BANCO CENTRAL DE NICARAGUA: A CASE HISTORY OF A HIGH-RISE BUILDING THAT SURVIVED SURFACE FAULT RUPTURE

by

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SYNOPSIS

The Banco Central de Nicaragua was inadvertently built across an active trace of the Banco fault. During the 1972 Managua earthquake, surface faulting occurred on one trace of that fault and the strong security vault in the basement of the bank resisted the faulting. Near the building, the rupture deviated from the active trace and broke a series of new fault cracks through the tensional quadrant in the old fault zone. Northeast of the building, surface displacements again coincided with the northward projection of the fault trace. Model studies suggest that structures can be built in a fault zone if the characteristics of the fault and the soils are known so that fault displacements can be considered in design.

INTRODUCTION

On December 23, 1972, Managua was shaken by a magnitude 6.2 earthquake and two destructive aftershocks. Differential surface displacement occurred on four faults within the city. The faulting and the intense ground shaking either severely damaged or destroyed more than three-quarters of the buildings in the city (1, 2).

The Banco Central building survived the earthquake. Most of the damage it received was above ground level and can be attributed to seismic shaking (3). The bank had to be partially evacuated and the administrative offices and most personnel were transferred to temporary quarters. However, the storage vaults, which are the repository of the reserved and uncirculated Nicaraguan currency, were undamaged and remained in use.

Several fault maps were published after the 1972 earthquake that showed different locations for the postulated Bancos fault. The published locations varied; some investigators placed the fault under

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the Banco Central building and others placed the fault either east or west of the building. Faced with decisions regarding repair or replacement of the building, Banco Central management personnel and their engineering consultants needed to know the exact location of the fault, its characteristics, and the type of displacement that could be expected during a future earthquake.

Based mainly on detailed subsurface investigations in trenches, the locations of major fault traces and the limits of the fault zones before the 1972 earthquake were identified. The surface evidence of faulting and surface cracks were examined near the Banco Central property, and in reconnaissance along the fault zone to gain more data regarding the pattern of faulting.

FIELD INVESTIGATIONS

A plot was made of fault cracks near the property that showed more than a centimeter of lateral displacement, vertical displacement, or gap (Figure 1). Photographs of the excavation for the basement of the Banco Central indicated the fault crossed the basement; these photographs were studied to make a first approximation of the fault location. Trenches were excavated to examine the fault that was believed to pass under the bank building.

The trenches indicated on Figure 1 were excavated and examined to help determine the width of the fault zone and the amount of displacement per event. Detailed logs were prepared for all the trenches; an illustration of the type of geologic data recovered from the trenches is shown on Figure 2.

Figure 2 shows that gouge zones occurred between stations 60 and 70. The gouge zone at station 60 experienced minor displacement in the 1972 earthquake. The surface cracks deviated from the trend of the fault here, and went around the west side of the bank. The gouge zones between stations 65 and 70 had experienced faulting in the past; however, unbroken, cemented breccia in the shear zone, lack of disruption in the shear zone, and lack of disruption in the backfill and the asphalt of the bank parking lot indicate no displacement during the 1972 earthquake. A new crack can be seen at station 67. The apparent vertical displacement is less than 1 centimeter on the beds it cuts. The cracks between stations 55 and 60 have refracted through beds of varying hardness. Other cracks, which have undergone multiple displacements in the past, have progressively larger displacements in the lower beds.

SUMMARY OF FIELD DATA

The Bancos fault consists of numerous en echelon faults and fractures in a 70-meter-wide zone (Figure 3A). The fault zone is irregular, but generally trends about N30E. Individual surface cracks are generally oblique to the zone and have a more northerly orientation. The fault has ruptured at the site at least seven (and probably more) time in the past 25,000 years. Each event appeared to have no more than 1 to 5 centimeters of vertical displacement. The 1972 displacement was about 17 centimeters left lateral.

The Banco Central building is partially in the fault zone and partially in the unbroken alluvium east of the fault zone. Two large fault cracks were found in trenches on either side of the Banco Central; since the amount and sense of displacement is the same on both sides of the building, it is reasonable to assume the traces are continuous under the building (Figure 3C).

Differential Fault Displacement in the 1972 Earthquake: None of the fault cracks that intersect the basement of the Banco Central showed recent displacement near the basement, even though these cracks exhibit new displacement at other locations. The cracks suggest that the recent faulting had been deflected around the Banco Central. Near the building, new cracks formed west of the basement. These new cracks, as observed in trenches, were open or only loosely filled with uncemented material. Some appear to cross older, preexisting cracks. The new cracks parallel or are the downward extension of surface cracks shown on Figure 1. Essentially all the new cracks formed on the side of the building coinciding with the weakened alluvium in a zone of pervasive small shear fractures of the old fault zone.

CORRELATION OF FIELD DATA WITH MODEL STUDIES

The Banco Central studies and preliminary conclusions were made in the field in 1973. Independent model studies, not related to this investigation, were made at about the same time (4). There is good correlation between the observed field phenomona and the laboratory model studies.

Plan views of the Banco Central area and a model (4) are shown similarly oriented on Figures 3A and 3B. Figures 3C and 3D show idealized block diagrams of both the model and the field condition. There is a left slip at depth along one fault trace in the model; however, at the surface, the fault divides and passes on opposite sides of the modeled structure (Figure 3B). The forces on the structure can be divided into quadrants that are oriented about 45 degrees from the fault trace. In two quadrants, the earth moves toward the modeled structure to produce passive (compressional) pressures. In the remaining two quadrants, the earth moves away from the structure, producing active (tensional) failures.

The field conditions were more complicated than the model study due to the strong foundations of the adjacent Banco Nacional, and a deep, strong basement under Banco de America (Figure 3A). In the model study, the sand modeling the regolith was homogeneous. In the field, there were three regolith conditions: 1) strong, previously undeformed beds of conglomerate (cemented gravels) alternating with uncemented sand outside the fault zone, 2) weak, deformed and fractured beds of conglomerate and sand in the fault zone, and 3) very weak vertical zones of fault gouge on the large fault traces in the fault zone.

There was field evidence for the quadrants of tension and compression. Several parallel cracks opened in the tensional field west of the building; these were still open or only loosely filled when trenches were excavated several months after the faulting event. More than

1 foot of settlement occurred in one part of the ramp at the northwest corner of the building (3). Some minor horizontal cracks noted in the south basement wall of the structure may reflect a build up of earth pressure before the new cracks formed in the parking lot.

Some north-south compression was indicated by a small buckle in the sidewalk at the curb line north of the building. Similar north-south compression was seen at the northwest corner of the Banco de America, where an asphalt surface adjacent to the basement was thrust a few centimeters over that basement.

Had the characteristics of the fault and the soils been known at the time of design, the behavior of the basement of the Banco Central during the episode of faulting probably could have been predicted by model studies and computations. The extra strength, added for security, was essentially the construction adjustment needed for that fault zone. The survival of the bank indicates that, under certain circumstances, engineered structures can be fault resistant.

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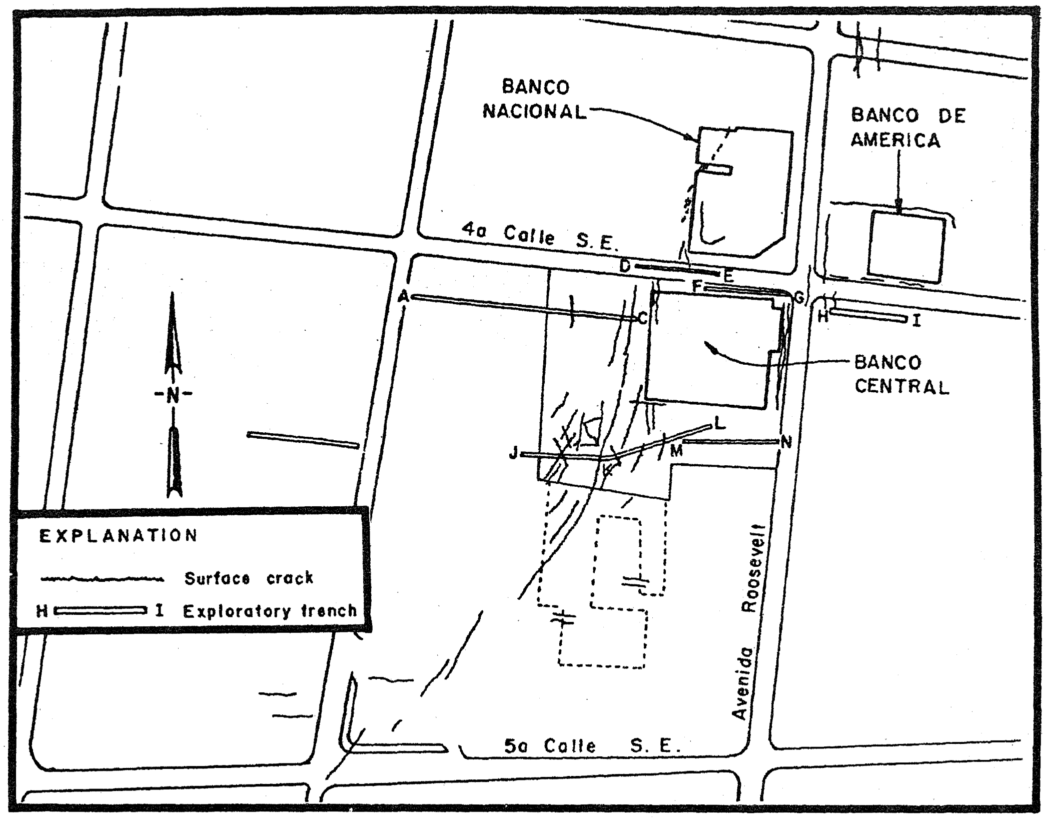

Figure 1 MAP OF SURFACE CRACKS AND TRENCHES

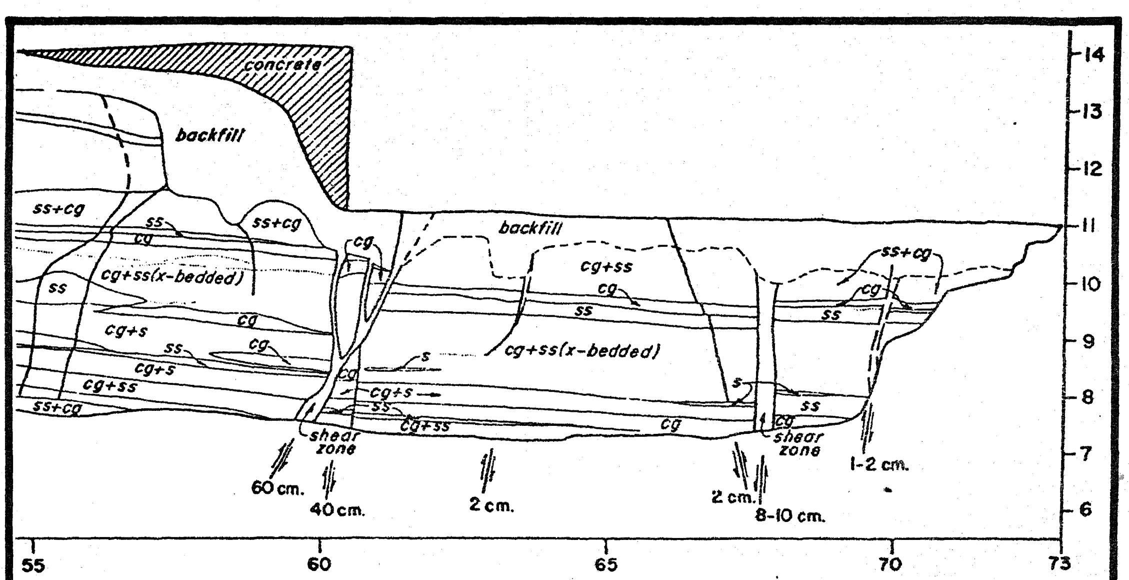

Figure 2 DETAIL OF TRENCH LOG

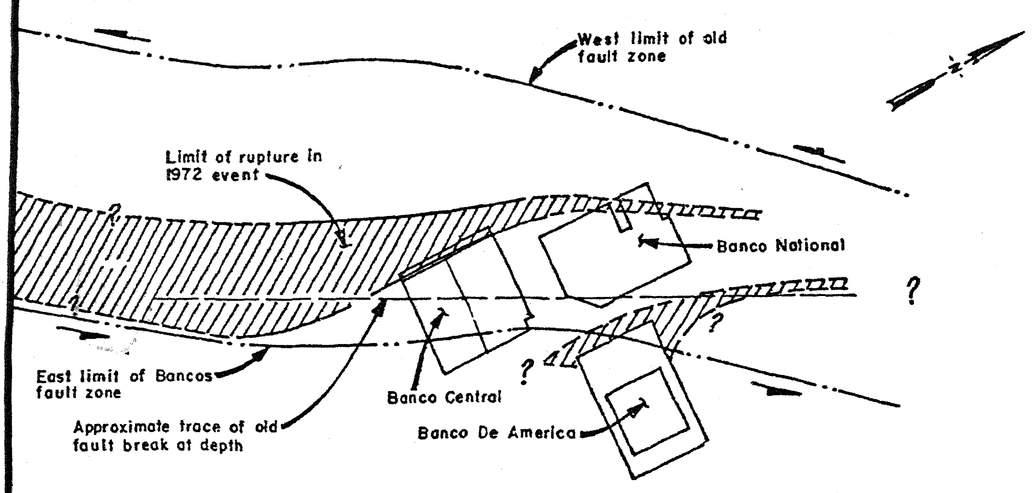

Figure 3A SURFACE FAULT RUPTURE OBSERVED IN THE FIELD

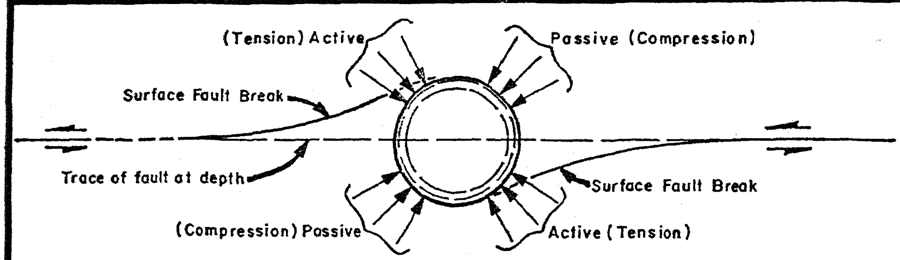

Figure 3B SURFACE FAULT RUPTURE OBSERVED BY DUNCAN AND LEFEBVRE (4) IN LABORATORY MODEL STUDIES

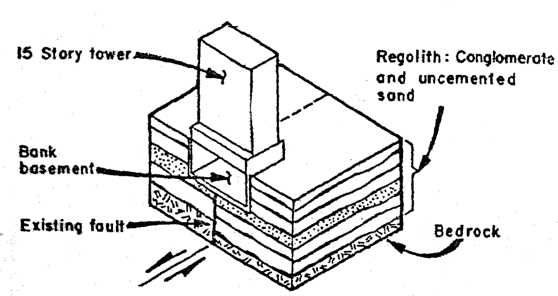

Figure 3C BLOCK DIAGRAM FIELD CONDITION

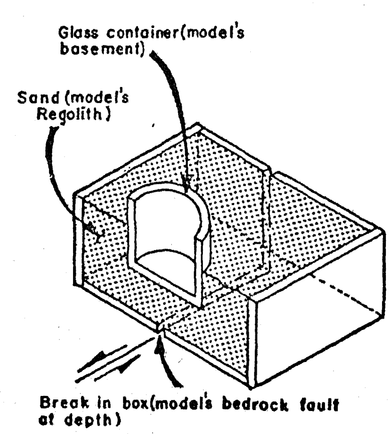

Figure 3D BLOCK DIAGRAM LABORATORY MODEL

Figure 3 COMPARISON OF FIELD AND LABORATORY MODELS