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Engineering Failure Analysis 12 (2005) 440–452
ENGINEERING FAILURE ANALYSIS
www.elsevier.com/locate/engfailanal

Experimental evaluation of buildings damaged in recent earthquakes in Turkey

İsmail H. Çağatay *

Civil Engineering Department, Cukurova University, 01330 Adana, Turkey

Received 15 January 2004; accepted 10 February 2004
Available online 5 November 2004

Abstract

In this study, concrete of many reinforced concrete buildings damaged during the 17th August 1999 İzmit Earthquake and 27th June 1998 Adana–Ceyhan earthquake has been investigated. Low concrete quality has been a major cause in the total collapse of minor or heavy damage in reinforced concrete buildings in the area affected by the earthquakes. Core specimens, which were extracted from the buildings which collapsed or were damaged during Adana–Ceyhan earthquake were tested for the compressive strength of concrete. In addition, further experiments were carried out on the sea sand, which had been left unused on the construction site of the collapsed buildings in Avcılar, İstanbul, for determining its effect on the compressive strength of concrete. In those buildings, in which sea sand was used, aside from low concrete strength, significant loss of cross-sectional areas of steel reinforcement bars caused by the corrosion due to the presence of excessive chlorine ions was observed. It is noticed that in addition to its yielding low compressive strength concrete, sea sand is more dangerous from the standpoint of reinforcement corrosion, which may result in failure of the structure in a period of 10 or 20 years even under static loads.

Keywords: Earthquake damage; Structural failures; Building failures; Concrete; Corrosion

1. Introduction

Turkey, with more than 90% of its land being in highly seismic regions (see Fig. 1), is an earthquake-prone country and has been struck by many devastating earthquakes throughout history. During the last century, 111, 55 and 21 earthquakes took place with magnitudes greater than or equal to 5, 6 and 7, respectively. More than 80,000 people died and about 500,000 building collapsed or were heavily damaged. A

* Tel.: +90 322 338 67 84; fax: +90 322 338 61 26.
E-mail address: hcagatay@cukurova.edu.tr.

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doi:10.1016/j.engfailanal.2004.02.007

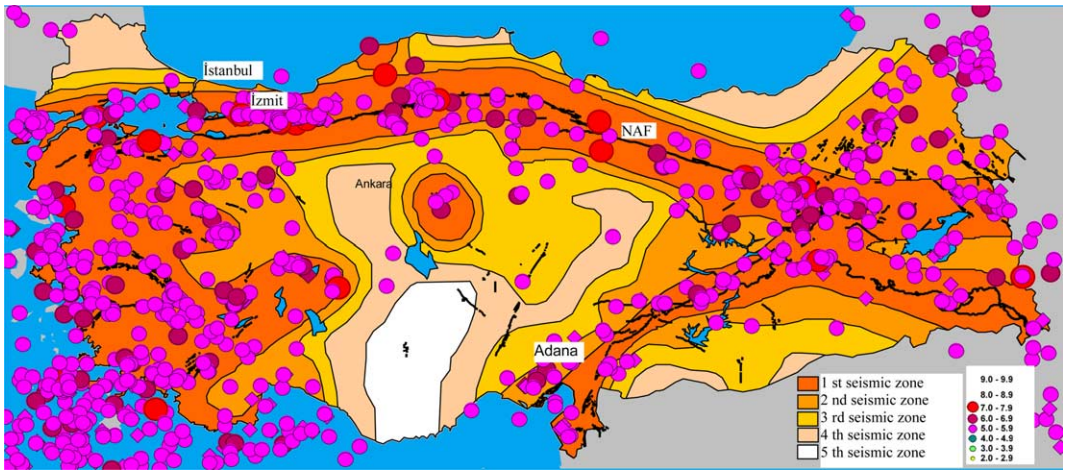

Fig. 1. Earthquake zone map of Turkey, (The zone in the map are classified as being apt to acceleration values characteristic of 1st, 2nd, 3rd, 4th, and 5th degree earthquakes: higher than 0.4 g, between 0.3 and 0.4 g, between 0.2 and 0.3 g, between 0.2 and 0.1 g, lower than 0.1 g (g = 981 cm/s^2), respectively. Only earthquakes with $M_w \geqslant 5$ have been shown).

summary of major earthquakes with magnitudes greater than or equal to 7 is given in Table 1 [1]. Amongst the earthquakes in Table 1, the last two occurred in densely populated cities. Tens of thousands of people died and hundreds of thousands of buildings collapsed or were heavily damaged.

Although it has been no secret that this region is vulnerable to high-intensity earthquakes, as it has been shown to be 1st degree severity area in the earthquake zone map, (Fig. 1), the negligence and ignorance in

Table 1
Earthquakes in Turkey during last century [1]

D/M/Y	M_s	Location	Dead	Heavily damaged buildings	N	E	Depth (km)
09.08.1912	7.3	Murefte	216	5540	40.6	27.2	16
31.03.1928	7	Izmir-Torbali	50	2100	38.18	27.8	10
06.05.1930	7.2	Hakkari	2514	3000	37.98	44.48	70
22.09.1939	7.1	Izmir-Dikili	60	1235	39.07	26.94	10
26.12.1939	7.9	Erzincan	32962	116,720	39.8	39.51	20
20.12.1942	7	Niksar-Erbaa	3000	32,000	40.87	36.47	10
26.11.1943	7.2	Tosya-Ladik	2824	25,000	41.05	33.72	10
01.02.1944	7.2	Bolu-Gerede	3959	20,865	41.41	32.69	10
06.10.1944	7	Ayvalik-Edremit	27	1158	39.48	26.56	40
23.07.1949	7	Izmir-Karaburun	1	824	38.57	26.29	10
17.08.1949	7	Karliova	450	3000	39.6	40.6	40
18.03.1953	7.4	Yenice-Gonen	265	9670	39.99	27.36	10
16.07.1955	7	Aydin-Soke	23	470	37.65	27.26	40
25.04.1957	7.1	Fethiye	67	3100	36.42	28.68	80
26.05.1957	7.1	Bolu-Abant	52	4201	40.67	31	10
06.10.1964	7	Manyas	23	5398	40.3	28.23	24
22.07.1967	7.2	Adapazan	89	5569	40.67	30.69	33
28.03.1970	7.2	Gediz	1086	9452	39.21	29.51	18
24.11.1976	7.2	Caldiran-Muradiye	3840	9552	39.12	44.16	10
17.08.1999	7.4	Kocaeli	15000	50,000	40.7	29.91	20
12.11.1999	7.3	Duzce	550	3000	40.79	31.21	11