JANUARY 25TH 1999 EARTHQUAKE IN THE COFFE GROWING REGION OF COLOMBIA: DAMAGE DESCRIPTION IN THE AREA AND EMERGENCY RESPONSE

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SUMMARY

Despite its moderate magnitude the January 25, 1999, earthquake affected the “coffee growing region" of Colombia, causing heavy damages in the cities of Armenia, Pereira, and in many neighboring towns. The combination of shallow focus, closeness to the city, and amplification as a result of soft soils and topographic forms may explain the damage severity in Armenia. The building damage emphasized the lessons learned in previous earthquakes with reference to the bad behavior of brittle unreinforced masonry buildings and reinforced concrete frames built without appropriate earthquake resistant requirements. The adverse interaction between structural and nonstructural elements and bad influence of stiffness and mass irregularities of buildings was verified; main issues why the Colombian building seismic code was updated recently. In the other hand, although the National System for Risk Mitigation and Disaster Preparedness responded in a satisfied way, on the whole, it was proved that the capability of the National Directorate for Risk Mitigation and Disaster Preparedness to convene and coordinate the national system were weak. Once it was detected that the event over passed the local level capacity response, it shows its political, technical and operational weakness, because the other national agencies responded lonely according to their emergency response plan with out the leadership and support of that important coordination agency.

INTRODUCTION

On January 25, 1999 at 1:19 p.m. local time (18:19 GMT), an earthquake of 6.2 M_L occurred in the Central-Western zone of Colombia (4.41º N, 75.72º W). The event caused serious damages in the city of Armenia (pop. 270,000), capital of the Quindío Department; in the city of Pereira (pop. 380,000), capitol city of the Risaralda Department; and in many villages (35) that surround these cities. The earthquake primarily affected the populations in the coffee growing region of Colombia. The earthquake was registered in real time by the National Seismic Network via satellite from the Instituto de Investigaciones en Geociencias, Minería y Química, INGEOMINAS; by the Observatorio Sismológico del Sur Occidente, OSSO; and by the Red Sismologica del Eje Cafetero. At 5:40 p.m. local time, of the same day, an aftershock of 5.8 M_L occurred, which caused the collapse of a significant number of buildings that had been damaged during the first earthquake. In Armenia, the recorded acceleration in areas of volcanic ash with high plasticity, approximately 30 meters thick, was of the order of 0.6g. In Pereira, accelerations reached 0.3g in areas of artificial fill. Given that vertical accelerations were equally high, it is presumable there was a significant amplification in soft soils. In the city of Armenia vertical acceleration was recorded at 0.45g. Figure 1 and 2 show the acceleration component EW and its response spectral acceleration.

From the observed building damage, it can be deduced that the amplification of the earthquake was high due not only to the presence of artificial fill areas and soft soils of volcanic origins, but also to the topographic shapes of the land (Photos 1 and 2). In the upper part of the hills of Armenia, as in other smaller towns, the acceleration values were higher than those measured by strong motion instruments.

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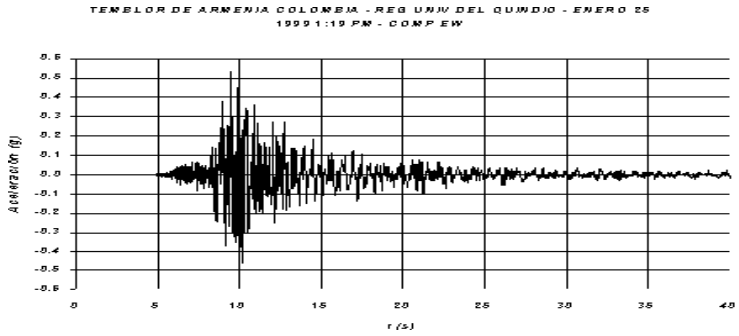

Figure 1: EW acceleration time history of earthquake in Armenia

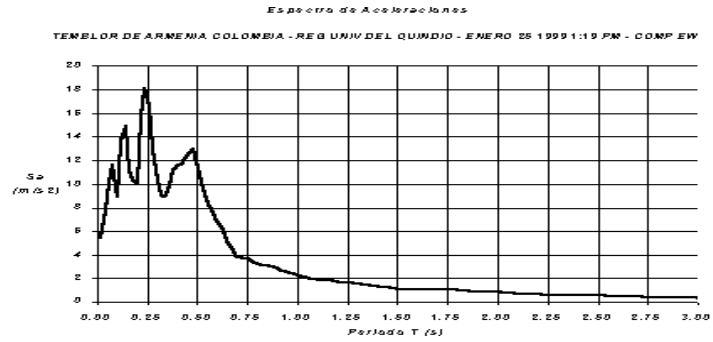

Figure 2: Response spectral acceleration of component EW in Armenia

EFFECTS OF EARTHQUAKE

Social and Economic Impact

Recent figures indicate that 1,230 people died and 5,300 were injured and attended to in hospitals. The number of people affected, who lost their homes and places of employment, is calculated at 200,000. About 50,000 structures in the coffee growing region sustained damage, which symbolizes a direct economic loss of approximately US$ 1,800 million dollars (US$ 1.8 billion) without including losses in the commercial and industrial arenas. The total impact of the earthquake can be estimated to be 1.5% of the GDP. Moreover, Colombia's GDP only achieved 0.2% economic growth in 1998, considered to be the worst rate in the last 57 years. This earthquake seriously affected one of Colombia's most prosperous zones which contributes the most to the national treasury; nevertheless, in the past years, the coffee growing region has experienced an economic crisis due to the economic inequilibrium of coffee at the international level.

Of the affected buildings, it is estimated that only 18,000 had insurance coverage. For the most part, coverage was only for 72% of the building value since many were co-insured by the property owner. The majority of these buildings were residential and had outstanding balances on mortgages. In the coffee agricultural sector, about 8,000 buildings sustained damage, which will most certainly compromise future coffee production.

Building Damage

Damages were concentrated mainly in older buildings, unreinforced masonry buildings without confinement in elements of reinforced concrete and in buildings designed and constructed before the first national earthquake resistant construction code was introduced (Photos 1 - 4). The first nationwide code was legislated in 1984 as a positive product of the 1983 earthquake that affected the city of Popayán. A majority of more modern structures, constructed after development of the nationwide seismic code of 1984, only sustained non-structural damage to walls, partitions, ceilings, architectural finishes, etc. owever, this type of damage was expected in case of a very strong earthquake. Consequently, in 1997 the Asociación Colombiana de Ingeniería Sísmica convinced the

Congress of the Republic to approve a new law to update the 1984 code. The new design and earthquake resistant standards, NSR-98, accounted for the necessity to further restrict horizontal displacements or drift in structures in order to protect structural finishes. It also required the design of non-structural elements and required the seismic vulnerability evaluation, repair and retrofit of indispensable structures. Consequently, it has not been necessary to adjust the current code with respect to its regulation, even though relative complementary dispositions were developed regarding how repair permits should be granted as well as the technical and legal criteria that should be met for the repair and reinforcement of structures affected in earthquakes.

In general, many buildings in the central sector of the city of Armenia as well as a significant number in Pereira suffered severe structural damage due to the use poor quality materials and poor design and construction. Inadequate dimensions of structural elements and lack of confinement by transversal steel in columns and beams facilitated the occurrence of failures due to shear force and, in some cases, caused the total or partial collapse of buildings (Photos 5 - 9). Infill brick masonry walls and nonstructural elements were heavy damaged because the lack of displacement control (Photos 10 - 11). On the other hand, local traditional structures constructed by means of an empirical technology termed "bahareque de guadua" (bamboo), which in the last century was known as the " *temblorero* style" by the first residents of the zone, performed very well in the earthquake (Photos 12 and 13). However, while displaying a local seismic culture, some of these buildings themselves collapsed, or had roofs that collapsed, due to poor maintenance or due to the fact that along the years they were "contaminated" by unreinforced masonry walls in the interior of their facades. As the masonry walls collapsed due to instability, ties and resistance induced the total collapse of the building. Nevertheless, according to the information obtained during the emergency response efforts, these buildings caused the least number of injuries due to their light weight.

Photo 1: Seriously damaged non earthquake resistant brick masonry building

Photo 2: Collaps of unreinforced, non earthquake resistant brick masonry building

Photo 3: Collapse of old non earthquake resistant building.

Photo 4: Partial collapse of old reinforced concrete building

Photo 5: Photographic sequence of the collapse of modern building during the 5:40 p.m. aftershock.

Photo 6: Failure of beam-column joint due to lack of transversal reinforcement

Photo 7: Column failure due to lack of stirrups and confinement

Photo 8: Fragile failure of a column due to insufficient transversal reinforcement

Photo 9: Short column effect due to adverse interaction of brick masonry walls

Photo 10: Brick masonry infill walls failure because lack of connection

Photo 11: Shear failure in brick masonry infill wall of a reinforced concrete frame

Photo 12: Bahareque de guadua (bamboo) structure, "*temblorero* style"

Photo 13: Guadua structure displaying satisfactory, seismically resistant behavior

Damages in Critical Buildings

The structures of a large number of schools and colleges were greatly affected. It is estimated that nearly 80% of the educational buildings in the zone suffered moderate to severe damage (Photos 14 -15). Many health facilities serving small populations had serious damages; Armenia's main hospital had to be partially closed due to non structural damage that impeded its function. It is important to note that this hospital was in the process of being seismically retrofit but the intervention had not yet been completed. The main buildings of the National Police and the Fire Department both collapsed, killing a significant number of police and firemen; personnel critical to emergency response (Photos 16 - 17). The majority of the churches of the city and of the villages surrounding the epicentral zone suffered serious damage and some roofs suffered total collapse.

Photo 14: Collapse of structure belonging to educational sector due to short columns

Photo 15: Collapse of school building of reinforced concrete frame system

Photo 16: Condition in which fire trucks remained after the collapse of the fire station

Photo 17: Older structure housing police station, in which many policemen lost their lives

Damages in Lifelines

Basic services in a majority of the populated areas were seriously affected. The city of Armenia remained without potable water for many days; the central and southern sectors of the city without electricity and telephone service. Similarly, traffic through streets and roads was impeded for many weeks due to the debris and the necessity to demolish hundreds of buildings. The earthquake caused a significant number of landslides onto the roads connecting Armenia with the rest of the country -- many of them did not amount to more than 50 m^3 and few reached 500 m^3 or more. Nevertheless, this situation notably complicated the arrival of external assistance by land to the disaster zone. The Armenia airport suffered structural damages to its terminal; however, it was rapidly rehabilitated due to the fact that the runway did not suffer damages that compromised its function. In the city of Pereira the suspension of basic services was transitional.

EMERGENCY RESPONSE

Interinstitutional Response

Once the earthquake was located by the National Seismological Network, the National System for the Prevention and Response to Disasters was activated. This decentralized interinstitutional system was created by the Colombian Government after the disaster of Armero in 1985 (*Nevado del Ruiz* volcanic eruption). The Local Committees for the Prevention and Response to Disasters in each municipality of the zone responded to the emergency according to their capacity. In the city of Pereira, which had been seriously affected by another earthquake in February of 1995, the response of the local institutions led by the mayor of the city was efficient and assertive, in spite of the seriousness of the crisis. A seismic risk mitigation project, that had been initiated in Pereira many years ago, proved to be a very important achievement when compared to other cities, like Armenia, where there existed no study of seismic microzonation nor a response preparedness plan to be implemented in case of an earthquake. In addition, the magnitude of the disaster in Armenia was such that both the Local Committee and the Regional Committee for the Prevention and Response to Disasters were overwhelmed by the emergency. Consequently, it was necessary for the national level to act according to the procedures established within the system of interinstitutional response. Moving to the city of Armenia two days after the disaster occurred, the President of the Republic and his ministries directly managed the crisis. The technical and scientific institutions, particularly those that make the Advisory Commissions on Seismic and Volcanic Risk and the Regime of Earthquake Resistant Constructions, and the national operative organizations as well as organizations from other zones in the country (e.g., Red Cross, Civil Defense, Fire Departments and the Health sector) responded satisfactorily, activating their internal contingency and emergency plans.

Photo 18: Emergency response teams working in collapsed buildings

Photo 19: The collapse of buildings blocked some streets impeding the moving of rescue teams

Weaknesses in Coordination

Due to its technical, political, and financial debilitation, the National Directorate for the Prevention and Response to Disasters (moved from the Presidency of the Republic to the Ministry of the Interior some years ago), was not able to properly summon and coordinate the institutions of the national order, nor follow the pre-established procedures of the emergency plan. This prompted the President of the Republic to call upon other entities, like the Red de Solidaridad Social, that until then were not experienced in handling emergencies. These entities, then, found themselves needing to improvise and intuitively manage the crisis. In spite of the good intentions of the President of the Republic and the Nation's First Lady, who called for national and international solidarity and support, control of the public order was lost due to inefficiency in transport, storage and distribution of supplies. Furthermore, errors were made that had already been corrected in the past in response to other emergencies. The President of the Republic created a fund for the reconstruction of the zone by means of a decree with the strength of law and he gave responsibility of its management to people of the private sector, unaware of the interinstitutional organization of the National System for the Prevention and Response to Disasters, which by law is also responsible for the post-disaster rehabilitation and reconstruction. Currently efforts are being made to reconcile this dichotomy, attempting to coordinate the actions of the new "apparatus" or institutional scheme with those of institutions at the municipal, regional and national level that make up the National System established in 1989.

Reconstruction Program

One day after the earthquake, the President of the Republic declared a state of disaster in order to activate exceptional means for the response to the emergency and to activate a response, recovery, and post-disaster reconstruction action plan, in accordance with Colombian legislation. Afterwards, referring to article 215 of the Political Constitution, he declared a state of emergency due to serious public calamity and expedited lawful decrees with which he created a fund for the reconstruction of the zone and defined actions to facilitate low interest, subsidized credit for the reconstruction and repair of buildings to the affected population. In the first phase, US$ 360 million of the national budget, external credits with multilateral banking and the re-destination of contracted credits with the Inter American Development Bank and the World Bank were appropriated to the reconstruction plan. Currently, the Congress of the Republic is developing a project whose objective is the generation of tributary incentives and long term, low interest credits for the economic reactivation of the affected municipalities of the coffee growing region.

LESSONS LEARNED

There are various important lessons to be learned with respect to earthquake engineering and disaster prevention from the disaster in Armenia, Colombia:

- It was proven how dangerous it is for a city to count on an inventory of fragile buildings made of brick unreinforced masonry and on reinforced concrete structures with inadequate dimensions and steel reinforcement, that do not comply with the minimum earthquake resistant standards.

- The adverse interaction of non-structural elements with structures proved to cause serious damage, including the collapse of buildings. Short column effects, torsion by rigid eccentricity of asymmetrical infill walls and the poor performance of buildings with irregular forms were also demonstrated.

- Damage in reinforced concrete structures was mainly attributed to shear force, due to the inadequate detailing of reinforcement and the lack of transversal steel and confinement of concrete in structural elements. Typical failures were fragile in nature, demonstrating inadequate capacity to dissipate and absorb inelastic energy.

- The benefits of designing and constructing structures using earthquake resistant standards, in accordance with the current art and knowledge, were proven, signifying not only the protection of life, but also of the citizen's patrimony.

- The necessity to retrofit and rehabilitate key or indispensable structures for the community in case of a disaster was affirmed. Existing hospitals, fire departments and, in general, buildings that house entities responsible for attending to the community should be seismically evaluated and rehabilitated.

- The importance of the rediscovery and maintenance of the local seismic culture was validated. In this case, this seismic culture was developed through traditional bamboo buildings, which since last century constituted an evolving construction technology that was perfected and motivated by the community in their interest to confront earthquakes.

- The necessity to count on a local capacity to respond in case of an emergency was demonstrated. Local administrations should always count on a Local Committee for the Prevention and Response to Disasters that is supported and rightfully led by the political authority of each municipality.

- At the city level, the importance of depending on interinstitutional risk mitigation programs that involve technical aspects in planning, education, public information and preparation for responding to emergencies was proven.

- Although the interinstitutional response should initiate from the bottom up, starting with the response at the local level followed by that at the regional level, in case of an extremely severe disaster that overwhelms local and regional capacity, it is critical that adequate national coordination and capacity exist. In this case the national coordination and capacity were put to the test, demonstrating their current technical and operative weaknesses.

- The necessity to strengthen, in this case, the National Directorate for the Prevention and Response to Disasters was evident. Furthermore, the National Directorate for the Prevention and Response to Disasters should resume depending on the technical capacity that it had several years ago. This coordination agency should again be part of the Presidency of the Republic, where it was originally created.

ACKNOWLEDGEMENTS

A special acknowledgement should be paid to many engineers around the country of the Asociación Colombiana de Ingeniería Sísmica that lent their support to local engineers and architects in the affected zone by participating in the damage evaluation process.