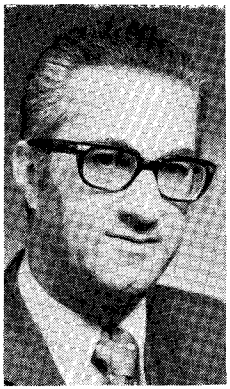
Special Report on

Performance of Precast Concrete Structures During Rumanian Earthquake of March 4, 1977



This report is based on observations the author made when he visited Bucharest between March 19-22, 1977.

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The earthquake that struck Rumania on March 4, 1977, at 9:22 p.m., registered a magnitude of 7.2 on the Richter Scale. The quake was felt as far away as Rome to the west, and Moscow to the northeast.

The epicenter was located at the foot of the Vrancia Mountains, 165 km (about 100 miles) from Bucharest. The focal depth was 110 km (68 miles).

While the main damage was in the city of Bucharest, there was also extensive damage in towns close to the epicenter.

Seismic Damage

Bucharest, the capital city of Rumania, has a population of 1,800,000. It suffered severe damage, including 35 collapses which caused approximately 1500 deaths.

Thirty-two of the 35 collapsed buildings were multistory buildings erected before World War II when seismic design code criteria were not established. Modern construction, designed for earthquake resistance, performed very well. Among the thousands of recent buildings, there were only three collapses.

Interestingly, most of the collapsed buildings were in the 10-story category built in the boom years of the thirties. Many of the collapses occurred along Magheru Boulevard, the main street in the center of the city.

A number of the older multistory

Typical high rise residential precast buildings (Bucharest) survived earthquake.

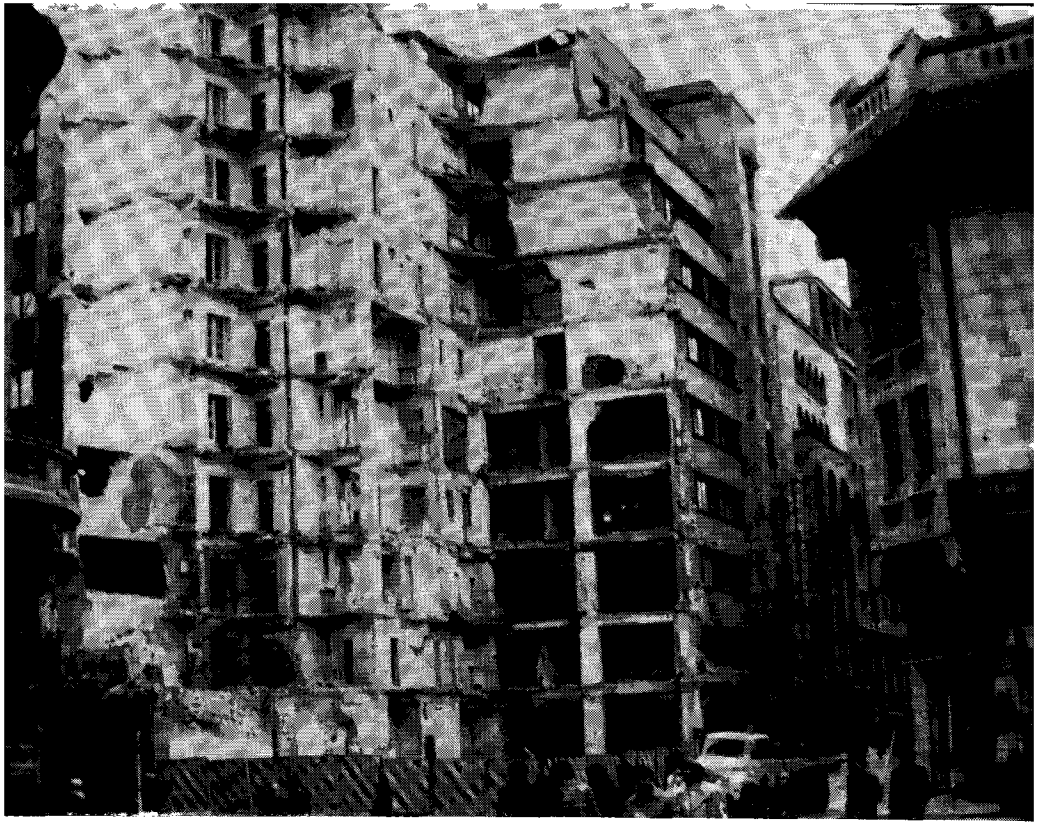
buildings in Bucharest have severe cracks and are out-of-plumb, making questionable their ability to resist gravity loads and withstand possible future earthquake shocks. No evidence of soil failures was observed in the city.

Seismic Data

The only strong motion accelerogram record obtained in the city for this earthquake was in the basement of the Building Research Institute. The approximately 25-second record shows, in both horizontal directions, a dominant one strong pulse (sinusoidal) having a maximum acceleration of 20 percent of gravity and a period of about 1.5 seconds.

Rumania introduced seismic provisions into its 1948 code, with subsequent revisions in 1960, 1963, 1972 and 1973. The seismic provisions are less stringent than those of the U.S. Uniform Building Code with respect to the seismic forces and to the required special details for ductility. The force requirements and zoning are patterned after the Russian Codes.

The Rumanian Building Research Institute (INCERC) of the Industrialized Construction Ministry has an active seismic research program, carried out by competent scientists. Also, at the University of Iasi, seismic research is carried out using a large outdoor shaking facility, 10 x 10 m (33



Many pre World War II buildings suffered serious collapse. At the time of construction, seismic design criteria were not established.

x 33 ft), having a lateral force capacity of 140 metric tons.

Construction

Beginning in the early 1950s, a large number of new residential, some commercial, and many industrial buildings were constructed. Initially, 4-story walk-up buildings were constructed; at present, residential buildings are constructed 9 and 11 stories high, with some 13, 15 and 18 stories high.

All residential construction is precast or cast-in-place reinforced concrete. There is practically no steel construction used for buildings in Rumania.

Precast Concrete

Precasting on a large scale was introduced in Rumania in 1958, partly following the Russian experience in this field. Being in a seismically active region, the Rumanians introduced precasting gradually and with deliberation.

A number of combinations of cast-in-place and precast systems were tried out. Some had precast slabs and beams with cast-in-place columns or walls. Others had the end bay frames cast in place, while still others had only the joints between horizontal and vertical members cast in place.

Quarter-scale models of 10-story structures of several types were tested at INCERC by subjecting them to forced vibration until damage occurred.

Only in recent years have fully precast large panel structures been utilized for buildings up to nine stories

Most casualties occurred in older buildings such as this.

high. A quarter-scale model of such a building type was tested on the shaking table at Iasi. Horizontal and vertical connections were made by field welding of protruding reinforcing bars or by interlacing of protruding reinforcing loops. At present 5 percent of all housing constructed in Bucharest is completely precast.

General Performance

With a few exceptions, the thousands of modern buildings appeared to have performed within the elastic range. In numerous instances cracking of the rigid plaster on partitions of framed structures was observed; also, hairline diagonal shear cracking of beams and walls was observed

in lower floors in a number of buildings.

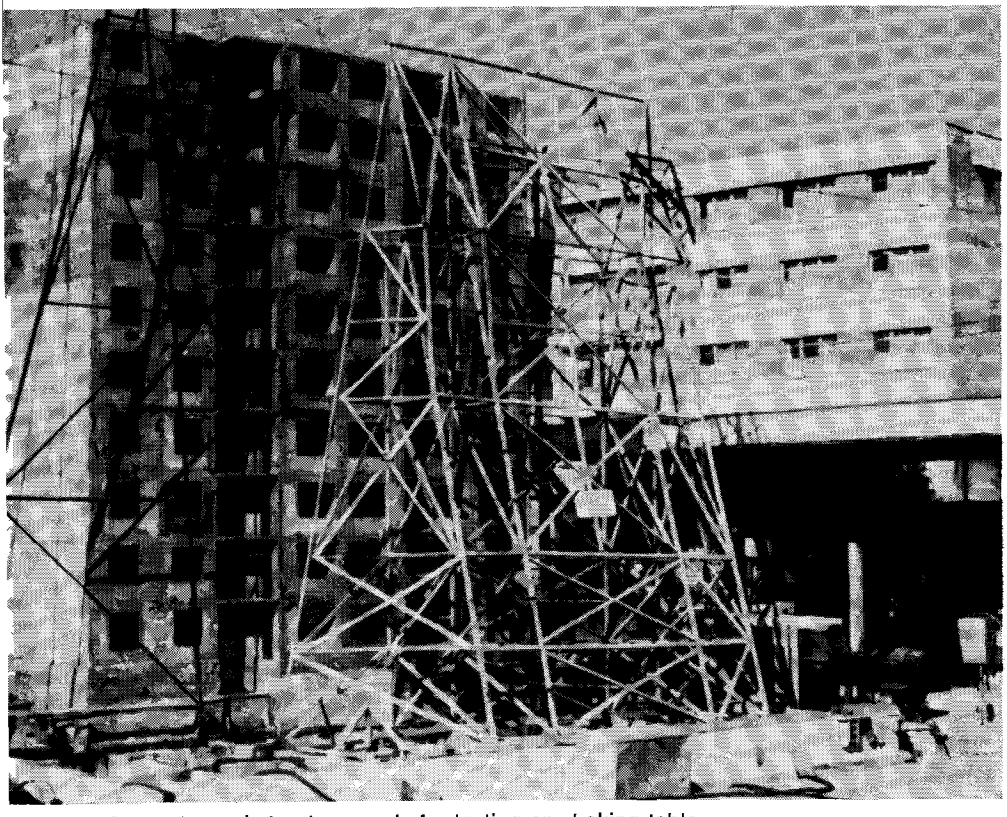
These cracks have an effect on the stiffness, but not on the strength of the members. In a few instances, diagonal cracking of lower story columns was seen; some were already shored for repairs, either by removing the concrete of the column and recasting a new column, or by adding thickness all around the cracked column.

Failures

Of the three collapses of recent buildings, one was a combination of precast and cast-in-place concrete. It occurred in a one-year-old 10-story building in a new section of the city. There a 40 m (130 ft) middle unit of a six-unit block collapsed between the expansion joints, falling south towards the street, in a direction perpendicular to its longitudinal axis.

The building has precast slabs with cast-in-place longitudinal and transverse walls. The adjacent unit to the west in the same block showed severe cracking of the south end of the transverse structural shear wall in the first floor, exposing a concrete of apparently inferior quality. The 150 mm (6 in.) thick walls had light reinforcement. The longitudinal wall of the first floor showed light diagonal cracking. All other identical units of several similar blocks showed no apparent distress.

One other case of severe damage



Precast panel structure ready for testing on shaking table.

Precast buildings designed to withstand quakes held up well.

was observed in two structural walls in the first floor of an 11-story building of precast concrete floors and cast-in-place walls. The transverse walls had diagonal cracks in the first floor and some slight concrete crushing of the end of the wall, with some of the bars becoming visible. The same diagonal cracking in diminishing intensity was visible in the second, third and fourth floors.

Summary and Conclusions

1. Reinforced cast-in-place concrete multistory buildings, built in Rumania in the last 25 years, had sufficient strength and reasonable stiffness to withstand this particular earthquake without structural distress and with a minimum of nonstructural damage.

2. Precast concrete buildings of various configurations and large panel buildings, designed for earthquake resistance, withstood this earthquake with minimum distress; thus, for the first time, providing evidence of the earthquake resistance of a large number and variety of precast concrete structures.

3. With only a very few exceptions, the modern structures appear to have responded within the elastic range. Therefore, it is hard to make comparisons between the various structural systems as to their relative merits for earthquake resistance.

4. Most of the 1500 people who perished in Bucharest during the March 4, 1977, earthquake were in the thirty-two 8 to 10-story buildings constructed prior to World War II.

5. In the case of the collapsed precast 10-story structure, it seems that inadequate construction procedures and inferior quality concrete were the apparent reasons for collapse.