Special Report

First Impressions of Earthquake Damage in San Francisco Area

by

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On October 17, 1989, at 5:04 p.m., during rush hour, the San Francisco area was hit with a major earthquake. The entire nation witnessed the dramatic event on television as the two local baseball teams prepared for the third game of the World Series.

The epicenter of the earthquake was located southeast of San Francisco, near Santa Cruz, and occurred on the San Andreas fault system. Seismologists now call this the Loma Prieta earthquake and its intensity has been set at 7.1 on the Richter scale.

Fig. 1 shows a portion of a map prepared by the California Division of Mines and Geology. The map shows the location and extent of the aftershock area as a stippled line and locations of ground response stations are shown as dots. As can be seen, one station is almost directly on the aftershock zone and this Corralitos station acceleration record is given in Fig. 2. Maximum horizontal accelerations of 0.64g were measured.

The California report also notes maximum horizontal ground accelerations in San Francisco that ranged from 0.06g in Pacific Heights to 0.21g at the Presidio station. Across the bay in Oakland, values of 0.18g to 0.29g were recorded and south in San Jose values of

Presents a preliminary report on the performance of structures during the October 17, 1989, San Francisco area earthquake. Primary emphasis is placed on the behavior of precast and prestressed concrete structures.

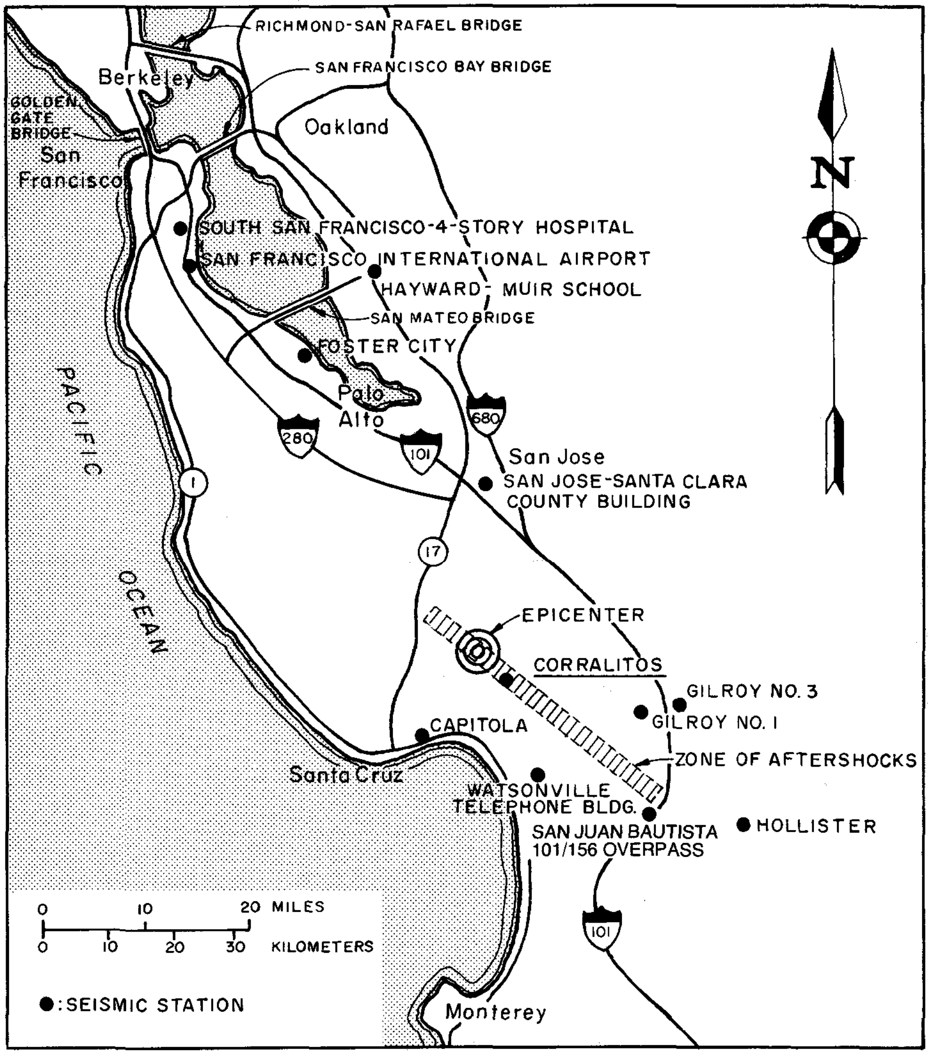

Fig. 1. Map of San Francisco area showing places affected by earthquake.

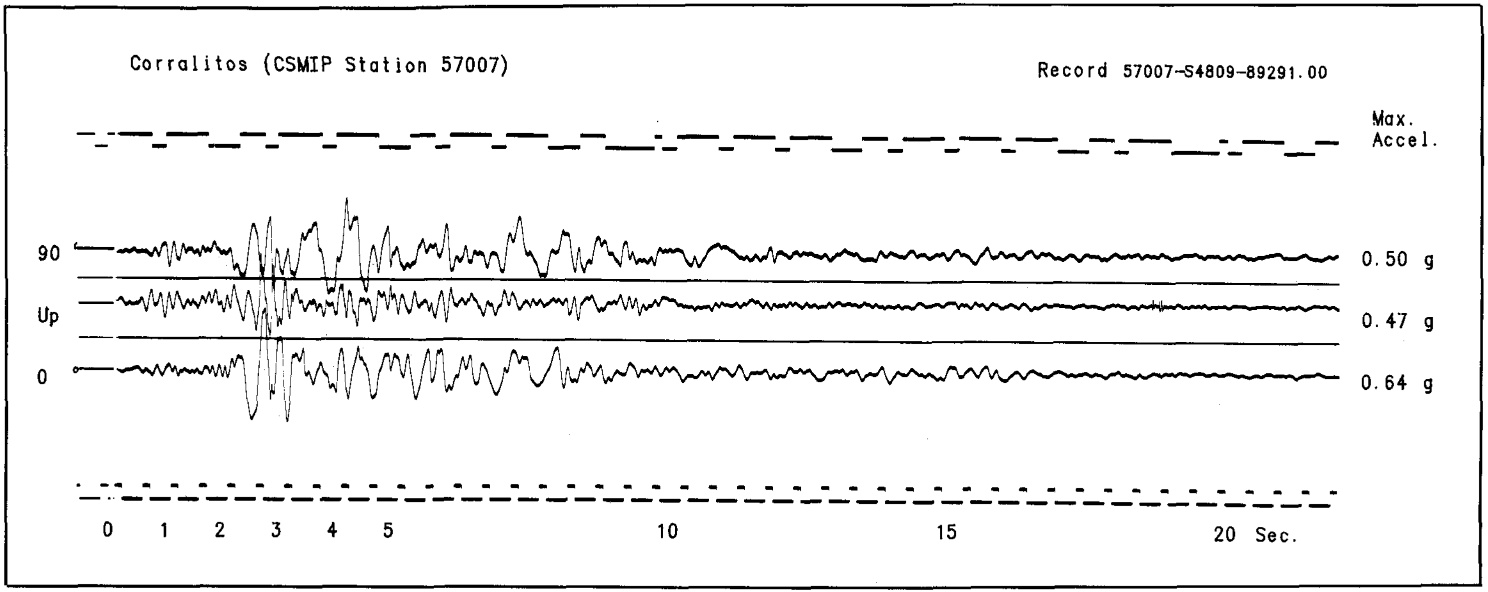

Fig. 2. Corralitos accelerogram, recorded almost directly above the fault, showed a horizontal peak acceleration of 0.64 *g*.

Fig. 3. Collapsed portion of I-880.

about 0.12g were reported. The current UBC seismic design code is stated to be predicated on assumed maximum ground acceleration of from 0.5g to 0.6g.

The rupture zone for this earthquake is estimated at about 30 miles (48 km) in length. In comparison, the 1906 San Francisco earthquake was estimated to have had a 300 mile (484 km) rupture length.

Damage was widespread, and current dollar estimates have climbed to over $7 billion. It is estimated that more than 100,000 homes have been evacuated. Thousands of buildings were damaged or destroyed.

The largest loss of life occurred on an elevated section of Highway I-880 which collapsed. The half mile (0.8 km) long section of two-level structure ran south through Oakland from the intersection of I-80 and I-580 at the Bay Bridge. By the first week of November it had yielded 42 casualties. Total deaths attributed to the earthquake were listed at 67 at this time.

The overpass collapse has been widely reported in the media. Fig. 3 shows typical collapsed column sections and the sandwiched deck sections. Initial reports have noted that the mid-1950s standard bridge design and detailing of the columns and pier bents may have contributed to the collapse. Several of the other elevated highway structures accessing the Bay Bridge on the San Francisco side, also experienced damage and have been closed.

The Bay Bridge which carries I-80 from Oakland to San Francisco and provides the main access to the city, experienced damage to two of its deck sections as shown in Fig. 4, which is taken from the earthquake report in ENR.* By the first week in November replacement units were already under construction

Engineering News-Record, October 26, 1989.


Fig. 4. Failed deck section of Bay Bridge (from *Engineering News-Record* report).

and the contractor targeted completion of the work by the Thanksgiving holiday. Basalt Precast, located in Napa, working around the clock, finished casting 42 stay-in-place prestressed concrete deck panels for the repair. The panels were in place on the bridge by November 6. The Bay Bridge was reopened to full service on November 18.

Heavy localized damage was noted in several areas of Oakland and San Francisco and is attributed to poor soil conditions. An example of this was the devastation of the Marina residential area, which was also widely reported on television. One such view is shown in Fig. 5. Only blocks away from these heavily damaged homes, identical structures experienced only minor cracking and many are occupied today.

This paper presents a preliminary review of the performance of precast and prestressed concrete construction in the Loma Prieta earthquake. The primary precast product in this region is architectural concrete cladding panels. Many of the structures utilizing these panels are high rise offices in the downtown areas. Several of these buildings were reviewed. There are also many structural applications of precast and prestressed concrete in the affected region including parking garages and other types of buildings. Again, a number of these structures were inspected.

The inspections were intended to be preliminary and many of the buildings were viewed only from the outside. The review emphasized the downtown regions of San Francisco and Oakland, both of which received significant earthquake damage and contain numerous structures utilizing precast concrete.

A telephone survey of about eleven precast manufacturers that supply products in this area was also made. The intent of this survey was to summarize the damage reports that producers had received as a means to provide an early

Fig. 5. Damage to homes and pavement in the Marina area of San Francisco.

estimate of the amount and types of problems that precast concrete products had experienced in the earthquake.

PERFORMANCE OF PRECAST CONCRETE

This section of the article discusses the performance of the architectural precast concrete and the precast prestressed concrete structures.

Architectural Precast Concrete

The overall response of precast cladding to the earthquake was excellent. Most of the structures in downtown San Francisco were undamaged and only a few buildings suffered minor cracking. About half of the producers in the area reported no damage calls and the others received only a few inconsequential messages. The typical problem concerned minor problems existing before the earthquake. In one case, in downtown San Francisco, an older adjacent building pounded against a newly constructed hotel. Two phone calls involved minor cracking in cast-in-place concrete at panel supports of a high rise building. After a preliminary inspection, the cracking was believed to have been caused by insufficient design allowance for story drift.

The results of the visual inspection of buildings were very good. In about thirty clad structures that were inspected, only two showed any signs of significant cladding cracking or movement. Various views of typical structures in both San Francisco and Oakland are shown in Figs. 6a through 6l.

Several of these structures are approximately forty stories tall. Their cladding performance was judged to be excellent. Many of these structures feature unusual geometry in both layout and panel configuration and numerous cutouts in the structure at higher stories. These conditions always present problems in connection detailing and layout and apparently were well handled in the affected area.

The two structures with cracking are in Oakland, and both contain telephone functions. One is a telephone exchange building located in downtown Oakland only slightly over a mile (1.62 km) from the collapsed I-880 strucure. It is reported that the telephone exchange equipment has operated continuously throughout the earthquake and the recovery period. A view of the building is shown in Fig. 7.

The cracking is apparently limited to column covers on the lower level steel columns. No damage was observed in

Fig. 6a. Hyatt Regency Hotel, San Francisco.

Fig. 6b. Stevenson Place, San Francisco.

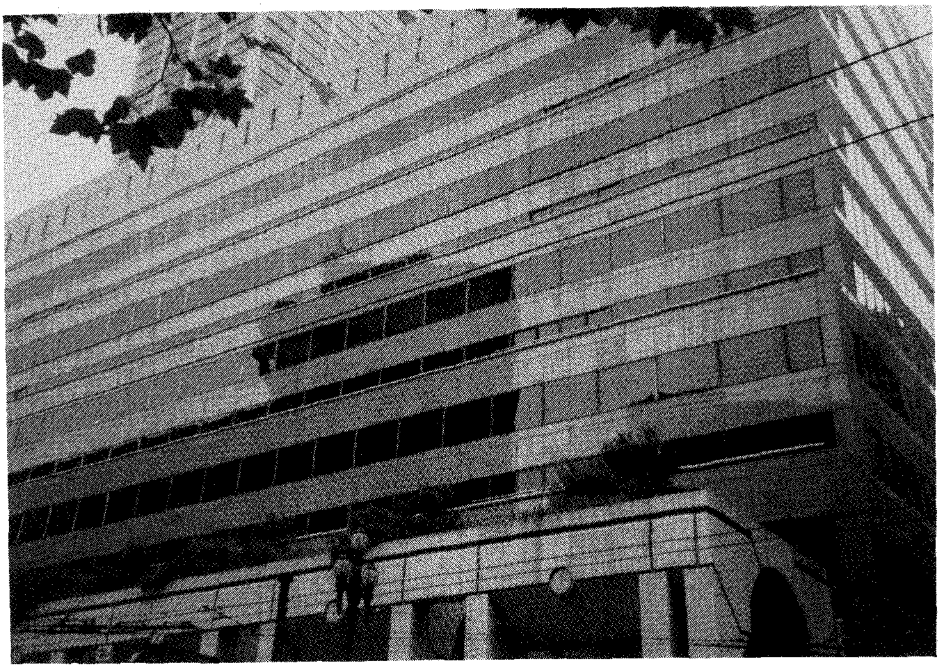

Fig. 6c. Federal Reserve Bank, San Francisco.

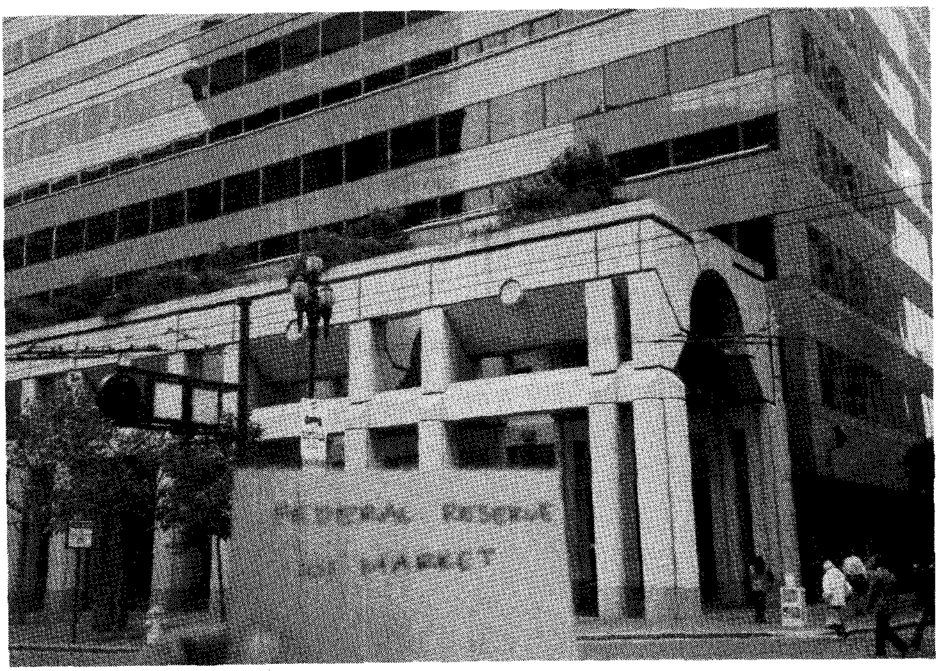

Fig. 6d. Federal Reserve Bank, San Francisco.

Fig. 6e. Marriott Hotel, San Francisco.

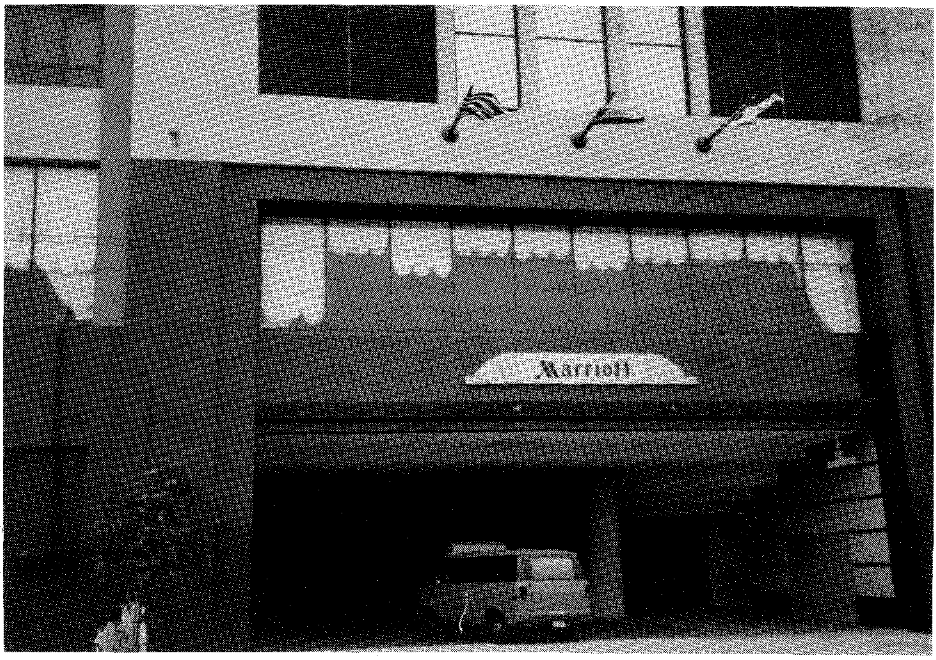

Fig. 6f. Marriott Hotel, San Francisco.

Fig. 6g. Standard Oil Building, San Francisco.

Fig. 6h. Kaiser Permanente Parking, Oakland.

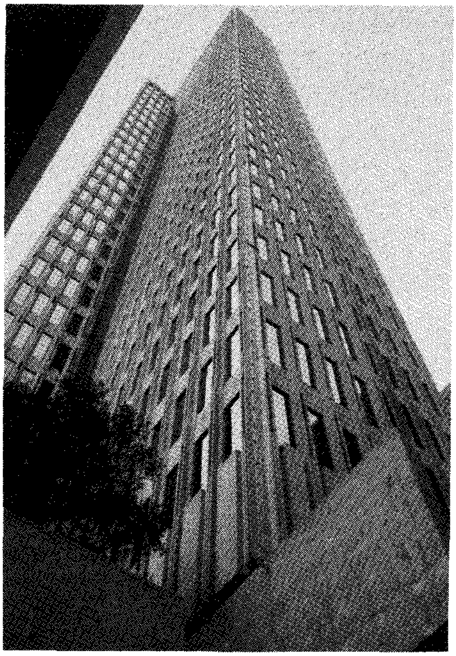

Fig. 6i. Embarcadero Office Building, San Francisco.

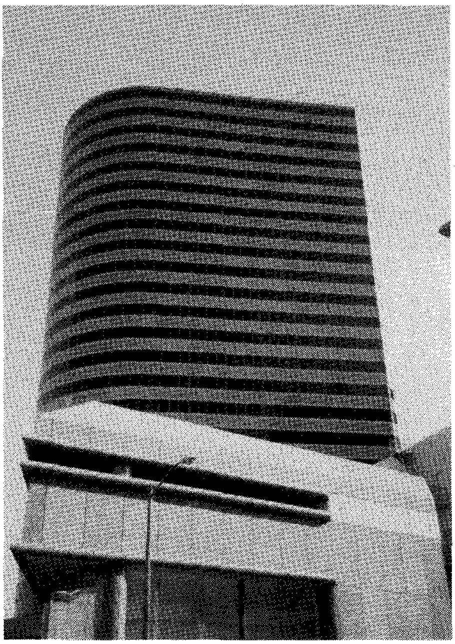

Fig. 6j. Lake Merritt Plaza, Oakland.

Fig. 6k. Office building, Oakland.

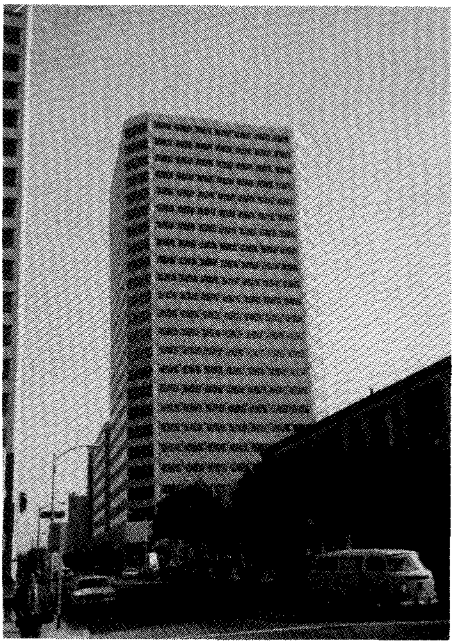

Fig. 6l. Office building, Oakland.

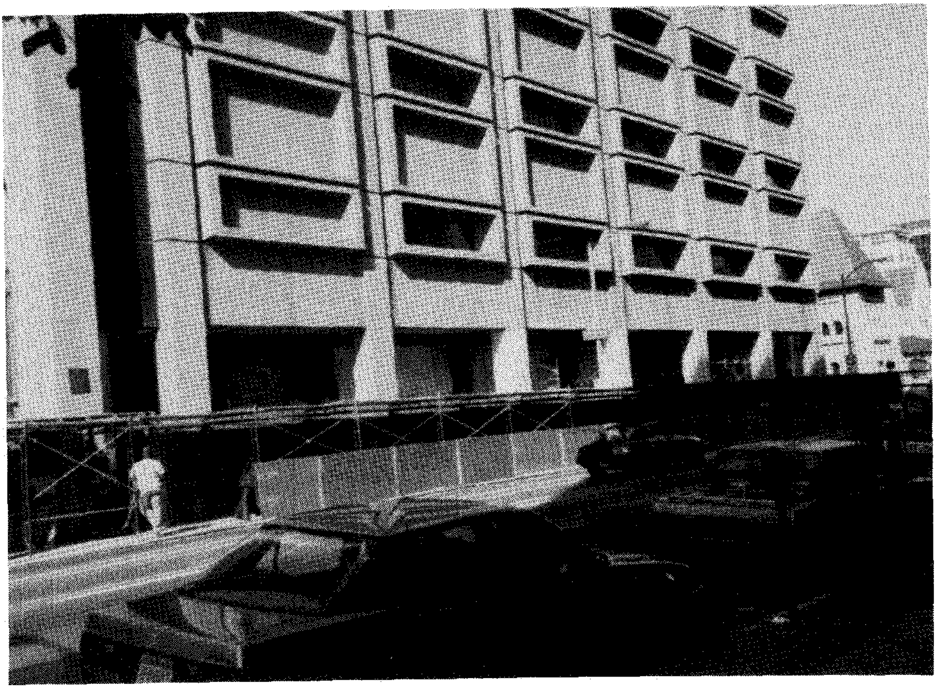
Fig. 7. Telephone Exchange Building, Oakland.

the upper level panels. The column covers are already under repair and the corner column is shown in Fig. 8. Note that these column covers were concrete filled, which leaves little allowance for story drift between the steel columns and concrete cladding.

A concrete shear wall at the first level in this structure also experienced cracking and can be seen in the background of Fig. 8. This dual system structure functioned as expected, with the stiffer concrete shear walls taking loads at lower displacements and the more flexible steel frame taking greater loads at larger movements when the shear wall has cracked.

The second building experiencing cracking in the cladding is a few blocks from the first structure and is called the Trans Pacific Centre. It contains offices of several companies including AT&T. This steel structure is clad with glass fiber reinforced concrete panels. A view

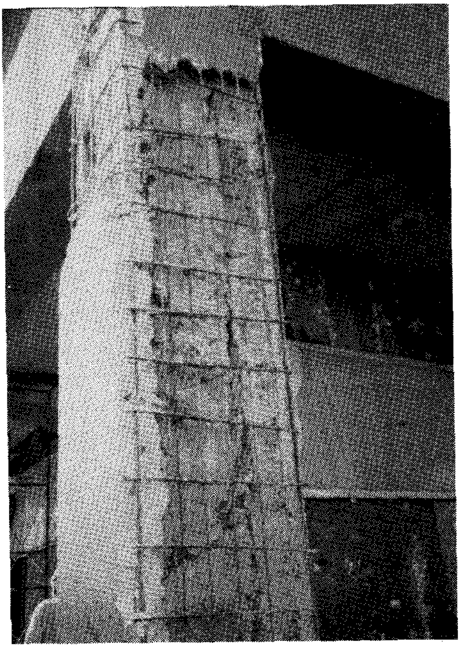
Fig. 8. Corner column under repair.

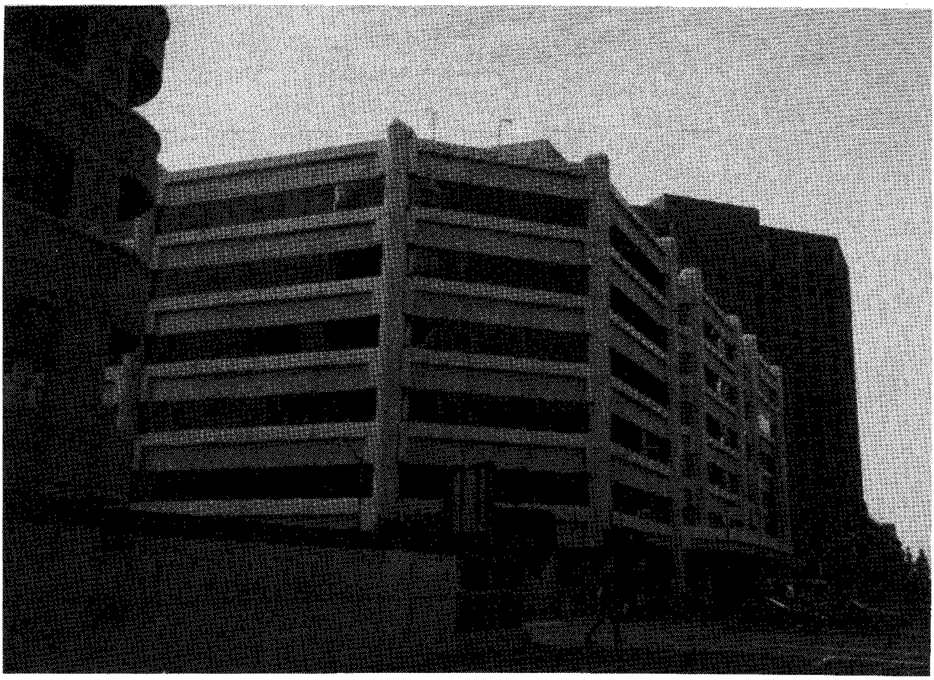

Fig. 9. Trans Pacific Centre, Oakland.

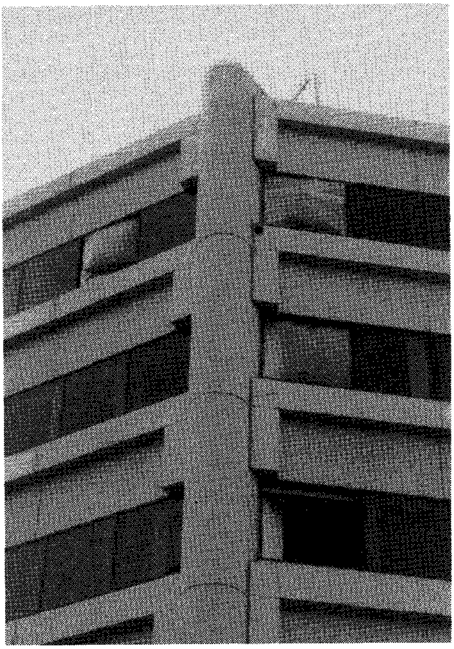

Fig. 10. Panel cracking.

Fig. 11. Opened seismic joint.

of the building is shown in Fig. 9. The closeup in Fig. 10 shows cracking along the edges of panels near a corner of the building and Fig. 11 shows an opened seismic joint at a column cover.

All of the cladding damage is apparently associated with large movements at seismic separation joints in the structure. At the locations where cracking occurred there are dual columns and the structure is divided into independent portions which react separately to earthquake motions. Movement between these independent building sections caused most of the cracking.

Precast Prestressed Structures

Several precast prestressed concrete structures were reviewed. Garages in Oakland, Emeryville and Berkeley, all within a few miles of the collapsed I-880 bridge, were unaffected by the seismic motions. The structures were generally constructed with topped, double-tee diaphragms and had reinforced cast-in-place concrete shear walls and frames.

Minor slab cracking adjacent to a shear wall was noted in one garage and in general there was topping cracking over the tee joints. It was difficult to assess whether the cracking was the result of previous volume change effects or due to the earthquake, and in any case the cracks were minor. In Emeryville near an office structure adjacent to the garage, clear indications of about an inch (2.54 cm) of ground subsidence between a sidewalk and stairs could be noted.

A two-story garage in Berkeley near the University of California campus was an exception, with a precast single-tee frame and post-tensioned slab, with diaphragm ties to adjacent retaining walls. Fig. 12 shows a view of the concrete ties. Only minor cracking in the ties was noted.

All of the inspected structures were in use. One garage, owned by the City of Oakland and located on Telegraph St., had several earlier repairs from previous cracking at the beam seats at the double-tee bearings and to increase lateral bracing. This garage is shown in Fig. 13. It survived the earthquake exceptionally well.

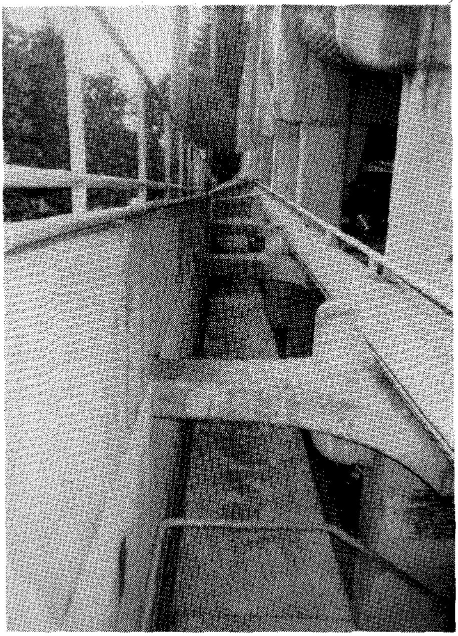

Fig. 12. Diaphragm ties between garage and retaining wall in Berkeley.

A circular garage utilizing pie-shaped double tees is shown in Fig. 14. This unusual structure had no apparent damage and was practically full of automobiles at the time of review.

Within about a half mile (0.8 km) of the I-880 collapse, a housing development project utilizing reinforced concrete block and prestressed hollow-core slab construction was occupied and showed no signs of cracking. Fig. 15 shows two of the 12-story structures from this housing development and a closeup of the exterior is shown in Fig. 16.

One structure of note is the Santa Cruz County Administration Building, located in Santa Cruz only a few miles

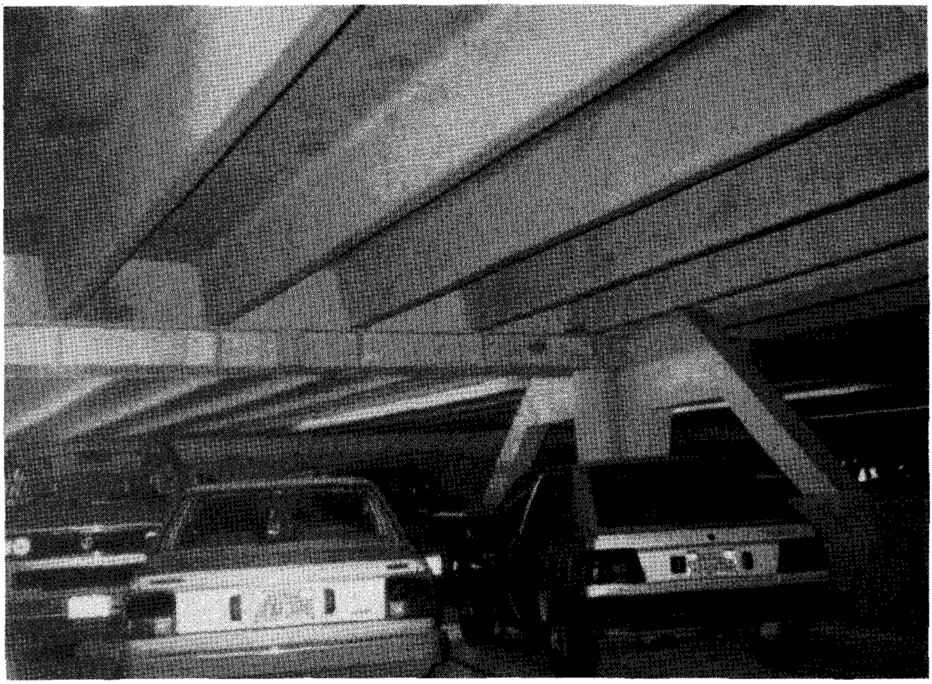

Fig. 13. Parking garage in Oakland.

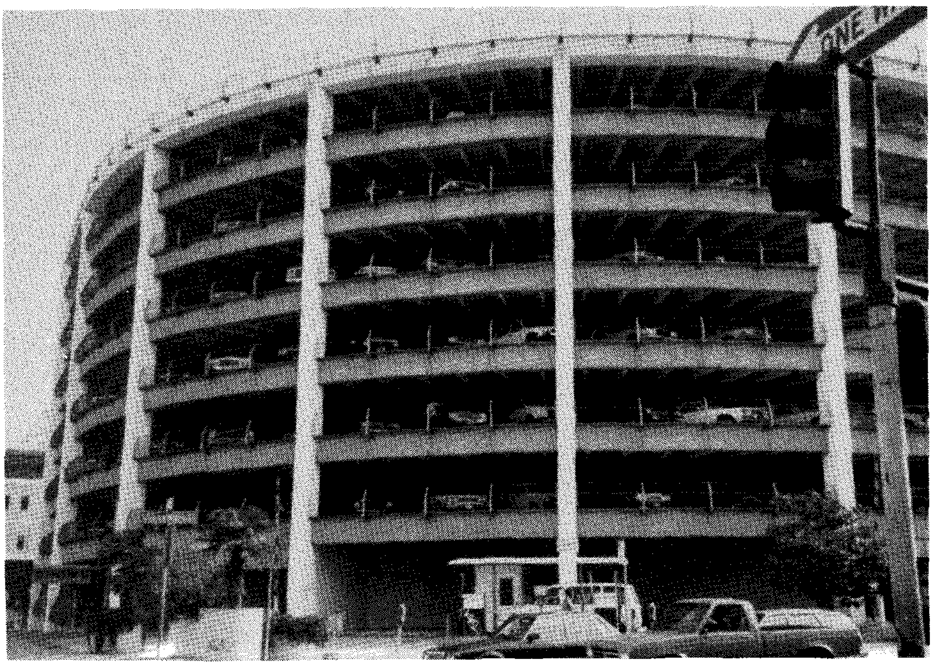

Fig. 14. Circular parking garage in Oakland.

Fig. 15. Housing buildings.

Fig. 16. Closeup of hollow-core balcony.

from the epicenter. This unusual structure was constructed using Vierendeel trusses, consisting of precast concrete segments, post-tensioned together. Time did not allow review of this structure but other investigators have reported that this building performed very well, with no significant cracking.

CONCLUDING REMARKS

The Loma Prieta earthquake caused considerable damage and grief. The California Transportation Department is carefully examining the seismic design criteria of its bridges in the aftermath of a collapse that was extremely costly in human lives.

In retrospect, the overwhelmingly positive evaluation of the precast concrete that was reviewed is most gratifying. The precast and prestressed concrete components withstood the earthquake with practically insignificant problems. In the very few cases where cracking did occur, poor design or inappropriate detailing appear to be at fault.

The general conclusion is that the structures designed according to the latest codes of practice and sound engineering principles performed exceedingly well.

ACKNOWLEDGMENT

The author wishes to thank several people who contributed generously to this article. The Northern California precasters were most cooperative and helpful in their response to telephone calls.

In particular, Mr. Ray McCann was extremely helpful with directions and locations and accompanied the writer on one of the inspection trips.

Many thanks to all!

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NOTE: Discussion of this paper is invited. Please submit your comments to PCI Headquarters by August 1, 1990.