PERFORMANCE OF BANCO CENTRAL RELATED TO FAULTING

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SYNOPSIS

The Banco Central de Nicaragua is located on an active fault trace which displaced about 17 centimeters left lateral in the earthquake of December 23, 1972. The deep basement of the structure had sufficient strength and rigidity to resist the faulting and displace the surface trace to the west. The extensive structural and non-structural damage to the Banco Central was related solely to ground shaking. In this paper, structural observations are related to the documented faulting and backfill settlement.

STRUCTURAL PERFORMANCE

The Managua, Nicaragua, earthquake of December 23, 1972, caused considerable damage to structures of all types in the City of Managua[(1)]. One of the major buildings to sustain damage was the fifteen-story Banco Central de Nicaragua building. A companion paper, "Banco Central de Nicaragua: A Case History of a High-Rise Building that Survived Surface Fault Rupture" by Niccum, Cluff, Chamorro and Wyllie, describes the results of fault investigations conducted near the Banco Central building. The building was inadvertently built across an active trace of the Banco fault. Trenching and fault studies disclosed that, in the vicinity of the Banco Central building, the rupture deviated from the active fault trace and broke a series of new fault cracks in the old fault zone.

The Banco Central building is a fifteen-story reinforced concrete structure, as seen in Photograph Number 1. The tower is approximately 45 meters (148 feet) by 14 meters (46 feet) in plan and is framed with reinforced concrete beams spanning 13 meters to rectangular columns closely spaced at 1.40 meters (4.6 feet) on center. At the fourth floor, the closely spaced tower columns terminate at large transfer girders supported by a total of ten substantial concrete columns. The plan area enlarges to the south below the fifth floor to accommodate an assembly hall and additional office space.

The basement of the Banco Central building is shown in Figure 1. The basement is 9.40 meters (31 feet) deep with an intermediate mechanical level in the northwest corner. The exterior walls are 45 centimeters (18 inches) thick with many interior concrete walls both 45 centimeters (18 inches) and 20 centimeters (8 inches) thick, The basement contains numerous heavy security walls as it houses the repository of reserved and uncirculated currency for the Government of Nicaragua. The basement slab and first floor slab are both 45 centimeters (18 inches) thick and contain substantial reinforcement. The footings are spread footings at a depth of 2.3 meters (7.5 feet) below the basement slab and are interconnected with seismic tie beams.

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The building sustained considerable structural and non-structural damage in the December 23, 1972, earthquake which as been described in detail. The tower columns were cracked at each end in each story and the tower floor slabs were cracked at the edge of the concrete elevator cores. The roof and walls of the assembly hall collapsed. Except for the collapsed roof of the assembly hall, structural damage, which was substantial in the upper floors, actually reduced significantly in the lowest floors. The large columns and transfer girders were carefully inspected and were found to be crack free. All damage above grade was clearly found to be the result of seismic shaking.

The basement complex was also inspected in detail by several of the authors at the request of the owner in light of the possible fault intersecting the building's base. The retaining wall at the west end of the structure providing basement access for vehicles sustained considerable damage, as seen in Photograph Number 2. The wall bowed inward probably 10 to 15 centimeters and struts at the top to the building failed. The other exterior walls had no evidence of cracking except one area on the south wall where fine horizontal cracks at about 40 centimeter centers suggested high earth pressures. After the fault trenching, this area was shown to be exactly in line with the active fault trace, as indicated on Figure 1. No corresponding area of horizontal cracking was present on the other side of the building. The only other cracking of concrete basement walls discovered was of such a random and minor nature that it could not be correlated with the seismic event.

Observations on the ground around the site were also noted with interest. Settlement was noted in the backfill immediately east of the structure, as seen in Photograph Number 3. During trenching operations a small diameter broken water pipe was noted in this area. Erosion of backfill from the pipe trench under the sidewalk probably accounted for a portion of this settlement after the shaking had ceased. Similar settlement was noted at the top of the ramp at the west end of the structure. No broken water pipe or subsurface erosion was found in this area. Along the west exterior wall south of the retaining walls adjacent to the ramp, a sizable crack was noted at the wall line in a surface driveway, indicating a tendency of the earth to separate from the structure. This is shown in Photograph Number 4. Similar settlement or cracking was observed along the north or south basement wall lines.

CORRELATION WITH MODEL AND ANALYTICAL STUDIES

Completely independent of the Banco Central investigation, model and finite element analytical studies were reported discussing the effect of fault displacement underneath a rigid circular structure[3]. The qualitative idealized pressures resulting from this independent study are illustrated in Figure 2 and are also mentioned in the companion paper in the Proceedings. The active pressure zones, which reflect a reduction in at rest pressures or a tensional tendency in the soil, correspond to the east and west sides of the Banco Central where settlement and ground cracks were observed. However, pressures on the west side also must have increased significantly at some period during the earthquake to cause the failure and inward movement of the retaining wall next to the ramp. The passive or increased pressure areas that the study indicated correspond to the north

and south sides of the bank, where no soil distress was observed. It appears that the 1972 fault displacements were insufficient to develop any substantial passive pressures. The one area of observed basement wall cracking due to high earth pressures does not appear to directly correlate with the independent studies, although the fact that the structure was not completely within the fault zone undoubtedly affected this observation.

STRUCTURAL RESPONSE RELATED TO FAULTING

The Banco Central building responded structurally primarily in the east-west direction. This was clearly evident throughout the building in observing both structural and non-structural damage. The attempt has been made to correlate this structural response with the faulting and ground surface observations. However, it should be noted that structural damage in most buildings in downtown Managua was primarily in the east-west direction.

It might be reasoned that the tensional tendency in the soil on the east and west sides of the building permitted greater movement or variation in pressure on those sides, thereby increasing the response in that direction. Similarly, it could be argued that the apparently unyielding soil on the north and south sides had the effect of holding the structure in a vise while the variation in pressure on the east and west faces resulted in the primary response. However, it could also be argued that the response of the super-structure was due to general ground shaking from the entire Managua fault system that offset in 1972 and that the Banco fault had little affect on the directional input of motion to the Banco Central. Conclusive results do not appear to be possible in this area.

CONCLUSIONS

1. The basement structure of the Banco Central de Nicaragua had sufficient strength and rigidity to resist surface faulting. Rupture deviated from an active trace intersecting the structure and broke a series of new fault cracks to the west of the structure.

2. Structural damage of the Banco Central was attributed solely to ground shaking, not to faulting.

3. It could not be concluded that the faulting of the Banco fault was the cause for the primarily east-west response of the structure.

4. The conclusions of this study should be approached with considerable caution when evaluating the potential performance of structures located on faults which exhibit large fault offsets.

REFERENCES

1. Wyllie, L.A. Jr., Wright, R.N., Sozen, M.A., Degenkolb, H,J., Steinbrugge, K.V., and Kramer, S., "Effects on Structures of the Managua Earthquake of December 23, 1972", Bulletin of the Seismological Society of America, Vol 64, No. 4, August 1974, pp 1069-1133.

2. Wyllie, L.A. Jr., "Performance of the Banco Central Building", Earthquake Engineering Research Institute Conference Proceedings, Vol II, November 1973, pp 571-585.

3. Duncan, J.M., ard Lefebvre, G., "Earth Pressures on Structures Due to Fault Movement", Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol 99, No. SM12, December 1973, pp 1153-1163.

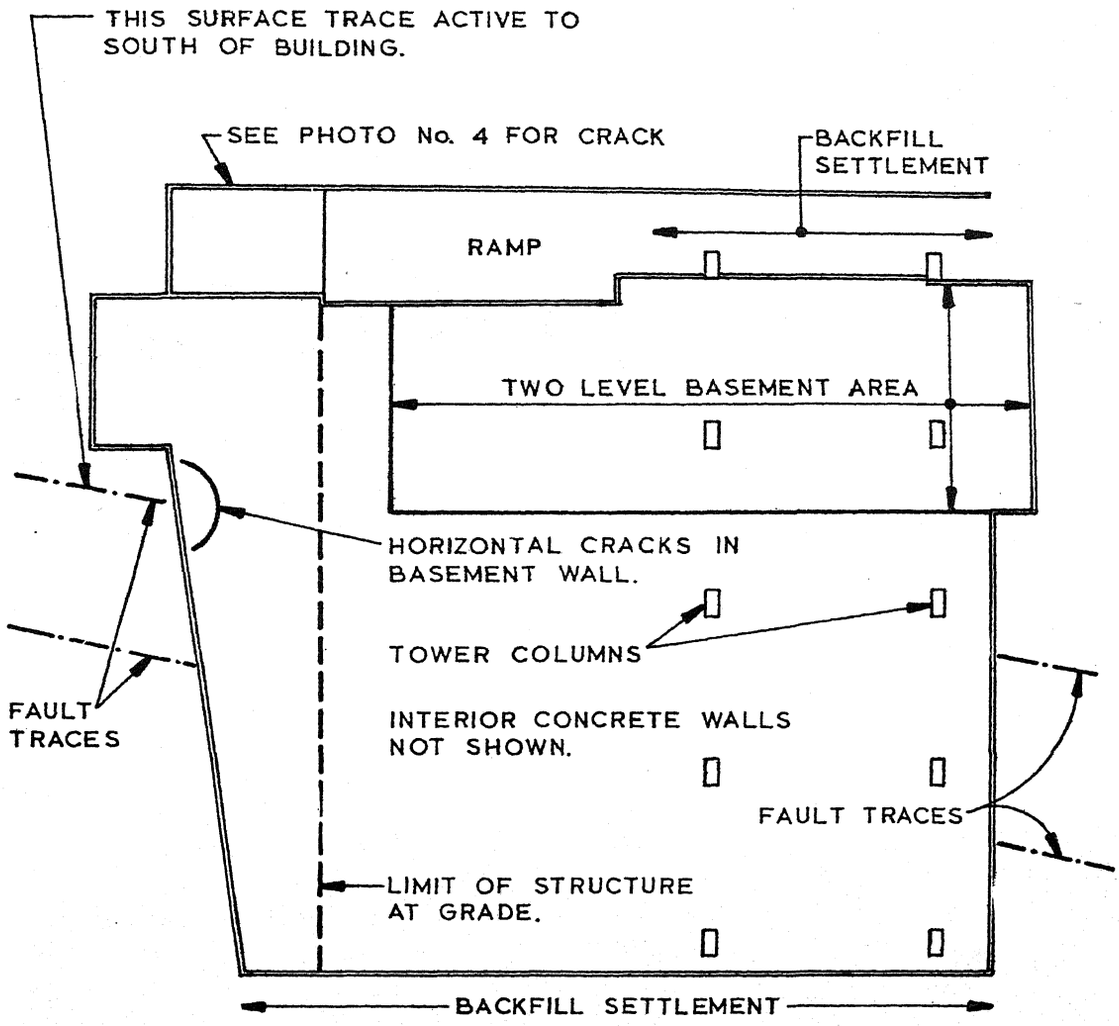


FIGURE 1.
PLAN OF BASEMENT OF BANCO CENTRAL

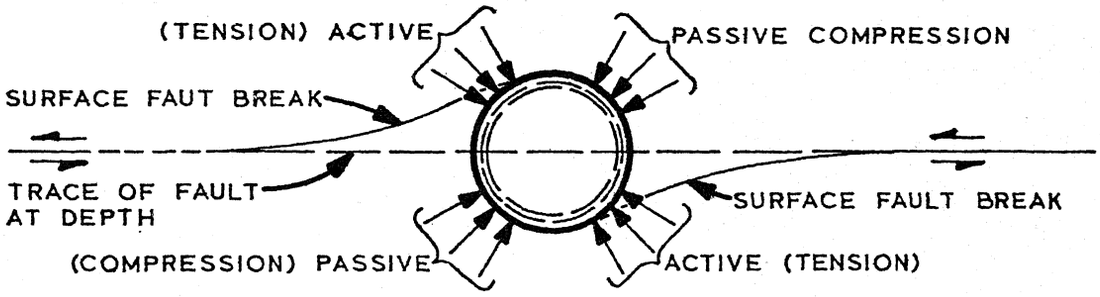
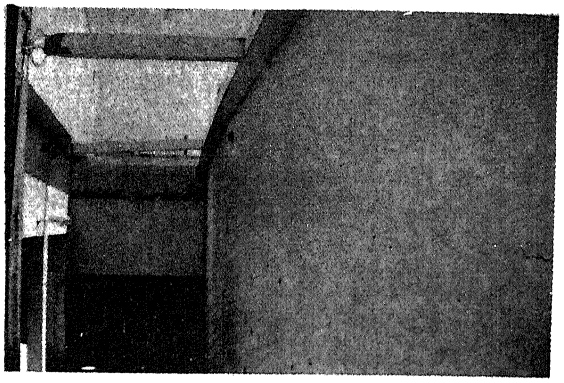


FIGURE 2.
IDEALIZATION FROM MODEL STUDIES (REF. 3)

Photograph Number 1. View of Banco Central from south. Banco de America to right. Banco's fault goes from lower left to upper right.



Photograph Number 2. Retaining wall at ramp, looking south. Struts have failed at top and wall has bowed in. Note horizontal cracking.

Photograph Number 3. Sidewalk settlement on east side just outside basement wall.

Photograph Number 4. Crack in driveway covering enlarged basement area at west perimeter near south corner. Wall at right is end of top of retaining wall see in Photo 2.