CHAPTER

13

SEISMIC RISK MITIGATION PRACTICES IN SCHOOL BUILDINGS IN ISTANBUL, TURKEY

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Abstract: In 1999, 820 schools were affected by the Kocaeli earthquake in Istanbul, 22 of which were subsequently demolished. This paper describes the impact of the earthquake on school buildings in Istanbul and the subsequent rehabilitation and reconstruction activities. It assesses the vulnerability of the existing school building stock in Istanbul, providing an estimated budget for strengthening buildings that predate the 1998 Building Code and a review of the methodology, criteria and priorities required to implement such a project. The paper concludes with recommendations for implementing a practical macro-project plan for improving seismic safety in schools.

Introduction

Following the two major earthquakes that struck Turkey in 1999, there has been broad recognition by Turkey's governmental, non-governmental and academic institutions of the urgent need for an appropriate seismic risk mitigation strategy, as well as systematic retrofitting of key structures, using a rationalised policy. After the 1950s, earthquake disaster risk in Istanbul increased, mainly due to the high rate of urbanisation, faulty land-use planning and construction, inadequate infrastructure services and environment degradation. Istanbul also faces an unprecedented increase in the probability of the occurrence of a large earthquake, which is 65% over the next 30 years. The inevitability of such an event – of a magnitude between M6.0 and M7.5 – requires a comprehensive approach that addresses all engineering, legal, institutional, urban and financial requirements in risk mitigation and disaster management in the Istanbul Metropolitan Area.[1]

The Building Code in Turkey was updated in 1998 to include modern earthquake provisions. However, weaknesses in construction, which were exposed in the 1999 Marmara earthquake, revealed that compliance with the intent of the code was often poor and the effectiveness of the code enforcement insufficient. Thus, legislation was enacted in April 2000 to enforce mandatory design checking and construction inspection of all buildings by government-licensed private supervision firms. For new buildings, this supervision aims to ensure compliance with earthquake-resistant design codes and nominal construction quality standards. Furthermore, in June 2000, a professional qualification expert system under certification by chambers of civil engineers and architects was established. Legal activities are still underway to enhance professional training and professional liability insurance, and to involve professionals in the official inspection and production process.

Physical impact of the 1999 Kocaeli earthquake on school buildings

Although the 1999 Kocaeli earthquake of magnitude M7.6 damaged a considerable number of primary and secondary schools in the earthquake-affected region, the performance of school buildings was on average much better than for the general building stock. A total of 22 elementary and 21 secondary schools were damaged beyond repair. Another 267 elementary and 114 secondary schools reported minor to moderate damage. In Istanbul, a total of 820 schools were reportedly affected. However, following detailed damage assessment by teams of engineers and Ministry of Education provincial authorities, it was found that 689 schools had been only slightly damaged and could be repaired quickly, without causing any educational disruption. Educational activities were temporarily terminated in the remaining 131 schools. Among these, 13 schools were found to be heavily damaged and were replaced with new seismically safer schools. Of the remaining 118 schools, 59 were repaired, 37 were strengthened and 22 were demolished (and reconstructed) due to the high cost of foundation rehabilitation. The following rough prioritisation criteria were used for the repair and rehabilitation of these damaged schools:

- Boarding schools and facilities that provide accommodation received highest priority.
- Schools located in the 12 provinces with the highest risk zones – Avcılar, Bagcılar, Bakırkoy, Buyukçekmece, Kadıkoy, Kartal, Kucukcekmece, Maltepe, Pendik, Silivri, Tuzla and Zeytinburnu – were given high priority. Schools situated close to Marmara Sea, which is on the fault line, were also prioritised.

Costs for rehabilitating Istanbul schools

In Istanbul, due to the certainty of a major earthquake occurring, it was necessary to assess the seismic vulnerability of existing school buildings and to develop a project plan to facilitate their technical inspection, strengthening or reconstruction. During the initial phase of the project, the existing data on school building stock in Istanbul (Figure 13.1) was improved by collecting additional information on the year of construction, number of floors, total construction area, availability of design projects, and the geological and soil condition of the region. Special attention was paid to the inventory of school buildings that pre-date the 1998 Building Code. This is summarised in Table 13.1.

Table 13.1. A general overview of school building stock in Istanbul

	2003		Pre-1998 code		Already retro-fitted	Already rebuilt	To be retrofitted according to 1998 code	Post-1998 code
School type	No. of schools	No. of buildings	No. of schools	No. of buildings	No. of buildings	No. of buildings	No. of buildings	No. of buildings
Primary (ages 6-14)	1 329	1 692	1 028	1 305	24	27	1 254	387
Secondary (ages 14-17)	402	674	362	603	14	8	581	71
Other	133	138	31	28	2	0	26	112
Total	1 864	2 504	1 421	1936	40	35	1 861	570

The total cost of the project, including design and construction, was estimated at approximately USD 320 million. The computations (Table 13.2) are based on the total construction area of the buildings that pre-date the Code.

Figure 13.1. School building stock in Istanbul overlain on Code Hazard Map, with 50% probability of exceedance in 50 years

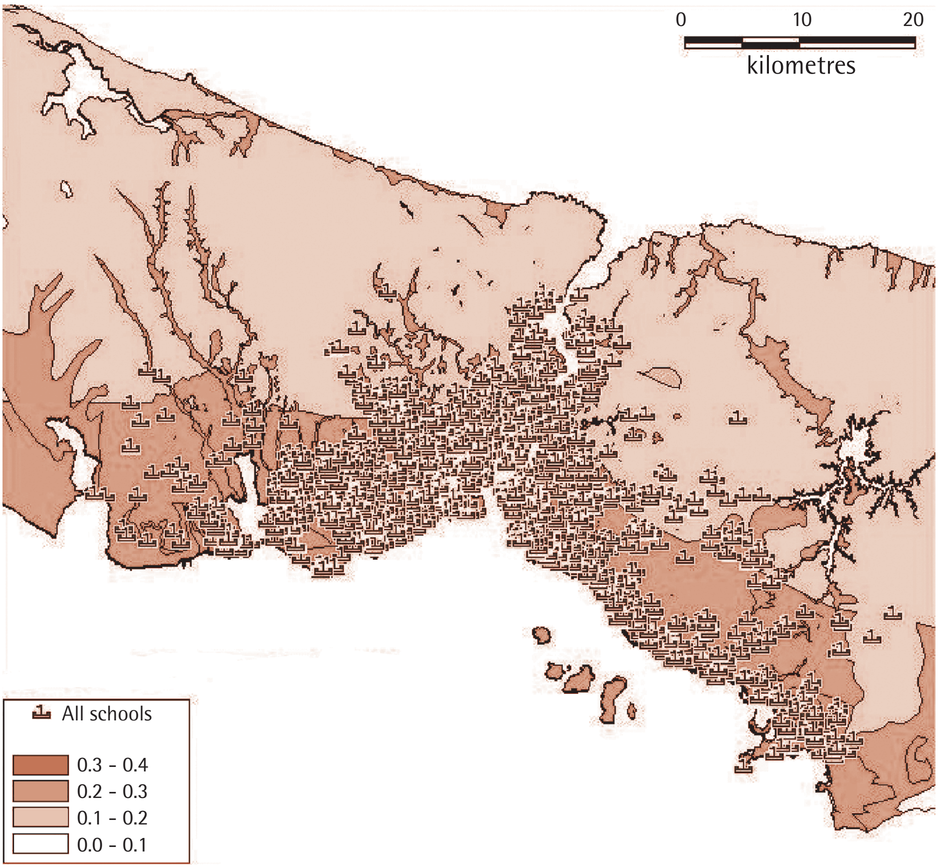


Table 13.2. Estimated strengthening cost of school buildings in Istanbul in 2003

(P = USD 4/m2; G = USD 200/m2; USD 1 = TL 1 500 000)

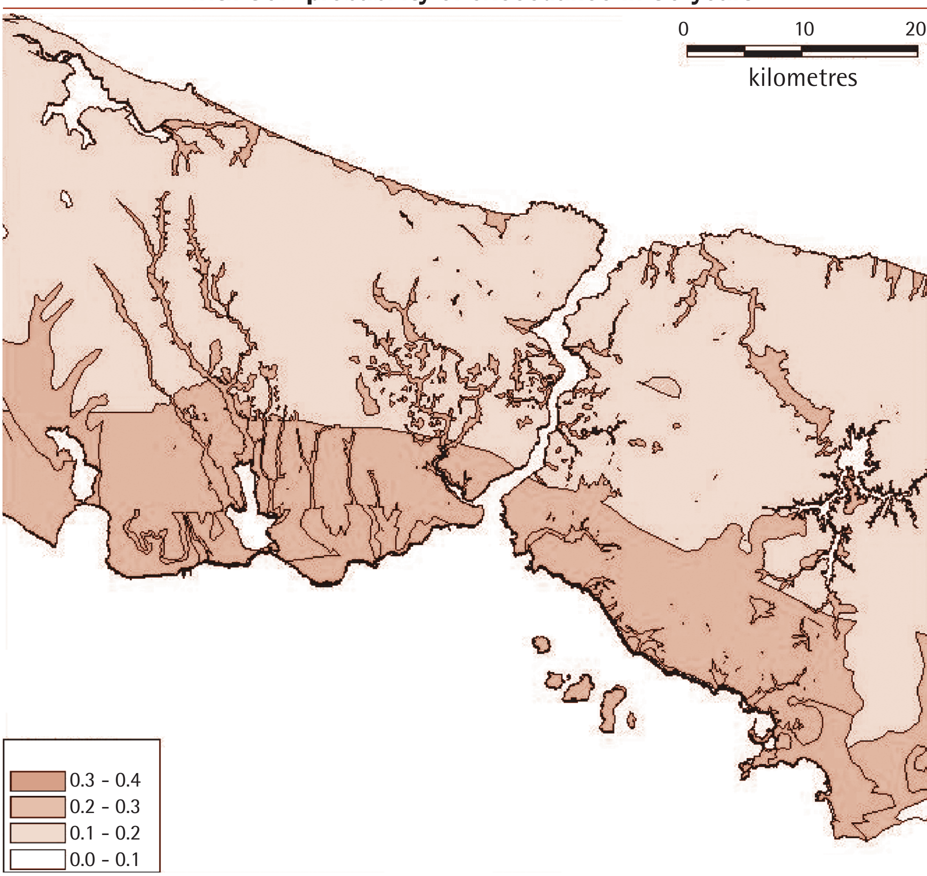
	Total area (m^2)	Project cost (USD)	Construction cost (USD)	Total cost (USD)
School type	A	B = (P) x (A)	C = 0.4 x (G) x (A)	(B) + (C)
Primary (ages 6-14)	2 130 000	8 520 000	170 400 000	178 920 000
Secondary (ages 14-17)	1 663 000	6 652 000	133 004 000	139 656 000
Total	3 793 000	15 172 000	303 404 000	318 576 000

Current seismic rehabilitation practice used in Turkey

At present, any repair or rehabilitation work should follow the requirements of the 1998 Earthquake Code, which is normally used for new buildings. According to the provisions of the 1998 Code, the performance of school buildings is improved through the use of *I*, the importance factor. Earthquake hazard is expressed in a more general sense as earthquake zones, essentially based on probabilistic hazard assessment that corresponds to 10% probability of occurrence in 50 years. The probability of a damaging earthquake occurring was increased because of stress migration after the 1999 earthquake and also due to non-Poissonian characteristics of the North Anatolian Fault.

The expected earthquake performance of school buildings in Istanbul is "immediate occupancy", which is an enhanced rehabilitation objective described in FEMA 356 for earthquakes that have a high probability of occurrence (about 50%) during the economic life of the school (about

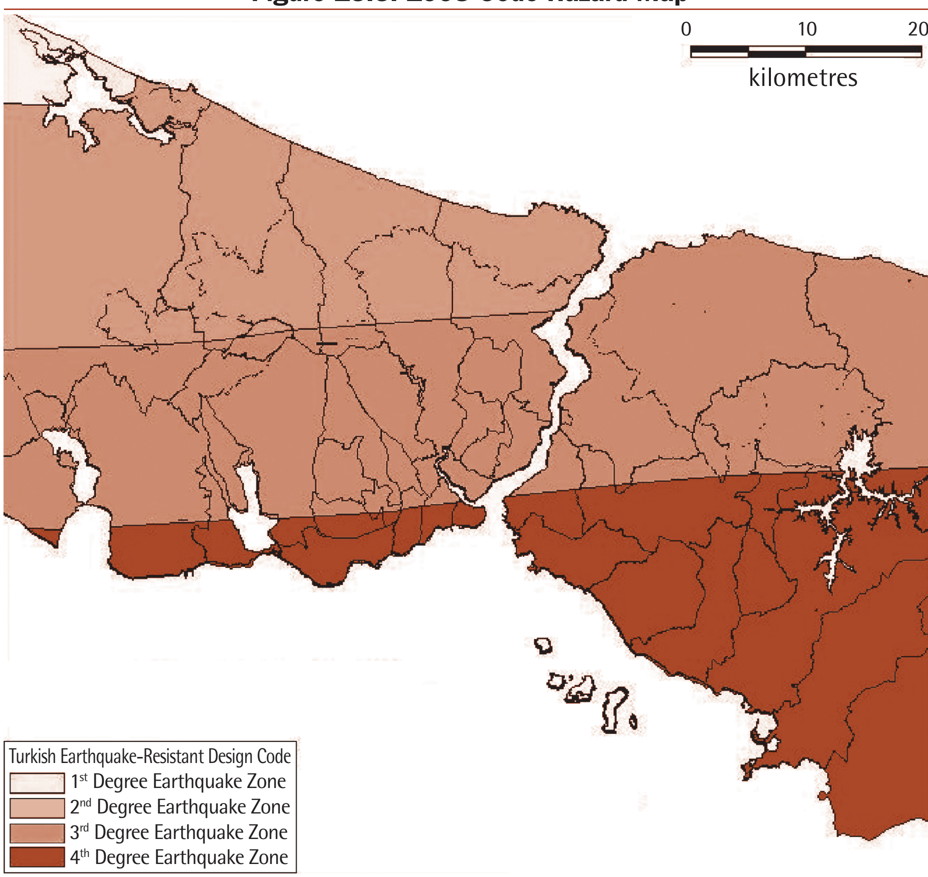
Figure 13.2. Earthquake hazard map for Istanbul, with 50% probability of exceedance in 50 years



50 years). It should be noted that with this earthquake exposure, the school building should perform almost linearly with a Seismic Load Reduction Factor of Ra(T) less than or equal to 1.5. Erdik *et al.* (2004) have prepared an earthquake map for Istanbul that corresponds to 50% probability of occurrence in 50 years (Figure 13.2) using sophisticated state-of-the-art techniques. Hazard information is provided in terms of peak ground accelerations at 0.2 s and 1 s periods. Figure 13.3 presents the seismic hazard zoning map currently used for the retrofit design of school buildings.

To illustrate the application of the present code using this approach, in Bakırkoy, a district in a first-degree earthquake zone with Ao = 0.4, the spectrum co-efficient is S(T) = 2.5 (Figure 13.4). For a reinforced-concrete frame structure with shear walls, the code allows the use of a seismic load reduction factor Ra(T) = 7. The importance factor for schools is specified as *I* = 1.4 in the code. Therefore, the spectral acceleration co-efficient A(T) specified in the code is A(T) = Ao. I. S(T) or A(T) = (0.4) (1.4) (2.5) = 1.4, and

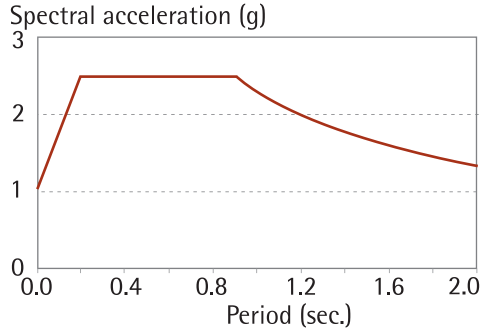
Figure 13.3. 1998 Code Hazard Map



the corresponding total equivalent seismic load Vt = W.A(T)/Ra(T) or Vt = (1.4) / 7 * W or Vt = 0.2 * W, where *W* is the total weight of the structure.

If a similar computation is carried out, but instead using the spectrum developed for the same district corresponding to an earthquake hazard of 50% probability of occurrence in 50 years, with a spectral acceleration of 0.78 (Figure 13.5): Ra(T) = 1.5, the total equivalent seismic load becomes Vt = (0. 78) / 1.5 * W or Vt = 0.52 * W.

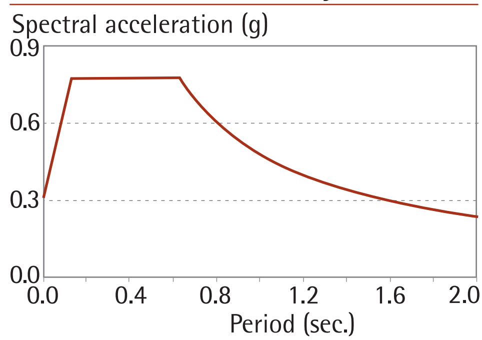
Figure 13.4. Site-specific spectrum for Bakirkoy (1998 Code)



Conclusion

As the overall school rehabilitation project budget is high and financial resources are limited, a comprehensive cash retrofitting should be completed with minimum disruption and temporary relocation of on-going educational activities. Furthermore, *advanced prioritisation and cost effective and rational rehabilitation methodologies* should be used. The FEMA 356 Pre-standard serves this purpose until a similar standard or guideline is developed that is specific to Turkey.

Figure 13.5. Site-specific spectrum for Bakirkoy, with 50% probability of exceedence in 50 years



For the rehabilitation of schools in Istanbul, the minimum performance level of school buildings is "*immediate occupancy*", with an earthquake hazard of 50% probability of occurrence in 50 years.

Additional retrofit design approaches (base isolation, energy absorption, etc.) – taking into account cost, building use, architectural value and location criteria – should be introduced.

The concept of cost-benefit analysis in the design process of retrofitting should be established, in addition to more effective design-review mechanisms for retrofitted structures.

Notes

1. Erdik, M. (2002), "Rehabilitation and Construction Activities after the 1999 Kocaeli and Duzce Earthquakes", Working Paper.

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