Reconnaissance Trip Report

GUATEMALAN EARTHQUAKE OF FEBRUARY 4, 1976

by

Karl V. Steinbrugge

Purpose and Scope of Field Investigation

The purpose of the writer's field trip from February 6 through February 12, 1976 to Guatemala was to investigate and report on earthquake damage to buildings in Guatemala with special emphasis on earthquake resistive structures as well as other building types having engineering relevance to construction in the United States. Since essentially all of the buildings meeting the above criteria were located in Guatemala City, investigations were confined to that city. Exception was part of one day during which the surface expressions of the faulting as well as building damage in and adjacent to the fault trace were looked at from the air.

The views expressed in this reconnaissance report are those of the author. As in any quickly prepared report released prior to the completion of data collection, it is subject to change in some of its details. However, the general findings expressed in a section are firm.

The liaison mechanisms with other American engineers and scientists and with the Guatemalan Government allowed for quick access to damaged buildings and for rapid exchange of preliminary views and findings. The writer, along with two USGS scientists (Alvaro Espinosa and Raul Husid) were housed in a pension along with 7 persons who comprised the Earthquake Engineering Research Institute (EERI) team. The writer worked closely with the EERI team and exchanged information each evening for mutual benefit. As one result, substantial amounts of additional data will become available in the near which may materially supplement Appendix B to this report.

Liaison with the Guatemalan Direccion General de Obras Publicas began with my offer, along with that of my EERI colleagues, to be of assistance. They accepted our offers, formed 7 teams (later expanded to 9 teams) to inspect and report on major public buildings (excluding city buildings). Each of the American engineer was assigned to a different team and given a pass (Appendix A). The writer's team consisted of two very competent Guatemalan engineers who freely gave of their personal knowledge. Half of each day was spent in the review of assigned buildings and the other half on structures of professional interest, normally privately owned structures. A total of 150 buildings was assigned by Obras Publicas to the 9 teams, and 80% of these assigned buildings were inspected before the Americans withdrew due to completion of their mission. These inspected buildings, plus those inspected by each team on its "own time have resulted in an excellent overall reconnaissance review of damage in Guatemala City and have provided their government with competently prepared reports accomplished in record time.

A summary description of the buildings inspected by the writer is given in Appendix B. A selection from the several hundred 35mm colored slides taken by the author is also included and is keyed to Appendix B.

Geologic and Seismic Context

The description of the damage in Guatemala City and the findings drawn therefrom must be placed in the context of the geology and seismology of the earthquake. The engineering analysis and findings are based on the following data received orally from various USGS scientists and from the University of California at Berkeley, and are repeated here in summary form to prevent misunderstandings regarding source data.

The earthquake's magnitude has been reported at 7.5 to 8.0, and having a shallow focal depth. (For crude damage comparison purposes, this would place the magnitude of the Guatemalan earthquake as being larger than the 1952 Kern County, California shock but less than the 1906 San Francisco shock.) The length of the surface rupture on the Cabañas fault within the Motagua fault zone is probably 200 km, probably(? a continuous fracture, and with maximum left lateral surface movement of slightly over 1 meter.

Figure 1 is the author's interpretation of the fault location with the arrow pointing to the epicenter (Fault location is by David Schwartz of Woodward-Clyde Consultants). On the basis that the energy release is distributed within a volume along each side of the rupture, the centroid of the energy release is closer to Guatemala City than is the focus. Indeed, with the westerly end of the rupture being perhaps 20 miles north of Guatemala City, some significant amounts of energy were released quite close to the city.

Structural Setting

Life Loss and Construction:

Guatemala City (and environs?) may have about 750,000 persons in the city according to one source. While the actual total population may vary substantially from that stated, the 3,000 estimated life loss in the city (one person in about 250) contrasts with the very high casualty percentages for the villages and cities located much closer to the fault rupture. The loss in Guatemala City resulted essentially from the collapse of adobe construction; this construction type appeared to be more prevalent in the northern sections of the city (older part) which was closer to the faulting and energy release. However, general flattening of city blocks consisting of adobe construction was not found in Guatemala City, and this, of course, is in contrast to the damage patterns found in locations closer to the faulting.

Ground Motions:

Returning to the previous discussion on the geologic and seismic context, it seems reasonable that the high frequency components of the ground motion had been sufficiently attenuated when they reached Guatemala City due to distance. This can explain the substantial reduction in damage to the rigid "collapse hazard" adobe structures in the northern sections of the city compared to those along the faulting, and even less damage to those in the southern sections. On the other hand, damage to the longer period structures (i.e., usually the taller buildings) did not seem to vary significantly in similar structures from the northern to southern sections of the city, with this being consistent with theory. However, construction variations among these longer period buildings, plus possible soil amplification and other factors at some sites allow for no firm observational statements at this time.

As a postscript, the foregoing discussion becomes necessary in a discussion of damage because, as is the case in too many recent foreign earthquakes, the local stron motion instruments did not function.

Design and Construction Practices:

Consistent with many Latin American countries, there is no effective building code and enforcement in the usual American sense. Each design professional is allowe to establish his own design criteria and supervise his own construction without independ scrutiny on the basis that he is a registered professional. This practice does not precl good construction, but in effect it places no limitations on the extent of poor constructio or "cutting corners."

On the other hand, the local structural engineers and architects are, in general, excellent design professionals and comparable to their American counterparts. Many Guatemalans have been competently trained in the United States or elsewhere, and this is borne out by the writer's technical discussions with a number of them and upon a brie review of several sets of construction drawings. This is not to say that poor design doe not exist.

The quality of construction appeared to be generally good for the newer buildings High strength concrete seems to be common. The quality of reinforcing steel, however may be open to question in some instances since this steel does not appear to be locally tested and the strength characteristics (and other qualities) of imported steel are often not known.

There apparently are only two structural steel multi-story buildings in Guatemal City. In these two known instances, special quality control efforts were taken during fabrication and erection, and no significant damage was found in them.

Since the large majority of multi-story buildings have been built in recent years, design and construction practices are modern. Guatemalan practices generally follow United States practices, therefore the performance of many Guatemalan buildings will have counterparts in the United States.

With respect to seismic design, California SEAOC (or Uniform Building Code) appears to be the norm for the usual building design.

General Damage Patterns

Damage patterns by class of construction material followed those which have been established in studies of previous earthquakes. The effects of the ground motion's frequency content (i.e. long period vs. short period) on building types have already been discussed.

Heavy mass structures without earthquake bracing (such as the usual adobe building) suffered badly as they have in all previous earthquakes.

On the other end of the scale, light mass all metal structures such as one-story warehouses or aircraft hangers, performed excellently as expected. Any comparative wind vs. earthquake analysis would show that if these light mass structures can withstand a moderately strong windstorm, then they can survive a major earthquake.

Multi-story concrete construction generally performed well, and consistent with their distances from the energy sources. The writer knows of and inspected two partially collapsed buildings of the hundreds of multi-story reinforced concrete buildings. Thus overall performance was satisfactory, but this must be taken in the context of the geologic and seismic setting. Normally, the newest of these buildings were designed with earthquake in mind. They generally consisted of waffle floors and roofs, concrete interior and exterior columns, and reinforced brick (or hollow clay tile or similar unit masonry) panel walls. (Reinforcing of unit masonry walls consisted of a framework of small reinforced concrete beams and posts within the brick wall.) A few buildings had reinforced concrete shear walls in otherwise concrete columned buildings (see Appendix B). Any statistical breakdown of damage would be premature at this time, and will require the input of data being compiled by the other American engineers.

As previously stated, structural steel was used in two multi-story buildings. Both structures performed excellently (Appendix B), but the sample is too small to be other than suggestive.

Functional problems were commonly in the form of elevator outages, and most elevators were still non-operational when the writer returned to the United States.

Standby power remained in service at all of the locations inspected by the writer, but undoubtedly instances of failure did occur. Batteries generally did not shift, or if they shifted, did not fall or break cables. This good performance probably can be attributed to the type of ground motion, namely that the longer periods predominated.

Specific Topics:

Tall buildings in close contact pounded together. Structural damage was minimal in most cases, and architectural damage was usually not excessive. However, whenever a building consisted of two independent structural units, such as a stair/elevator tower which was structurally independent of the rest of the building, then the electrical, plumbing, mechanical, etc. was broken at the floor lines, reducing the functional capacity of the building.

Folded shells and plates performed well, and no instances of internal damage is known to the writer. (However, the writer understands that there were one or more instances of such damage.) Sometimes columns supporting these shells and plates were damaged, but the causes of the damage were not attributable to the shell or plate.

Few instances of precast concrete construction were inspected. One hospital structure, being a one-story "shear wall" building, had no damage to its roof which consisted of long span precast concrete planks ("Spancrete"). There was no interconnection between the planks according to the design engineer who accompanied the inspection team. A precast concrete double-tee roof at the American School collapsed, but this building was in the course of construction and its final bracing was incomplete.

Clearly, a better understanding of the earthquake importance of "non-structural" walls is vital to Guatemalan engineers as well as to many American architects and engineers. Brick infill walls between exterior columns as well as brick "partitions" used for tenant's improvements within a building were often well constructed and of rather substantial strength. Not only did these "non-structural" walls change the dynamic characteristics of their building, but often they led to column failure or other significant damage; classic examples of this occurred to the two-story administration building at the airport and also at the American School. Restated, a brick "non-structural" panel wall is an effective shear wall in a concrete frame as long as the "non-structural" wall remains intact. There were cases where the engineer, by intending to strengthen his building, accomplished the reverse.

The number of hospitals evacuated in Guatemala City due to structural damage and due to functional impairments was most serious. Most evidently, current California design practice for new hospitals is justified.

The nearest American counterpart to the adobe building in Guatemala are the brick buildings in the older sections of almost every American city, including San Francisco and Los Angeles. These older non-earthquake resistive brick buildings, with their sand-line mortar which "holds brick apart", are a major potential source of life loss. All possible steps should be taken to phase out this type of brick construction as soon as practicable if we are to learn a lesson from Guatemala.

NERAL DE OBRAS PUBLICAS
7, Zona 1 - Guatemala, C. A.
nos: 84391-5 - 84286-9

Archivo No. ....
C.L.F.T.S./cesr.

Guatemala, 7 de febrero de 1976.

Por este m dio se hace constar que el INGENIERO KARL STEINBRUGGE forma part del COMITE DE EMERGENCIA Y EVALUACION y está encargado de la inspección y evaluación de edificios y estructuras, tarea para la que está plenamente autorizado por el MINISTERIO DE COMUNICACIONES Y OBRAS PUBLICAS por lo que se ruega a las autoridades y público en general la COLABORACION que la EMERGENCIA NACIONAL requiere.

Ing. Luis Felipe Toledo Sáenz
COORDINADOR DEL COMITE
DE EVALUACION.

APPENDIX A

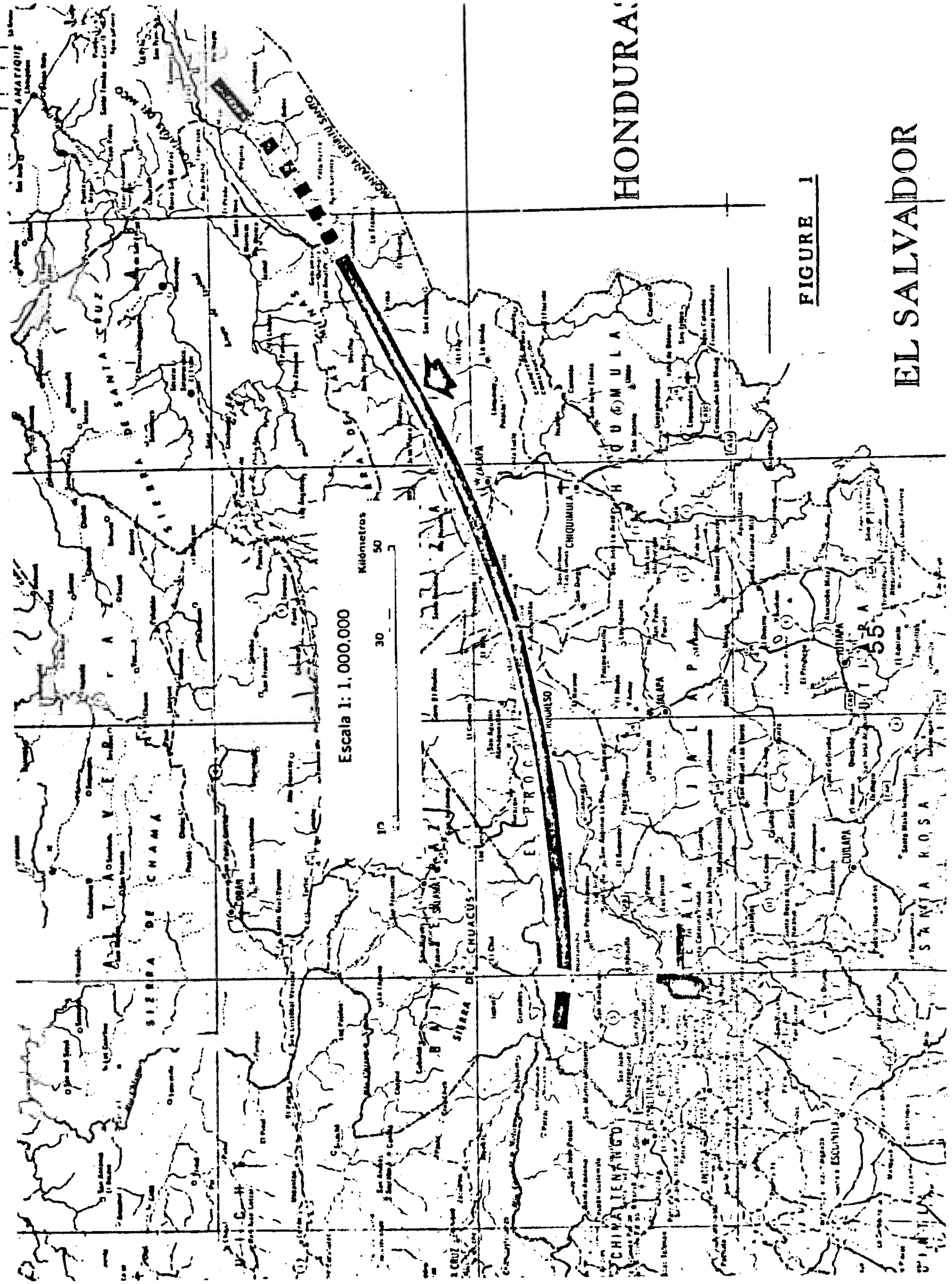

FIGURE 1