1 Introduction

1.1 1999 Izmit Earthquake

At 3:02 a.m. local time, on August 17, 1999, a M_w 7.4 earthquake occurred on the North Anatolian fault in northwestern Turkey. The hypocenter was located at a depth of 15.9 km at 40.70N, 29.91E, near Izmit, the capital of Kocaeli province, 90 km east of Istanbul. The official death toll was more than 17,225, with approximately 44,000 people injured and thousands left homeless. The majority of deaths and injuries were in the cities of Golcuk, Adapazari, and Yalova (see Figure 1-1). Approximately 77,300 homes and businesses were destroyed, and 244,500 damaged. The total direct cost of the earthquake was estimated to be U.S.$ 6 billion.

Following the earthquake, the Pacific Earthquake Engineering Research (PEER) Center, which is headquartered at the University of California, Berkeley, sent a reconnaissance team to the epicenter region. The team consisted of Ken Elwood, Khalid Mosalam, Halil Sezen, and Andrew Whittaker of UC Berkeley; John Stanton of the University of Washington; John Wallace of UCLA; and Atila Zekioglu of Ove Arup and Partners, Los Angeles. The team was joined by Jay Love and Chris Smith of Degenkolb Engineers, San Francisco, and Nesrin Basoz of K2 Technologies, San Jose. A geotechnical engineering team supported by PEER and others complemented this team.

1.2 Seismological and Geotechnical Aspects

The 1500-km-long North Anatolian fault, which has many characteristics similar to the San Andreas fault in California, is one of the most extensively studied right-lateral strike-slip faults in the world. During the August 17 earthquake, approximately 110 km of the North Anatolian fault ruptured, with a maximum horizontal offset of 5.5 m (west of Golcuk) and a maximum vertical offset of more than 2.3 m (east of Golcuk). Figure 1-1 shows the measured horizontal and vertical offsets at selected locations. Figure 1-2 is a photograph of the vertical offset near the Ford plant in Golcuk; team member Atila Zeikoglu is standing in front of the ledge formed by the faulting.

The peak ground accelerations recorded in the region affected by the earthquake are shown in Table 1-1. Ground motion data were collected by the Kandilli Observatory and Earthquake Engineering Research Institute of Bogazigi University, and the Earthquake Research Department of the General Directorate of Disaster Affairs. The closest distance to the fault rupture plane and site classifications are also shown in the table. Strong motion stations are listed according to their locations from east to west

An acceleration time history recorded at the Yarimca (YPT) station across the Izmit Bay from Golcuk is shown in Figure 1-3. The secondary shaking evident at 40 sec appears in most acceleration time histories from the Izmit earthquake. However, when these accelerations histories are integrated, this high-frequency shaking has very little effect on the ground velocity and ground displacement. Response spectra for selected acceleration histories for 5% damping are shown in Figure 1-4. (The instrument at Sakarya failed to record the ground motion in the north-south direction.) The spectra have been divided into north-south (Figure 1-4a) and east-west components (Figure 1-4b). Since the fault line runs approximately east-west, these components can be interpreted as approximately fault-normal and fault-parallel, respectively.

Table 1-1 Recorded peak ground accelerations

Station	*Distance**	*Site class*	*Peak Acceleration*		
			N-S	*E-W*	*Vertical*
Duzce (DZC)	14	Soft soil	37	32	36
Sakarya (SKR)	3	Stiff soil	NA	41	26
Izmit (IZT)	8	Rock	17	22	15
Yarimca (YFr)	4	Soft soil	32	23	24
Iznik (IZN)	30	Soft soil	9	13	8
Bursa (BRS)	67	Stiff soil	5	5	3
Arcelik (ARC)	17	Stiff soil	21	13	8
Gebze (GBZ)	17	Stiff soil	26	14	20
Yapi Kredi (YKP)	63	Rock	4	4	3
Istanbul Airport (DHM)	69	Stiff soil	9	8	6
Fatih (FAT)	65	Soft soil	18	16	13
Ambarli (ATS)	79	Soft soil	25	18	8

*Distance from rupture

1.3 Scope and Organization of Report

This report presents information on the development of building and seismic codes in Turkey (Chapter 2), behavior of buildings (Chapter 3), and industrial facilities (Chapter 4) in the epicenter region. The observations presented in the following chapters are those of the PEER reconnaissance team. Because there was minimal damage to bridges during the earthquake, only summary information is presented below. Chapter 5 presents a brief summary and conclusions.

The reconnaissance team documented the collapse of two bridges. Each collapse was a result of fault rupture beneath the piers. Figure 1-5 shows the collapse of the bridge over the Trans-European Motorway. This bridge was composed of four 26-m-long simply supported spans. Each of the spans was positioned on elastomeric bridge bearings. Each span lost the support of at least one end. Figure 1-6 is a view of the bearings and an unseated span from one abutment. Another bridge near Akyazi collapsed (see Figure 1-7), reportedly due to movement of the supporting piers; much of the bridge is submerged in the photograph.

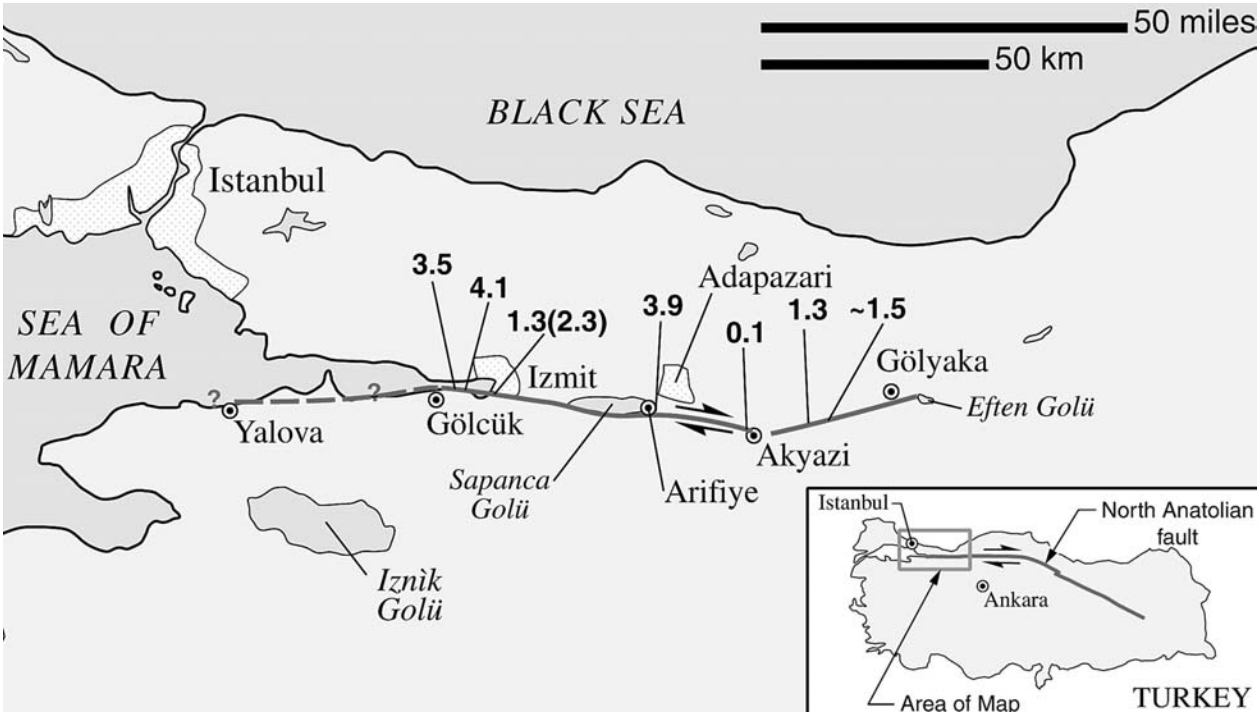
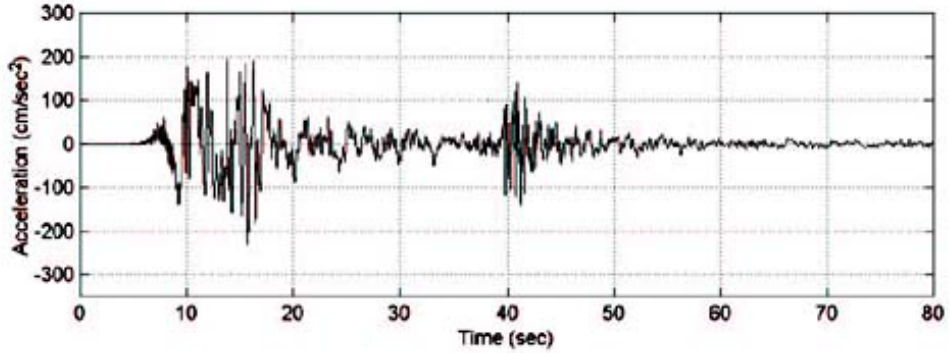
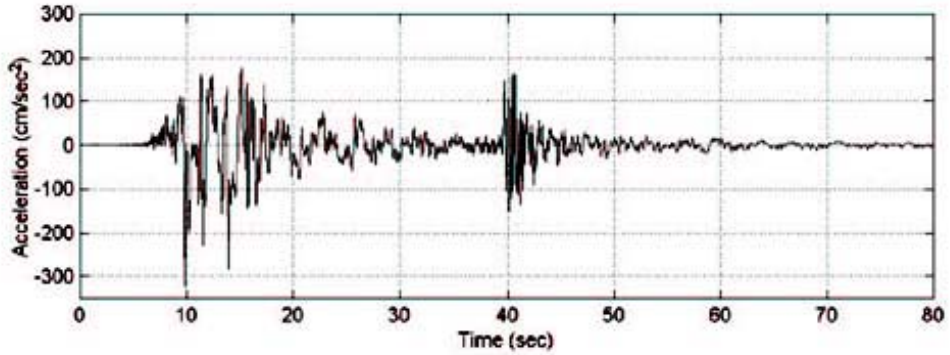


Figure 1-1 Map of affected region showing locations and size (meters) of horizontal offsets and a vertical offset (in parentheses)

Figure 1-2 Vertical offset near Ford Plant in Golcuk

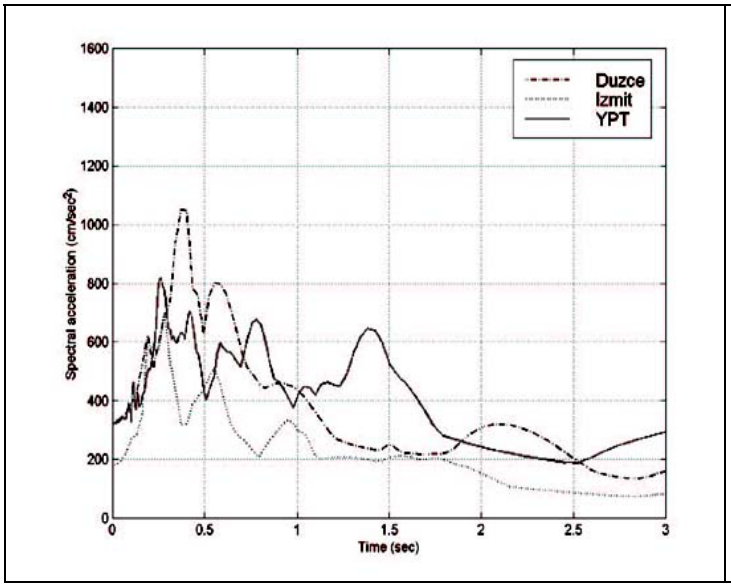


a. east – west component

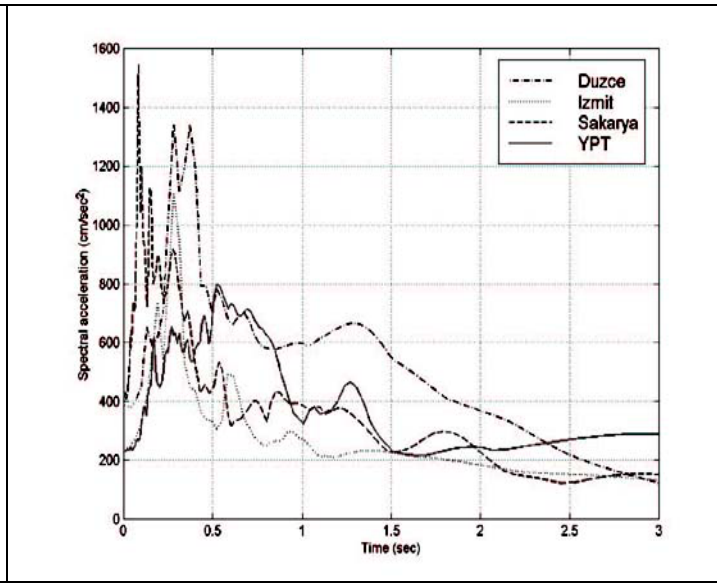


b. north – south component

Figure 1-3 Acceleration time histories from the Yarimca (YPT) Station



a. north – south components



b. east – west components

Figure 1-4 Acceleration Response Spectra for 5% Damping

Figure 1-5 Failure of a bridge over the Trans-European Motorway

Figure 1-6 Unseating of the simply supported span from the abutment-mounted bearings

Figure 1-7 Collapsed and submerged bridge near Akyazi