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July 16, 1990 Luzon (Philippines) earthquake

R.L.Sharpe
Cupertino, Calif., USA

ABSTRACT: The purpose of this paper is to present an overview of the July 16, 1990 Luzon, Philippines earthquake, what was learned, and what can be learned. The earthquake was one of the largest in several decades. Its impact on the local populace and the country as a whole was major.

The geoscience and geotechnical aspects are examined, followed by a discussion of structural damage, and the socio-economic aspects.

1 GEOSCIENCE-GEOTECHNICAL

The Philippines Archipelago lies between two of the world's major tectonic plates. The Philippines Sea Plate moving northwesterly is being subducted beneath the archipelago at about 7 cm per year while parts of the Eurasian Plate are being subducted below Luzon and Mindanao at about 3 cm per year. As a result there have been about 10 000 earthquakes in the Philippines from 1960 to 1990, most of them recorded but only a few felt.

Some of the major faults lie in the Philippine Fault Zone and its many branches including the Digdig Fault. This fault zone is at least 1300 km in length and is mostly strike slip.

The July 16, 1990 earthquake is attributed to the Philippine Fault Zone and its major branch, the Digdig Fault. The Digdig is apparently nearly vertical and cuts under or near Baguio City. The epicenter is estimated to be located about 13 km north-northeast of Cabanatuan. The main shock was magnitude 7.8 (Ms) with a focal depth of 25 to 36 km. There were nearly 700 aftershocks, with about 80 felt and 17 greater than Richter 5, in two and one half days after the main shock (fig 1).

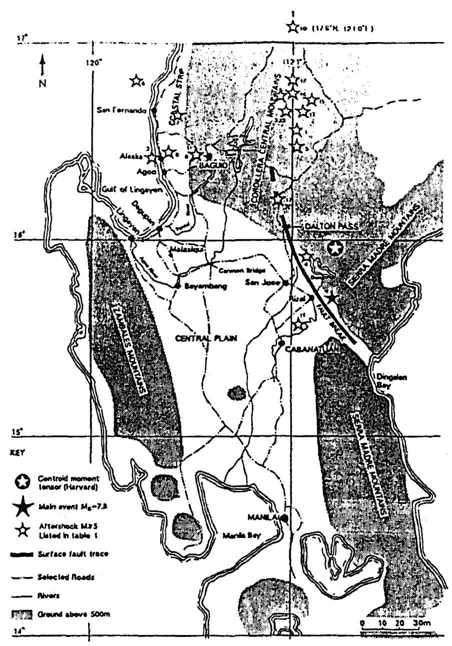

Fig 1. Fault break and major aftershocks (from USGS data and EEFIT, 1990)

The Philippine Fault Zone splays into two independent faults — the Digdig and the Dingalen. The head of the Seismology Department at the Manila Observatory attributes this earthquake to the sudden release of strain along a seismic gap in the Dingalen Fault. There had been ominous quiescence and streets.

The city of Agoo on the west coast of Luzon is one of the main population centers in the region. Large areas around Agoo liquefied, settled, and were flooded with sea water. Northwest of Agoo the Village of Alaska with some 30 houses was totally destroyed (fig 2). Although there was extensive liquefaction around Agoo, apparently there was none in the city itself.

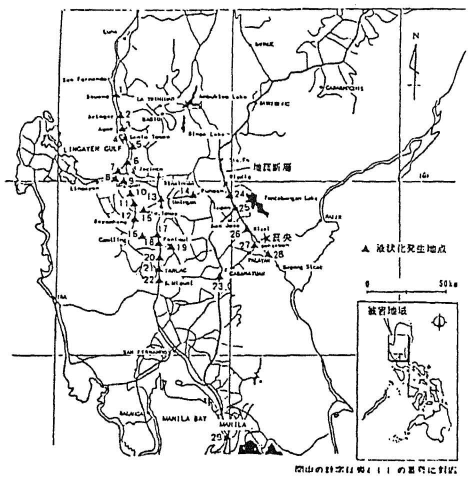

Fig 2. Major liquefaction sites (from JICA, 1990)

Slope instability caused large economic loss. Rock- and landslides were caused by the main shock and aftershocks. The monsoon rains exacerbated the sliding. It was estimated that in some places in the northern mountains ten percent of the top soil was lost during the earthquake and up to 30 percent more in the weeks following due to aftershocks and the heavy rains. All major roads through the Central Cordillera Mountains were closed by literally thousands of landslides.

In the city of Baguio at many cut and fill sites, the downhill fill slopes displaced damaging the structures supported thereon.

Fault surface rupture damaged buildings and structures located on the rupture area. Other buildings immediately adjacent to the rupture suffered minor or no damage. In the city of Rizal buildings close to or on the surface rupture were damaged but most others in the city were not. One of two bridges northwest of Rizal straddled the rupture and was destroyed. The other bridge closer to Rizal but about 80 m from the rupture had no damage.

The heavy rains were a strong factor in liquefaction (raised water table), landslides, mudslides and rockslides. Foundation settlement induced structural damage in many buildings.

2 STRUCTURAL DAMAGE

Major structural damage due to strong ground shaking was limited mostly to the cities of Baguio, Agoo and Cabanatuan.

Many of the most spectacular building failures occurred in the mining, light industrial and resort center of Baguio. Baguio, a city of about 200 000 permanent residents is located about 270 km north of Manila, at an elevation of about 1500 m. At the peak of the tourist season the population increases by about 120 000 tourists.

Six buildings over four stories suffered partial or total collapse and another ten had major damage. However, 26 other buildings (60 percent) over four stories had minor or no discernible damage. Only about five percent of low buildings sustained more than minor damage. Most engineered buildings are reinforced concrete moment resisting frames, often with unreinforced or under-reinforced masonry infill walls.

A major collapse was the 11-story Hyatt Terraces Hotel. One section, the Aparthotel, collapsed onto an adjacent structure in the initial shock and then the main portion of the hotel collapsed during an aftershock a short time later. Observers noted that there was insufficient transverse reinforcement to adequately confine the longitudinal rebars. In some areas the vertical reinforcement appeared inadequate. The hotel was damaged in the 1985 Baguio Earthquake, was closed for seven months for repairs, and reopened after a satisfactory structural inspection. The facility was initially built in about 1975 with some later additions.

The seven-story Baguio Park Hotel largely collapsed. The nine-story Hilltop Hotel suffered a total pancake collapse. The building had been condemned after the 1985 earthquake and a few illegal occupants were in the building at the time of the earthquake.

Several soft first story buildings failed. The first story is often taller than the other stories and has limited seismic resistance. The first two stories of the six-story FRB Hotel collapsed while the top four stories had little damage.

The lower floor of the five-story Nevada Hotel collapsed. A nine-story reinforced concrete frame building with block infill walls at the University of Baguio collapsed. There appeared to be some torsional irregularity at the fifth floor which collapsed while several floors in another part of the structure collapsed pancake style.

At the Baguio Export Processing Zone, a three-story building on filled ground collapsed while a similar nearby building on the cut side of the site had limited damage. A timber building built on a steep slope was seriously damaged and declared unsafe for occupancy.

It is of interest that the two-to-three-story Baguio City Hall of masonry construction suffered minor damage. Similarly, the massive Baguio Cathedral, built of masonry, had only cracking of some parapets but otherwise was not damaged. In Baguio almost all of the structural damage was induced by ground shaking. Some homes had chimney damage.

Aftershock studies as well as observations of damage at Baguio and Rizal indicate that Baguio had large amplification of ground motion as compared to Rizal. The reasons for this are not clear.

In Agoo many low rise buildings were seriously damaged. A steel frame single-story classroom was badly damaged as was the two-story town center, a soft first story reinforced concrete structure.

The Christian College building in Cabanatuan collapsed while nearby buildings of similar construction sustained only minor damage.

3 SOCIO-ECONOMIC ASPECTS

The socio-economic impact was severe throughout the affected region. There were approximately 1300 deaths and 3000 persons injured. Of these approximately 666 deaths and 1600 injuries occurred in Baguio and surrounding areas. The total number of deaths was probably greater because the massive landslides on mountain roads and areas may have hidden numerous casualties. The number of injured may be much greater because early victim treatments were not recorded.

A large proportion of the fatalities were caused by building collapses. Perhaps 10 to 20 fatalities were due to fire in a large building in Baguio's export zone.

In Nueva Vizcaya there were no injuries from falling buildings because of light weight material used in building construction. However, many were killed or injured by massive landslides.

Liquefaction appeared to contribute to about 40 fatalities.

4 SEARCH AND RESCUE

Most organized urban rescue work took place in Baguio, Cabanatuan, and Agoo — for the many large high-occupancy collapsed buildings in Baguio, the six story Christian College building and the partial collapse of the library building at Central Luzon State University at Cabanatuan, and the many badly damaged low rise buildings in Agoo.

Organized rescue shifted to mountainous areas after a few days. Most rescues were made by fellow building occupants and local rescue personnel. A lack of search and rescue training and adequate equipment hampered local rescuers. Early rescues were by hand. Later Philippine and US military personnel and equipment from Subic Bay and Clark Air Force Base provided much needed generators, torches, etc to Cabanatuan to assist in rescue work at the college buildings.

Foreign heavy-rescue specialists from the US, Britain, Japan, France and Singapore began arriving two days after the earthquake. Passage of time decreases chances for survival — 84 percent of survivors were reached within the first hour and 99 percent within 24 hours. One survivor in the Baguio Hyatt Hotel was rescued 17 days after.

The role of foreign rescue teams should be examined. Their arrival was too late to make a significant difference. This has been true in many other earthquakes. Rescue teams generally did not fit in too well with local rescue efforts although the Singapore Team and US military based in the Philippines participated in all aspects of rescue and stayed much longer than others.

Future foreign assistance should be directed to delivering needed technology and equipment, improving search and rescue capabilities before a major earthquake, and providing assistance in a manner consistent with local customs.

The overall health care effort was greatly hampered by lack of communications and impaired access to stricken areas. Light aircraft and helicopters delivered some supplies to Baguio, but roadway damage limited heavy transport. The first access road to Baguio opened four days after the earthquake. Bridge and roadway failures constrained emergency response and rescue in the lowland areas.

The health care situation in the mountainous areas northwest of Baguio was very serious because of the poor access. Landslides masked many injuries because buses, trucks and autos as well as houses were buried.

Baguio and Cabanatuan had sufficient medical facilities to handle the most serious cases. Helicopters aided in evacuating the seriously injured to Manila hospitals and medical care at Clark Air Force Base and Subic Bay Naval Base.

Damage to hospitals and perceived risk of building collapse made many medical personnel reluctant to reoccupy some hospital facilities. An estimated 12 hospitals with about 600 beds (25 percent of total in region) had to be totally reconstructed while the 350-bed Baguio General Hospital and the 300-bed Garcia Medical Center at Cabanatuan needed extensive repairs. One major Manila hospital required structural repairs and some patients had to be transferred. In almost all hospitals there was extensive damage to mobile equipment such as oxygen tanks.

Occupant perception of damage and safety of buildings may be as important as the actual safety of the structure. When occupants see surrounding buildings of apparently similar construction evacuated, they are hard to convince that their building is safe. More than one hospital moved patients and equipment into makeshift tents despite heavy rains because of the perception that their facilities were unsafe.

Post-earthquake inspection procedures and communication to occupants probably need to be modified to reassure occupants as well as the structural engineers.

5 SOCIETAL IMPACTS

Thousands of families set up temporary shelters regardless of the conditions of their homes. One estimate showed about two-thirds of newly homeless had intact homes.

Nearly 80 000 families with a total population of about 500 000 were affected. Of these, at least 8200 homes were destroyed and over 15 000 homes partially damaged.

The economy of the region will be adversely impacted for a long time. Three of the four roads to Baguio were closed for four to six months thus hampering reconstruction. Dagupan lost more than one-half of its central business district. There was a shortage of skilled labor and technicians, building supplies, and most important financial resources.

There was widespread anxiety and depression among the population. A rudimentary treatment program was started several weeks after the event and continued for many months.

The provision of clean potable water was a major problem. The Baguio hospitals purified water by boiling which in turn used up scarce timber supply that could have been used to repair homes. Electric power, water supply and telephones were out of service as follows.

	Days outage		
City	Electrical	Water	Telephone
Agoo	7	14	5
Baguio	2	Up to 14	1
Dagupan	3	10	7 hr

6 CONCLUSIONS

It can be seen from the preceding text that the earthquake was disastrous for a large number of people and a large geographical area. The following conclusions and suggestions are offered.

In the matter of geosciences,

- Large magnitude does not necessarily equate to high peak ground accelerations
- Long rupture length probably means long duration
- **Near-fault intensities were apparently** lower than normally expected
- Strong-motion instrumentation should be installed and maintained on a regular basis

Geotechnical factors caused more widespread damage than strong ground shaking:

- Many roadways were closed due to liquefaction, bridge failures, soil spreading and landslides
- Liquefaction was the villain in many cities and rural areas
- Water distribution lines and sanitary sewers were ruptured in Dagupan
- Slope instability caused damage to roadways and structures
- Landslides blocked roadways and wiped out some small villages in the mountains
- Liquefaction was predictable
- Soil conditions should be assessed, especially for bridges and large buildings
- Foundation conditions of bridges should be evaluated especially on main highways
- Fault rupture areas should be avoided if possible
- Cut and fill sites for buildings and roadways should be engineered to ensure slope stability
- Site amplification should be assessed for important facilities

It appears that high frequency motions near the epicenter were less than would be normally expected. The lack of ground shaking-induced damage to longer period structures in the central plains would indicate that longer period motions were also low. There appeared to be large amplification of motions at Baguio — but the reasons therefor are not clear. One possibility could be long duration of low amplitude motions with predominant frequencies in the range of those for certain structures.

The structural damage, other than at Baguio, Agoo and the isolated failures at Cabanatuan, induced by strong motion appeared to be less than would be expected for a magnitude 7.8 earthquake. The epicentral intensities were relatively low, on the order of Rossi-Forel VII. Baguio had higher intensities for medium rise structures while Agoo had higher intensities for low rise structures.

The building damage due to strong motion revealed several major contributing factors:

- Building configuration — soft first story, torsional (plan) irregularities, insufficient transverse confining reinforcement, insufficient splice lengths and/or anchorage of rebar, and nonengineered infill walls — often resulted in "short" columns
- Lateral force resisting system should be continuous
- Quality control for design and construction is essential
- Consideration should be given to possible amplification of structural response to low amplitude long duration motions
- Hazardous buildings should be assessed and upgraded
- Procedures for post-earthquake inspections and communications to occupants and the public need to be assessed

On socio-economic issues,

- Effects on people of ground shaking and destructive damage (such an anxiety and depression) should be studied and treatment procedures developed

- o A major seismic event can cause extensive economic impact from: disruption of electric power, potable water suplies, sanitary sewers, and communications; loss of retail and production facilities; lack of skilled workers and materials
- o This earthquake impacted all of Philippines, caused more than US $2 billion in losses, extensive loss of agricultural land from liquefaction-induced subsidence, and more than 30 000 jobs were lost
- o Foreign assistance procedures in search and rescue operations should be reviewed and possibly be focused on pre-earthquake training of locals and furnishing of rescue equipment
- o Healthcare facilities including structures and contents should be evaluated and strengthened

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