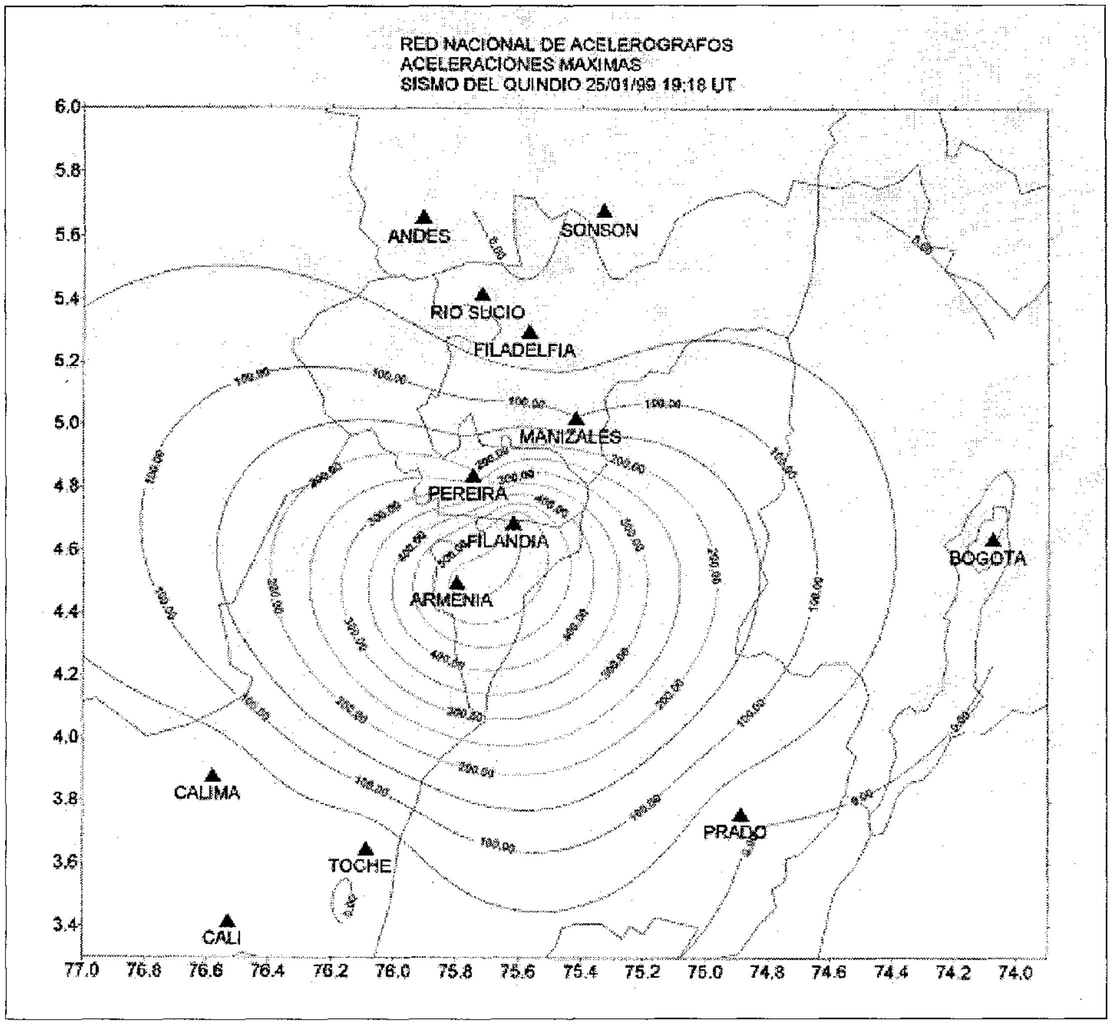
Source: Ingeominas

Figure 2-5 Time Histories for Recorded Motion



Source: Ingeominas

Figures 2-6 Time Histories for Recorded Motion

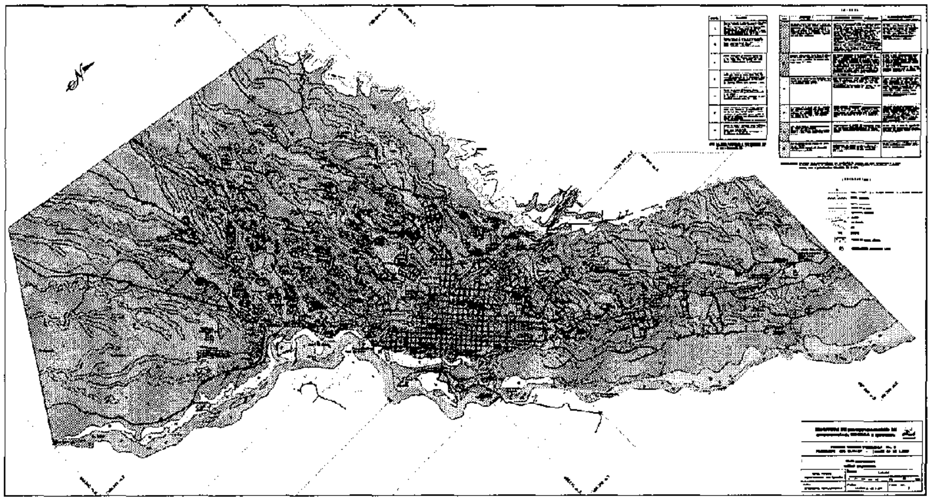


Source: Ingeominas

Figure 2-7 Map of Recorded Accelerations

Section 3
Structural Damage Due to Shaking

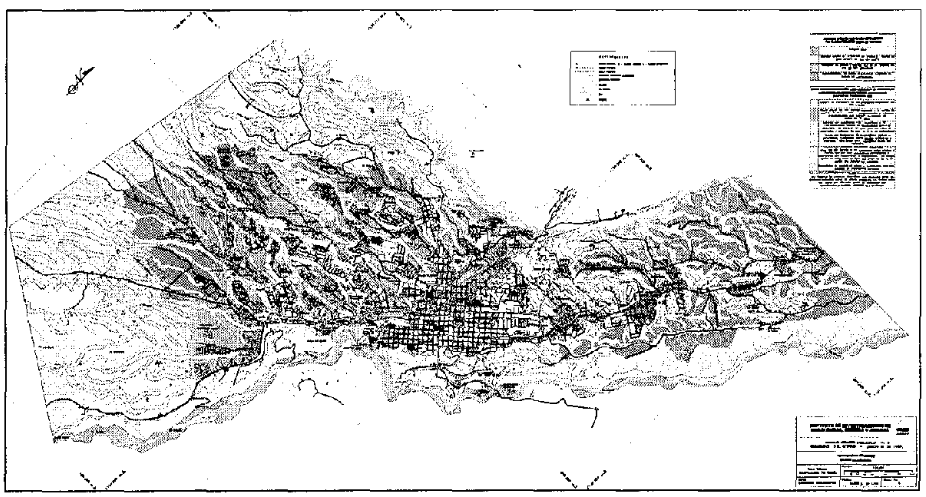
Most of the structural damage was concentrated mainly in the areas with deep layers of volcanic ash and volcanic sedimentary deposits or man-made non-engineered fill (see figure 3-1).



Source: City of Armenia

Figure 3-1 Geotechnical Map of Armenia

In Armenia, the damage was concentrated in the southern and central part of the city in a very close correlation with the quality of the soil (see figure 3-2). In those sectors, the destruction was widely spread. In neighborhoods such as Brasilia toward the south of Armenia, the initial estimate of the destruction level was 95% (Figure 3-3). Most of the damage was to one and two-story houses and apartment buildings of four or five stories.



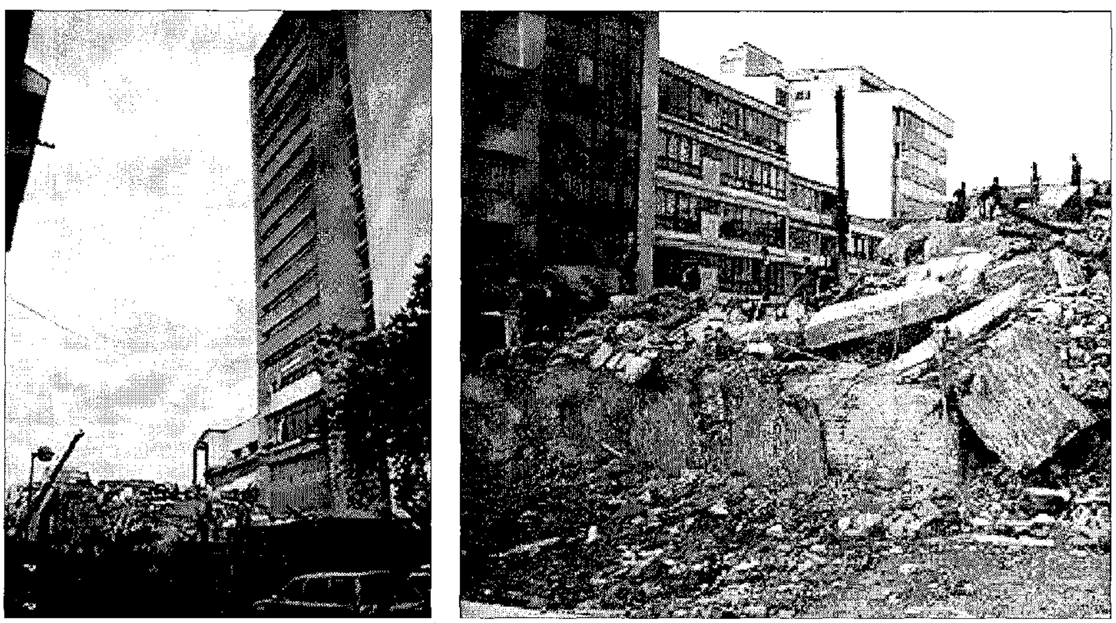
Source: City of Armenia

Figure 3-2 Armenia Damage Zonation Map

The Armenia's central business district or downtown was also severely damaged. A large number of engineered buildings collapsed or will have to be demolished (see figure 3-4). The Municipal Government building, a 20-story concrete frame tower with two lateral five-story separated wings suffered extensive damage and had to be evacuated. The left wing was severely damaged during the main shock and collapsed during the 17:44 aftershock.

Source: AP

Figure 3-3 Complete Damage in Brasilia, Armenia



Source: EQE International

Figure 3-4 Damaged Wing of Armenia Government Building

An accelerometer belonging to Ingeominas was located at the University of Quindío in Armenia, relatively close to downtown. This instrument is located in an area of natural soil consisting of a layer of volcanic ash of approximately 27 meters overlying a deep sedimentary deposit. The maximum ground accelerations recorded for the main shock were 0.53g for the N-S direction, 0.58g for the E-W direction, and 0.48g for the vertical direction. Thus, it can be assumed that these were approximately the input ground accelerations for the buildings in downtown. For the low period range, the actual spectral values are 2 to 3 times the elastic spectral values given by the design codes of 1984 and 1998.

Towns such as La Tebaida and Barcelona, located on a deep layer of soft soil, were severely damaged (see figure 3-7). In comparison, the town of Córdoba, much closer to the epicenter and located on bedrock, suffered less damage. In Pereira, the area most affected was between *calles* 15 and 26 and *carreras* 8 and 16, which is located on man-made non-engineered fill (see figures 3-5 and 3-6).

Source: EQE International

Figure 3-5 City of Pereira: Damage on Corner of Carrera 11 and Calle 21, 4-Story Building

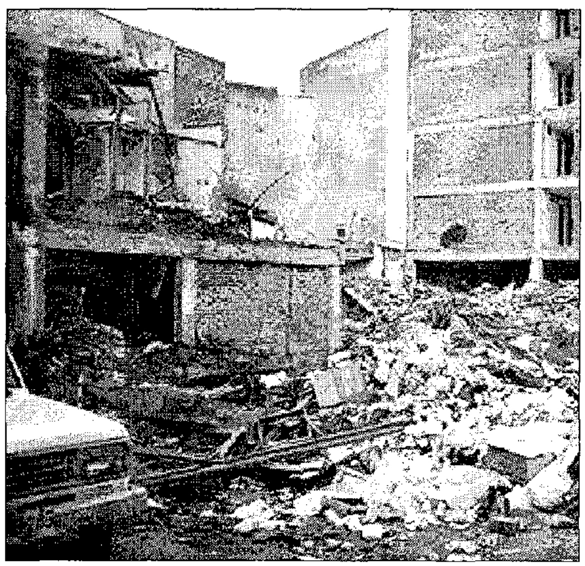
Source: EQE International

Figure 3-6 City of Pereira: Carrera 12/Calle 22, 3-Story Building, Collapsed

Source: EQE International

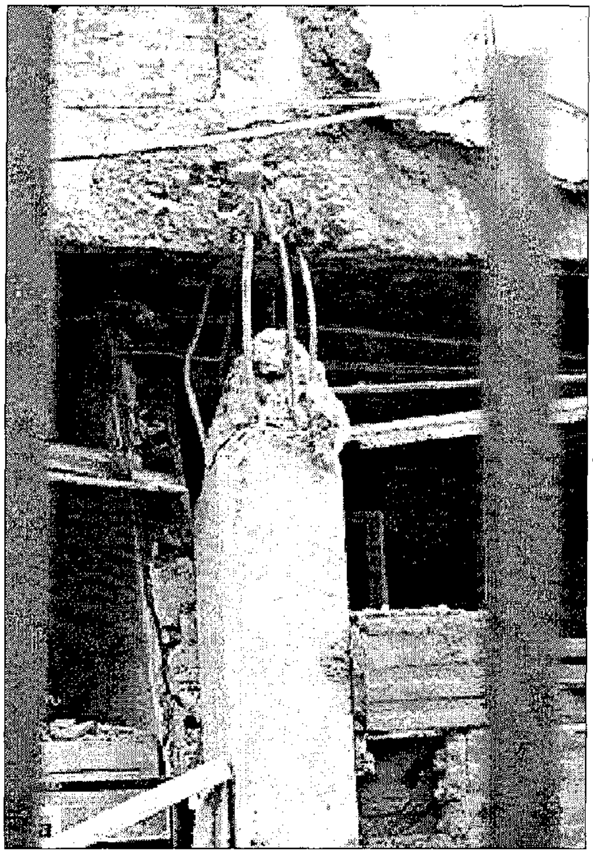
Figure 3-7 City of La Tebaida: Damage on Carrera 6

The typical construction in the area affected by the earthquake consists of unreinforced masonry for low structures and concrete frames with either solid clay brick or hollow clay tile unreinforced infill panels for taller structures. The infill panels are normally not connected to the concrete frames. As expected, heavy damage in the unreinforced masonry structures and unreinforced infill panels occurred (see figure 3-8 through 3-10). Poor confinement and detailing was typical in the concrete frame structures that collapsed or were damaged.



Source: EQE International

Figure 3-8 Hotel Armenia-Plaza, Unreinforced Masonry Calle 22/Carreras 14 y 15, Armenia



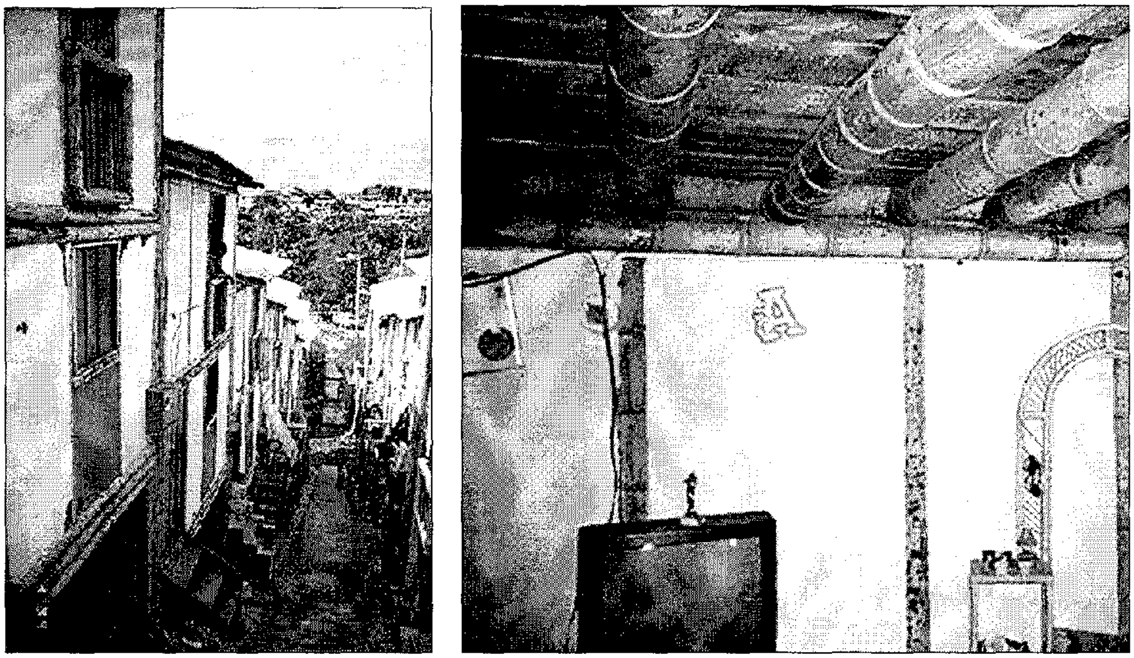
Source: EQE International

Figure 3-9 Brasilia Neighborhood, Armenia

Source: EQE International

Figure 3-10 Kokorico Restaurant, Carrera 15/Calle 21, Armenia, 4-Story, Concrete Frame, Masonry Infill

A group of 73 two story houses in the Miraflores neighborhood of Armenia, built with frames of *guadua* (similar to bamboo), behaved well and did not suffer any damage (see figure 3-11). Many masonry houses in this neighborhood were damaged. The same was observed in some rural areas.

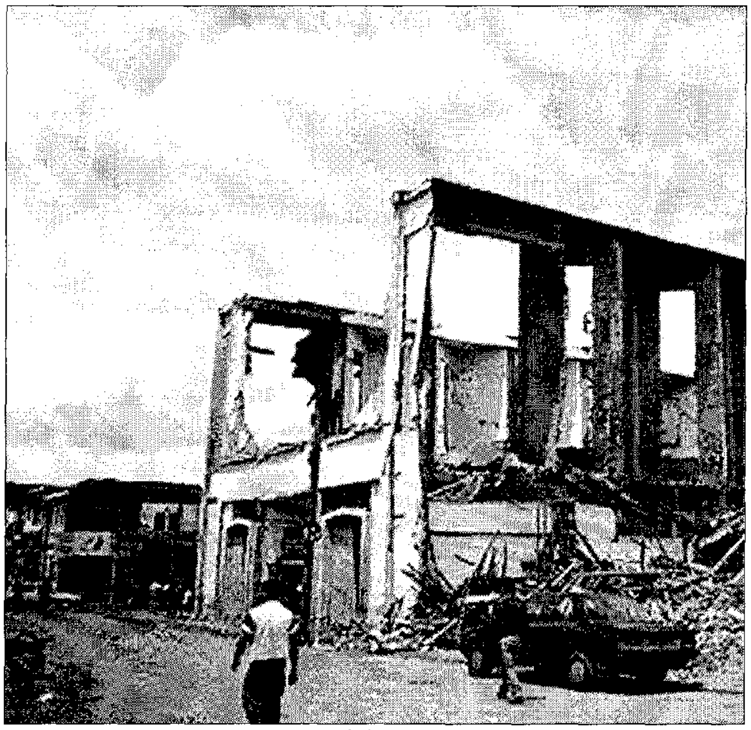


Source: EQE International

Figure 3-11 Miraflores Neighborhood, Armenia: 73 Houses Built with Guadua Frames, No Damage

The age of the structures was an important factor in their behavior. The first seismic code in Colombia was published in 1984. A more modern code was published in 1998. Thus, structures designed before 1984 behaved worse than more modern structures. However, many structures apparently designed after the 1984 code, collapsed or resulted severely damaged.

Churches built with unreinforced stone or solid brick masonry were severely damaged in the whole area affected by the earthquake. Also, churches built with concrete frames and unreinforced masonry infill panels suffered severe damage in those panels (see figures 3-12 and 3-13).



Source: EQE International

Figure 3-12 Pereira Church on Carrera 12/Calles 22 and 23

Source: EQE International

Figure 3-13 Damaged Church in Pijao

The educational infrastructure suffered considerable damage. It is estimated that about 35% of the school buildings in the city of Armenia collapsed during the earthquake or needed to be demolished afterward (see figure 3-14). Fortunately, the school year had not started at the date of the earthquake, otherwise the casualty toll could have been dramatically higher.

Source: EQE International

Figure 3-14 Damage to San Francisco Solano School in Armenia. URM Building

Section 4
Effects on Lifelines and Associated Structures

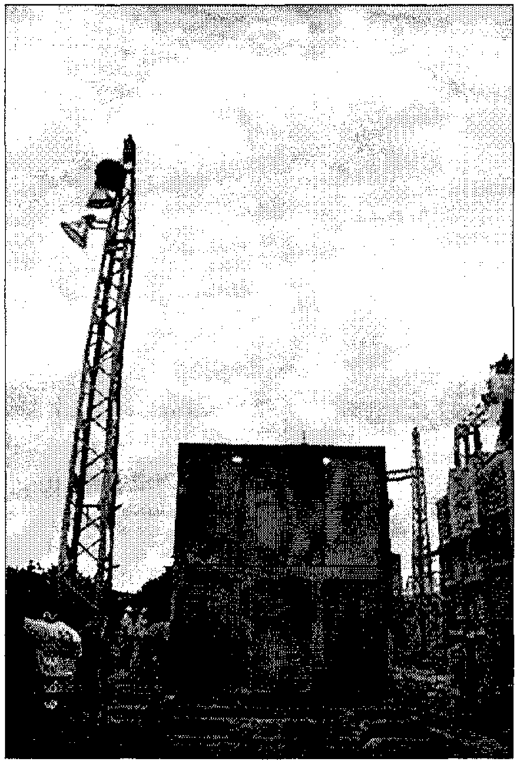
4.1 Electric Power

The region affected by the earthquake is connected to the Colombian electric grid which practically provides all the energy for the area. This energy is generated mainly in hydroelectric plants located far from the earthquake's epicenter. In the Quindío Department, there are only four small hydroelectric plants, one of 2.28 MW and three of 2.0 MW. No damage was reported in these 4 plants.

The Quindío Department's energy demand is 90 MVA and the installed substations have 180 MVA. The service to hospitals and clinics was resumed 3 1/2 hours after the earthquake. The service was practically normal after approximately one week.

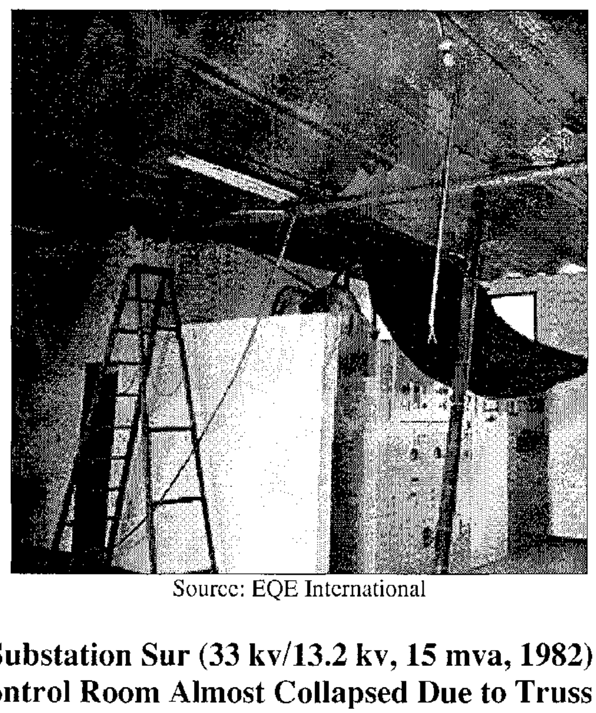
During the earthquake, two substations were damaged:

- ❑ Substation Regivit (115 KV/33 KV, 60 MVA, built in 1960). It is one of the two substations that connect the Colombian grid to the department grid, suffered damage in the transformers and circuit breakers. The three transformers (20 MVA each) were not anchored and mounted on wheels and they jumped out of their rails. One of them fell inside the oil-pit and suffered heavy damage, the other two did not completely fall inside the pits but suffered damage in the supports and the bushings. Two ceramic column circuit breakers broke close to their base. This substation is located in the north area of Armenia, in a zone with very little reported damage; however, the transformers were located about 4 meters from a very deep ravine (about 200 meters deep). The substation was out of service at the time of the visit (see figure 4-1).
- ❑ Substation Sur (33 KV/13.2 KV, 15 MVA, built 1982). Located in the south area of Armenia has two transformers (10 MVA, 5 MVA) mounted on wheels, they moved but did not fail. Some oil leakage in the 10 MVA transformer was reported. The equipment in the control room was not anchored and moved approximately 2". No equipment failure was reported though. The control room is a one story URM building. The walls and roof were damaged. This substation was still in service (see figure 4-2).



Source: EQE International

Figure 4-1 Substation Regivit (115 kv/33 kv, 60 mva, 1960) in Armenia: Damage on Tower Due to Transformer Fall



Source: EQE International

Figure 4-2 Substation Sur (33 kv/13.2 kv, 15 mva, 1982) in Armenia: Roof Control Room Almost Collapsed Due to Truss Failure, Temporary Support

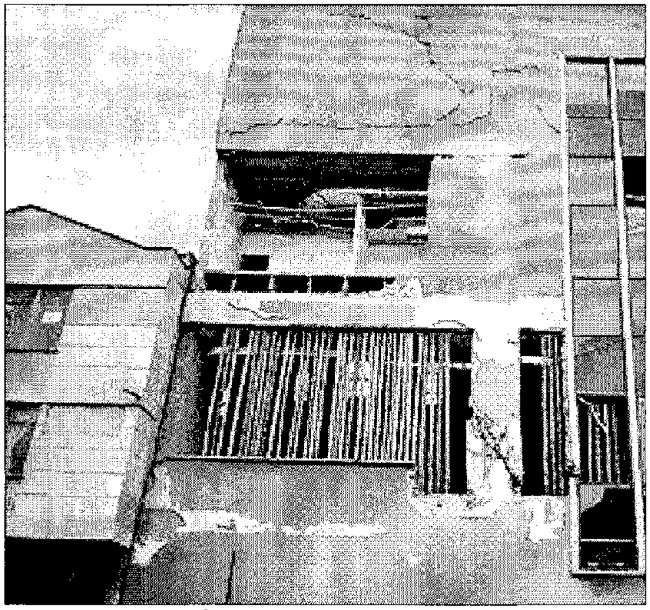
The distribution lines in the cities were damaged due to collapsing structures; however, they were repaired very quickly. The large majority of the street poles and the distribution elevated transformers did not suffer any damage due to the earthquake shaking (see figure 4-3).

Source: EQE International

Figure 4-3 Damage to Electrical Distribution Lines in Brasilia, Armenia

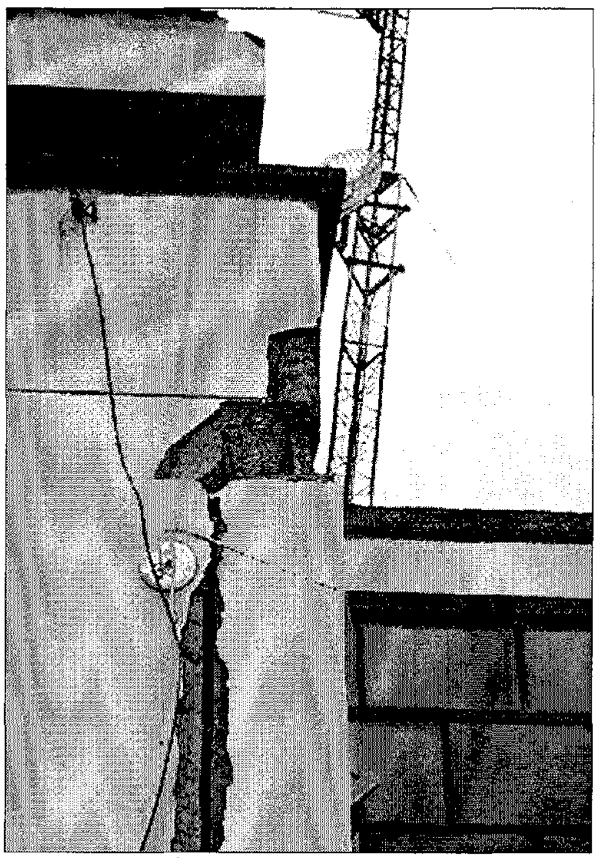
4.2 Telecommunication

The telecommunication equipment did not suffer important damage and service was resumed to the areas less affected one to three days after the earthquake. By the Thursday following the earthquake, all but two towns (Cordoba and Buena Vista) had telephone service restored. Elevated lines were damaged due to collapsing structures, but the behavior of buried lines in areas of heavy building damage was not determined. The buildings housing the telecommunication equipment in the city of Armenia (Telecom Central Plant), at a distance of 17 km from the epicenter, and in the towns of Barcelona, Córdoba, Pijao, and La Tebaida, in the epicentral zone, suffered severe damage (see figures 4-4 and 4-5). However, the equipment was not damaged and was back in operation shortly after the earthquake.



Source: EQE International

Figure 4-4 Telecom Building in Armenia Suffered Severe Structural Damage



Source: EQE International

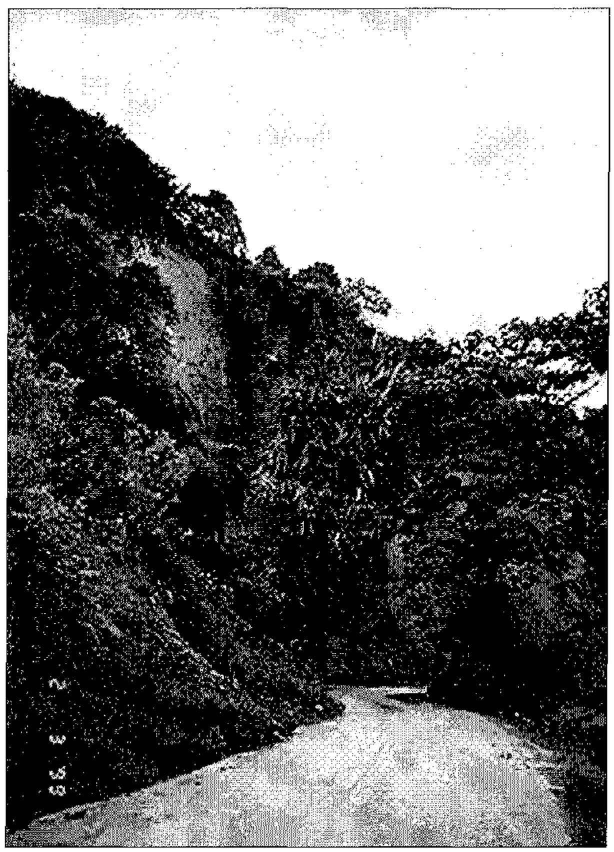
Figure 4-5 Telecom Building in Cordoba Suffered Severe Damage (Concrete Columns with Masonry Infill)

4.3 Water System

Very little damage was reported to water systems, although in some areas of Armenia, water was not available for three days. According to official reports, there was no contamination detected and the quality of the water remained as it was prior to the earthquake. According to reports from the water utilities, the majority of the aqueducts did not suffer important damage, although damage was reported to an aqueduct near the town of Calarcá. The treatment plants and the storage tanks stayed operational. Some problems were reported in the distribution lines in the municipalities of Filandia, Circacia, Pijao, Buena Vista and Calarcá.

4.4 Roads and Bridges

Several two-line paved roads, highways, and bridges were affected by the earthquake. No major damage was detected in the pavement, only some local cracks in the road between Armenia and Pijao were observed. However, four roads were blocked (Armenia-Buena Vista, Armenia-Pijao, Armenia-Córdoba, Armenia-Ibagué) and three municipalities of Quindío were isolated due to landslides. The most affected road was the Armenia-Pijao, which, in about 14 km, had approximately 100 landslides, several of them large enough to completely block the road (see figures 4-6 and 4-7).



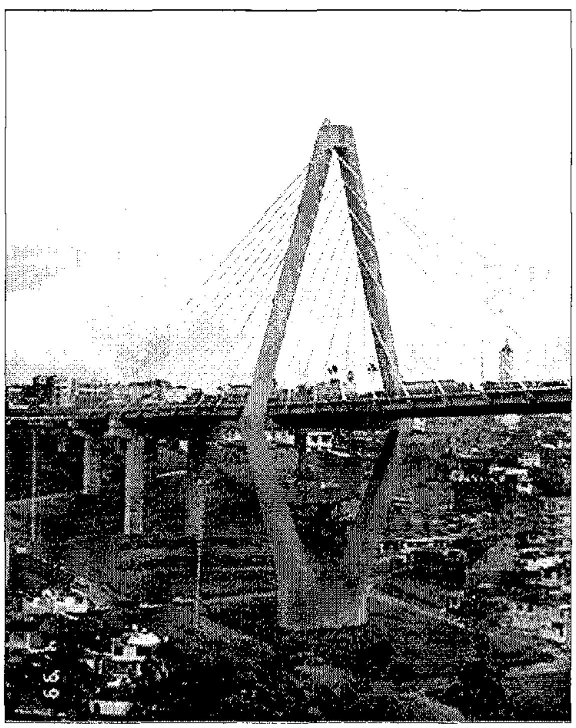
Source: EQE International

Figure 4-6 Landslides on Road Armenia-Pijao

Source: EQE International

Figure 4-7 Crack on Pavement Due to Movement of Downhill Side of the Road on Road Armenia-Pijao

Bridges behaved well in the affected area and no structural damage or settlement was observed. Near Pereira (between Pereira and Dos Quebradas) there is a newly built cable stayed bridge, with two tall central towers and a total length of approximately 1 kilometer, with absolutely no damage (see figure 4-8).



Source: EQE International

Figure 4-8 Pereira: Bridge Between Pereira and Dos Quebradas

4.5 Airports

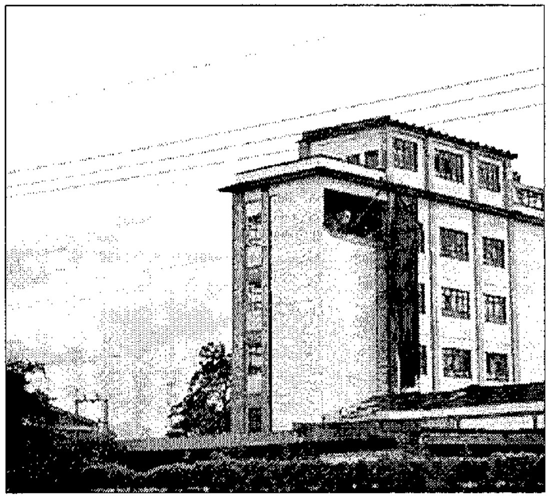
The buildings of the airport El Edén of Armenia were damaged. However, the runway and the outside equipment were not affected and the airport remained functional and able to receive flights carrying emergency personnel and resources. The terminal building is a one-story concrete frame building with masonry infill. It suffered heavy nonstructural damage and damage on the roof (see figure 4-9). The columns of the top floor (3rd) of the control tower were damaged. The concrete slab on top of the tower is supported by two columns located at the back corners of the slab and by two very close columns at the central part of the slab. This floor will be demolished. Apparently, none of the equipment was damaged.

Source: EQE International

Figure 4-9 Structural Damage to Armenia Airport Terminal and Tower

4.6 Industrial Facilities

In the industrial area of Dos Quebradas, north-east of Pereira and about 48 kilometers north of the epicenter, damage was observed in concrete frame buildings of two industrial installations (see figure 4-10). No equipment failure was observed or reported. This area is on layers of natural soil. Very close to the two visited installations, there is an accelerometer. The maximum acceleration recorded were 0.184g in the e-w direction, 0.192g in the n-s direction, and 0.075g in the vertical direction.

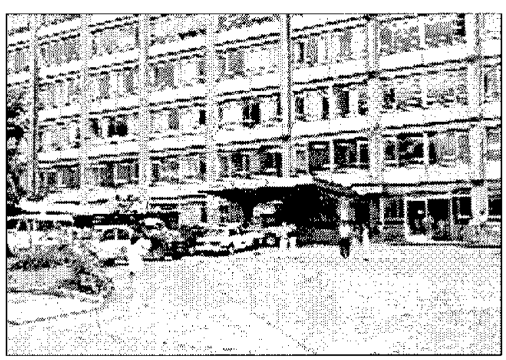


Source: EQE International

Figure 4-10 Industrial Building in Dos Quebradas was Damaged and Repaired in 1995, Suffered Damage in Nonstructural Panels and Some Deep Beams

4.7 Hospitals

Hospitals and other health care centers were severely affected by the earthquake. The regional hospital in Armenia is a five-story concrete frame structure with masonry infill. Significant non-structural damage was noted to the building, although the hospital continued operating (see figure 4-11). The emergency department was in a new wing of the hospital that suffered little damage. The hospital had emergency generators and was able to operate in the immediate aftermath. In addition to the regional hospital in Armenia, seven of the twelve primary care health centers in the city were also damaged. Three of the clinics, in the hardest hit areas of the city, collapsed. Four additional clinics suffered severe damage and were yellow-tagged although the clinics continued to function. The one clinic visited was a one-story masonry building. The roof of the structure collapsed over all but the front two rooms of the building. In addition, landslides under the rear of the structure were threatening the back two rooms.



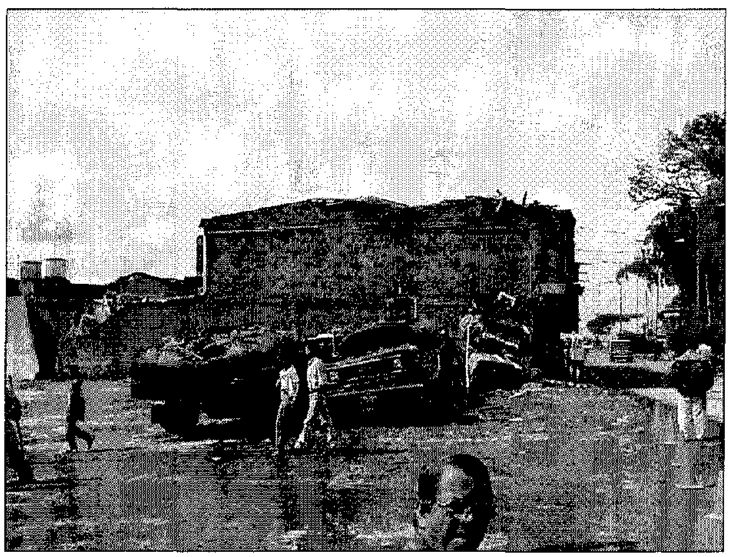
Source: EQE International

Figure 4-11 Regional Hospital in Armenia Suffered Extensive Nonstructural Damage but was Kept Operational

The hospital in Calarcá, near Armenia, it is a five-story building with concrete frames and masonry infill and masonry partitions. It suffered severe damage in the nonstructural elements during the earthquake. A substantial portion of the building had been rebuilt following the 1995 Pereira earthquake. There was a substantial amount of cracking in the upper floors, making them unusable. The emergency department continued functioning on the first floor. The hospital had emergency generators, which maintained the power and there was no interruption in water supply. The hospitals of Circasia and Córdoba both collapsed.

4.8 Fire Stations

The fire department for the city of Armenia was centralized. The city's fire department and all of its personnel and equipment were housed in only one facility. The building collapsed during the earthquake, destroying all the fire trucks and killing several fire fighters (see figure 4-12). The building was a three-story concrete frame building with masonry infill (mainly in the two top floors). According to the information available, it was built around the 1950's. Fortunately, only one fire broke out due to the earthquake, in a collapsed three-story building, where the first floor was used as a warehouse for chemical products.



Source: EQE International

Figure 4-12 Damaged Fire Trucks in Area Where Armenia's Centralized Fire Department Facility Stood

4.9 Police Stations

The police department of Armenia was also centralized, and one facility housed all personnel and equipment. This building also collapsed, killing 18 policemen (see figure 4-13). The station consisted of three sections forming a U. They were three-story and five-story concrete frame buildings with masonry infill. It was founded on approximately three meters of volcanic ash. It had a new section that opened in 1998. This new section was severely damaged and will need to be demolished.

Source: EQE International

Figure 4-13 Collapse of Armenia's Centralized Police Station

Section 5
Emergency Response and Recovery

In the City of Armenia, the hardest hit municipality, the extent of damage was so great that emergency response operations were severely hampered and recovery efforts will be long and difficult

5.1 Emergency Response

At the time of the earthquake, the City of Armenia had an emergency plan developed according the national guidelines. According to this plan, an emergency council called Comité Local Para la Prevención y Atención de Desastres (COLPAD), has responsibility for the overall management of a disaster situation. This council is chaired by the mayor and composed of representatives from key city departments, the Colombian Red Cross, and Civil Defense, a non-governmental volunteer organization. Nevertheless, the effects of the earthquake made it extremely difficult to carry out emergency operations in an organized and efficient manner. The initial emergency response (first 72 hours) was complicated by debris in the streets and resultant traffic jams, the loss of telecommunications, and the collapse of the centralized fire and police department facilities.

Source: AP

Figure 5-1 Debris Blocking Streets in Brasilia, Armenia

The debris on the streets of Armenia was so extensive that during the first few days after the earthquake, the only way for emergency personnel to get around was by using motor scooters. Even though the debris began to be removed almost immediately after the earthquake, the streets remained heavily congested (see figure 5-1). For security reasons, traffic into the city's downtown area was restricted, further adding to the congestion. At the time of the team's visit, debris was being removed and temporarily stored in several of the many ravines that transect the city (see figure 5-2). The earthquake produced over 1 million cubic meters of debris. According to city officials, the debris will eventually be removed from these ravines and recycled.

Source: EQE Internationsl

Figure 5-2 Debris Storage Area in Armenia

The disruption to telephone service (landlines and cellular) made the coordination of the emergency response organizations next to impossible. Nevertheless, the city's amateur radio groups were able to establish communication with rest of the country. Radio amateurs were also credited with keeping the extensively damaged airport functioning by acting as air traffic controllers for in-bound flights carrying emergency personnel and other resources.

Perhaps the most debilitating effect on the emergency response was the collapse of the city's fire department and police department facilities. These were centralized facilities housing personnel and equipment. These two agencies are primarily responsible for the management and coordination of emergency situations and neither was able to respond effectively.

Further adding to these problems, the city's municipal government building ("city hall") was evacuated due to uncertainty about its structural safety. This is the building that housed the COLPAD. Not until the third day following the earthquake was a temporary Emergency Operations Center (EOC) established at the Civil Defense headquarters to better coordinate emergency operations (see figure 5-3).

Even though the Civil Defense facility was small and space was very limited, it provided a centralized point of coordination for government operations. Most key agencies were forced to operate temporarily from buildings that were not seriously damaged. At the time of the team's visit to the temporary EOC, plans were underway to centralize emergency and "normal" government operations at a museum located in the northern part of the city, which suffered relatively little damage.

Source: EQE International

Figure 5-3 The Civil Defense Building in Armenia Temporarily Housed Key City Agencies

According to official accounts, the initial search and rescue activities were performed by uninjured citizens, but soon continued by professional domestic personnel from Bogota and other unaffected cities. Within days, numerous international urban search and rescue teams began arriving from Japan, Europe, the United States, Mexico, and other Latin American countries to assist with the search and rescue operations. To facilitate the effort, an incident command-type system was established. The city was divided up into four geographic sections with the Fire Department, the Red Cross, Civil Defense, and Japan's team serving as the incident commanders, who in turn reported to COLPAD.

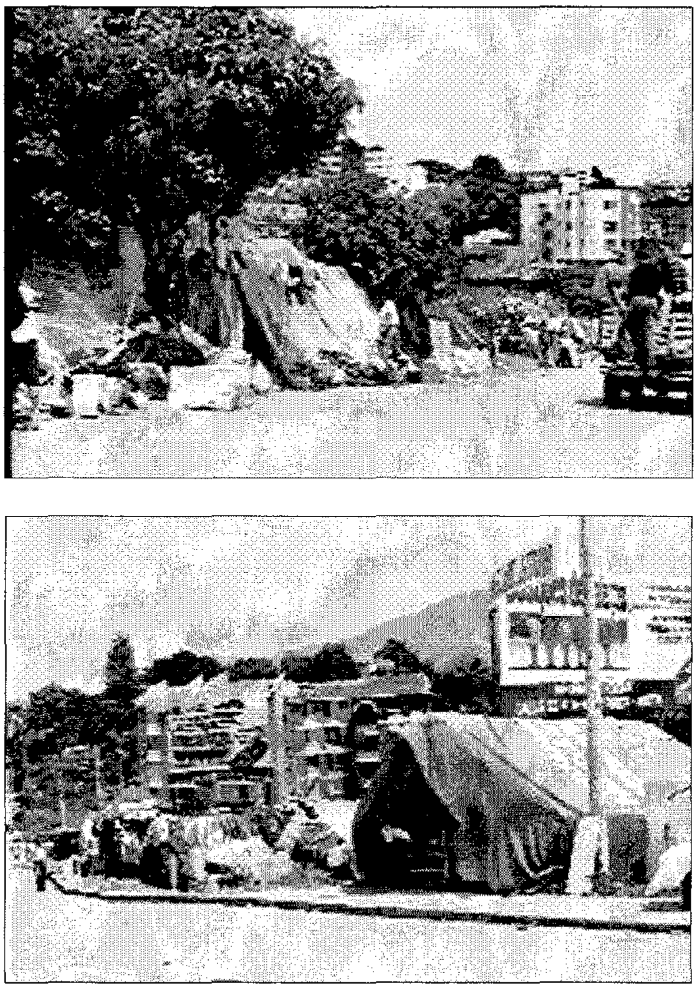
The looting that followed the earthquake is a phenomenon rarely seen in disasters (see figure 5-4). By all accounts, the "looters" were from outside the city and took advantage of the crippled status of the city's police force. The Colombian President's decision to deploy national military personnel into Armenia was effective in quickly restoring law and order and protecting major commercial centers, such as downtown.

Source: Internet (no source identified)

Figure 5-4 Looters Attacking a Red Cross Food Storage Facility

5.2 Emergency Shelter and Temporary Housing

The provision of emergency shelter to those displaced by the earthquake damage, is perhaps the most critical issue currently facing the city. Approximately 90,000 families were displaced by the earthquake. In the City of Armenia alone, the number of displaced persons is conservatively estimated to be over 100,000. While many of the displaced have found shelter with unaffected family members or friends, many had no place to seek shelter or refused to leave their damaged property. This led to the creation of spontaneous emergency shelters (see figure 5-5). Most of these shelters are tents or lean-tos that displaced persons have constructed on sidewalks, roadsides or parks in the vicinity of their destroyed homes, using plastic sheeting and materials recovered from the debris.



Source: EQE International

Figure 5-5 Spontaneous Shelters, Downtown Armenia

The immediate need for and short supply of qualified building inspectors initially compounded the shelter problem. Many people in these makeshift shelters were waiting for an inspector's decision about whether their houses could be reoccupied or must be demolished. Initially, the requests for inspections were coming to the Engineering Society of Armenia, the Red Cross, and other agencies involved in the emergency response. However, to improve coordination, the city's Planning Department began to centralize all requests at their temporary office at the Civil Defense headquarters. Residents were being asked to fill out a form that attempts to identify owners vs. renters and types of damaged suffered.

At the time of the EERI team's visit, the Armenia Planning and Health Departments were conducting a census of these shelters to better understand the demographic make-up and health needs of the displaced population. Since that time, the national government has financed a much more detailed census of both affected persons and buildings for all 28 of the affected municipalities.

To better meet the needs of displaced families, the City of Armenia has initiated a major effort to relocate displaced families to temporary settlements constructed by the Fondo Nacional de Vivienda (FNV) using a combination of large military (10-30 people) and single camping-type tents (5-7 people). Intended to be used as temporary housing, these settlements will have basic services (water, sanitation, and common cooking facilities). As of June 1999, as many as 40 of these settlements had been established by the FNV. The establishment of these temporary settlements is an important element of the government's overall reconstruction strategy.

5.3 Recovery and Reconstruction

Immediately following the earthquake, the President of Colombia established a national reconstruction commission called Fondo de Reconstrucción del Eje Cafetero (FREC) comprised of the major national departments, representatives of the affected departments (regional units of government), mayors of the 28 affected municipalities, and representatives of the coffee industry. The FREC has been allocated approximately $400 million dollars to initiate the recovery effort.

In Armenia, the city's initial reconstruction strategy is based on the recently approved urban development plan, approved by the City Council on the Sunday before the earthquake. The plan, which took a year to develop, includes a thorough technical review of the seismic and flood hazards in the city. The plan's most ambitious goal is the relocation of highly vulnerable neighborhoods, currently located in areas of man-made fill, to safer undeveloped land surrounding the city. Many of the plan's provisions, such as "eminent domain," transfer of development rights, and other types of incentives will be used to accelerate the development of these safer zones.

The City of Armenia was the first municipality to have adopted this urban development plan, which was a national mandate. Having such a plan in place is perceived to be a very positive factor for ensuring a more systematic and orderly approach to the reconstruction effort since the goal of the plan is to transform the city into a more disaster resistant urban area. This particular situation has greatly influenced the national government's overall recovery strategy. The FREC is requiring that the other 27 municipalities affected by the earthquake complete their plans as a condition for receiving rebuilding funds. To expedite the major planning initiative, each municipality has received funds to add technical personnel to their city planning departments and to purchase state of the art computer equipment.

Section 6
Rebuilding Strategies

The Fondo de Reconstrucción del Eje Cafetero (FREC) has adopted some key strategies to guide the rebuilding process in the affected region:

- An extensive public information program has been initiated. The goal of the program is to keep the public as informed as possible on the rebuilding effort. All means of communications, including the Internet, are being used to carry out the program.

- Owners of damaged properties will not be allowed to rebuild in zones that have been identified to be hazardous due to bad soils or other safety considerations. Instead they will be provided with a financial credit that they can apply in rebuilding in safer zones. To combat the pressure from owners who want to rebuild as quickly as possible or without meeting the necessary seismic resistant standards, a major public education campaign aimed property owners and building contractors has been initiated. Technical workshops are being sponsored by the FREC to educate approximately 3,000 design professionals and construction technicians on more seismic resistant building practices.

- Each of the 28 affected municipalities are establishing reconstruction zones. For each zone, not-for-profit organizations are being established to administer and manage the rebuilding process. This strategy is aimed at addressing public concerns that financial resources being allocated to the recovery effort be appropriately spent and monitored. These organizations are composed of representatives from government, business and industry, academic institutions, professional associations, and property owners.

- The rebuilding of schools and colleges is a high priority in the reconstruction effort. An ambitious program to repair or rebuild these facilities by September 1999 has been funded. According to the FREC, all of these structures will be brought up to the most current version of the Colombia building code. The Colombia Society of Architects will be responsible for contracting with the most qualified firms to do this work.

Multidisciplinary Center for Earthquake Engineering Research
List of Technical Reports

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) publishes technical reports on a variety of subjects related to earthquake engineering written by authors funded through MCEER. These reports are available from both MCEER Publications and the National Technical Information Service (NTIS). Requests for reports should be directed to MCEER Publications, Multidisciplinary Center for Earthquake Engineering Research, State University of New York at Buffalo, Red Jacket Quadrangle, Buffalo, New York 14261. Reports can also be requested through NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. NTIS accession numbers are shown in parenthesis, if available.

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NCEER-87-0002 "Experimental Evaluation of Instantaneous Optimal Algorithms for Structural Control," by R.C. Lin, T.T. Soong and A.M. Reinhorn, 4/20/87, (PB88-134341, A04, MF-A01).

NCEER-87-0003 "Experimentation Using the Earthquake Simulation Facilities at University at Buffalo," by A.M. Reinhorn and R.L. Ketter, to be published.

NCEER-87-0004 "The System Characteristics and Performance of a Shaking Table," by J.S. Hwang, K.C. Chang and G.C. Lee, 6/1/87, (PB88-134259, A03, MF-A01). This report is available only through NTIS (see address given above).

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NCEER-87-0006 "Symbolic Manipulation Program (SMP) - Algebraic Codes for Two and Three Dimensional Finite Element Formulations," by X. Lee and G. Dasgupta, 11/9/87, (PB88-218522, A05, MF-A01).

NCEER-87-0007 "Instantaneous Optimal Control Laws for Tall Buildings Under Seismic Excitations," by J.N. Yang, A. Akbarpour and P. Ghaemmaghami, 6/10/87, (PB88-134333, A06, MF-A01). This report is only available through NTIS (see address given above).

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