Appendix: Performance of the Adapazari City Hall

A.1 Introduction

Construction of Adapazari City Hall was started in 1959 and completed in 1964. This five-story reinforced concrete frame building was heavily damaged during the July 22, 1967, Akyazi M7.1 earthquake and retrofitted using conventional methods in the eight-month period after that earthquake. Adapazari was 36 km east of the epicenter of the 1967 earthquake. The estimated intensity in Adapazari was MMI 7.

The building is located in downtown Adapazari where many buildings either collapsed or suffered substantial damage during the August 17, 1999, Kocaeli earthquake. Since the retrofitted building suffered only minor damage, it was used as the headquarters of the city crisis center to direct earthquake-relief efforts. Aftershocks of the August 17 earthquake and the main shock of the November 12, 1999, Duzce M7.2 earthquake caused existing cracks to open more and new cracks to form in the frame members and infill walls.

A.2 Background Information

Like most other buildings in Adapazari, the City Hall building does not have a basement, since the water table lies 1 to 2 m below grade. The building is located on relatively soft soil deposits (Anadol et al. 1972). The foundation is composed of tapered footings (Figure A-1) connected with 400 mm by 900 mm grade beams in the x (longitudinal) direction and 500 mm by 1500 mm base beams in the y (transverse) direction.

The building has a clear height of 17 m above ground level. The plan footprint is 14.2 m by 40 m with 13 frames in the transverse direction and 3 frames in the longitudinal direction. A typical floor plan and elevation in the original structure are shown in Figure A-1. The shear walls in the transverse direction were not placed symmetrically in plan and created a stiffness eccentricity of 3.7 m. Anadol et al. (1972) reported that the concrete strength was 16 MPa (2350 psi) and that the yield strength of the smooth reinforcing bars was 220 MPa (32 ksi).

Resistance to lateral forces in the original structure was provided by two shear walls and 35 columns. The depth of the columns varied between 300 mm and 700 mm, and the width varied between 230 mm and 400-mm. Typical floor framing consisted of a 370-mm-deep joist system infilled with lightweight bricks, and 370-mm-deep beams varying in width from 400 mm to 1000 mm. The lightweight brick infill walls, which ranged between 100 mm and 150 mm in thickness, were not designed to carry lateral or gravity loads. Light steel sections were welded to the window frames at each story level on the facade. These steel sections were not part of the gravity- or lateral-load-resisting system.

A.3 1967 Akyazi Earthquake: Damage and Bung Retrofit

The damage observed after the 1967 M7.1 Akyazi earthquake was concentrated in the shear walls (Figure A-2) and columns in the lower stories. As shown in Figure A-3a, no ties were observed in one column (Grid A-1 in Figure A-1). In this figure "Etriye yok" translates as "No tie." Figure A3b shows shear failure in a column; this column was located at Grid T4 in the basement. Damage to stairwells, slabs, and beams was also reported at several floors. Large shear cracks were observed in many of the infill walls.

The 1967 retrofit program included repair and strengthening of damaged slabs, beams, columns and shear walls, and the addition of new beams and shear walls. Columns were typically retrofitted by the addition of transverse reinforcement and an increase in the column size by 140 mm to 180 mm. New transverse perimeter shear walls were added on Grids 1 and 13, and transverse interior shear walls were added on Grids 8, 9, and 10 to match existing walls on Grids 4, 5, and 6. Short longitudinal walls were placed in the four corners of the building. Figure A-4 shows the locations of the new reinforced concrete shear walls. ("B.A. perde" translates as "RC shear wall"). Existing perimeter longitudinal beams were retrofitted and new perimeter longitudinal beams were added as indicated in Figure A-5. The new longitudinal walls are shown hatched in this figure.

The fundamental periods of the building were calculated to be 1.38 and 1.08 sec in the longitudinal and transverse directions, respectively (Anadol et al 1972). After the retrofit work had been completed, the periods of the building were measured at 1.10 sec and 0.31 sec in the longitudinal and transverse directions, respectively (Aytun 1972). A summary of the building characteristics before and after retrofitting is given in Table A-1.

Table A-1 Characteristics of Adapazari City Hall (Anadol 1972)

	Original building	*Retrofitted building*
Average soil pressure	7.20 ton/m^2	7.92 ton/m^2
Strength of the building	Stronger in the y direction	Almost equal in both directions
Fundamental period (x-dir)	1.38 sec	1.10 sec
Fundamental period (y-dir)	1.08 sec	0.31 sec
Total weight	4370 tons	4732 tons
Stiffness eccentricity	e_x=17.7%,e_y=14.2%	e_x=0%,e_y=1.1%
Estimated ductility	1.5-2.0	4
Lateral force coefficient	C=0.04	C=0.07

A.4 1999 Kocaeli Earthquake and Aftershock

The North Anatolian fault ruptured within 10 km of the City Hall and devastated many reinforced concrete moment-frame buildings in the immediate vicinity of the City Hall, but this retrofitted building sustained negligible structural damage. The nonstructural components and contents suffered only modest damage. Because the City Hall was one of the few buildings in downtown Adapazari that suffered little to no structural damage, it was used as an Emergency Crisis Center to direct response and recovery after the earthquake. Figure A-6 presents two photographs of the City Hall taken in mid-November 1999.

The solid line in Figure A-7 presents the 5% damped pseudo-acceleration response spectrum prepared using the east-west ground acceleration history recorded a few kilometers from the City Hall during the August 17, 1999, earthquake. The zero-period acceleration for this recorded ground motion was 0.41g. The spectral acceleration at 1 sec, the approximate period of the City Hall building, was 0.4g. Because the building sustained little to no structural damage, and assuming that the strength of the building was no greater than 15% of the weight (calculated by doubling the allowable-stress-design lateral-force coefficient of 0.07), the intensity of shaking at the site of the building was likely substantially less than that indicated by the solid line in the figure. Parenthetically, the elastic spectral demands associated with the earthquake shaking in Adapazari were large, and it is not surprising that many nonductile reinforced concrete moment frame buildings in this city collapsed because the spectral demands greatly exceeded the lateral strength of these buildings that likely did not exceed 5% to 10% of their weight.

On November 11, 1999, an aftershock of the August 17 earthquake produced substantial shaking in Adapazari. The dashed line in Figure A-7 is the 5% damped pseudo-acceleration response spectrum prepared using the east-west ground acceleration history recorded at the site described in the previous paragraph. The zero-period acceleration for this motion was 0.35g. Additional damage to structural and nonstructural components in the City Hall was reported.

The lack of damage to the structural frame of the City Hall building, and the almost complete destruction of reinforced concrete moment-frame buildings around it clearly show that reinforced concrete walls are an effective means of retrofitting older reinforced concrete construction in Turkey. The strategic placement of new structural walls can reduce the plan and vertical irregularities of an existing building, thereby substantially improving its performance. The addition of a modest number of structural walls to the original City Hall building more than doubled the strength and substantially increased the stiffness of the building. The walls protected the vulnerable nonductile columns and joints from the gross damage and collapse that was observed in adjacent buildings.

A.5 Summary Remarks

The excellent performance of the retrofitted Adapazari City Hall in the August 17, 1999, main shock and the November 11, 1999, aftershock is, by comparison with the poor performance of most reinforced concrete moment-frame buildings in the immediate vicinity of the City Hall, a clear endorsement for retrofitting using reinforced concrete shear walls. The introduction of a modest number of strategically placed ductile structural walls into an existing nonductile reinforced concrete moment-frame building will protect the vulnerable nonductile components and substantially improve the performance of the building. Such conventional methods of retrofitting are the most promising and cost effective means of reducing the vulnerability of the large inventory of nonductile moment-frame buildings in Turkey.

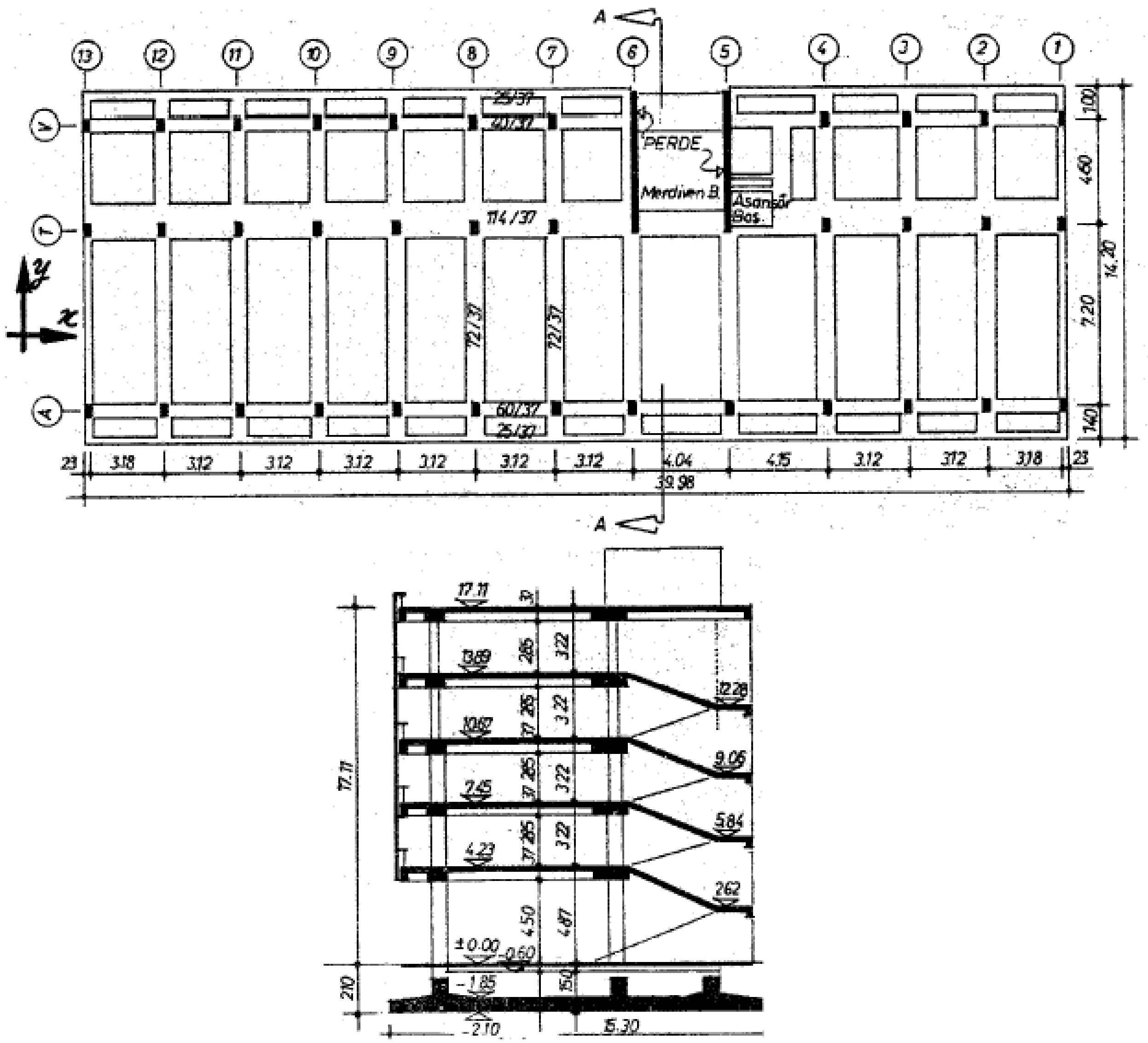


Figure A-1 Typical plan and elevation of the original building (Anadol et al. 1972)

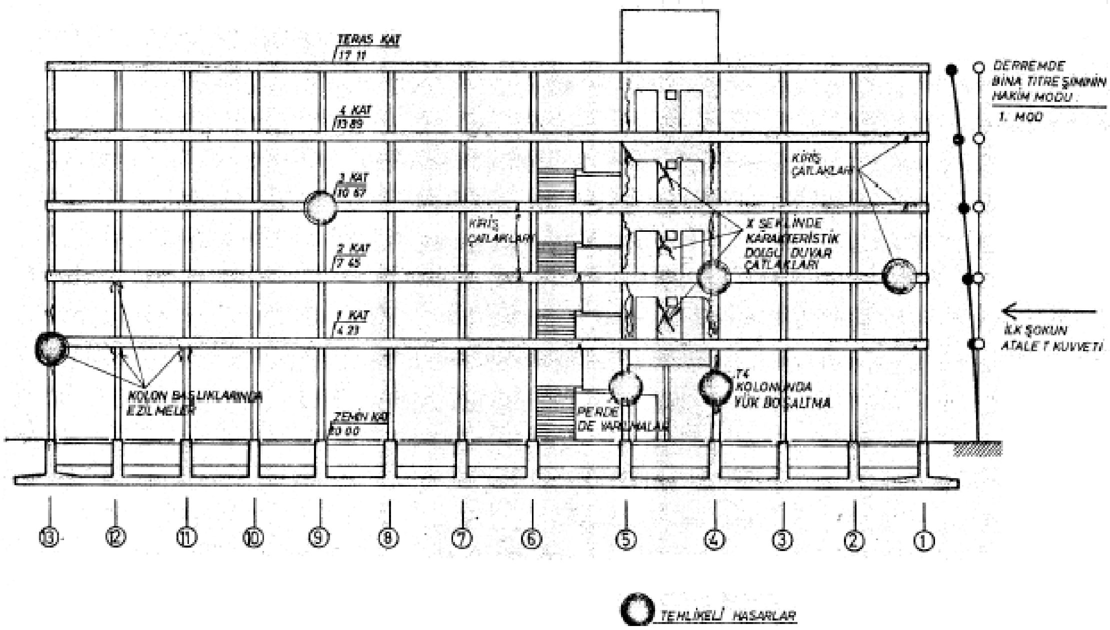
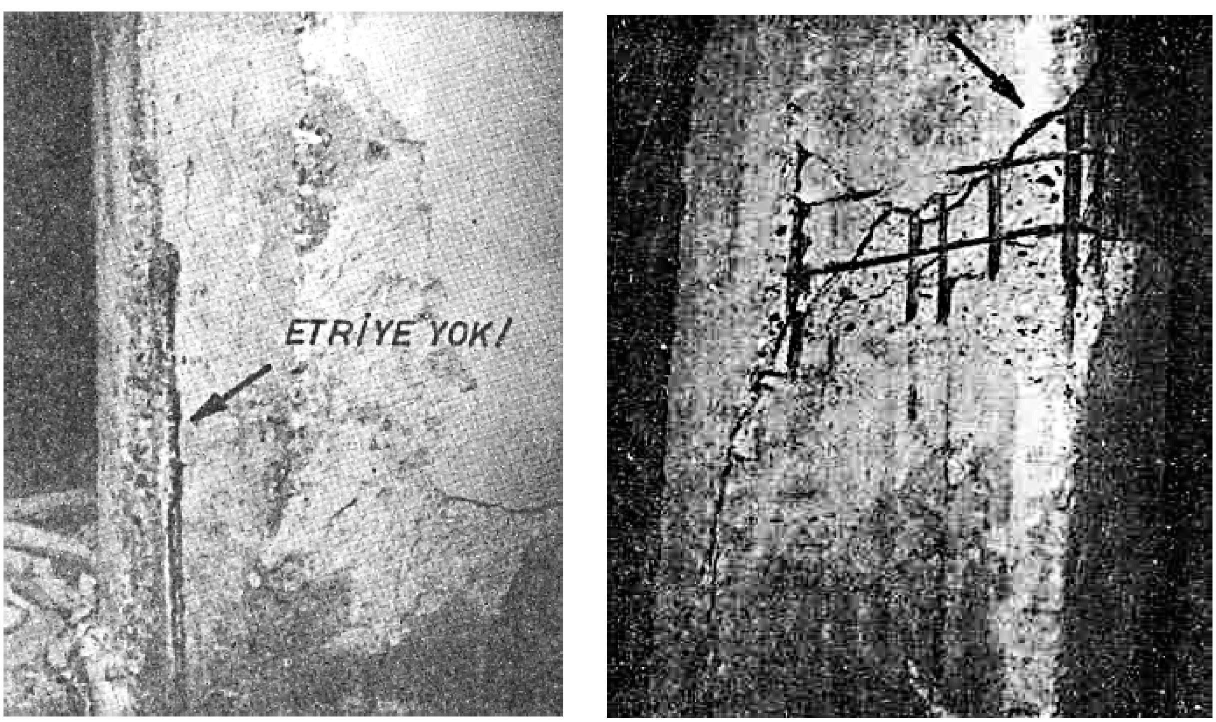


Figure A-2 Building damage after the 1967 Akyazi earthquake



a. no tranverse ties in a column

b. column shear failure

Figure A-3 Damage in the original building columns in the 1967 Akyazi earthquake

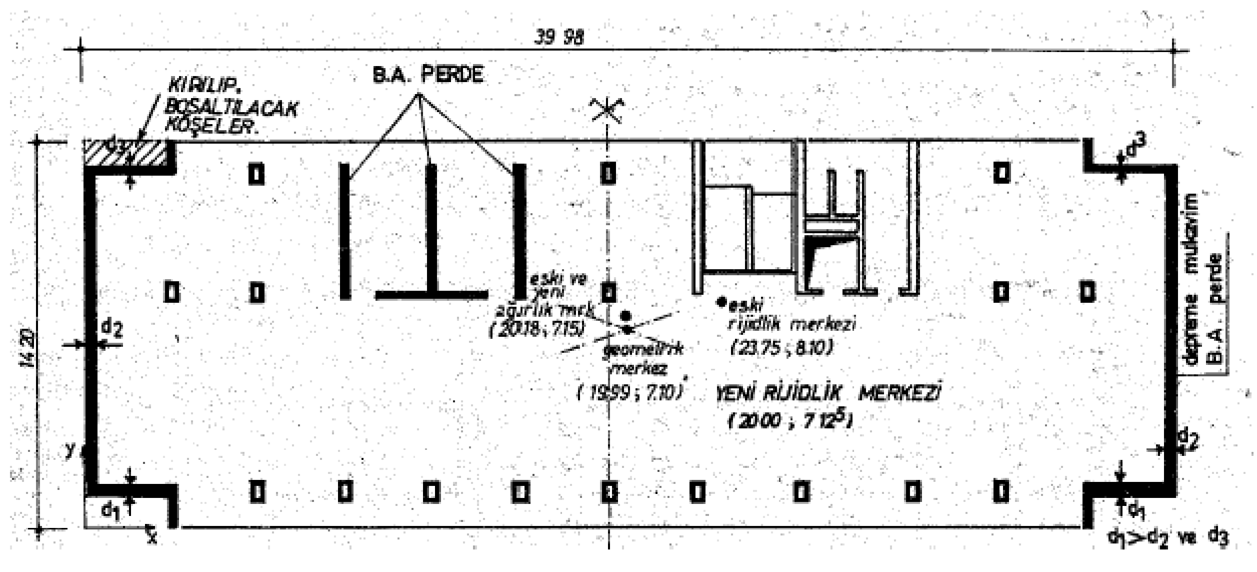


Figure A-4 Typical floor plan after retrofit showing the location of new shear walls (Anadol et al. 1972)

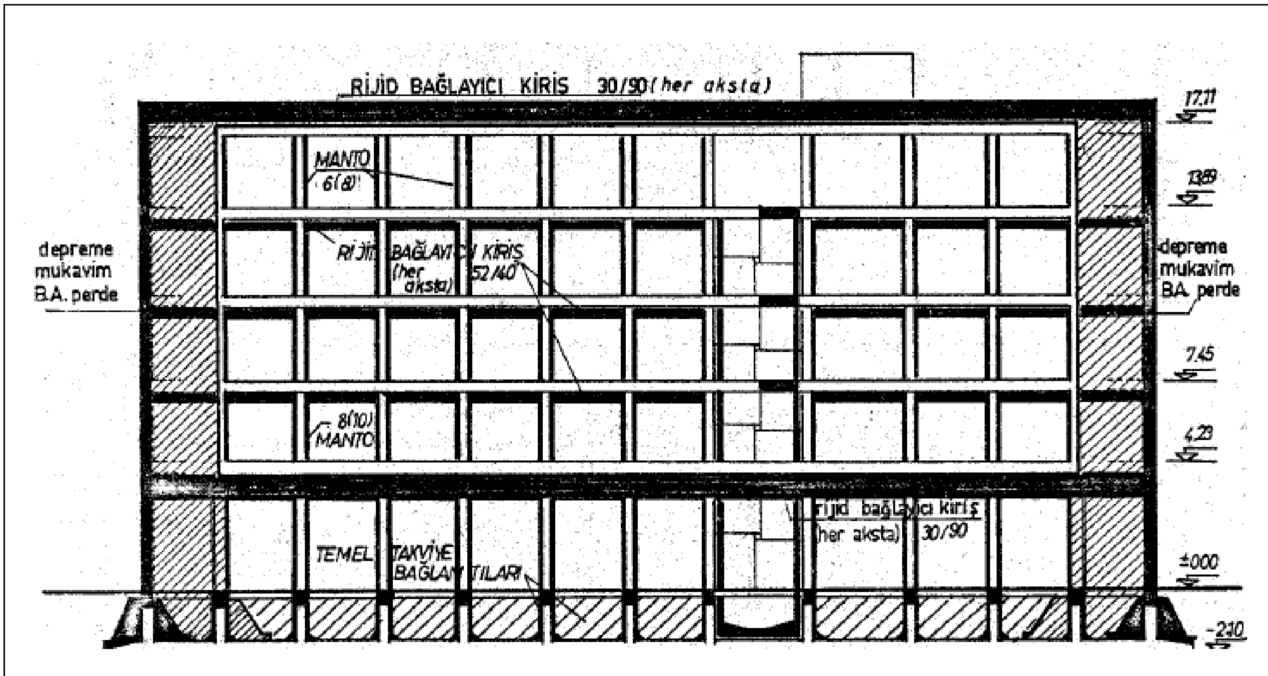


Figure A-5 Front elevation after the retrofit in 1968 (Anadol et al. 1972)

a. back view (V and 1 axes on plan, Fig. A-1)

b. front view (A and 13 axes on plan, Fig. A-1)

Figure A-6 City Hall after the November 12, 1999, Duzce earthquake

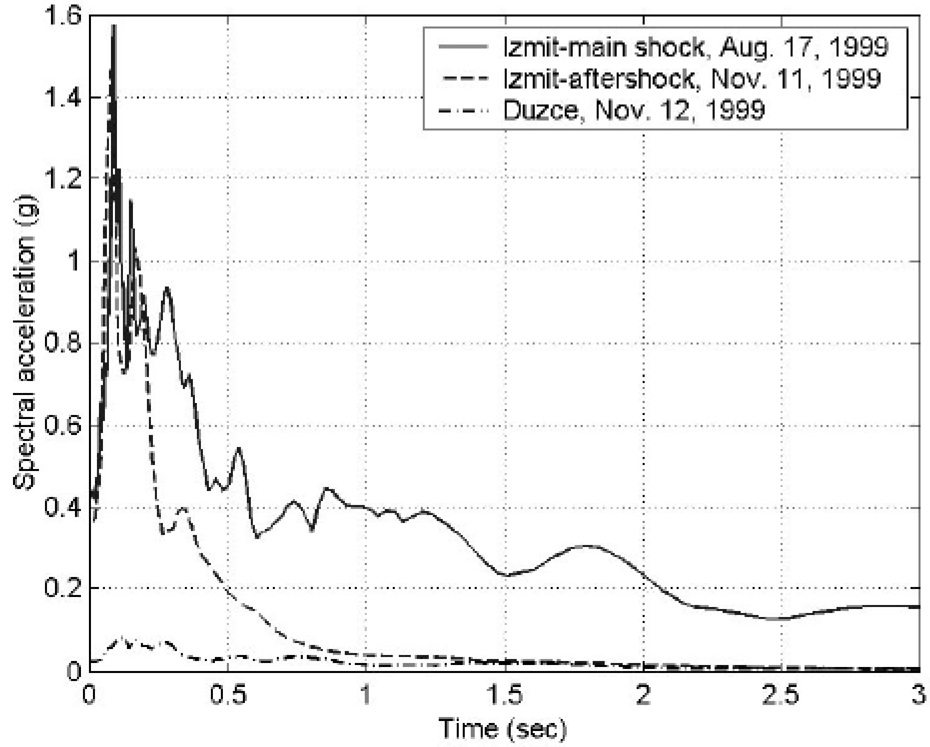


Figure A-7 Acceleration spectra for the August 17, 1999, Izmit main shock; the November 11, 1999, Izmit aftershock; and the November 12, 1999, Duzce main shock