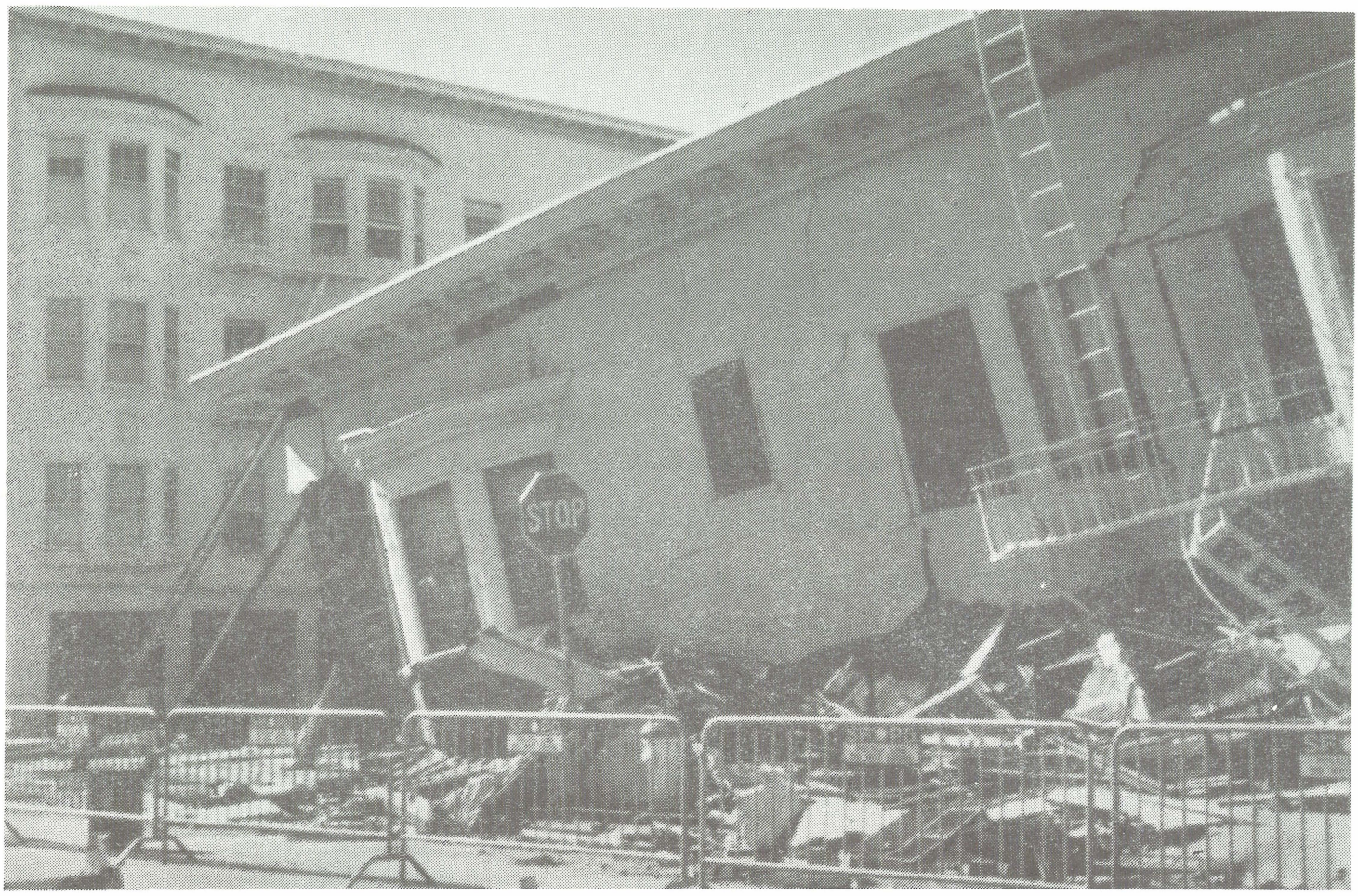
EARTHQUAKE DAMAGE
LOMA PRIETA EARTHQUAKE
OCTOBER 1989

PART 2: EFFECTS IN SAN FRANCISCO AND OAKLAND



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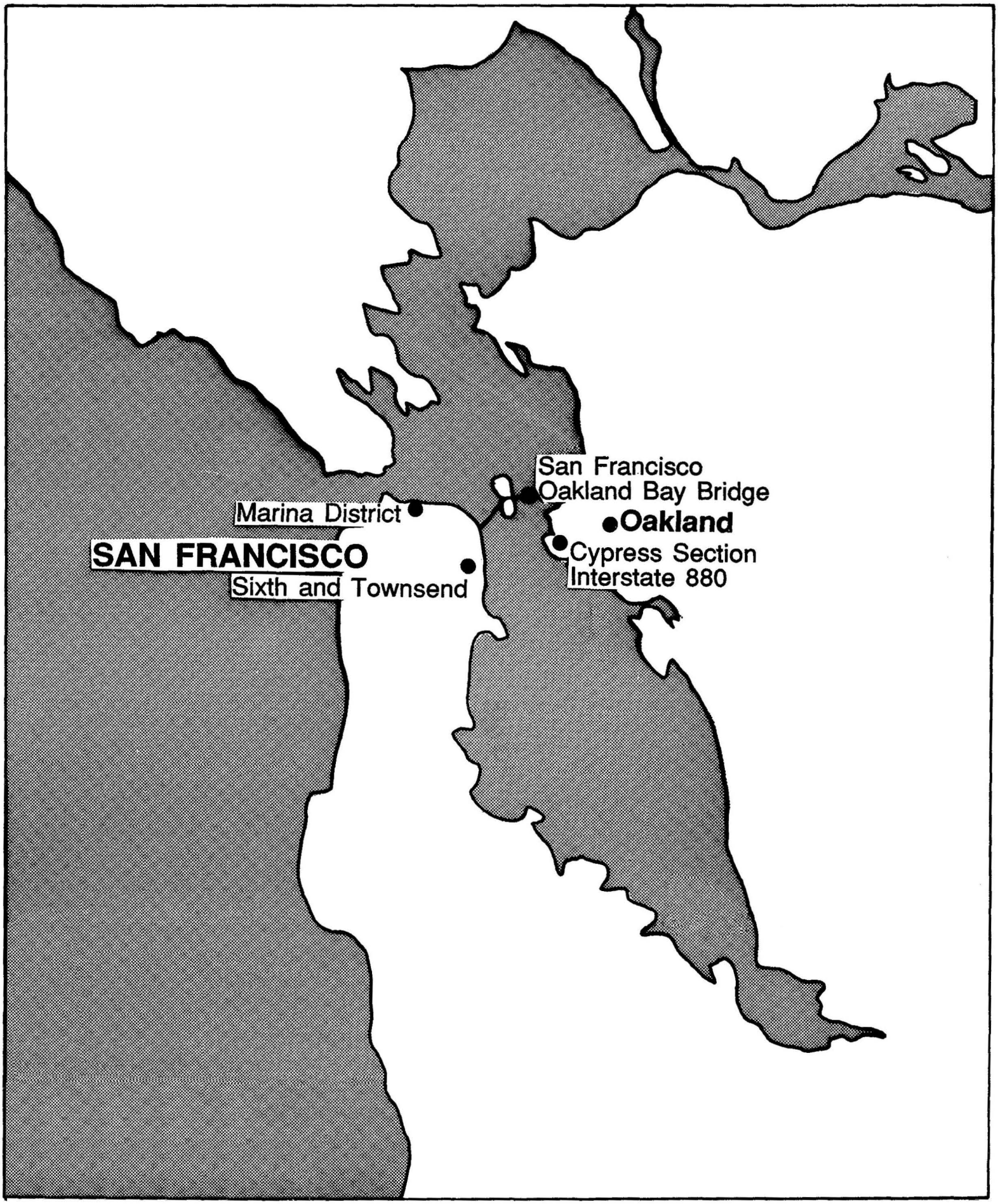

San Francisco
Oakland Bay Bridge
Marina District
Oakland
SAN FRANCISCO
Cypress Section
Interstate 880
Sixth and Townsend

THE LOMA PRIETA EARTHQUAKE
(a.k.a., The San Francisco World Series Earthquake)

OCTOBER 1989

PART 2: EFFECTS IN SAN FRANCISCO AND OAKLAND

On October 17, 1989, at 5:04 P.M. (PDT), a 7.1 magnitude earthquake occurred in the Santa Cruz mountains. Movement occurred along a 40-km segment of the San Andreas fault from southwest of Los Gatos to north of San Juan Bautista. Measurements along the surface of the Earth after the earthquake show that the Pacific plate moved 1.9 m to the northwest and 1.3 m upward over the North American plate. The upward motion resulted from deformation of the plate boundary at the bend in the San Andreas fault. At the surface the fault motion was evident as a complex series of cracks and fractures.

Even though the earthquake occurred in the remote Santa Cruz Mountains, it caused severe damage in San Francisco and Oakland 80 km to the north. This is somewhat unusual for an earthquake of this magnitude. Some of the statistical results of the disaster were: more than $7 billion in property damage (2.5 billion in San Francisco alone), 414 single-family homes destroyed, 104 mobile homes destroyed, 18,306 homes damaged, 97 businesses and 3 public buildings destroyed, 2,575 businesses damaged, 12,000 people displaced from homes and housed in shelters, 3,757 injuries, and 67 deaths.

One of the areas in San Francisco that sustained major damage was the Marina District. This area was a lagoon at the time of the 1906 San Francisco earthquake. During that earthquake the margins of the lagoon shook violently. However, after the 1906 earthquake, the lagoon was filled with sand and rubble of destroyed buildings to make a fairground for the 1915 Panama-Pacific International Exposition. This fill area later became the site of an expensive real-estate development known as the Marina District. The unconsolidated soils amplified the shaking and became liquefied (behaved like a dense fluid) causing permanent deformation of the ground. This was one of the causes of the increased damage in the area. Construction practices also contributed to the damage. Some four-story buildings built above garages had inadequate lateral bracing. Thirty-five of the buildings in the Marina District were eventually torn down and 150 others were structurally damaged. The two major causes of structural failures were poor soil conditions and inadequate structural design.

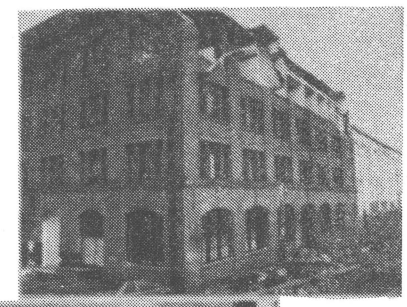
South of Market Street, several buildings between 5 and 10 stories high were damaged. Old masonry buildings were badly damaged, including a warehouse where collapse of fourth floor exterior walls killed five people parked in cars along the street. There were also severely damaged buildings in the Mission District. In Oakland, severe damage occurred to several mid-rise buildings and many old brick buildings in the downtown area.

Primarily due to the effects of liquefaction, buried underground utilities such as gas pipelines, water lines, and sewer lines were heavily damaged. This left about one thousand homes without gas or water. As in the 1906 earthquake, fires in the Marina District could not be fought with city water because water mains had failed.

One of the sources for concern produced by the earthquake is the damage or failure of transportation systems at comparatively large distances from the epicenter. The most deadly structural failure of the earthquake occurred when the upper deck of the Interstate 880 (Nimitz Freeway) in Oakland fell onto the lower roadway causing an official death toll of 41. Another spectacular failure occurred on the Oakland Bay Bridge. Interstate 280, the Embarcadero Freeway, and Highway 101 at Fell Street were also damaged. In Oakland, Highway 980 and the MacArthur Maze developed cracks in the support columns. It will cost about $1.5 billion to rebuild state and local roads damaged in the earthquake. In addition to damage to roads, the Oakland International Airport, naval port, and the Alameda Naval Air Station runways were damaged by liquefaction.

It is interesting to compare this earthquake with the slightly smaller (magnitude 6.9) Armenian earthquake of December 1988 that killed 25,000 people and destroyed entire towns. Good construction and engineering practices in the Loma Prieta area obviously contributed to the preservation of property and human lives.

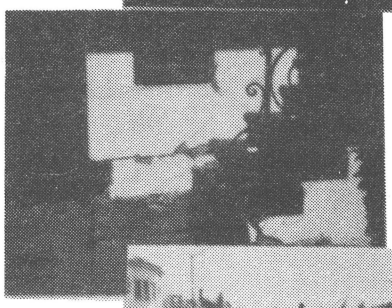
Effects in San Francisco and Oakland
Part 2



1 The fourth-story wall of this unreinforced masonry building on Bluxome Street near Sixth and Townsend collapsed onto the street, crushing five people in their cars. No one in the building was killed. Photograph Credit: U.S. Geological Survey (E.V. Leyendecker).

2 Detail of damage to cars in which five people were killed by parapet collapse of the four-story building on Bluxome Street. The 6th Street freeway on-ramp is visible on the left of the photo. This building is located in an area south of Market Street that had a number of damaged buildings. An eight story building in the same area was damaged severely and had to be demolished. Photograph Credit: U.S. Geological Survey (D. Perkins).

3 These cracks in a building along Jefferson Street in the Marina District of San Francisco are typical of the damage in that area. One hundred eighty-five buildings were structurally damaged in the area. Photograph Credit: U.S. Geological Survey (D. Perkins).



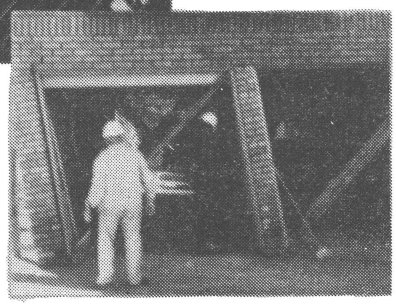
4 This house along Jefferson Street in the Marina District shifted more than 10 cm on its foundation. Houses that were not bolted to their foundations were particularly vulnerable to damage. Photograph Credit: U.S. Geological Survey (D. Perkins).

5 This collapsed and demolished building along Jefferson Street is typical of about 35 buildings that were eventually torn down. Note buildings that remain standing at left and at right top. Photograph Credit: U.S. Geological Survey (D. Perkins).

6 Demolition of above building on Jefferson Street. View is taken around the corner from location of previous photograph. Note damage to the remaining building with an open first floor. Photograph Credit: U.S. Geological Survey (D. Perkins).

7 Another view along Jefferson Street in the Marina District. Tenants try to salvage items from the rubble. Photograph Credit: U.S. Geological Survey (D. Perkins).

8 Shored building on Beach Street in the Marina District. Note the garage area on the first floor beneath the apartments. This common construction practice weakened the first floors of the structures. Photograph Credit: U.S. Geological Survey (D. Perkins).



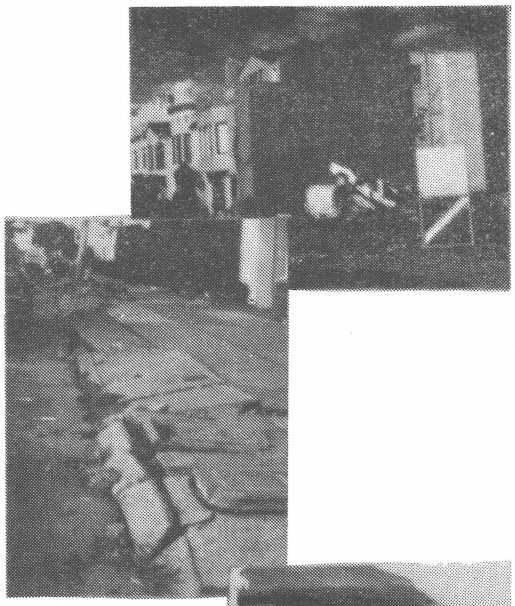
9 Detail of shoring to garage area in building on Beach Street in the Marina District. The practice of using the first floor for garages left the building with inadequate lateral bracing on the ground level. Photograph Credit: U.S. Geological Survey (D. Perkins).

10 A collapsed building in the Marina District. The first story of this three story structure failed when ground shaking was intensified by liquefaction. The second story collapsed, leaving only the third story. Photograph Credit: U.S. Geological Survey (D. Perkins).

11 A second view of the collapsed building shown in the previous slide. Nine people were killed in the Marina District as a result of the fires and the building collapses. Photograph Credit: U.S. Geological Survey (D. Perkins).

12 Rubble after the fire at North Point Street and Divisadero in the Marina District. As in 1906 water mains failed and fires in this area could not be fought with city water. Water was pumped from a fireboat to extinguish this fire. Photograph Credit: U.S. Geological Survey (D. Perkins).

13 Demolished cars and rubble. This view is looking east across the street from fire at North Point and Divisadero in the Marina District of San Francisco. Photograph Credit: U.S. Geological Survey (D. Perkins).

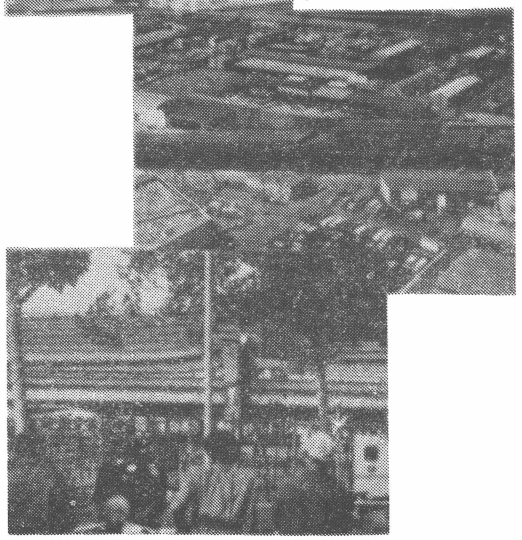


14 View south on Webster Street in the Marina District. Sidewalk damage is the result of liquefacation of the land fill upon which the area was built. Note the upheaved section in background near pole. The manmade fill beneath the Marina was permanently deformed by liquefaction. Structures resting on the fill had to accommodate the deformation. Photograph Credit: U.S. Geological Survey (D. Perkins).

15 The fine sand deposited near the curb is evidence of the liquefaction that took place in the Marina District of San Francisco. Some sand boils in the area spewed forth charred wood and other debris, remnants of the San Francisco that was destroyed by earthquake and fire in 1906. Photograph Credit: U.S. Geological Survey (D. Perkins).

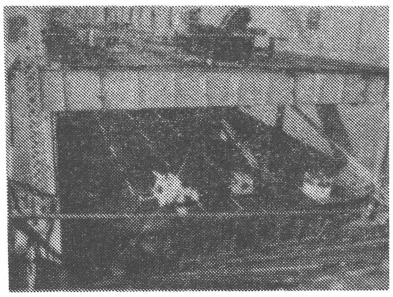
16 Damage to the upper floor of the three-story Clay Building at the corner of 10th & Clay Streets in Oakland, California. Photograph Credit: U. S. Geological Survey (C. Stover).

17 Aerial view looking west of part of the collapsed Interstate 880 double-decked highway structure. Fifty-one spans of this structure were involved in the collapse which killed 41 motorists. Only one 1.2 km span, shown in the center of the photo, did not collapse. Photograph Credit: U.S. Geological Survey (E.V. Leyendecker).

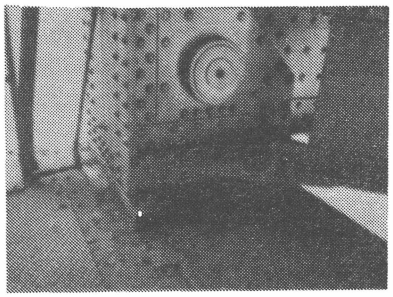


18 Side view of the collapsed Cypress section of the Interstate 880. Note the failed column support in the center of the photo and the ambulance to remove survivors. Photograph Credit: U. S. Geological Survey (C. Stover).

19 View of the San Francisco Oakland Bay Bridge looking west showing the failed 15-m long section at Pier E-9. The view is looking west from the upper deck of the 88-m truss (beam) supported by Pier E-9. A 153-m-long truss, also supported at Pier E-9, is shown on the west side of the opening. The 15-m span of the upper deck was supported at the west end by bearings attached to the large north-south girder visible on the west side of the opening. These support bearings allowed expansion movement of the 15-m sections. Similar supports were provided on a girder on the east side of the opening, except the bearings were attached to prevent movement. Failure of the bearings of the 88-m (east) truss allowed movement toward the east. This pulled the 15-m sections (upper and lower), which were attached to it, off their expansion bearings on the west end. The spans then collapsed but remained partially attached at the east end. Photograph Credit: U.S. Geological Survey (E.V. Leyendecker).



20 Truss support bearing shoe at Pier E-9 of the San Francisco-Oakland Bay bridge. This bearing shoe was located at the northeast corner of Pier E-9 and supported the northwest corner of the 88-m truss shown in photo 16. An identical bearing shoe was located in the southeast corner. Together, these bearings provided support for the 88-m truss at Pier E-9. Each bearing shoe was attached to Pier E-9 with 20 2.54 cm diameter bolts. During the earthquake all of the bolts in both bearing shoes failed. This allowed movement of the previously attached 88-m truss. As evidenced by the exposed paint, the bearing shoe came to rest about 14 cm to the north and 1.58 cm to the east of its original position. Photograph Credit: U.S. Geological Survey (E.V. Leyendecker).



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