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NBS TECHNICAL NOTE 807

Building Performance in the 1972 Managua Earthquake

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[2] Part of the Center for Radiation Research.
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Building Performance in the 1972 Managua Earthquake

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ABSTRACT

Following the Managua, Nicaragua, earthquake of December 23, 1972, a team of engineers representing the U.S. Department of Commerce's National Bureau of Standards (NBS) and the National Academy of Engineering (NAE) performed field investigations in Managua, Nicaragua, from December 26, 1972, to January 4, 1973. The objectives were to assist the Nicaraguan government in surveying major buildings to determine whether each was suitable for emergency use, repairable, or appropriate for clearance. The team also viewed the patterns of successful performance and damage to identify needs for improvements in building practices for mitigation of earthquake hazards and opportunities for more detailed investigations which could provide information for future improvements in practices.

The Managua earthquake, estimated at Richter magnitude 6.25, was not a great earthquake, but the loss of life approached 10,000, approximately 75 per cent of Managua's 450,000 occupants were rendered homeless, and property damages are estimated to approach $1 billion. In general, these damages cannot be attributed to unusual intensities of ground shaking or severity of surface faulting. Most damages appeared to result from deficiencies in building practices; deficiencies which had been exhibited many times before in previous earthquakes, deficiencies which would be avoided by implementation of up-to-date provisions for earthquake resistant design and construction. However, Managua did not employ a building code with seismic design requirements appropriate to its earthquake risk, and furthermore, did not have a building regulatory system capable of effective implementation of its building code provisions.

This report documents the observations of damages by the NBS/NAE team and points out relationships to inadequacies in the building practices employed. Most of these inadequacies have been well known; however, the Managuan experience may serve as an incentive to improvement of building practices in many other areas which are subject to substantial earthquake risks and have not consistently accounted for these risks in their building codes and building regulatory system.

Key words: Building codes; buildings; earthquakes; hazards; natural disasters; structures.

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BUILDING PERFORMANCE IN THE 1972 MANAGUA EARTHQUAKE

by

Richard N. Wright[1/] and Samuel Kramer

1. INTRODUCTION

This report summarizes the field investigation conducted by a National Bureau of Standards' team following the Managua, Nicaragua, earthquake of December 23, 1972. The major emphases in the investigaiton were to assist Nicaraguan authorities in evaluating the conditions of public buildings immediately following the disaster, and to observe causes of building failures for guidance toward improvements of practices for design, construction and occupancy of earthquake resistant buildings.

1.1 General Situation

Nicaragua, shown in figure 1, is the largest of the Central American republics. Its area is approximately 57,000 sq. miles and its population was 2 million in a 1972 estimate [1][2/]. Managua is located in the western central portion of the country at the south edge of Lake Managua. A chain of volcanoes traverses Nicaragua from the northwest to the southeast. As noted by the Geological Survey [2], Managua earthquakes may arise from the discontinuity in the line of volcanoes near Managua.

Managua has had earlier disasterous earthquakes, most recently in 1931 [3 and 4]. The whole of western Nicaragua is a seismicly active region. Geological theory attributes this activity to the relative movements of crustal plates; the Cocos and Caribbean plates intersect in the vicinity of the lines of volcanoes traversing western Nicaragua. An aerial view of the city on December 26, figure 2, shows the line of

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[1/] Dr. Wright, formerly Deputy Director-Technical, Center for Building Technology, is now Professor of Civil Engineering, University of Illinois, Urbana, Illinois.

[2/] Figures in brackets indicate the literature references at the end of this paper.

Figure 1 Map of Nicaragua.

Figure 2 Aerial view of Managua on December 26, 1972.

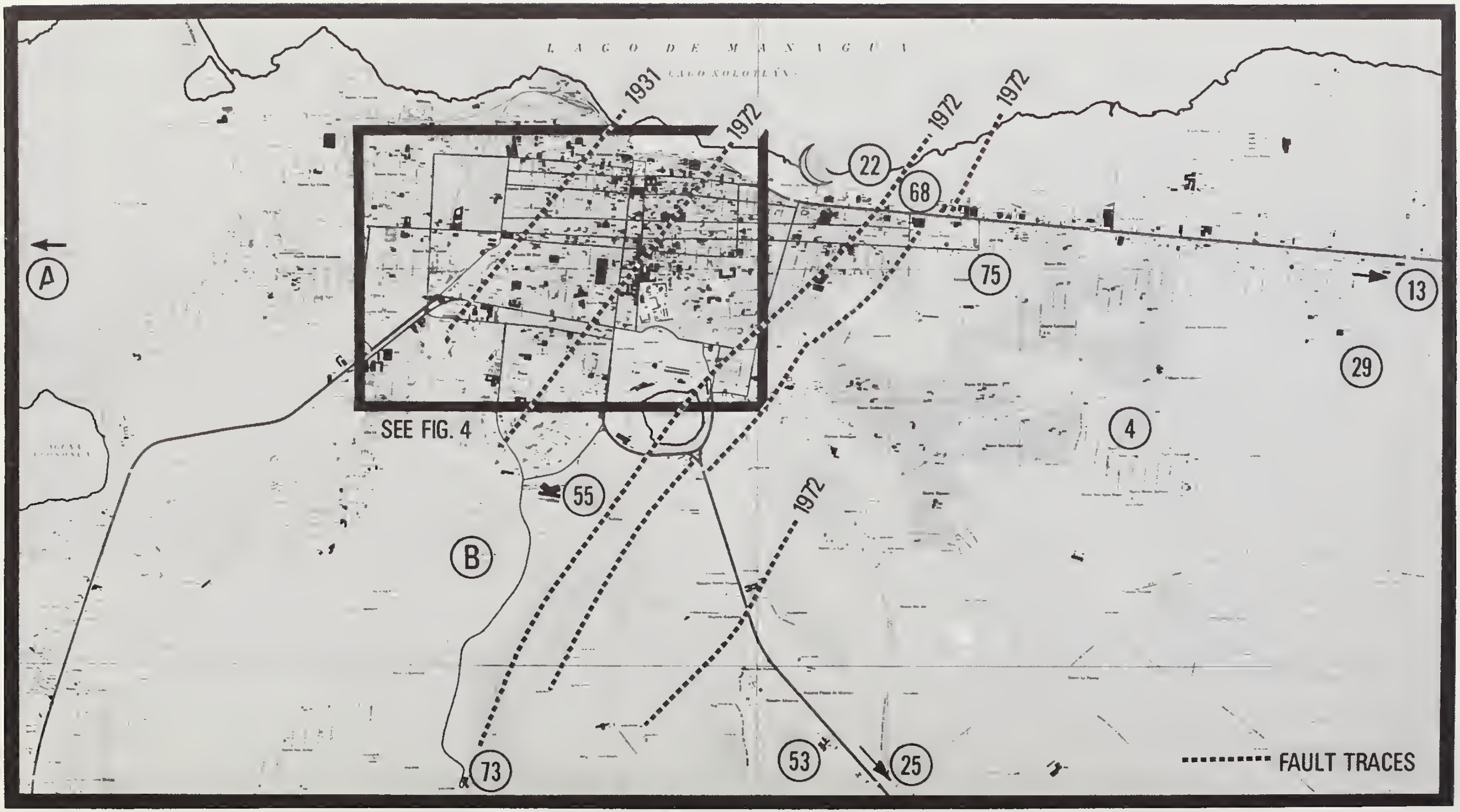

Figure 3 1962 Map of the City of Managua.

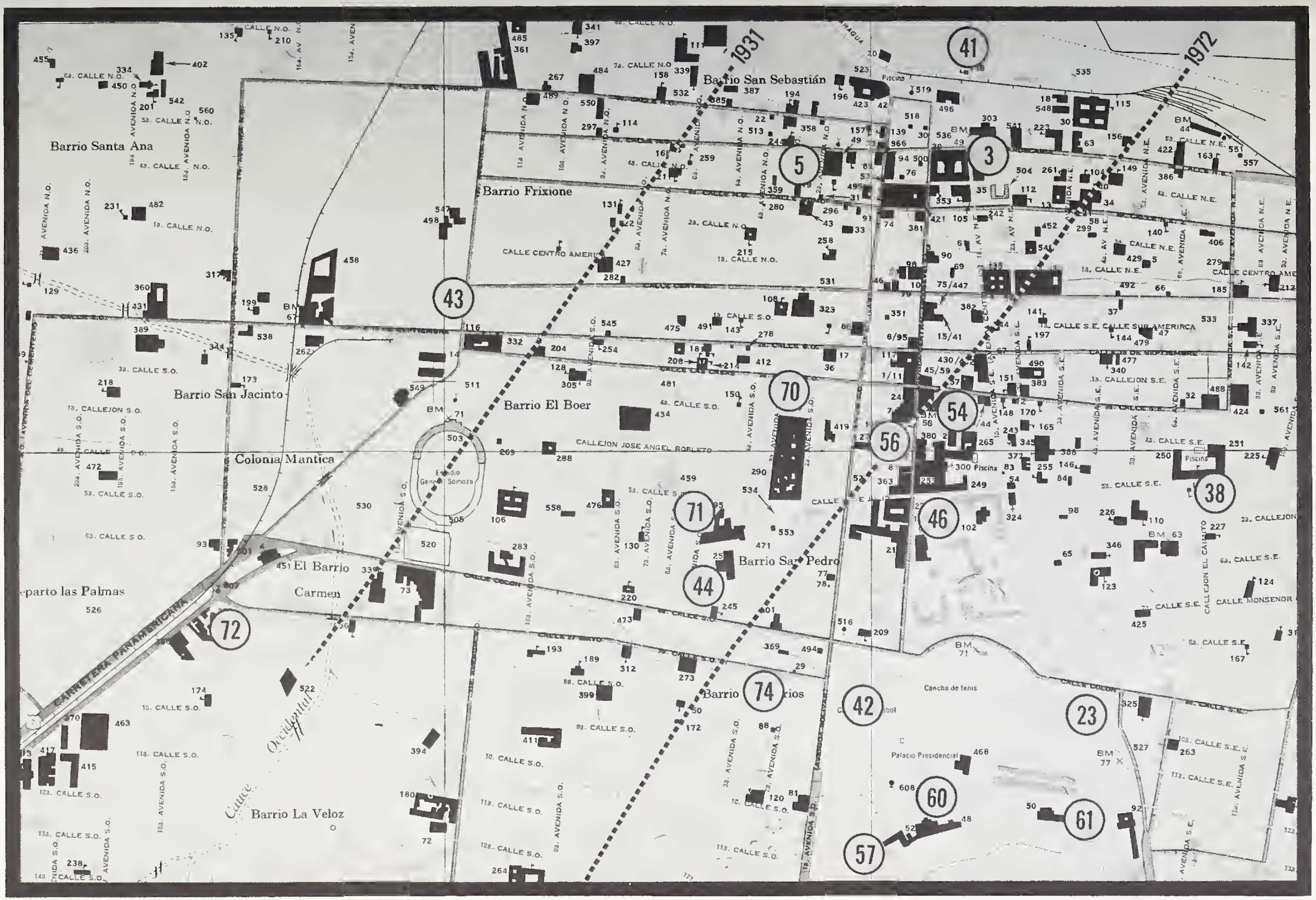

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Figure 4 Map of Center of City.

volcanoes to the northwest and smoke arising from the damaged city.

The city of Managua, shown in figure 3, has a populated region of approximately 10 kilometers from east to west and 4 kilometers from north to south. The surficial deposits are volcanic in origin. In both the 1931 and the 1972 earthquakes, fault traces were observed in the central portions of the city. Traces of the earthquake faulting transmitted through the overburden material appeared as ground breakage lines trending from the southwest to the northeast as shown in figure 3. In 1931 [3 and 4] the principal faulting was near the stadium in the west central portion while in 1972 [2] traces traversed Laguna Tiscapa and the Aduana building in the east central portion.

1.2 Earthquake Characteristics

A preliminary report on the earthquake characteristics has been provided by the Seismological Field Survey, National Oceanic and Atmospheric Administration (NOAA) [5]. The main shock of the earthquake occurred at 06:29:42 GCT (12:29 a.m. Nicaraguan time) on December 23, 1972. The Richter magnitude of the main shock was 6.25. The AR240 accelerograph at the ESSO refinery (location A, figure 3) 4 kilometers west of the Estadio General Somoza recorded the following peak accelerations in g's: 0.39 EW, 0.34 NS, and 0.33 V. The duration of shaking for peaks above 0.20g was 5 seconds. Seismoscope records, two at the ESSO refinery, one at the prestressed concrete plant west of the city, and the other at the National Agricultural School near the Las Mercedes airport, showed no generally pronounced directionality of motion. Since the ESSO refinery was about 5 kilometers west of the area of major faulting near Laguna Tiscapa, it appears that peak acceleration in the center of the city may have approached or exceeded 0.5g.

The population of Managua at the time of the earthquake was approximately 450,000. The initial damage survey by local authorities [6] showed 4,000-6,000 dead; 20,000 injured; 220,000-250,000 homeless; 13 km^2 destroyed; 14 km^2 damaged including water, sewerage, and power distribution systems; 7,000,000 m^3 of rubble; 53,000 dwelling units lost or seriously damaged; 95 per cent of the shops and small factories lost or seriously damaged; 400,000 m^2 of commercial buildings lost or seriously damaged; 340,000 m^2 of public and private offices lost or seriously damaged; 4 hospitals with a total of 1,650 beds lost or seriously damaged; 51,700 persons lost employment; and $851.1 million total loss in building, equipment, inventory, emergency assistance, and accounts receivable. The State Department reported [7] 10,000 people dead, 20,000 injured, 300,000 displaced from their homes, and 600 city blocks destroyed by the earthquake. Indications of the general extent of the damages are shown in photographs taken from the Banco Central, looking to the south, figure 5; southeast, figure 6; east, figure 7; northeast, figure 8; north northeast, figure 9; north, figure 10; and northwest, figure 11.

1.3 Disaster Investigation

This section describes the conditions of the disaster investigation. An earthquake striking a major metropolitan area creates needs for technical assistance in relief activities and provides valuable information on earthquake effects. Both responses must be prompt. Delay can mean additional losses from use of hazardous facilities or destruction of repairable facilities. Emergency response activities will remove valuable scientific and technical evidence.

The situation for attaining access and conducting the investigation is described here to guide future disaster investigations.

The National Bureau of Standards was informed of the earthquake on December 23, 1972, by the warning service of the National Oceanic and Atmospheric Administration. The preliminary notification included reports of substantial damage to the city of Managua, and as a result of this information NBS and NOAA activated plans for dispatching teams to the disaster site. The situation was reviewed with Dr. Nathan M. Newmark of the University of Illinois who indicated that the event could be of substantial technical interest and that the National Academy of Engineering was sending Dr. Mete A. Sozen of the University of Illinois to investigate the earthquake. Mr. Samuel Kramer, Chief, Office of Federal Building Technology, Center for Building Technology, arranged for State Department authorization of a combined National Bureau of

Figure 5 View south from atop the Banco Central.

Figure 6 View southeast from atop the Banco Central.

Figure 7 View east from atop the Banco Central.

Figure 8 View northeast from atop the Banco Central.

Figure 9 View north northeast from atop the Banco Central.

Figure 10 View north from atop the Banco Central.

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Figure 11 View northwest from atop the Banco Central.

Standards/National Academy of Engineering (NBS/NAE) team to investigate the disaster. The team consisted of Dr. Mete Sozen, Mr. Samuel Kramer and Dr. Richard Wright, Deputy Director-Technical Center for Building Technology, National Bureau of Standards. At the same time arrangements were made for entrance of a team of seismologists from the National Oceanic and Atmospheric Administration led by Dr. S. T. Algermissen.

Authorization to enter Nicaragua was issued by the State Department on the evening of December 24, 1972. The team members, who traveled from Urbana, Illinois; Cayuga, New York; and Potomac, Maryland, met at Bethesda Naval Hospital at 6:00 p.m. on December 25, 1972, to obtain necessary immunizations and departed for Managua at 11:25 p.m.

While the commercial flights to Managua were not running on regular schedules, the team managed to enter Managua by flying from Washington, D.C. to Panama; from Panama to San Jose, Costa Rica, by LACSA airlines; and from San Jose, Costa Rica, to Managua by TACA airlines, and arrived at the Managua airport at approximately 2:00 p.m. on December 26, 1972. The NBS/NAE team was the first United States group of professional and research engineers responding to the earthquake to arrive on the site of the disaster. The U.S. Embassy personnel at the airport, who were expecting the team, provided maps and transportation to a camp located on the grounds of the residence of General Anastasio Somoza at El Retiro, (location B, figure 3). Tent quarters and C-rations at El Retiro were provided by a detachment of the U.S. Army 3rd Civil Affairs Group, USSOUTHCOM Disaster Area Survey Team (DAST), who were working on restoration of water supply and power services. A view of the camp is shown in figure 12.

The NBS/NAE team was warmly received by the Nicaraguan authorities. Immediately upon arrival on December 26, 1972, the team was escorted on a preliminary survey of the city by Ing. Max Kelly who was acting as an aide to General Somoza. On December 27, 1972, the team continued informal investigations of the damage with the assistance of helicopter transportation provided by General Somoza and ground transportation provided by the Nicaraguan Army. At El Retiro contacts were made with various segments of the Nicaraguan government, and liaisons were established with the Nicaraguan Ministry of Public Works for coordinated efforts in investigations of building damage.

Figure 12 View of the Camp at El Retiro.

On December 28, 1972, the NBS/NAE team plus Mr. Karl Steinbrugge, a consulting structural engineer with the NOAA seismological team, were granted a pass, figure 13, for access to the restricted areas of the city and for conducting investigations of building damage.

The NBS/NAE team conducted its investigations in conjunction with the Department of Construction and Maintenance of Public Buildings of the Ministry of Public Works which is headed by Ing. Jorge Hayn. Ing. Raul Amador of the Ministry of Public Works accompanied the NBS/NAE team in most of its building inspections. Dr. Abdel Karim, Head of the Civil Engineering Department of the University of Nicaragua, also worked closely with the team during its investigations. These investigations continued until January 4, 1973, when the NBS/NAE team returned to the United States.

In addition to those previously mentioned, the NBS/NAE team interacted with many agencies of the Nicaraguan Government, the Organization of American States, international relief organizations, and U.S. Federal agencies who subsequently responded to the earthquake. A list of principal contacts is given in Appendix A.

The following chapters of this report describe the general observations of damage, causes of damages, and reports on the buildings inspected in conjunction with the Nicaraguan Ministry of Public Works during the disaster investigations.

The assistance rendered the Ministry of Public Works and the observations noted were possible only because the NBS/NAE team arrived at the site soon after the disaster. However, even at that time some documentation was lost since recovery actions had already been initiated and some evidence of damaged buildings was removed. At the time of the team departure, January 4, 1973, substantial portions of the city were demolished and actions were underway to fence off and virtually clear an area of over 500 square blocks in the downtown area. This resulted in the removal of most of the evidence of damage.

CUARTEL GENERAL GENERAL DE LA GUARDIA NACIONAL DE NICARAGUA
CENTRO DE COMANDO DEL COMITE NACIONAL DE NICARAGUA

A: Los puestos de vigilancia de la ciudad:

De acuerdo con instrucciones del escalon superior, se le concede permiso a los Sres. SAMUEL KRAMER
RICHARD N. WRIGT
METE SOZEN
KARL STEINBRUGGE

para entrar y salir a cualquier edificio en la ciudad de Managua que se encuentre afectado por el terremoto en su calidad de evaluadores y como representantes del OFFICE OF FEDERAL BUILDING TECHNOLOGY CENTER FOR BUILDING TECHNOLOGY.

Todo este servicio lo hacen por su propia voluntad y directa responsabilidad.

Rogamos a todas las autoridades prestarles su cooperacion siempre que la necesiten o soliciten.

Diciembre 28, 1972.

Roger Bermudez B.
General de Brigada GN.
Coordinador General.

Figure 13 Pass for access of the NBS/NAE team to the City.

2. GENERAL OBSERVATIONS

This chapter describes the overall performance of various classes of buildings. In general, these observations are consistent with experiences in earlier earthquakes [8].

2.1 Taquezal Construction

Much of the older residential and commercial construction in Managua was of the type called "taquezal." This is timber framed adobe construction made up of wood posts approximately 4 in square, spaced on approximately 2 ft centers, and connected horizontally by wooden slats which were about 1/2 in by 2 in and spaced at 8 in vertically. The space between the wooden slats was packed with mud, figure 14. These structures usually had timber framed floors and roofs with the roofs often covered by clay tile. The exterior surface would be plastered and painted, figure 15, to form a building of substantial appearance. However, these buildings were inherently quite weak, and heavy enough to generate large lateral forces under ground shaking. In addition, the timber framing was frequently weakened by termites. Over much of the Managua area, these buildings collapsed, figure 16; most of the deaths were suffered in this type of building.

2.2 Critical Facilities

The damage in Managua provides many examples of the need to construct buildings housing critical facilities in a manner such that they will be functional when desperately needed following an earthquake. Most critical facilities in Managua were destroyed. Examples are: the fire station which collapsed upon the fire equipment, figure 17, the Red Cross building, figure 18, which collapsed upon their ambulances and emergency supplies, the INSS Hospital, figure 70-1[3/], which suffered severe structural and nonstructural damages making it not just useless, but definitely hazardous to its occupants. The General Hospital, figure 55-2, also suffered

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[3/] Hyphenated figure numbers denote figures from Appendix B. The first number denotes the report in Appendix B where the figure is located.

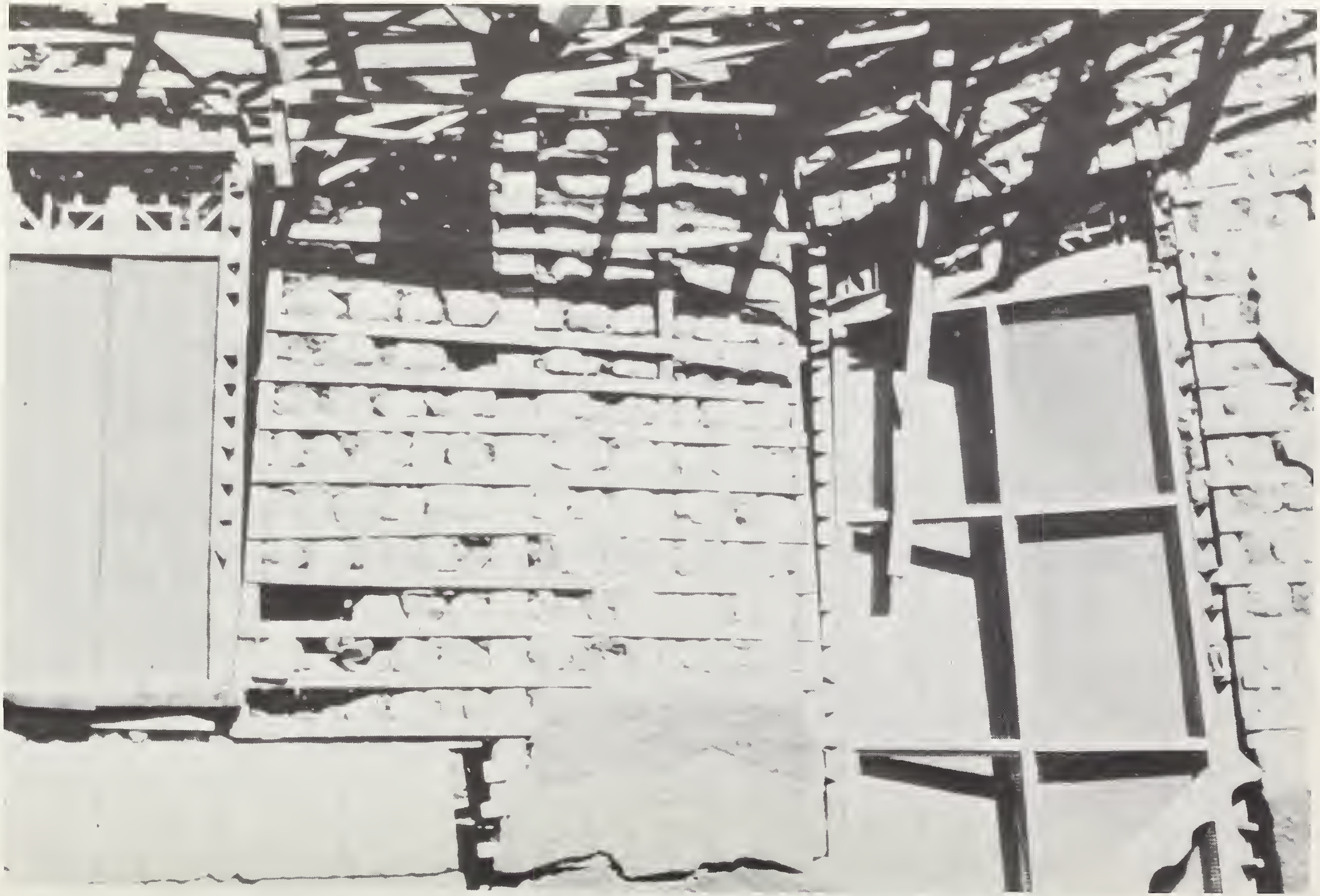

Figure 14 Example of taquezal construction showing interstices between posts and slats filled with mud or stone.

Figure 15 Taquezal construction where the substantial appearance after plastering and painting is belied by the resistance.

Figure 16 View of the taquezal areas of Managua which were largely collapsed.

Figure 17 The Fire Station collapsed upon fire equipment.

Figure 18 Red Cross building collapsed on ambulances and emergency supplies.

very severe damage; fortunately, the critical medical supplies stored in a warehouse behind the hospital were on steel shelving, figure 55-8, which supported the building when its walls fell and columns sheared and kept these supplies available for use following the earthquake. Radio communications were dependent on a very feeble building, figure 62-1; however, it was far enough south of town that the collapse was incipient rather than actual. Similarly, the vital switch gear at the power generation plant, figure 22-4, were located in a weak masonry building with a very heavy roof; the building was close to collapse.

2.3 Comparison of Shear Wall and Unbraced Frames

There were examples of moment resisting unbraced frame structures for which the structure endured the earthquake without severe damage, but with motions great enough to cause extensive property losses and loss of functionality. The Banco Central tower exhibited extensive cracking of framed-tube columns and floor diaphragm cracking in the upper stories; structural damage was moderately severe, but nonstructural damages were very extensive, figure 52-3. An insurance building, Seguros la Protectora, figure 19, showed severe nonstructural damage to the facade panels and to the contents of the building, figure 20, but not extensive structural damage. It may be questioned whether this constitutes successful structural performance when occupants of the buildings would be severely threatened by falling lights, partitions, and shelving; exit doors jammed and fire hazards were increased with the difficulties in egress. It is questionable whether the property losses were appreciably less than they would be if these buildings had collapsed completely.

Shear wall-frame buildings were much stiffer; the limited deformations resulted in very little property loss and continuation of functionality. However, some of these buildings showed sufficient structural damage to call into question their safety for an earthquake of similar intensity but longer duration. For instance, the ENALUF (electric utility company) administration building looked sound from the outside, figure 23-1, but exhibited definite structural damage. There was localized crushing of certain shear walls on the ground floor at interruptions for a duct,

Figure 19 Severe exterior nonstructural damage in unbraced frame building, Seguros La Protectora.

Figure 20 Severe damage to contents of unbraced frame, Seguros La Protectora.

figure 23-4, and for a telephone chase, figure 23-3. On the upper floors there were many diagonal cracks in the shear wall, figure 23-5. The 17 story Banco de American Building also looked quite sound from the outside and showed little nonstructural damage on the inside, figure 54-2. However, many tie beams connecting the four shear wall towers at the corners of the core broke in shear at their mid-span where they were penetrated for ducts, figure 54-1.

2.4 Performance of Housing

The generally poor performance of taquezal housing which led to large losses of life and property has been previously discussed. Also some modern houses, using materials such as prestressed concrete, reinforced concrete, and masonry with precast members and prefabrication techniques as well as other so called modern technologies, were designed or constructed without adequate attention to the potential earthquake forces and performed poorly. A housing development under construction with reinforced concrete frames infilled by concrete block walls, figure 21, showed wall failures because of inadequate attachment to the frames. Some more expensive modern houses also collapsed, figure 22. A development of cast-in-place concrete houses, with prestressed, precast channel roof elements approximately 8 ft wide by 20 ft long, failed due to inadequate attachment of the roofs to the walls, figure 24-1. At best the precast channels were connected only at the four corners by an inch or two of small fillet weld, figure 24-3. On duplex units where two roof channels bore on a party wall, it apparently was considered inconvenient to make any connection whatsoever, figure 24-4.

While damage to housing in Managua was severe, it should be pointed out that much of the modern housing in Managua performed excellently. There were major developments of masonry or concrete houses with lightweight roofs in areas of strong ground shaking between the ESSO Refinery and the center of town for which no damage could be observed from the outside. Other houses, specifically designed to resist earthquake forces, were virtually undamaged, while adjacent structures collapsed.

Figure 21 Failures of inadequately anchored walls of houses under construction.

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Figure 22 Collapse of modern house of "good quality."

3. CAUSES OF DAMAGES

The field inspections conducted substantiate the need for recognizing the forces that develop in structures subjected to earthquakes. The deficiencies in design and construction which are the causes of damages are discussed in this section.

3.1 Inadequate Strength in Vertical Planes

Many of the structural failures in Managua can be attributed to inadequacy of the structural systems for the lateral forces imposed by the earthquake. Heavy barrel shell roofs such as that of the Aduana (Customs House), figure 68-3, sheared their columns, figure 68-4, and collapsed or came to rest upon the contents of the building. Many multistory reinforced concrete buildings collapsed such as the Guerrero Pineda five story building, figure 74-2. Some modern one story buildings such as the INCET (National Granary) administration building, figure 16-1, appear to have been constructed with unnecessarily heavy roofs and framing systems inadequate for the resulting lateral forces. There was evidence in the Instituto Pedagogico, figure 46-3, that flat slabs showed some distress in functioning as the horizonal framing member between columns.

3.2 Inadequate Strength in Horizontal Planes

The need for proper horizontal distribution of the lateral forces induced by the earthquake also was evident in many situations. Trussed roof systems without lower chord bracing did not provide adequate horizontal diaphragm action. In a laboratory addition to the INCEI administration building, figure 16-2, the roof trusses severely displaced the end walls of the building. A similar failure occurred for the same reasons in the gymnasium of the Ramirez Goyena School, figure 38-4.

3.3 Detailing for Energy Absorption

Many failures could be attributed as much to inadequate toughness as to inadequate strength. The two story administration building for the Aduana, figure 68-1, collapsed completely; the columns employed some undeformed bars and widely spaced ties, figure 68-2. The absence of proper anchorage and energy absorbing capacity beyond maximum load probably contributed to the collapse. Careful attention to anchorage is needed for the reinforcement at corner connections between bond beams and columns for reinforced masonry walls; damages in the Salvadore Mendieta School, figure 25-2, appear to have been caused by such absence of anchorage. Elements of masonry intended to resist lateral forces should be confined by reinforced columns rather than having the masonry elements outside of the reinforcement as in the new, unused and unusable, Simon Bolivar School, figure 35-5. Attention must be given to construction joints to assure that planes of weakness are not developed in the structure as they were in the nursery school of the Mercado Oriental, figure 4-1. Cavity infill walls must be tied across the cavity and keyed to the frame beams and columns to avoid the failures occurring at the Geographical Institute, figure 75-2. Careful attention must be placed on achieving adequate continuity for precast elements as exemplified by the Bello Horizonte development, figure 24-3.

3.4 Adequate Clearances or Connections

Avoidance of earthquake damage requires very definite decisions on the part of the designer and constructors as to whether they wish elements to be connected or to be separated. Indecisive details lead to damage from pulling apart of inadequately connected elements or the pounding of inadequately separated elements. Courtyards were created in the Supreme Court building by omitting floor and roof slabs for certain panels but leaving the exterior beams in place. These beams, figure 43-1, were not adequate to keep adjacent parts of the building moving together. The monumental structure of the National Palace was quite stiff and its movements quite small; however, the separation between the legislative chambers and the outer portion of the building was not enough to avoid pounding damage, figure 3-4.

3.5 Direct Hazards from Nonstructural Elements

In addition to structural failures as previously noted, there are direct hazards from nonstructural failures. These include: heavy, weak masonry partitions and curtain walls as in the INCEI warehouse, figure 16-3, and the Supreme Court building, figure 43-2; falling shelving, as in the insurance building, figure 20; displaced light fixtures as in the Central Bank, figures 52-3 and 52-4; parapets as in the Social Security Clinic, figure 71-1; and inadequately attached exterior finishes as in the Supreme Court, figure 43-4.

3.6 Anchorage of Equipment and Industrial Facilities

Equipment which should be functional following an earthquake must be adequately designed and anchored for earthquake forces. The power generation facilities for Managua were put out of service by small movements of the generators, inadequate anchorage of the boiler columns, figure 22-2, fractures of condenser castings, and sliding of unanchored transformers. The grain storage tanks of the INCEI, figure 16-4, showed uplifting of their anchor bolts to the south, figure 16-5, and local buckling of the tanks to the north, figure 16-6, as well as near the top, figure 16-4.

3.7 Structural Effects of Nonstructural Elements

A lack of attention to these elements during structural design does not assure that they will not affect the performance of the structure. Irregularly placed infilled walls stiffen portions of the structural frame, and result in attraction of force, concentration of deformation, and loss of energy absorbing capacity. This phenonemon led to local damage in the IBM building, a multistory steel frame building, figure 72-3 and 72-4. The cracking of fully infilled masonry walls, as shown for the General Hospital at El Retiro, figure 55-5, leads to failure of reinforced framing members due to the concentration of deformation; there is no independent frame action. A sharp difference in stiffness of elements intended to act in parallel, as caused by the partial height infilled walls on the interior column line of the Ramirez Goyena School, figure 38-1, can lead to progressive failure and complete collapse, figure 38-2.

3.8 Additions and Modifications

Additions to buildings require careful attention in design because adequate continuity is difficult to achieve. The additions to the fourth floor of the Palace of Communications received their lateral support from parapet walls rather than the shear towers of the building. When the parapet walls failed, figure 5-3, complete collapse was prevented only by diaphragm action of the roof. The capacity of the roof was barely sufficient, figure 5-4, for this unintended diaphragm action.

Care must be used in penetrations of structural elements for building services to assure that sufficient structural capacity remains. Examples of incipient failure appeared in the ENALUF administration building where the shear wall was weakened by a telephone chase, figure 23-3, and by penetration for a duct, figure 23-4. Duct penetrations also contributed to shear failures in the beams connecting the shear wall towers in the Banco de America, figure 54-2.

3.9 Building Codes and the Building Regulatory System

Discussions with Nicaraguan engineers indicated that the building codes did not apply strict seismic design provisions. The subject had received considerable attention by Nicaraguan professional engineers. In fact, Professor Mete Sozen had visited Nicaragua in February 1972 to discuss the need for improved seismic design regulations.

A number of responsible engineers in Nicaragua have been applying up-to-date seismic design provisions in their own work. However, in the absence of legally enforceable requirements for earthquake resistant design, it could be economical from a short term, pre-earthquake perspective, to employ architectural or engineering services which gave inadequate attention to the threat of an earthquake. Seismic design provisions, approximately comparable to those for Seismic Zone 3 in the United States, had been considered for the Nicaraguan building code. However, it was the understanding of the NBS team that the code adopted in 1972 used seismic design provisions considerably less stringent than those originally suggested.

It also was pointed out to the NBS team that adoption of strict, up-to-date seismic design provisions in the Nicaraguan building code would not alone assure earthquake safety. Apparently, Nicaragua at the time of the Managua earthquake did not have a building regulatory system capable of assuring compliance with the building code in either design or construction phases. It was indicated that zoning requirements were the only enforced element of a building regulatory system.

In summary, most of the damages observed in Managua were caused by deficiencies in design or construction which are well known to the engineering profession [9]. These are deficiencies in the sense of being practices which are known to be inadequate in areas of strong ground shaking. However, well designed and well constructed buildings did show satisfactory performance in the Managua earthquake. This suggests that the primary cause for the extensive losses of life and property in Managua was the inadequacy of the building code for the existing degree of seismic risk and the lack of an effective building regulatory system for code enforcement.

4. REPORTS OF INSPECTIONS OF BUILDINGS

Appendix B presents translations of reports prepared for the Ministerio de Obras Publicas following inspections of the cited buildings by members of the NBS/NAE team in conjunction with Nicaraguan engineers. Field notes and photographic records were consulted in preparation of the reports given here from translations of the reports prepared in Nicaragua. Therefore, those reports presented here are not literal translations. The report numbers are those used in the Nicaraguan records. The location of these buildings are denoted by the report numbers on the maps in figures 3 and 4. Gaps in the sequence of report numbers pertain to reports on investigations in which no member of the NBS/NAE team participated.

Indicated on each of the reports is the date of investigation, that is the date in which the team visited the building, and the persons who participated in the inspection. These must be viewed as screening reports. The objectives were to determine swiftly which buildings could be used immediately with reasonable safety for vital emergency functions, which buildings could be cleared immediately where repair would obviously be uneconomical, and which buildings required more detailed studies but had reasonable prospects for rehabilitation. The time available for most of the investigations ranged from 1/2 to 2 hours, plans were generally unavailable, and equipment was not at hand for stripping off trim and finishing materials for close inspection of structural damage. It is felt that these preliminary views are useful for the record, but it must be recognized that more careful investigations will reveal damages not noted in these preliminary investigations and provide improved hypotheses for the causes of damages.

5. SUMMARY

This successful performance of much modern housing and many multistory buildings in Managua is additional evidence that good building practices can provide resistance to strong earth shaking at moderate cost. However, the many failures and large losses of life and property illustrate that earthquake hazards threaten disaster for unprepared areas.

Most damages appeared to result from deficiencies in building practices; deficiencies exhibited many times before in previous earthquakes, deficiencies which would be avoided by implementation of up-to-date provisions for earthquake resistant design and construction.

Managua did not employ a building code with seismic design requirements appropriate to its earthquake risk, and furthermore, did not have a building regulatory system capable of effective implementation of its building code provisions. The same statements apply to many seismic risk areas of the United States.

The disaster investigation team, by virtue of its early arrival at the scene, was able to assist Nicaraguan authorities when help was needed and to document seismic effects before evidence was destroyed in emergency and recovery activities. It is hoped that this information will be useful in more intensive studies leading to improvements in earthquake resistant building practices.

REFERENCES

[1] Republic of Nicaragua Background Notes, Department of State (December 1972).

[2] Brown, R. D., Jr., Ward, P. L., and Plafker, G., Geologic and Seismologic Aspects of the Managua, Nicaragua, Earthquakes of December 23, 1972, U.S. Geological Survey, Geological Survey Professional Paper 838, 34 pages (1973).

[3] Sultan, D. I., The Managua Earthquake, Military Engineer, 23, (1931).

[4] Freeman, John Ripley, Earthquake Damage and Earthquake Insurance, pp. 589-595 (McGraw-Hill Book Company, Inc., New York, 1932).

[5] Matthiesen, R. B., and Knudson, C. F., Strong-Motion Instrumental Measurements, Managua, Nicaragua Earthquake of December 23, 1972, Earthquake Engineering Research Institute, pp. 21-25 (May 1973).

[6] Evaluacion Preliminar de Danos Causados par el Terremoto de Managua de 23 de Diciembre de 1972, Instituto Centroamericano de Administracion de Empresas, Apartado Postal 2485, Managua, Nicaragua, 24 pages (5 Enero 1973).

[7] Annex to Nicaraguan Background Notes, Department of State (May 1, 1973).

[8] Lew, H. -S., Leyendecker, E. V., and Dikkers, R. D., Engineering Aspects of the 1971 San Fernando Earthquake, National Bureau of Standards (U.S.), Building Science Series 40, 419 pages (December 1971).

[9] Building Practices for Disaster Mitigation, National Bureau of Standards (U.S.), Building Science Series 46, Wright, R. N., Kramer, S., Culver, C. G., editors, 483 pages (February 1973).

APPENDIX A

List of Contacts

During the period of December 25, 1972 - January 4, 1973, the NBS/NAE team made contact with many individuals. Among those contacted were:

Nicaraguan Government and Organizations

Gen. Anastasio Somoza
Director of the National Guard

Sr. Alfonso Lovo Cordero
Member of National Governing Council

Sr. Cristobal Rugama
Nicaraguan Minister of Public Works

Ing. Jorge Hayn Vogel
Director del Departmento de Construcciones y
Mantenimiento de Edificios Publicos
Ministerio de Obras Publicas

Ing. Raul Amador Kuhl
Departmento de Construcciones y
Mantenimiento de Edificios Publicos

Ing. Edmondo Roeder
Nicaraguan Highway Department
Mechanical Maintenance Division

Ing. Adan Cajina
Director
Departmento Nacional de Acueductos y Alcantarillados

Col. Villata
Nicaraguan Air Force, C. O.

Col. Franklin Wheelock
Nicaraguan Air Force, C.O.
Airport Manager

Col. Stan Threlfall
Staff of Gen. Somoza

Dr. Abdel Karim
Head of Civil Engineering
University of Nicaragua

Dr. Carlos Muniz
Oficina de Estudios Economicos
Banco Central de Nicaragua

Sr. Arturo Roa
ENALUF

Ing. Max Kelly
Nicaraguan Engineer

Sr. Enrique Pereira
Contractor

Ing. Gaston Penalba
Nicaraguan Engineer & Contractor

United States Government and Organizations

Mr. Turner B. Shelton
American Ambassador to Nicaragua

Mr. Karl V. Steinbrugge
Chairman, U.S. National Committee
International Association of Earthquake Engineering

Mr. James Hargrove
Counsel
U.S. Embassy

Mr. Carl D. Koone
US/AID Nicaragua

Dr. S. T. Algermissen
Director
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NOAA/ERL/ESL/R1OX4

Dr. R. B. Matthiesen
Director
Seismological Field Survey
NOAA

Mr. Charles F. Knudson
Geophysicist
Seismological Field Survey
NOAA

Major Merritte H. Wilson
3d CAGP
Ft. Clayton
Canal Zone (DAST)

Mr. Alfred Chase
Madden Hydrographic Office
Balboa Heights
Canal Zone, Representing Canal Zone Red Cross

Miss Marlise Simons, Mexico City, Mexico
Latin American Correspondent to the Washington Post and Newsweek

International Organizations

Dr. Carr Donald
Organization of American States (OAS)

Col. Claudio Luis Gutierrez
Representative of the Secretary-General
Organization of American States (OAS)

Mr. Leroy Anstead
American Geologist with the
Servicio Geodesico Interamericano

Others

Dr. Cinna Lomnitz
UNESCO Seismologist
National University of Mexico

Ing. Roberto Meli
Structural Engineer
National University of Mexico

Mr. Jan Sandquist
Rapport - TV 2
Swedish Broadcast Corporation
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Captain M. M. Driver
Miami, Florida
(Lanica Airlines)

APPENDIX B

Appendix B presents translations of reports prepared for the Ministerio de Obras Publicas following inspections of the cited buildings by members of the NBS/NAE team in conjunction with Nicaraguan engineers. The report numbers are those used in the Nicaraguan records. The location of these buildings are denoted by the report numbers on the maps in figures 3 and 4. Gaps in the sequence of report numbers pertain to reports on investigations in which no member of the NBS/NAE team participated.

Report Number	Building	Type		Damage	Page No.
3	Palacio Nacional	Monumental	RC	Moderate	43
4	Mercado Periferico Oriental	Frame	RC	Severe	47
5	Palacio de Comunicaciones	Monumental	RC	Moderate	50
13	Terminal de Pasajeros del Aeropuerto Internacional "Las Mercedes"	Frame	RC	Light	54
16	Edificio Administrativo (INCEI)	Various	RC Steel	Light-severe Light-moderate	57
22	Estacion Generacion ENALUF	Steel Frame		Light	63
23	Edificio Administrativo ENALUF	Shear Wall	RC	Moderate	66
24	Subdivision Bello Horizonte	Precast	RC	Severe	70
25	Centro Escolar Salvador Mendieta	Reinforced Block		Moderate	73
35	Centro Escolar Simon Bolivar	Frame	RC	Severe	75
38	Instituto Nacional de Ramirez Goyena	Frame	RC	Collapse	79
41	Edificio del Teatro Nacional Ruben Dario	Shear Wall	RC	Light	84
42	Hotel Intercontinental	Frame	RC	Moderate	87
43	Corte Suprema de Justicia	Shear Wall Frame	RC RC	Moderate Severe	90
44	Edificio Administrativo del INSS	Frame	RC	Moderate	95
46	Instituto Pedagogico	Flat Plate Arches	RC RC	Moderate	98
52	Banco Central	Frame	RC	Moderate-collapse	102
53	Gimnasio Jorge Buitrago	Frame	RC	Severe	105
54	Banco de America	Shear Wall	RC	Light	108

Report Number	Building	Type		Damage	Page No.
55	Hospital General El Retiro	Frame	RC	Severe	110
57	Bodegas de Almacenamiento de Casa Presidencial y Mocoron	Miscellaneous		Light-severe	115
60	Casa Presidencial	Monumental	RC	Severe	121
61	Casa del Jefe Director	Monumental	RC	Severe	125
62	Radio-Difusora Nacional	Reinforced Block		Severe	128
68	Aduana	Frame Shell	RC RC	Collapse Severe	130
70	Edificio del Hospital del Seguro Social	Frame	RC	Severe	133
71	Policlinica Central del INSS	Frame	RC	Light	138
72	IBM	Frame	Steel	Light	140
73	Country Club Tejapa	Frame	RC	Collapse	144
74	Edificio Guerrero Pineda	Frame	RC	Collapse	146
75	Instituto Geografico Nacional	Infilled Frame	RC	Severe	149

Report No. 3

Date of Investigation: December 29, 1972

Building: Palacio Nacional

Inspected by: Jorge Hayn V.
Samuel Kramer
Richard Wright
Raul Amador

This is a massive reinforced concrete building with both bearing walls and columns for vertical load bearing elements and beams and slabs for horizontal load bearing elements. It is a two-story structure with a semi-basement occupying a full city block. It has four outside wings forming a hollow square and a central building on the north/south axis which contains the meeting rooms of the senate and the Chamber of Deputies. The building replaces one destroyed in the March 31, 1931 earthquake and is reputed to have been constructed with deliberate attention to earthquake resistance.

The exterior columns on the north and south facades, which appear to be primarily decorative in function, all show cracking about one meter above their base, figure 3-1. In general these cracks are very fine, however, one was noted to be open about 1/16 in on the north facade. Several minor cracks spaced about 45 in apart were noted in this column. It appears that these cracks may represent working of construction joints in these columns. There is extensive x cracking in the panels between columns on the north and south facades of the buildings, figure 3-2. This cracking is more severe where these panels have been pierced for the installation of air conditioners. The panels on the east and west sides of the vestibules for the north and south entrances of the building appear to be major lateral force resisting elements. These are reinforced concrete walls with columns of reinforcement revealed by substantial cracking, figure 3-3. The eastern stairway to the second floor at the north entrance is severely cracked. Substantial cracks cut through the roof beams and slabs in the eastern portion of the north wing and the northern portion of the east wing. There is pounding damage to the north wing, central building and south wing at their zones of contact, figure 3-4.

None of these damages appear to have severely limited the safety of the structure. However, these damages should be repaired so that the structural resistance is returned to its original level and a careful inspection should be conducted to determine whether other damages have occurred. The structure may be cleaned of broken glass and concrete which endanger occupants and returned to function while the major repairs are conducted.

Figure 3-1 Lightly cracked columns in facade, Palacio Nacional.

Figure 3-2 Cracking in panels between columns where pierced for air conditions, Palacio Nacional.

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Figure 3-3 Cracking of wall and columns at north entrance to the Palacio Nacional.

Figure 3-4 Pounding between central building and north wing, Palacio Nacional.

Report No. 4

Date of Investigation: December 29, 1972

Building: Mercado Periferico Oriental

Inspected by: Samuel Kramer
Richard Wright
Jorge Hayn V.
Raul Amador

This is a group of one-story buildings occupying a full city block. They are constructed of reinforced concrete and are from the period of 1963 to 1967. The building used by the police was given only cursory examination but appears to have escaped major structural damage. The nursery building has a heavy reinforced concrete roof supported by 12 in x 12 in reinforced concrete columns with masonry infill walls. The columns are severely damaged by the earthquake forces and appear barely capable of supporting the gravity load from the roof. There is evidence of poor, unbonded construction joints at the tops of the columns which may have contributed to their failure, figure 4-1. This building is unusable and questionably repairable.

The elementary school building shows some structural damage, but it appears to be repairable. The differences responsible for the lesser damages merit further investigation, figure 4-2.

At the principal entrance for the market, single columns support roof slabs of differing elevations; there are column damages from the high-shear forces generated by out-of-phase motions of these slab elements, figure 4-3. In the principal market building, the exterior columns are ruptured by the concentrated deformations which followed cracking of the infill exterior walls, figure 4-4. The interior columns, roughly on a 15 ft x 20 ft grid, show incipient flexural failures at both top and bottom. This building shows very substantial structural damage. A careful inspection should be conducted to assess the extent of the damage and to determine whether repairs are feasible.

Figure 4-1 Column failure at construction join in nursery building, Mercado Periferico Oriental.

Figure 4-2 Less damaged school part of the Mercado Periferico construction appears similar to nursery.

Figure 4-3 Damaged canopy columns at change of canopy elevation, Mercado Periferico Oriental.

Figure 4-4 Wall and column damage in market building, Mercado Periferico Oriental.

Report No. 5

Date of Investigation: December 29, 1972

Building: Palacio de Comunicaciones

Inspected by: Samuel Kramer
Richard Wright
Jorge Hayn V.
Raul Amador K.

This is a four-story reinforced concrete building with a basement, figure 5-1. It was completed in 1946 with only partial construction of the fourth story. Since then, the fourth story has been completed by use of steel roof trusses, and steel purlins supporting a corrugated steel roof. The principal lateral force resisting elements of this building appeared to be shear walls around towers located at the center of the north facade and at the southeast and southwest corners.

The original part of the construction appears to have suffered very little damage in the earthquake. Only limited, light cracking was observed in the shear wall towers. Secondary beams in the north facade show severe cracking. The decorative mural inside the first floor entrance has crumbled as it tried to act as a shear resisting element, and there are a number of cracks in the interior walls on the first floor, figure 5-2. Very little damage is observed on the second and third floor; it is noted that the third floor is heavily loaded by telephone switching equipment.

The new construction on the fourth floor is at a state of incipient collapse, figure 5-3. The parapet walls along the eastern and western sides of the building are strongly displaced out, hanging over the streets below, and prevented from falling only by the tension forces in the steel roof sheeting, figure 5-4. It appears that this failure resulted from inadequate attention to providing lateral force resisting elements in the additional construction or to tying it to lateral force resisting elements in the original structure.

It was recommended immediately to personnel of the Palacio de Communicaciones that measures be taken to protect people in the streets adjacent to the east and west sides of the building. It is also recommended that valuable communications equipment installed on the fourth floor be relocated to eliminate hazards to the equipment and personnel using it, since the roof structure easily could fail from a strong wind or an earthquake aftershock. It is further recommended that the new construction on the fourth floor be removed and reconstructed appropriately. Elsewhere, repair should eliminate glass, blocks, walls, and other elements showing nonstructural damage. It is important to remove glass panels from the third floor which are particularly dangerous to people working nearby.

Figure 5-1 Front of the Palacio de Comunicaciones, limited damage except at fourth floor.

Figure 5-2 Main floor with light cracking of columns and damage to infilled mural, Palacio de Comunicaciones.

Figure 5-3 Side of the Palacio de Comunicaciones, note the tottering fourth floor walls and roof.

Figure 5-4 Tube column split by pulling of roof framing, Palacio de Comunicaciones.

Report No. 13

Date of Investigation: December 27, 1972

Building: Terminal de Pasajeros del Aeropuerto Internacional "Las Mercedes"

Inspected by: Richard Wright
Samuel Kramer
Mete Sozen

The building is 21 modules long by four modules wide, each module of 6 meters, open to three floors in the north passage and the five central modules of the lobby. The three adjacent modules to the east and west of the central lobby are open from the second floor to the roof, figure 13-1. The building employs a reinforced concrete frame with slab roof and floors, except that in the central lobby area the roof employs a metal truss with skylights.

The visible damages are essentially nonstructural. There are strong cracks in the curtain wall to the east of the lobby which is built-in between the beams and columns and attempted to perform as a shear wall, figure 13-2. Cracks to the western curtain wall are less severe because this one overlays the beams abd columns; there are deformations of anchors of this wall to the supporting elements and some crushing of the concrete around the anchors, figure 13-3. There is some cracking and displacement of finishing materials. The principal structural elements appeared to be in good condition. Some nonstructural elements of the building require repairs for proper function and security of the building occupants. The building may be cleaned up and returned to service promptly.

Figure 13-1 Aisle on the ground transportation side showing superficial damages, Terminal de Pasajeros Aeropuerto Internacional.

Figure 13-2 Cracked infill wall east of lobby, Aeropuerto Internacional.

Figure 13-3 Overlayed curtain wall cracked at anchorage to frame, Aeropuerto Internacional.

Report No. 16

Date of Investigation: December 30, 1972

Building: Edificio Administrativo (INCEI)

Inspected by: Samuel Kramer
Richard Wright
Raul Amador

This facility is composed of various buildings built at different times using different systems. The nature of the buildings and their condition are described in the following paragraphs.

Terminal No. 1. This one story building is made of reinforced concrete; the columns and roof are apparently in good condition except for one infilled wall on the west which has fallen. It is believed that this building may be used following repair of minor cracks and a thorough inspection of the structural system.

The Scale Building. This is a one story, four by three bays, reinforced concrete building with infill walls enclosing six bays at the southwest. The infill walls are cracked and bulging and some columns have severe cracks. People using the northern aisle of the building are severely threatened by the collapse of these walls; they should be evacuated. The building encloses valuable scale machinery which would be damaged by its collapse.

The building should be investigated carefully to determine whether its repair is feasible and immediate measures should be taken to provide for the security of its contents.

Administration Building. This one story building consists of a reinforced concrete roof and lightly reinforced brick masonry infill walls. Exterior infill wall panels are severely cracked and the cracks have penetrated and ruptured the enclosing columns and beams, figure 16-1. Interior columns show local crushing at the top and bottom and permanent drift to the east amounting to about one inch. The building is in very insecure condition and will require extensive further study to determine whether repairs are feasible.

A new laboratory building is partially constructed at the northwest corner of the Administration building. This one story building has reinforced concrete columns, masonry infill walls and a steel truss roof. Because of the absence of diaphragms or bracing in the lower plane of the roof, it has moved sharply north and induced lateral forces in the walls which have damaged them severely, figure 16-2. It appears most effective to remove the existing column and wall construction and rebuild it; this time with appropriate attention to achieving adequate lateral force resistance.

Plant Building. This is the major grain handling and storage facility site. It consists of 18 major grain storage tanks in two rows. Each tank is some 40 ft high and 20 ft in diameter. Six smaller steel tanks are located immediately north of these. A reinforced concrete frame tower with masonry infill walls houses the elevator equipment which lifts the grain to the conveyors loading these tanks. A one-story steel frame shed at the south of the tanks is employed for grain handling operations.

There is no apparent damage to the steel frame or cladding of the shed. Some masonry interior walls show severe cracking and present a hazard to the workers in the shed, figure 16-3. These should be rebuilt either to move with the steel frame structure without undergoing damage or to stand independent of it.

Some local shear buckling is visible in the walls of the 18 tanks in the upper panels, figure 16-4. At the base of the tanks, anchor bolts are lifted as much as 5/8 in and some are broken, figure 16-5. Opposite the lifted anchor bolts some of the tanks show local buckling due to compressive forces in the lower band, figure 16-6. These damages do not appear to present hazards to personnel or use of these tanks. However, careful inspection should be made of the conditions of the conveyor systems at the top of the tanks, which was not observed in this investigation, and appropriate repairs be made where damages have been observed.

Benefico de Cafe. These are tall steel frame, steel clad mill buildings located at the north of the site. There are two major buildings which meet each other at an angle of approximately 15 degrees. They are connected by a gore in this region, it was interesting to note that the buildings were stiff enough to prevent apparent damages in spite of the differences in motion at this connection. There were some nonstructural failures of masonry walls in offices at the north of these buildings. These should be replaced by properly reinforced walls for the safety of the personnel.

Figure 16-1 Severely damaged modern reinforced concrete frame building, INCEI administration building.

Figure 16-2 Damage from movement of inadequately braced roof, INCEI laboratory.

Figure 16-3 Hazardous partition in an undamaged steel industrial building, INCEI shed.

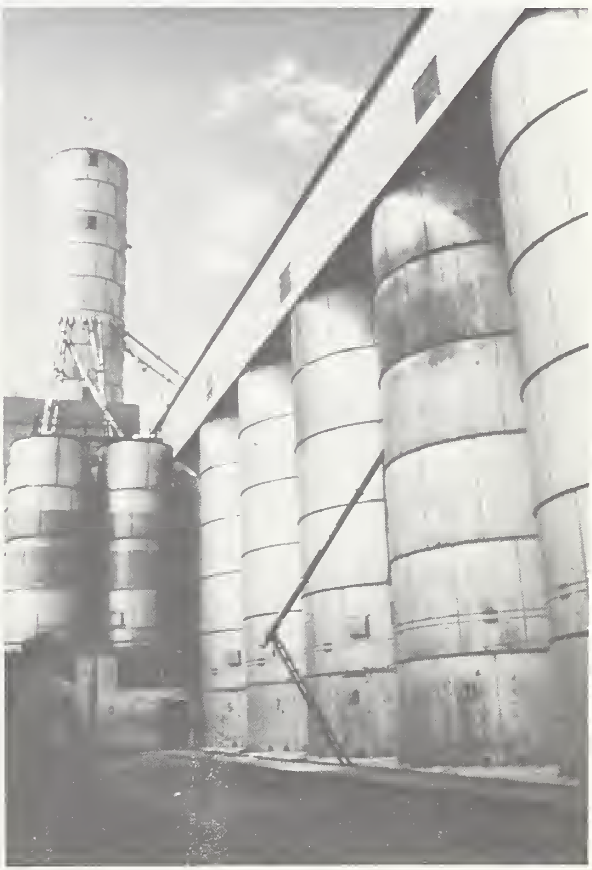

Figure 16-4 Shear buckling is visible at tops of INCEI elevators.

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Figure 16-5 Anchor bolts lifted at base of INCEI elevators.

Figure 16-6 Compressive buckling at base of INCEI elevators.

Report No. 22

Date of Investigation: December 28, 1972

Building: Estacion Generacion ENALUF

Inspected by: Mete Sozen
Richard Wright

The steel frame buildings which enclose the turbines 1 (45 MW), 2 (15 MW), and 3 (15 MW) showed no structural damage, figure 22-1. There was some breaking of glass and detachment of electrical wiring for the overhead cranes. Some of the equipment was displaced from its foundations because of inadequate anchorage. Boiler anchor bolts were broken and firebrick walls were bulged, figure 22-2. A stack showed a cracked weld at the top of the third segment, figure 22-3.

The one story, 30 ft x 50 ft switch gear house consisting of lightly reinforced concrete block walls 15 in thick and a heavy reinforced concrete roof supported by beams at 6 ft spacing showed very severe cracking in the concrete block walls, figure 22-4. The building is very close to collapse upon the vital equipment it encloses. It should be braced immediately and given high priority for reconstruction since the electrical supply for the city is dependent upon the equipment it shelters.

Figure 22-1 Only window damage notable in the main turbine building, Planta Electrica ENALUF

Figure 22-2 Broken anchor bolts in boiler columns, Planta Electrica ENALUF.

Figure 22-3 Cracked weld in stack, Planta Electrica ENALUF.

Figure 22-4 Severely damaged concrete block bearing walls of switch gear house at Planta Electrica ENALUF.

Report No. 23

Date of Investigation: December 28, 1972

Building: Edificio Administrativo ENALUF

Inspected by: Richard Wright
Samuel Kramer
Mete Sozen
Abdel Karim

This is a reinforced concrete building with basement, ground floor and six additional floors with a reinforced concrete frame braced by reinforced concrete shear walls around the central core of the building, figure 23-1. In general the exterior of the building and the interior space dividers are in excellent condition, figure 23-2. The shear walls functioned effectively in reducing the earthquake deformations of the building to a level producing little cosmetic damage. However, a substantial amount of cracking was found in the shear wall structure. On the ground floor, local crushing of the shear wall was observed at a splice zone near the floor level where the wall was weakened by a telephone chase, figure 23-3, and at the ceiling level adjacent to a penetration in the shear wall for a duct, figure 23-4. Additional cracking in the shear wall was noted at the basement level. Light cracking in the shear wall was noted from the third through the fifth floors of the building, figure 23-5. The absence of notable cracking on the first and second floors, perhaps was due to an unintended bracing action of the decorative exterior arches. It was noted that the counter weights for the elevators had been displaced by the shock, and other minor cosmetic damage was visible in the building.

Since the damages to the shear wall represent a partial failure of the structure, a detailed engineering inspection and repairs of the damages are required before the structure is returned to service.

Figure 23-1 Shear wall-frame building with little exterior damage, Edificio Administrativo ENALUF.

Figure 23-2 Relatively light interior nonstructural damage, Edificio Administrativo ENALUF.

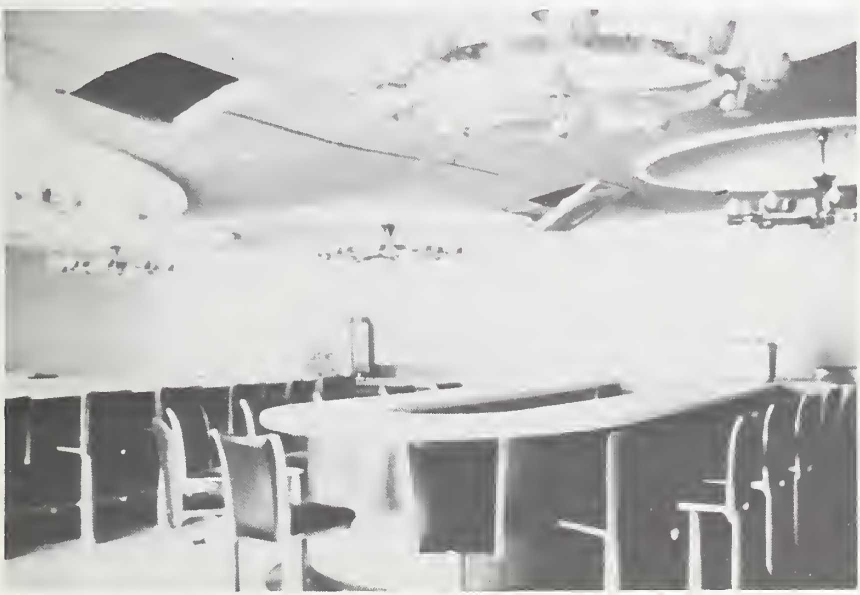

Figure 23-3 Shear wall crushing at first floor where weakened by telephone chase, Edificio Administrativo ENALUF.

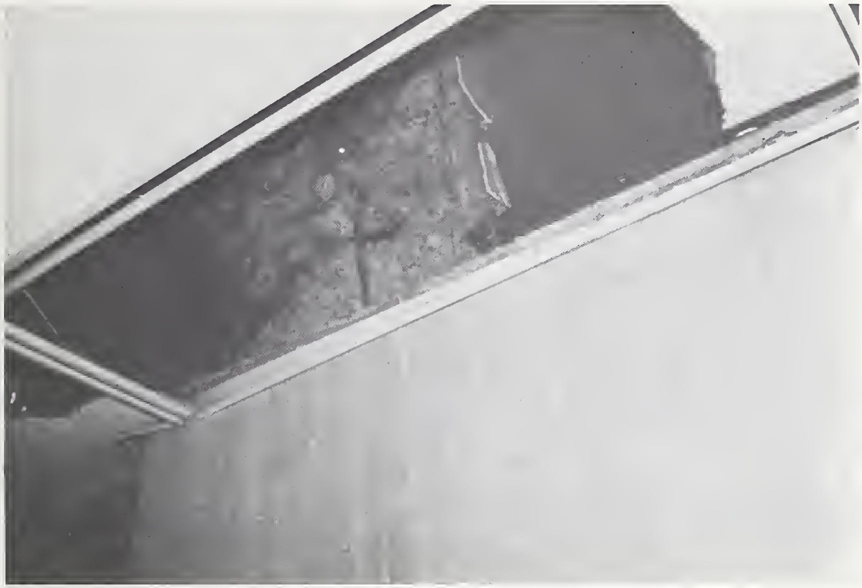

Figure 23-4 Shear wall crushing near ceiling on first floor where penetrated by duct, Edificio Administrativo ENALUF.

Figure 23-5 Cracking in shear wall on third floor, Edificio Administrativo ENALUF.

Report No. 24

Date of Investigation: December 30, 1972

Building: Subdivision Bello Horizonte

Inspected by: Raul Amador K.
Samuel Kramer
Richard Wright

The houses of the subdivision are single and duplex units with cast-in-place reinforced concrete walls and prefabricated roof panels in the form of a channel, figures 24-1 and 24-2. The dwelling units are approximately 20 ft wide by 40 ft deep. The prefabricated roof panels bear on the precast concrete walls hich are about 4 in wide. The concrete roof slabs are approximately 3 in thick with the flanges of the channel approximately 12 in high; the panels are about 8 ft wide and 22 ft long. Metal pads at the four corners of the roof slabs are used for connection to similar pads embedded in the walls. The connection is by a 3/16 in fillet weld about 1 in long, figure 24-3. In single houses, the roof slabs overhang the walls at each side by about 8 in. In the duplex units, one wall supports two panels so that the zone of contact is limited to about 2 in and welds may have been omitted.

In most of the dwelling units, the roof slabs were observed to have broken loose from the walls and to have translated, sometimes enough to allow the roof slab to fall into the dwelling unit, particularly for the duplex units which have very little overlap of the roof slab on the wall, figure 24-4. The degree of damage to the walls themselves appears quite small; there were small cracks in the walls near the apertures and sometimes cracking where the connecting pads were anchored in the wall slabs. Most of these buildings appear to be repairable. In the repairs, attention should be given to achieving a stronger connection between the roof slab and the walls to prevent repetition of this damage in a future earthquake.

Figure 24-1 The tilted precast roof channels have slid off walls, Bello Horizonte.

Figure 24-2 Cracking in walls at attachment of roof channel, Bello Horizonte.

Figure 24-3 Broken weld at connection of roof channel, Bello Horizonte.

Figure 24-4 Unfastened roof channel in duplex unit, Bello Horizonte.

Report No. 25

Date of Investigation: December 30, 1972

Building: Centro Escolar Salvador Mendieta

Inspected by: Ing. Raul Amador K.
Ing. Samuel Kramer
Ing. Richard Wright

The Centro Escolar Salvador Mendieta, located in the Colonia Centro America, consists of buildings with 6 in concrete block walls reinforced with bond beams and columns and covered by a light corrugated metal roof supported by timber trusses. The buildings of the school are connected by a corridor covered by a slab of concrete supported on 4 in diameter steel pipes as well as some panels of brick and columns of concrete.

This school is located in the area most damaged in the 1968 earthquake. The block walls had been cracked in the earlier earthquake and repaired and the supports for the covered corridor had been strengthened following damages in the earlier earthquake, figure 25-1. Many of the school walls are severely cracked by the recent earthquake with the cracks penetrating the bond beams. Poor anchorage of reinforcement at the intersections between bond beams and columns contributed to the damage as did inadequate grouting of the reinforcing steel in the voids of the blocks, figure 25-2. There is severe cracking in the curtain walls in the areas of the bathrooms.

Because the roof is light, reducing the earthquake forces in the structure, it appears feasible to repair these damages and return the structure to service. Attention should be given to improving the reinforcing of the block wall during the repairs.

Figure 25-1 New damage over repaired cracks from the 1968 earthquake, Centro Escolar Salvador Mendieta.

Figure 25-2 Failure of bond beam and column near aperture, note inadequacy of anchorage of reinforcement at corner.

Report No. 35

Date of Investigation: December 30, 1972

Building: Centro Escolar Simon Bolivar

Inspected by: Ing. Raul Amador K.
Ing. Samuel Kramer
Ing. Richard Wright

This school has two types of buildings. An old building of taquezal (timber posts with wood slats on both sides at about 12 in spacing packed with mud) wall construction and a tile roof has suffered major damage which would require very costly repairs, figure 35-1. The other two buildings are two story reinforced concrete buildings, figure 35-2. The southernmost of these is made up of two parts separated by an expansion joint. These buildings have reinforced concrete frames with infill tile exterior walls, and tile cross walls separating the classrooms. The second floors are composed of concrete joist construction with block fillers and finishing courses amounting to a total weight of approximately 60 psf. The roofs are of lightweight construction with steel trusses at 3.6 meters supporting an asbestos cement corrugated roof.

Damages to the latter structures were confined to the first story. On the south faces, the infill walls are interrupted by windows and on the north faces by ventilation spaces. The columns and brick piers between these windows or ventilators have been sheared, figures 35-3, 35-4, and 35-5. All of the fence around the school has overturned.

These buildings cannot be used without extensive repairs. One approach to repair would be to place shear walls of reinforced concrete, reinforced vertically and horizontally and well-keyed into the second floor framing. It is notable that these buildings were recently completed and have never been occupied.

Figure 35-1 Old building of taquezal construction, Centro Escolar Simon Bolivar.

Figure 35-2 New building of reinforced concrete and masonry construction, Centro Escolar Simon Bolivar.

Figure 35-3 Sheared columns above infill wall, Centro Escolar Simon Bolivar.

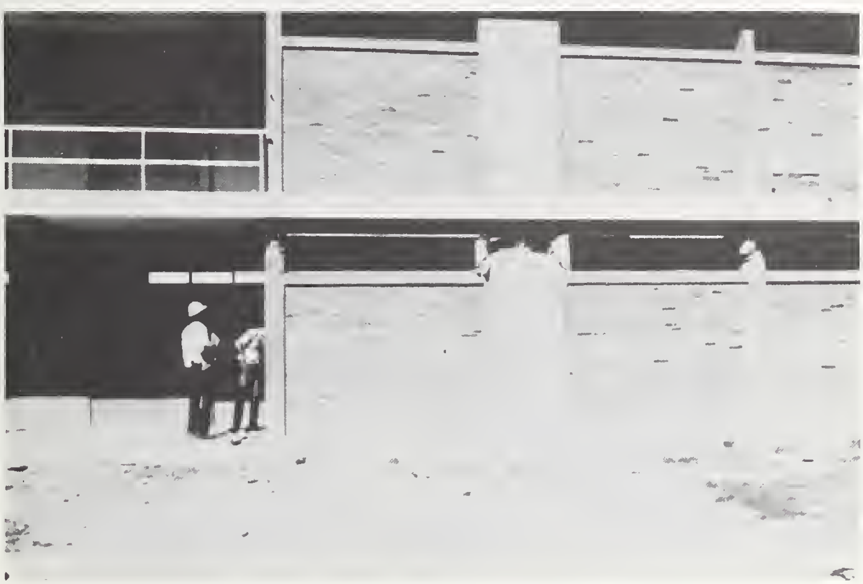

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Figure 35-4 Fallen end wall and sheared columns, Centro Escolar Simon Bolivar.

Figure 35-5 Arrows show masonry piers on either side of reinforced concrete columns were ineffective, Centro Escolar Simon Bolivar.

Report No. 38

Dates of Investigation: December 30, 1972

Building: Instituto Nacional de Ramirez Goyena

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

This school building is made up of three major wings. The west wing was three stories tall plus a semi-basement with a central corridor and classrooms on both sides. The south wing is two stories tall with offices and classrooms on the south side and an open corridor on the north. The east wing is two stories tall with a central corridor and classrooms on both sides. Connected to the east wing at the northeast side is a gymnasium. The roof is supported by steel trusses running north to south. The trusses are supported by concrete columns infilled with concrete block walls.

On the second floor of the east wing and on both floors of the south wing, the interior columns are broken and sheared at the top of the partial height infilled wall which separates the rooms from the corridor, figure 38-1. The small section of column subject to deformation at the interior column line is much stiffer than the exterior columns, attracts more load, fails, then the exterior columns must carry the total earthquake and gravity forces.

The top two stories of the west wing and the stair tower at its northern end are completely collapsed, very likely from progressive failure after the type of failure of the interior columns observed in the other two wings, figure 38-2 and 38-3. It was apparent that undeformed reinforcing steel had been used in the construction of this building which was completed in 1954.

There was no bracing in the lower chord plane of the trusses of the gymnasium to transfer the lateral forces to the walls at the east and west ends. Therefore, the trusses have shifted north as much as 12 in which fractured the columns and wall on the south side, where connections to the east wing of the building stiffened the supporting columns and wall, and bulged the north wall of the building, figure 38-4. The westerly columns and wall were severely cracked in shear but not strongly displaced, figures 38-5 and 38-6.

The building appears to be in very insecure condition. The portions which have not fallen may fall at any moment. The damages are so severe that repair appears to be impracticable.

Figure 38-1 Sheared columns above partial height wall, Instituto Nacional Ramirez Goyena.

Figure 38-2 Collapse of upper two stories of the west wing from the courtyard, Instituto Nacional Ramirez Goyena.

Figure 38-3 Street view of the collapsed upper two stories of the west wing, Instituto Nacional Ramirez Goyena.

Figure 38-4 Broken wall on south side of gymnasium where school wing connects, Instituto Nacional Ramirez Goyena.

Figure 38-5 Lesser damage of south wall of gymnasium at more flexible west end, Instituto Nacional Ramirez Goyena.

Figure 38-6 Shear of columns at west wall of gymnasium, Instituto Nacional Ramirez Goyena.

Report No. 41

Date of Investigation: December 31, 1972

Building: Edificio del Teatro Nacional Ruben Dario

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

This building which was completed in 1969 has steel exterior columns at the facade and a reinforced concrete shear wall and frame system at the interior of the building, figure 41-1. There are two reinforced concrete access bridges leading to the building.

The slabs of the access bridges are in perfect condition. There are minor damages at the abutements of the bridges resulting from hammering out of the expansion joints and perhaps some settlement of the abutments, figure 41-2. The columns which support the slab show light cracking at various elevations. These do not appear to be important but a careful engineering investigation should be carried out as part of the program of repair.

The only damages visible from the outside of the building involve the breaking of a few panes of glass and some damage to exterior masonry walls. The interior could not be carefully inspected because of the lack of electric illumination. There were some interior damages to the Chiltepe block and a few panels of the suspended ceiling had fallen, figure 41-3 and 41-4. However, there were no visible evidences of structural damage. A careful examination of the structure should be carried out as part of the repair program, but it appears that the structure will be ready for use following the minor cosmetic repairs.

Figure 41-1 South facade of theatre showing some loss of finish, Teatro Ruben Dario.

Figure 41-2 Pounding of access pedestrian bridge on abutment knocked out joint material, Teatro Ruben Dario.

Figure 41-3 Minor finish damage amounted to fallen ceiling panels and some chips from the chandeliers, Teatro Ruben Dario.

Figure 41-4 Fallen bust of Ruben Dario, Ing. Raul Amador of Nicaraguan Ministry of Public Works, Teatro Ruben Dario.

Report No. 42

Date of Investigation: December 31, 1972

Building: Hotel Intercontinental

Inspected by: Abdel Karim C.
Mete A. Sozen

The structure is a moment resisting concrete frame, figure 42-1. Preliminary investigation revealed two failed columns in the first floor. The columns carrying the mechanical penthouse also have failed, figures 42-2 and 42-3. It is recommended that:

A. All beam-column connections (currently covered by architectural details) be inspected.

B. The building reanalyzed before repairs for ground motion 1.5 times that measured at the Esso refinery or for ground motion resulting from a site study.

Figure 42-1 General view of Hotel Intercontinental.

Figure 42-2 Minor facade cracking and displacement of mechanical penthouse, Hotel Intercontinental.

Figure 42-3 Failures of columns supporting mechanical penthouse, Hotel Intercontinental.

Date of Investigation: December 31, 1972

Building: Corte Suprema de Justicia

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

This building, which was completed in 1967, consists of two main wings. At the east, there is a six-story tower on a semi-basement with a reinforced concrete frame and shear walls at each of the four corners. On the west, there is a two-story plus semi-basement structure with a reinforced concrete frame. There are a number of courts cut into the west wing by omission of floors and walls.

There is very severe damage to the finishing materials in the west two-story wing. Structural damages seem less severe. In the region where courts have been out from the building, the beams crossing the courts have been severely damaged, completely pulled apart in many instances by relative movements of the nearly separated elements of the building, figures 43-1 and 43-2. Columns adjacent to these courts show evidence of severe damage. Where the interior columns lines change at the south of this building (the northwest corner of the library) there is severe damage to the column apparently generated by the concentrated deformations induced from a crack in the reinforced concrete wall at the north of the library which is framed in by this column. Here, the roof slab over the stairway is pulled loose and ready to collapse, apparently by relative movements between the elements of the building which could move independently because of the interruption in the floor slabs.

This building has very severe non-structural damage and some important structural damage. The damaged non-structural elements should be removed and a careful inspection carried out prior to planning the structural repairs. The extensive failures of non-structural elements (decorative grills, windows, tile walls, etc.) would have represented a severe hazard to the lives of the building occupants if the earthquake had occurred while the building was occupied. The replacement non-structural elements should be designed to be much less hazardous to the occupants. It appears that the building is structurally repairable, however, consideration should be given to means of strengthening the structure for future earthquakes when the repairs are conducted.

The six-story east wing of the building shows much damage to the covering materials on the outside, figures 43-3 and 43-4. Again, the falling marble panels constitute a severe hazard to personnel. There is substantial cracking in the walls around the elevator shaft and stairway at the west of the building. The infilled tile walls for the penthouse on the roof have fallen out and access to the roof was difficult. However, no visible damage to the penthouse frame could be observed from a vantage point near the top of the access stairway. The columns of the building showed evidence of structural damage only in the sixth floor where the southwest column is crushed at the top of the parapet wall, and the southeast, northeast and northwest columns are cracked at similar positions. The four shear walls for the building show evidence of light cracking in the first and second floors, figure 43-5, and some pounding damage at the roof level of the two story wing. The remarks made about replacement of the finishing elements with less hazardous material applied to the six story building as well as the three story building. The structural damage in the six story building is more limited, repairs are certainly required for the columns on the sixth story and a careful inspection should be made of the shear walls and other column and frame elements to determine whether any additional repairs are required.

In general, it appears that these buildings can be returned to service following appropriate repairs which will include moderate repairs of damaged structural elements and major repairs of the non-structural elements of the buildings.

Figure 43-1 Ruptured beams connecting building elements across a courtyard, Corte Suprema de Justicia.

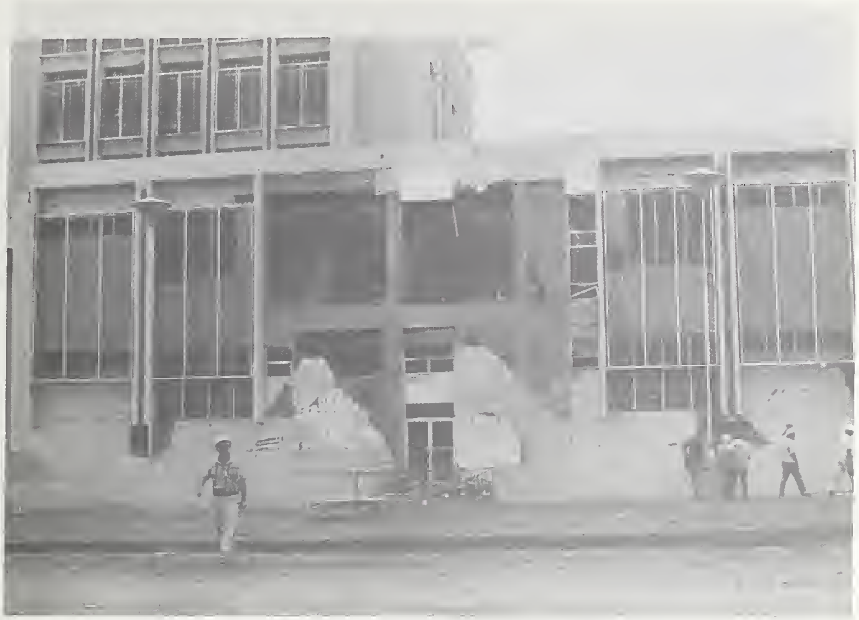

Figure 43-2 Extensive nonstructural damage in two story wing, Corte Suprema de Justicia.

Figure 43-3 Nonstructural damage on 6 story wing, Corte Suprema de Justicia.

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Figure 43-4 Extensive loss of exterior finish panels on 6 story wing, Corte Suprema de Justicia.

Figure 43-5 Damage to shear walls at first floor level, Corte Suprema de Justicia.

Report No. 44

Date of Investigation: December 31, 1972

Building: Edificio Administrativo del INSS

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

This is a nine-story reinforced concrete frame building with two story wings at the northeast and southeast corners, figures 44-1 and 44-2. The building was completed in 1962. It appears to be a moment resistant concrete frame with two lines of cylindrical columns[1] supporting the nine-story building, two intersecting lines of columns at the east support the wings, major beam elements connect the columns; the floors are waffle slabs with tile fillers. There was no indication of shear wall elements.[2]

There is extensive damage to the curtain walls and windows, the walls around the stairway, and the light concrete frame and infill masonry walls[2] around the elevator shaft, and in the masonry infill wall at the west of the building. The only apparent structural damage in the main frame appeared in the columns on the ninth floor. This consisted of small flexural cracks at the tops of some columns and crushed column tops at the east of the building under the mechanical penthouse. The mechanical penthouse on the roof had collapsed on the top of the water tank and elevator equipment, figure 44-3.

It appears that the building is basically in sound structural condition and suitable for repair. The damaged non-structural elements should be removed, and the structure carefully inspected prior to restoration of the non-structural elements. The replacement roof for the mechanical equipment certainly could be of lighter construction.

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[1] Later investigations with access to plans note columns are spirally reinforced.

[2] Later investigators noted concrete walls around elevator shaft acted as shear walls.

Figure 44-1 Main entrance to nine story frame showing absence of structural damage, Edificio Administrativo INSS.

Figure 44-2 Facade shows limited nonstructural damage and collapsed mechanical penthouse, Edificio Administrativo INSS.

Figure 44-3 Collapsed mechanical penthouse, Edificio Administrativo INSS.

Report No. 46

Date of Investigation: December 31, 1972

Building: Instituto Pedagogico (on Avenue Roosevelt)

Inspected by: Abdel Karim
Ricardo Morales
M. A. Sozen

The buildings include three types:

1. <u>Old Two Story Building</u>

   These are made of sandstone and mixed taquezal-like construction with wooden floors, figure 46-1. Although they survived the earthquake, they would not qualify under an earthquake-resistant building code. Suggest demolition.

2. <u>Five Story Building</u>

   This "Reticular" flat plate building has a permanent deformation of approximately 15 cm toward the west at the top floor, figure 46-2. Cracks exist at bottoms of slabs along column lines where bottom reinforcement was stopped or lapped, figure 46-3. Flexural cracks appear in columns, figure 46-4. The structure is still intact and the building may be restored by adding reinforced concrete shear walls after an appropriate analysis. It should be closed until repaired.

3. <u>Chapel</u>

   Several arches were structurally damaged by transverse motion, as well as the structure near the east end, figures 46-5 and 46-6. The building is not in danger of collapse but should be repaired (after an appropriate analysis) as soon as possible. It should be closed until repaired.

Figure 46-1 Old building and chapel of the Instituto Pedagogico.

Figure 46-2 Displacement of building and cracking of slabs, Instituto Pedagogico.

Figure 46-3 Slab cracking along column lines,
Instituto Pedagogico.

Figure 46-4 Cracking of columns,
Instituto Pedagogico.

Figure 46-5 Cracking in arches of chapel, Instituto Pedagogico.

Figure 46-6 Damages at ends of beams at connections to arch, Instituto Pedagogico.

Date of Investigation: December 29, 1972

Building: Banco Central

Inspected by: A. Karim C.
M. A. Sozen

This report is limited to the main high-rise building of the bank, figures 52-1 and 52-2. The structure appears to have no critical damage in its main load carrying elements. However, it is recommended that the following actions be taken before it is repaired and occupied.

1. Check connections of the columns and beams on the "skin", especially at the fourth floor.
2. Check cracking of the shear walls below the seventh floor.
3. Check connections of the floor beams with the columns at levels above the fourth story, especially on the west end of the structure.
4. Analyze the structure for a base motion input at least 50 percent more intense than the one measured at the Esso Refinery on December 23, 1972 or according to the results of a complete site study.

The frame was sufficiently flexible to allow extensive non-structural interior damage, figures 52-3 and 52-4.

Figure 52-1 Banco de America (left) and Banco Central (right) survived amid collapsed low buildings of taquezal construction.

Figure 52-2 Collapsed auditorium and cracked infill walls on framed tube tower.

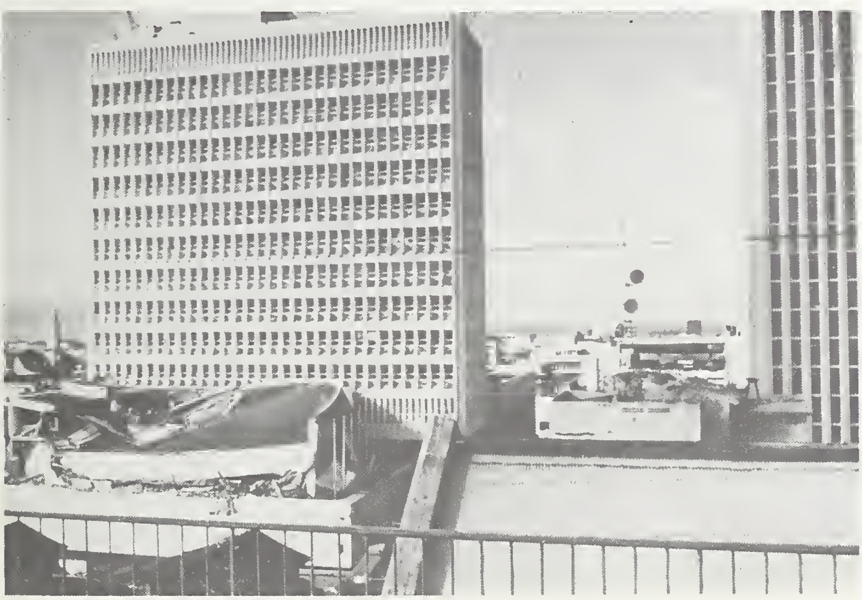

Figure 52-3 Nonstructural damage in an office, Banco Central.

Figure 52-4 Suspended ceiling fallen to floor of main lobby, Banco Central.

Report No. 53

Date of Investigation: December 31, 1972

Building: Gimnasio Jorge Buitrago (Catholic University)

Inspected by: A. Karim
Mete A. Sozen

The building is in precarious condition. Long prestressed concrete girders appear to have no continuity with the columns, figure 53-1. Several slab elements on the roof are detached, figure 53-2. The building should be closed immediately. (On December 31, 1972, it was being used for food storage with watchmen in the building.) Repair may be possible after analysis and provision of a structural system to resist the shear forces due to earthquake motions.

A one story building with a shell roof exhibits failures of the supporting columns, figure 53-3. A multistory reinforced concrete frame building, under construction and partially infilled shows frame failures in unfilled stories, figure 53-4.

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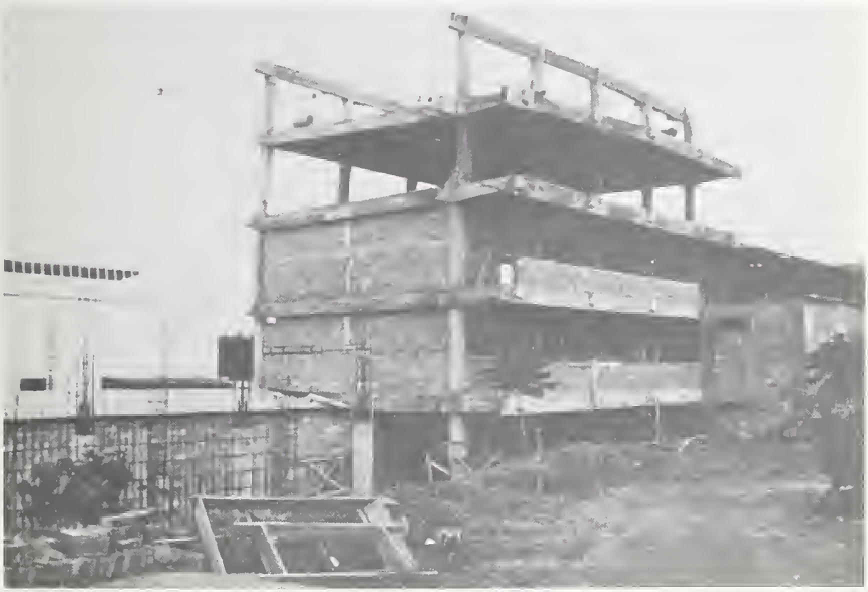
Figure 53-1 Poor continuity of girders to columns of gymnasium, Seminario Catolico.

Figure 53-2 Damaged framing of gymnasium, Seminario Catolico.

Figure 53-3 Severely damaged columns supporting shell roof, Seminario Catolico.

Figure 53-4 Frame failures in building under construction, Seminario Catolico.



Report No. 54

Date of Investigation: December 30, 1972

Building: Banco de America

Inspected by: A. Karim
Mete A. Sozen

This is a 17 story reinforced concrete shear-wall frame building, figure 52-1. The main shear cores of this building have survived the earthquake quite well. However, most of the connecting beams are destroyed, figure 54-1. The following actions are recommended prior to repair and occupation of the building:

1. Analyze the structure (in the form it is to be completed for a base motion input at least 50 percent more intense than the one measured at the Esso Refinery on December 23, 1972, or according to the results of a complete site study).
2. Check shear walls for alignment in the vertical direction.
3. Check connections between slab and edge of columns and shear walls at levels above the seventh floor.
4. Check slab between shear walls at levels above the 12th floor.

The good condition of the interior shows the advantages of the drift restraint provided by shear walls, figure 54-2.

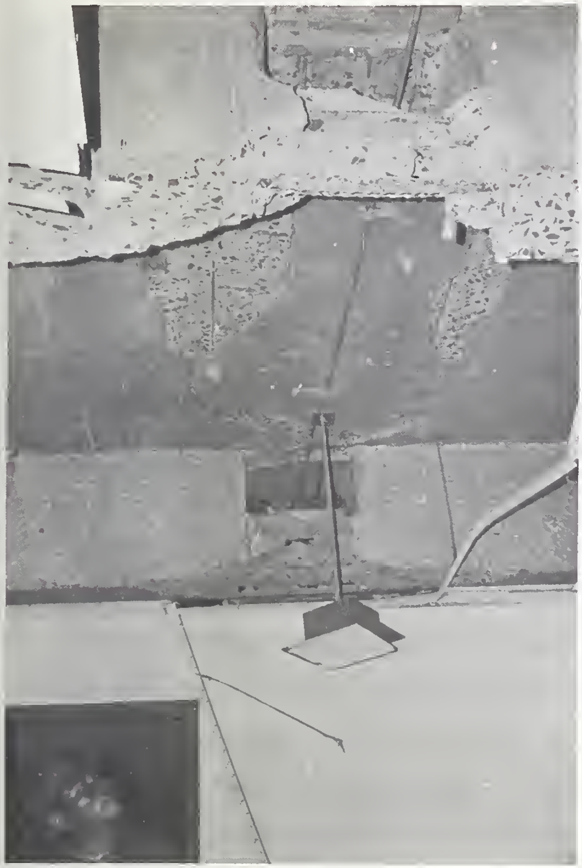


Figure 54-1 Failures of beams connecting shear wall towers, Banco de America.

Figure 54-2 Good condition of interior due to control of drift, Banco de America.

Date of Investigation: December 28, 1972

Building: Hospital General el Retiro

Inspected by: M. A. Sozen
Samuel Kramer
Richard Wright
Abdel Karim

This building with four, three-story wings on a semi-basement and a four-story central portion was completed in 1962, figure 55-1. It appears to be a reinforced concrete frame without shear walls. Damage at the north front of the building is substantial, figures 55-2, 55-3, and 55-4. Exterior columns in the walls of the wings are extensively broken by cracks originating in the infill walls which caused concentration of deformations in the columns, figure 55-5. Interior columns in the wings show little distress, figure 55-6. The four story building at the intersection of the wings shows severe damage to columns and partial collapse at the south of the third floor, figure 55-7. The damaged columns appear to be reinforced with undeformed steel which is very lightly tied.

Major repairs would be required to make the structure safe for future occupancy. Changes in the structural system, such as additions of shear walls, would appear to be necessary to avoid similar damages in future earthquakes.

The insubstantial warehouse for medicines was essentially collapsed; the vital supplies conserved by the strength of their shelving, figure 55-8.

Figure 55-1 Aerial view from the rear, Hospital General El Retiro.

Figure 55-2 Damage at north facade of Hospita General El Retiro

Figure 55-3 Column damage at entry canopy, column and wall damage on wing, Hospital General El Retiro.

Figure 55-4 Damage at base of canopy columns, undeformed reinforcing, Hospital General El Retiro.

Figure 55-5 Detail of column and wall damage in north facade, undeformed reinforcing, Hospital El Retiro.

Figure 55-6 Interior view at main entrance, only nonstructural damage apparent, Hospital General El Retiro.

Figure 55-7 Third floor of the Hospital General El Retiro near collapse at rear.

Figure 55-8 Medical supply warehouse supported by shelving inside, Hospital General El Retiro.

Report No. 57

Date of Investigation: January 1, 1973

Building: Bodegas de Almacenamiento de Casa Presidencial y Mocoron

Inspected by: Samuel Kramer
Richard Wright
Raul Amador Kuhl

The Presidential house and its storerooms are located at the crest of the extinct volcanic cone containing Lake Tiscapa. It appears that the ground at the crest is sliding to the north down the face of the cone and to the south into the lake. If there are any intentions to continue to use these buildings and storerooms, it will be necessary to make topographic surveys to determine how much movement occured during the earthquake of December 23, 1972, and whether this movement is continuing. There is considerable danger of new motions during the rainy season, even if motions are not presently occurring, and further motions in future earthquakes. Therefore, while the following paragraphs apply to the condition of individual storerooms, it should be recognized that the whole site around the Presidential house may be dangerously unstable and unsafe for any type of occupancy.

a. Storeroom located below the principal terrace of the Presidential House, figure 57-1.

   In spite of the fact that the roof and structural framing of the portico above this warehouse has collapsed on top of it, there is no apparent damage to the slab which forms the roof of the warehouse. We saw no damages of substantial magnitude. It may be considered secure while the rubble and the structure above do not affect it. The structure above and the rubble from the damaged part should be carefully removed to avoid damage from further collapses. The absence of cracking in this storeroom indicates that its foundations, if they have moved, have moved as a whole.

b. Storeroom next to the CCN.

   In this storeroom, there are serious damages to the beams, columns, walls and floors caused by the motions and settlements of the foundations. Its repair is not recommended while further motions or settlements of its foundations are possible; everything stored here should be removed.

c. Storeroom of the Pines, figure 57-2.
   This storeroom is located below the parking area and access drive to the north of the Presidential house. The retaining wall which forms the southern wall of this storehouse has failed completely at its eastern end. The reinforced concrete columns which support the ceiling of the storeroom (the slab of the parking area above) are severely crushed or cracked at the top throughout the length of the warehouse. There are also strong cracks in the north wall and in the interior and exterior floor slabs. It is clearly evident that there has been sliding and settlement of the soil around and under this warehouse to the north. It appears that the structure is ready to collapse; it should be evacuated totally. The passage of vehicles over its failing southern retaining wall should be minimized; those vehicles which must pass should move as far to the south of the road as possible. It may be possible to repair this storeroom if it has been determined that its foundations can be stabilized. There is substantial hazard that this storeroom will fail completely when its supporting soil is weakened at the beginning of the rainy season.

d. Combination magazine.
   This storeroom is apparently in good condition.

e. Gallery of the armored forces.
   The columns of concrete which support the wooden roof trusses show flexural failures at their bases. The damages may be repaired; however, repairs should include development of a lateral bracing system for the building capable of preventing such damages in the future.

f. Medical dispensary.
   This building is completely fallen.

g. Artillery barricks.
The columns are severely damaged; major repairs and reconstruction are required.

h. School
All of the timber columns have failed. The general condition of the structure does not justify its repair.

i. Storeroom of the water tank
The concrete structure supporting the old water tank is in good condition. However, large cracks are seen in the surrounding soil which indicate that the foundations of this structure are insecure.

j. The school of training for enlistees
This is completely fallen. The magazine below shows large cracks at the entrance caused by the settlements of the surrounding soil. Structural repairs should not be made until an investigation shows that stable foundation conditions exist. It was not possible to enter the storeroom to determine the conditions of the walls, columns, and slab.

k. Electric plant
These buildings appear severely damaged and unworthy of repair.

l. The storeroom of the tower
This is damaged severely as a result of soil motions and foundation instability.

m. Artillery magazine
Severely damaged

n. Jail
This building is apparently on an unstable foundation; it should be evacuated and demolished.

o. Storeroom under the residence of the Chief Director
This shows substantial damages to the columns, walls, and floors. It is evident that there has been vertical and lateral displacement of the building's foundation toward the lake. It is doubtful that the

foundations can be stabilized to permit effective repair of the building. It should be evacuated.

p. Storeroom in front of the barricks of Mocoron
This building is formed of concrete block walls with reinforced concrete bond beams and columns. The east faces are seriously deformed and cracked, the west wall has collapsed, the roof timbers are broken under the corrugated metal roofing. The building appears unstable and too severely damaged to justify repair. It should be evacuated.

q. Storeroom Nos. 13, 14 and 15 at Mocoron
The structures are in good condition except that the wing walls at the entrances of storerooms 14 and 15 have fallen and should be repaired prior to the rainy season, figure 57-3. The metal door of storeroom 15 should be adjusted for easier use.

Note that separate reports Nos. 60 and 61 have been prepared on the Presidential house and the residence of the Chief Director.

Figure 57-1 Collapse of roof over terrace, Casa Presidencial.

Figure 57-2 Cracking in road in front of house above retaining wall of the Storeroom of the Pines, Casa Presidencial.

Figure 57-3 Wing wall collapsed at right of entrance, Bodegas de Almacenamiento de y Morocon.

Report No. 60

Date of Investigation: January 1, 1973

Building: Casa Presidencial

Inspected by: Samuel Kramer
Richard Wright
Raul Amador K.

The building is located at the crest of an extinct volcanic cone as noted in Report No. 57. It is a two story building constructed of reinforced concrete, masonry, and some steel elements and evidently was constructed in many stages, figure 60-1.

The coverings of terraces at the northeast and northwest of the principal entrance have fallen, figures 57-1 and 60-2. These were steel truss roof elements supported by reinforced concrete columns and beams. The ground floor of the building shows extensive cracking in the reinforced concrete walls and columns with a concentration of cracking at the levels penetrated by doors and windows, figures 60-3 and 60-4. In these areas, the reinforcing was revealed to be undeformed bars. The floor at the back of the main lobby is settled; it was not ascertained whether there was earthfill or damaged structure below this. The western portion of the second floor shows very little damage. In the central portion, the fireplace wall shows extensive cracking and the south central portion of the floor is displaced south toward the crater lake Tiscapa. The roof of the building does not show cracking but major elements of the building are separated.

The building requires extensive and expensive repairs. However, it would be essential to assure stability of the foundations of the building prior to any consideration of repairs. At present, the building site appears to be sliding both to the north down the side of the hill and to the south into the crater lake, figures 60-5 and 60-6.

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Figure 60-1 Main entrance showing extensive damage, Casa Presidencial.

Figure 60-2 Detail of collapsed terrace roof, Casa Presidencial.

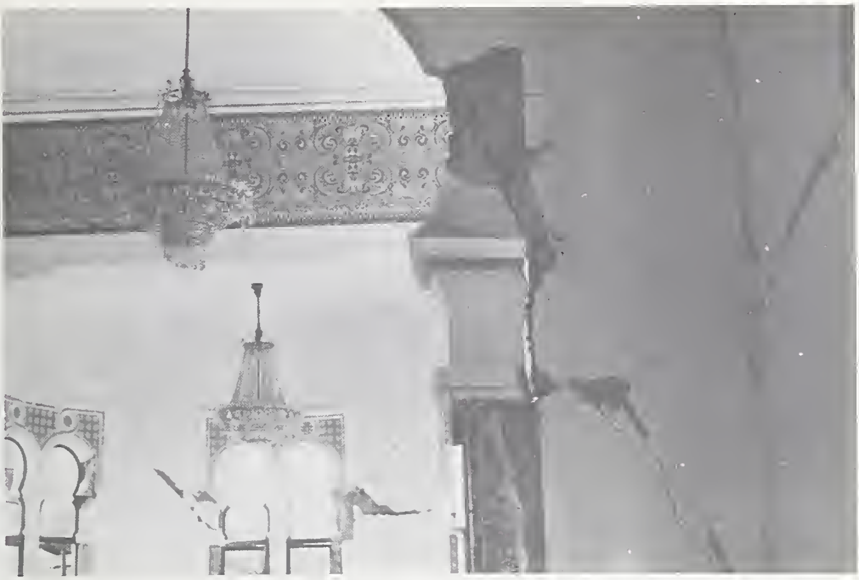

Figure 60-3 Details of interior damage, Casa Presidencial.

Figure 60-4 Interior damage in main lobby, Casa Presidencial.

Figure 60-5 Cracking of walls at rear of building, Casa Presidencial.

Figure 60-6 Subsidence cracking in road at northwest of Casa Presidencial.

Report No. 61

Date of Investigation: January 1, 1973

Building: Casa del Jefe Director (La Curva)

Inspected by: Samuel Kramer
Richard Wright
Raul Amador

This is a two-story reinforced concrete building completed in 1947 and located to the east of the Presidential house.

One of the two roof towers has fallen and penetrated the ceiling of the lobby at the entrance of the first floor, figures 61-1 and 61-2. The other tower is sheared and ready to fall. There is extensive wall, beam, and column cracking in the first floor of the building. In the basement of the building there is heavy cracking of the walls, light cracking of some columns, and heaving of the floor or penetration of the wall footings. At the west end of the basement, the east wall is heavily cracked, a west end column is crushed at mid height, figure 61-3, and many columns are lightly cracked.

The foundations of the building and the site in general show evidence of instability, figure 61-4. In this area, the movement of the building appears to be down and south into the crater lake. Repair of the building would be an extensive and expensive operation. It should not be undertaken unless stability of the foundations can be assured.

Figure 61-1 One roof tower near collapse, the other fallen, Residencia Jefe Director.

Figure 61-2 Tower fallen through ceiling of entrance lobby, Residencia Jefe Director.

Figure 61-3 Column crushed in basement, Residencia Jefe Director.

Figure 61-4 Slide movement in front of Residencia Jefe Director.

Date of Investigation: January 1, 1973

Building: Radio-Difusora Nacional (Road of the Colegio Centro-America)

Inspected by: Samuel Kramer
Richard Wright
Raul Amador

This is a one and two story building with some reinforced concrete columns, lightly reinforced or non-reinforced concrete block bearing walls, and concrete beams, figure 62-1. It employs a wood framed corrugated metal roof.

There are severe cracks in the walls and some beams and columns of the first floor. The walls of the second floor are partially collapsed and partially broken and bulging in very unstable condition. The valuable equipment in this building is seriously threatened by its instability. The remaining structure on the second floor should be carefully removed and the first floor walls, beams, and ceiling should be shored until the structure can be repaired.

Instructions to carry out the removal and shoring activities were given at once to the foreman in charge of repair works.

Figure 62-1 A very fragile building housing the country's radio transmission equipment, Radio-Difusora Nacional.

Report No. 68

Date of Investigation: December 27, 1972

Building: Aduana

Inspected by: Mete A. Sozen
Samuel Kramer
Richard N. Wright

The buildings of the Gerente General, the warehouse immediately west, and the vehicle storage building to the southwest were inspected. The two story building of the Gerente General which had a reinforced concrete frame employing undeformed reinforcing, was completely collapsed, figures 68-1 and 68-2. The warehouse was made up of barrel shells, about 30 ft wide and 200 ft long, supported by reinforced concrete columns at the edge lines on approximately 20 ft spacing. The exterior columns have failed completely at the top of partial height infill walls which increased the column stiffness and thereby the column shear, figures 68-3 and 68-4. Interior columns showed some damages at the top. Repair may be possible, but will require substantial reconstruction and improvement of the roof support system.

The vehicle storage for the Aduana consists of barrel shells about 35 ft wide and 40 ft long. The supporting columns have failed, in part due to poor anchorage of the column steel in the roof beams, and the roof has collapsed on the vehicles below. It is unlikely that the roof shells can be used again on a reconstructed support system.

Figure 68-1 View of general collapse, Aduana General de Managua.

Figure 68-2 Close up of columns showing undeformed, lightly tied reinforcement, Aduana General de Managua.

Figure 68-3 General view of damaged barrel shed, Aduana General de Managua.

Figure 68-4 Close up of sheared exterior columns, Aduana General de Managua.

Report No. 70

Date of Investigation: January 2, 1973

Building: Edificio del Hospital del Seguro Social

Inspected by: Samuel Kramer
Richard Wright
Raul Amador K.

This is a three story reinforced concrete frame structure completed in 1956, figures 70-1 and 70-2. It is a moment resistant frame building with reinforced concrete beams and columns; the infilled walls are variously of cement blocks, clay bricks and tile. The building has east and west wings, partially separated by courts, which differ in structure plan.

The second floor facades on the north and east sides shows severe column damage above the breast high infilled walls. The columns are approximately 14 by 12 in reinforced with four number eight bars. The corresponding columns on the west facade are much more lightly cracked. There was fire on the third floor of the building which burned the wood frame supporting the corrugated metal roof leading to collapse of portions of the roof. The first floor structure on the east side of the building is in reasonably good condition. Concrete block and heavy brick partitions appear to have braced the frame. Second floor columns on the east side are destroyed as noted above due to the concentration of deformations caused by partial height walls, figure 70-3. The structural system on the third floor of this east side appears to be in good condition in spite of the fire. On the west side of the building, there is major damage to some columns and beams on the second floor. In this region, there is severe cracking and falling of partitions. The first floor shows some shear cracking in stub girders where column spacings change between floors.

The repair of this building is possible but will be very expensive. It may be more economical to build a new hospital when the advantages of a modern building plan are considered. The present building cannot be considered for any use prior to major reconstruction.

Although the structure did not collapse, extensive damage to unreinforced masonry partitions and infill walls made the building dysfunctional and hazardous to occupants, figures 70-4 and 70-5.

Figure 70-1 East facade of the Hospital del INSS, extensive second floor damage, note roof collapse through third floor windows.

Figure 70-2 North facade Hospital del INSS, much wall and column damage.

Figure 70-3 Detail of wall and column damage on north facade, Hospital del INSS.

Figure 70-4 Structural and nonstructural damage on east wing, first floor, Hospital del INSS.

Figure 70-5 Structural and nonstructural damage in wards, Hospital del INSS.

525-814 O - 73 - 10

Date of Investigation: January 2, 1973

Building: Policlinica Central del INSS (adjacent to the administration building)

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

This is a three wing reinforced concrete structure with two story elements at the northeast and southwest corners. Portions of the building were completed in 1956 and in 1960.

There is no evidence of major structural damage. Some parapet walls have cracked and should be removed to eliminate the hazard to adjacent personnel, figure 71-1. It would be advisable to remove the undamaged parapet walls at the same time. There is some cracking of filler walls and some minor pounding damage of roof and wall elements at junctions of building elements. There is a severe crack in the infilled wall at the southeast corner of the building.

It is possible to clean out the building and put it to use immediately. A more thorough examination of structural and non-structural damages, and development of repair requirements, should be carried out during this clean up.

Figure 71-1 Cracked parapet walls, Policlinica Central del INSS.

Date of Investigation: January 3, 1973

Building: IBM

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

This is a four story steel frame building without a basement, figure 72-1. It is a moment resistant frame with corrugated metal floor decking on steel bar joists with 1 1/2 in of concrete floor surfacing. The exterior wall cladding is steel above the first floor level.

There is evidence of inelastic deformation in the first floor columns. Anchor bolts are lifted as much as 1/4 in along the north side of the building, figure 72-2. Infill concrete block panels at the first floor entrance have cracked; the resulting concentration of deformation has deformed the column at the door frame on the west side, figure 72-3. The weld of the staircase framing to the columns has fractured in this vicinity. At the east side of the south wing of the building, partial height partition walls have led to concentration of deformations in the columns, figure 72-4. This has broken a 6 by 6 in reinforced concrete column reinforced with four number three bars and has deformed the W12X31 steel columns about two in horizontally to the north in the first story at the southeast corner of the building.

On the interior of the first floors, concrete block walls are cracked in the lavatory areas. Other partitions are lightweight and not damaged. Several welded beam to column connections were inspected at the top of the first story level and showed no distress. This included the connection at the zone of the most severe deformation in the southeast corner of the building. Damage on upper floors of the building was very limited. There were signs of movement in the plywood fillers between flanges of the columns and some blocks in the masonry curtain walls around lavatories were displaced. The building's elevator was working.

The building appears safe for occupancy. Structural connections should be checked individually to look for weld cracking that is difficult to see in a cursory inspection. A more careful investigation should be conducted to define whether it is necessary or desirable to straighten the deformed columns in the first story.

Figure 72-1 General view of IBM building.

Figure 72-2 Lifted anchor bolts along north facade, IBM.

Figure 72-3 Column deformation at IBM building caused by cracked infill panel.

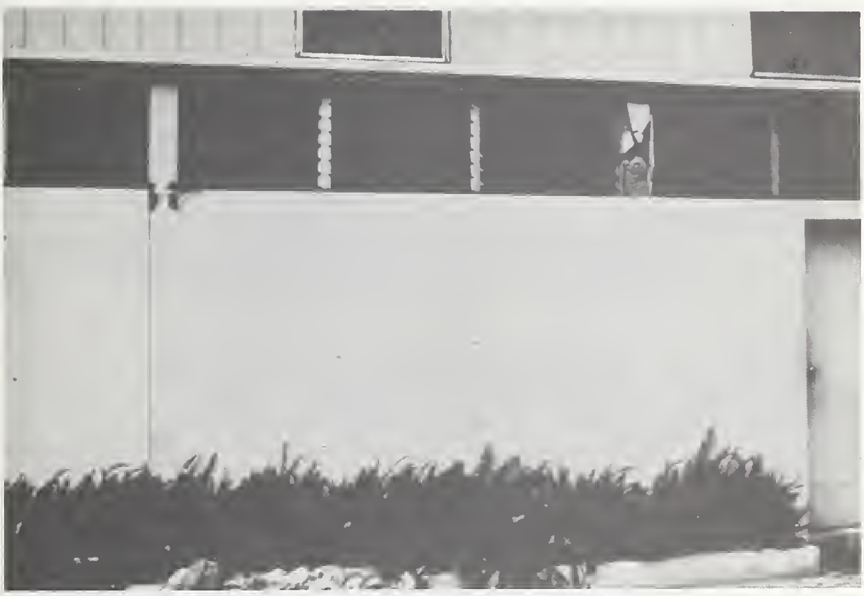

Figure 72-4 Column damage caused by partial height infill wall, IBM building.

Report No. 73

Date of Investigation: January 3, 1973

Building: Country Club Tejapa

Inspected by: Raul Amador
Samuel Kramer
Richard Wright

The building is a two story reinforced concrete frame structure with a semi-basement. There is a main wing of social rooms and a wing of showers and lockers at the southeast.

The main wing is severely damaged and partially collapsed, figure 73-1. The eight in thick canopy slab has swayed more than two ft on its steel pipe columns, figure 73-2. An attendant reported that the partial collapse of the reinforced concrete main wing occurred on the first shock of the earthquake. Although it was not closely inspected, the two story wing at the southeast showed no evident damage from the outside. It was pointed out, that new cracking appeared in the entry drive in front of the club at the time of the earthquake. This may be part of the fault breaking in the earthquake since there are no strong slopes in the vicinity suggesting sliding action.

The main wing of the club appears to require complete reconstruction.

Figure 73-1 Severe structural damage in main building of the Country Club Tejapa.

Figure 73-2 Sway deformation of heavy canopy slab, Country Club Tejapa.

Report No. 74

Date of Investigation: December 28, 1972

Building: Edificio Guerrero Pineda

Inspected by: Richard Wright
Samuel Kramer
Mete Sozen

This was a five story reinforced concrete frame building at the corner of Calle 27 de Mayo, one block from Bolivar Avenue. One column observed was reinforced with six No. 8 plain bars. A large portion of the building has collapsed, figures 74-1 and 74-2. In the remaining part of the building, it is evident that partial height infill walls contributed to failures of the columns.

It is interesting to note the contrasting lack of damage to a building across the street, figure 74-3.

Figure 74-1 Four of five stories collapsed, Edificio Guerrero Pineda.

Figure 74-2 Three of five stories of the Edificio Guerrero Pineda standing at this end.

Figure 74-3 Building across from Guerrero Pineda shows little damage.

Report No. 75

Date of Investigation: December 28, 1972

Building: Instituto Geografico Nacional

Inspected by: Richard N. Wright
Samuel Kramer
Mete A. Sozen

This is a one story reinforced concrete frame building with a column spacing of about 16 ft, of approximately 12 ft gross height and an 8 ft clear height inside the building. It is seven bays wide and 12 bays long on the side investigated in detail; a similar building is connected to it by a passageway, figure 75-1. The columns of the building are 12 in by 12 in and are reinforced by four No. 5 or 6 deformed bars. The columns are connected by 12 in by 12 in beams; seven concrete joists resting on top of the beams span each panel and support 4 in clay tile which in turn are covered by a built up roof. The wall panels consist of two wythes of 4 in concrete block separated by a cavity.

The building is extensively damaged. The cavity walls which were not tied together across the cavity or tied to the columns or beams have suffered a number of failures, some leaning out, some completely fallen, figure 75-2. Exterior columns are sheared at the top. Much of the suspended ceiling has fallen inside the building.

The building should be evacuated and repaired before further use. Special attention is required to repair and reforce the exterior walls and columns. It may be desirable to provide a shear wall in place of the present curtain walls.

Figure 75-1 Damages to canopy between buildings, Instituto Geografico Nacional

Figure 75-2 Falling of cavity walls and shearing of frame columns, Instituto Geografico Nacional.

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Following the Managua, Nicaragua, earthquake of Dec. 23, 1972, a team of engineers representing the U.S. Department of Commerce's National Bureau of Standards (NBS) and the National Academy of Engineering (NAE) performed field investigations in Managua, Nicaragua, from Dec. 26, 1972, to Jan. 4, 1973. The objectives were to assist the Nicaraguan government in surveying major buildings to determine whether each was suitable for emergency use, repairable, or appropriate for clearance. The team also viewed the patterns of successful performance and damage to identify needs for improvements in building practices for mitigation of earthquake hazards and opportunities for more detailed investigations which could provide information for future improvements in practices. In general, the damages cannot be attributed to unusual intensities of ground shaking or severity of surface faulting. Most damages appeared to result from deficiencies in building practices; deficiencies which had been exhibited many times before in previous earthquakes, deficiencies which would be avoided by implementation of up-to-date provisions for earthquake resistant design and construction. However, Managua did not employ a building code with seismic design requirements appropriate to its earthquake risk, and furthermore, did not have a building regulatory system capable of effective implementation of its building code provisions. This report documents the observations of damages by the NBS/NAE team and points out relationships to inadequacies in the building practices employed. Most of these inadequacies have been well known; however, the Managuan experience may serve as an incentive to improvement of building practices in many other areas which are subject to substantial earthquake risks and have not consistently accounted for these risks in their building codes and building regulatory system.

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