Learning from Earthquakes

The M$_{w}$ 7.1 Erçiş-Van, Turkey Earthquake of October 23, 2011

Introduction

At 1:41 pm local time on Sunday, October 23rd, 2011, a M$_{w}$ 7.1 earthquake struck Van Province in eastern Turkey (USGS, 2011). The earthquake claimed 604 lives. The town of Erçiş, with a population of 77,000 (GOVP, 2011), was hit hardest. Located about 40 km NNW of the estimated epicenter, it had 191 buildings collapse totally or partially, killing more than 600 people. Van, the larger provincial capital located about 15 km SSW of the estimated epicenter, was mostly spared, with only six buildings collapsed. On November 9th at 9:23 pm local time, a M$_{w}$ 5.6 earthquake struck about 10 km SW of Van (AFAD, 2011). This event claimed 40 lives and caused further damage in the city of 332,000, including collapse of 25 buildings, most of which had been condemned following the earlier earthquake.

Seismotectonics

The region around Van has a complex seismic setting due to the interaction between the Arabian and the Eurasian tectonic plates. The area has east-west thrust fault zones, as well as northwest-southeast right-lateral and northeast-southwest left-lateral translational fault zones (METU, 2011a) (see Figure 1).

The main shock is believed to have been on a WSW-ENE reverse fault with north-dipping fault plane (METU, 2011a) (Figures 2 and 3); the fault was not identified on the active fault map of Turkey (MTA, 1992). The November quake is believed to have occurred on a strike-slip fault also previously unidentified.

The largest earthquake recorded in the region during the last century was the 1976 M7.2 Çaldıran earthquake (Gulkan et al., 1978), although the 1945 M5.8 Çatak, 1972 M5.2 Van, and the 1977 M5.1 Erçiş were significant as well.

The strong ground motion station in Van did not record the ground shaking from the October main shock due to a malfunction. The closest station that recorded motion was the Muradiye station (38.99011N, 43.76302E), approximately 40 km NNE of the epicenter. Unprocessed records (Figure 4) indicate peak

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Figure 1. Above: Van and Erçiş are located in eastern Turkey by Lake Van (source: BBC, 2011). Right: fault zones around Lake Van (source: METU, 2011a).
ground accelerations were 178 gal (N-S), 170 gal (E-W), and 80 gal (U-D). Acceleration response spectra are shown in Figure 5. It is believed that Erciş had ground shaking stronger than that in Muradiye. The station in Van recorded the November ground motion with peak accelerations (unprocessed) were 148 gal (N-W), 246 gal (E-W), and 151 gal (U-D). The original and processed records from the October main shock can be found on http://eerc.metu.edu.tr/, and in METU, (2011b).

Performance of Structures

The seismic hazard map of the province (Figure 6) comprises the top two highest seismic hazard zones in Turkish earthquake-resistant design. The northern and southern thirds of the province are considered as seismic Zone 1, with effective PGA for design calculations equal to or higher than 0.4 g. Erciş is in the northern third of the province. The middle third of the province, which includes Van, is considered as a seismic Zone 2, with effective PGA in the range of 0.3g to 0.4g.

In 2000, following the devastating 1999 Marmara earthquakes, Turkish state authorities issued an ordinance on control of private building construction. However, the ordinance was struck down by the Constitutional Court within ten months, a setback that hindered establishment of independent and effective control mechanisms. In 2001, the Turkish Government passed a Building Control Law for privately built buildings; 19 of the 81 provinces were chosen as pilot districts to implement the 2001 law, but Van was not one of them. Only on January 1, 2011, did the Building Control Law go into effect in Van province, along with the rest of the country. It is believed that the 2001 Building Control Law will help improve the quality of construction as it establishes control authorities and prohibits unchecked construction. There are reports that 89 of the buildings in Van province that were built under the Building Control Law performed very well (Eyidogan, 2011).

Building stock and construction type. The dominant types in the region are one- to nine-story rein-
forced concrete (RC) buildings with infill walls and moment-frame or moment-frame and structural walls, and one- to two-story bearing-wall buildings. Buildings constructed before 2000 tend to be one to four-stories high. The majority of the buildings have full or half-basements. With the population growth in the provincial capital (Figure 7) and the economic boom in the region over the last decade, many taller buildings of eight to 12 stories have been put up in Erciş and Van in recent years. In Erciş, where nearly 200 buildings collapsed totally or partially, most of the casualties occurred in the newer and taller buildings. We learned from local engineers that ready-mix concrete became available in the last 3-4 years, and that there has been widespread use of poorly washed sand and gravel from local creeks. Inspecting the debris of collapsed structures showed a number of deficiencies: insufficient confinement reinforcement and 90-degree hooks in transverse rebars, use of smooth rebars, improper splicing of column longitudinal reinforcing bars, poorly graded concrete mix design, and substandard concrete casting (Figure 8). Apparently, the new RC structures were designed by engineers, but they had no quality control during the actual construction of the building. Our local contacts noted that the construction process had become so informal that landowners would hire separate local specialty workers (for formwork, rebar placement, concrete casting) and not even hire a contractor to organize the process. Few, if any, inspections or quality control checks were done.

The widespread poor material use and construction quality do not explain the variation in damage in the building stock. We observed that a majority of the damaged buildings suffered from obvious fundamental design errors such as inadequate lateral-load resisting systems, soft-story at ground level

Figure 5. Response spectra for the N-S and E-W records for the Muradiye station motion (unprocessed) recorded during the main shock (source: METU, 2011b).

Figure 6. Seismic hazard map for Van Province (MPWS, 1996) with epicenters of the October and November earthquakes.
In most of these buildings, mezzanine floors are constructed to provide additional office space. Typically, the mezzanine floor slabs are wrapped around the elevator core, which typically consists of structural walls. The resulting extreme difference in the stiffnesses rendered these structural walls vulnerable. Figure 11 shows a commercial building under construction in Erciş that sustained heavy damage in its core wall at ground story (including mezzanine level) and second story.

Residential buildings not on main streets are typically free of commercial units. These residential buildings performed generally better during the earthquake. Newer mass housing buildings north of Van built mainly by TOKI, the Housing Devel-

Figure 7. Population growth in Van and Erciş, 1935-2008.

Figure 8. Examples of deficient reinforcement detailing, poorly graded concrete mix, substandard concrete casting (photos: Alaluf, Dönmez, İrfanoğlu, METU group).

Figure 9. Typical mixed-use buildings in Van (top) and Erciş (bottom) (photos: Dönmez, İrfanoğlu).
Even though there are no ground motion records from Erciş or Van for the October event, it is believed that the levels of ground shaking in these towns were such that architectural infill walls, in general, assisted the actual lateral load-resisting structural systems in the buildings. However, in certain cases, these supposedly nonstructural walls interacted with the structural systems to the detriment of the latter by forming captive column conditions either from the beginning of (Figure 12) or during the dynamic response of the building (Figure 13). In adjacent buildings with insufficient separation, pounding damage was observed (Figure 14).

The typical floor structural systems in the RC structures are two-way slab systems and infill joist floor systems (Figure 15), the latter being found mainly in buildings built in the last five years.

There is a tendency to have structural walls in five-story or taller buildings constructed recently. However, we observed new or under-construction buildings with improperly positioned structural walls that resulted in floor torsion. One nearly completed building (Figure 16) had a single large structural wall on the back that created floor torsion, and block-infill...
Joist floors which were too flexible compared to the columns. There was concrete crushing and/or shear failure at lower ends of almost every column at the ground story, and flexural failure at the ends of the perimeter beam installed along one edge of the building. Furthermore, cracks developed at column-joist floor interfaces at every floor level, and a web of cracks spanning between column lines was observed in the joist floor slabs at every floor level (Figures 16 and 17). The concrete strength of the structure was determined to be around 30MPa with a Schmitt Hammer. Even though deformed bars were found in the columns, almost no confinement reinforcement was observed at the plastic hinge regions.

There are few buildings with structural walls. Except in some of the school buildings, which will be discussed below, structural walls were usually not adequately proportioned. Still, walls around elevator shafts did tend to reduce damage to the rest of the structure though they sustained considerable damage themselves.

In Gedikbulak, a large village with 250 buildings located about 15 km NW of the October earthquake epicenter, a three-story primary school building with structural walls collapsed during the earthquake (Figure 18). The building, constructed in 1988, had an approximately 14.4m x 21.4m footprint.

It had two 7.2m x 0.3m structural walls along its plan long direction built on one end of the building and only columns, some of which were captive, at the other end. Two 4.6m x 0.3 m structural walls bordering the stairwell, which was near the centerline, acted as the main lateral load-resisting elements in the plan short direction. The seven 0.5m x 0.3m columns around the building perimeter were the sole vertical structural elements along one half of the building front, although four 0.3m x 0.3m interior columns were also present. The collapse configuration evidenced floor torsion as it appeared that the building twisted in plan as it slumped.

Buildings in low-income districts in the region are typically constructed either with concrete masonry units as bearing walls for single-story buildings, or with reinforced concrete frames with masonry infill for up to two-story buildings. These structures commonly have light timber roofs with light gage metalconfigurations.
covers. Most of these structures survived the earthquake with no damage, an indication that their elastic limits were not exceeded. Buildings in villages are constructed typically as bearing-wall structures using concrete masonry units, bricks, or rocks. The typical failure mode in these structures was out-of-plane wall failure due to the absence of diaphragms tying the walls together (Figures 19 and 20).

Seismically strengthened buildings. There were several seismically strengthened buildings in the area, three of which were visited by team members. The Ziraat Bank building in Erciğ survived the earthquake with minor damage (Figure 21). The Kazim Karabekir Primary School in Erciğ is a four-story reinforced concrete frame/structural wall building with hollow clay tile walls used as partitions; it had been retrofitted by replacing some of the hollow clay tile infill walls with reinforced concrete structural walls (Figure 22). A survey of the structure revealed that the material quality and the reinforcement detailing in the original framing was inferior. During the October earthquake, there was widespread partition wall damage in the structure. Beams supporting the stairs exhibited damage as well,

Figure 16. Six-story commercial building under construction, column failures at the base on the first (ground) floor (photo: Dönmez).

Figure 17. Damage in the perimeter beam, and the joist floors seen from bottom and top of floor (photos: Dönmez and İrfanoğlu).

Figure 18. The three-story primary school in Gedikbulak village after collapse (photos: Erdil, İrfanoğlu).
but it was due to discontinuity in the flexural reinforcement. The existing (original) structural walls of the structure in the N-S direction had a diagonal web of hairline cracks up to the third story. There was separation at the interface between the added structural walls and the perimeter framing, particularly the beam to which the added structural reinforce-

ment was anchored. The damage pattern indicates that the added shear walls did not engage with the existing structural frame right away.

The Van Merkez İskele District Boarding School classroom building is similar to the school in Figure 22. The two-story RC building had diagonal nets of hairline cracks in some of its original structural walls. There were also signs of separation between the added structural walls and the perimeter framing, particularly at the wall-upper beam interface.

Reportedly, the Van branch building of the Turkish Central Bank had been reviewed for possible seismic strengthening, but that had been deemed unnecessary (Figure 23). This very irregular five-story building has a three-story atrium and wing walls at the perimeter as the primary structural elements of the system. No structural failure was seen in the system except for a crack on one of the beams; however, extensive partition wall failure in the building disrupted services.

**Government buildings.** Structural systems in government buildings varied depending on the age of the structure. The spectrum stretches from stone bearing-wall systems in old structures to RC frames in relatively new structures, but RC frames predominate. They are subject to special regulations depending on the ministry with which they are associated. The Erciş Palace of Justice is an example of the old bearing-wall systems. As shown in Figure 24, cracks formed in the walls and went through concrete lintels within the walls.
The Erciş District Governor's Office, a campus of two- to five-story plus basement modern RC buildings with frame and structural wall systems, sustained no structural damage and only minor damage in nonstructural walls. The main problems were failed water tanks in the basement, collapsed archive support systems (Figure 25), and ceiling tile failure in the conference hall on the top floor.

**Primary/secondary education buildings.** Primary schools inspected in both Van and Erciş had in-plane and out-of-plane damage to the hollow clay tile infill walls and minor structural damage in some of them. Many schools had cracking at the frame/wall interface, diagonal cracks, through-cracks, and crushing of the infill walls. Out-of-plane gable wall failure was typical in all of the schools that were observed throughout the area.

At the Cumhuriyet Primary School (Figure 26), a conglomeration of four-story buildings located approximately 0.5 km southeast of the collapsed building (“Sevgi Apartmanı”) that claimed 50 lives in the city center of Erciş, there was only minor damage to the structural system. Except for a corridor in which the infill walls were crushed, minor to moderate damage to the infill walls with cracking at the wall/frame interface.

At the Atatürk Primary School, approximately 0.5 km northwest of the “Sevgi Apartmanı” building, a three-story plus basement school building had out-of-plane gable wall failure, but the building was in a good enough condition for the military to use it for response operations.

Near the Van pier, a three-story building used as a teachers’ residence had out-of-plane wall failure.

![Figure 22. Kazim Karabekir Primary School in Erciş. Interface crack between the added RC structural wall and the original beam (photo: İrfanoğlu).](image)

![Figure 23. The Van branch building of the Turkish Central Bank (photos: Dönmez).](image)

![Figure 24. Severe damage to walls of Erciş Palace of Justice (photos: METU group).](image)
Above the third-floor ceiling slab, the structure consisted of wood post/beam framing supporting the roof with a story height equivalent to the floors below. The wood-framed portion had wood diagonals placed systematically to provide stability. On two sides of the structure at the uppermost story, out-of-plane wall failure was observed (Figure 27).

**Universities.** Van Yüzüncü Yıl University, established in 1982 with a population of approximately 18,500 students, is located approximately 20 km from the epicenter of the October earthquake. Overall, campus buildings performed well from a structural point of view, with most buildings having only minor to moderate damage to the hollow clay tile infill walls. The library, a five-story building with an irregular footprint and obvious inferior concrete quality and reinforcement detailing, sustained the most damage and is currently out of commission. The damage appeared to consist primarily of an out-of-plane collapse at a gable wall and the exterior wall at the exit stair well, heavy structural damage at the stairs and some beams in the structure (Figure 28). A few buildings were deemed to require further investigation, while others had only a little nonstructural damage with some cracking at the wall/frame interface.

The Medical School of the university is not on campus but in Van, with seven main blocks interconnected to each other. Four of these blocks were built 60 years ago. The other blocks were built in the last 15 years. All of the blocks are RC structures with two-way slab systems. Even though the overall construction quality was not good, no structural damage was observed in the buildings after the October earthquake. However,

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Figure 25. Archives in Erciş District Governor’s Office (photos: İrfanoğlu).

Figure 26. Cushioned infill walls in Cumhuriyet Primary School in Erciş (photo: İrfanoğlu).

Figure 27. Teachers’ housing in Van near the pier (photo: Hernandez).

Figure 28. Library building at Van Yüzüncü Yıl University (photos: Dönmez).
due to medium to heavy nonstructural damage, the university hospital was out of service. The nonstructural elements and contents that rendered the hospital inoperable were partition walls, molded gypsum ornaments at the ceilings, wall panels on top of partition walls, and laboratory glassware and hardware. The university was closed until February 2012.

Mosques. Construction of the mosques we observed generally consisted of concrete frame with hollow clay tile infill in the prayer hall and stone cladding in the minarets (see Figures 29 and 30).

The prayer halls of most mosques in Erciş and Van had little damage, largely minor diagonal cracks and/or cracks at the interface of the infill/frame, although the Kara Yusuf Paşa mosque in Erciş sustained heavy damage in its main structure (Figure 31). Minarets had damages that ranged from minor cracks in the shaft, toppled end ornaments, and toppling of the minaret just above the transition segment. Figure 32 shows that the toppled minaret punched through the elevated concrete slab above the ablution room.

At the Salihiye Mosque on the north side of Erciş, one of the minarets failed just above the transition zone and toppled southward, damaging the dome of the prayer hall. The other minaret showed signs of incipient failure well above the transition zone. In Gedikbulak, the local Bülbül Mosque collapsed totally (Figure 33).

Hospitals and health-care facilities. There is a wide range of hospital buildings in both Erciş and Van. The Erciş State Hospital, constructed in 1962 with five buildings, has a current capacity of approximately 134 beds. It is located approximately 100 m from the Sevgi Apartmanı. Most buildings on the campus are two- to three-story reinforced concrete buildings. Discussions with the security personnel at the site revealed that the building was red-tagged despite only minor damage. The hospital could have played a significant part in the emergency response had it been open. It received a green tag approximately one week after the earthquake, and was scheduled to resume normal operations shortly thereafter.

The Van State Children’s Hospital, located in the heart of Van and 22 km southwest of the epicenter of the October earthquake, consisted of several three-story buildings constructed in the 1960s. Most of the buildings had minor to moderate cracking at the frame/wall interface, with some local damage due to pounding and infill damage. Like its counterpart in Erciş, the entire campus was closed to patients.
The Van State Hospital is a state-of-the-art facility with several buildings that opened approximately one year ago. Located 30 km southwest of the epicenter of the October quake, it has deep foundations supporting the reinforced concrete frame building. Based on our discussion with hospital personnel, there was only minor nonstructural damage, such as some interior wall cracks and a partial collapse of a small portion of the exterior façade. There was no interruption in service and the hospital cared for injured immediately after the earthquake.

Industrial facilities. Industrial facilities in Van and Erciş had little to no damage to the primary structures. The industrial area of Van is located approximately 20 km SW of the epicenter of the October earthquake. The building inventory includes precast concrete buildings, concrete frame with hollow clay tile infill walls, and steel-framed buildings—sustained damage only to its administration building. A three-story concrete frame structure with a daylighting basement had some unreinforced hollow clay tile facades fall off at several locations and moderate infill wall damage. Neither of the plants had direct business interruption. The cement plant was going through its regular annual maintenance, and was not in operation. The sugar plant stopped production, though it was operable, because it was selected as the warehouse/center for aid distribution to earthquake victims.

Lifelines

Highway roads and bridges. Except for the road surface deformation near the epicentral region on the main Van-Erciş highway, no impact on the roads was observed. According to reports from the METU-EERC and civil engineering teams (METU, 2011a), damage in the 14 reinforced concrete highway bridges inspected by the teams was minimal. Most of the bridges were made of reinforced concrete piers.
Lake Van port. The port is constructed of deep foundations supporting a 84-m long by 14-m wide concrete pier (Figure 36) structure with a capacity to dock one large cargo ship on one side of the pier and several small to medium-sized boats on the other side of the pier. From our preliminary observations, there were two transverse cracks in the pier, the first near the beginning and the other approximately 20 m from the end. The crack near the beginning of the pier did not continue through the width of the pier, but the crack near the end was a through-width crack. At the time of our observation, the pier was in use and the damage did not appear to affect its operation.

A prefabricated one-story structure used to house passengers had minor cracking due to the spreading of soil in the vicinity. Small sand boils and spreading cracks approximately 2.5 to 3 cm wide were visible.

Electrical transmission stations. Observations were made at two local electrical substations in the affected area near the city Van. The 154-kilovolt transformer center approximately 22 km southwest of the October earthquake epicenter, which receives power from the local Kebean dam, had no

Railroad system. No damage was reported in the railroad system, including in the railroad tunnel in the epicenter region (METU, 2011a).

Airport. In the wake of the October quake, Van airport was put back into full service after a quick inspection of the runway and the navigation equipment. There was

Figure 35. The old and the new terminal buildings at Van airport (photo: İrfanoğlu).

Figure 36. Pier at Van (photo: Hernandez).

Figure 37. Transverse crack at the Van pier (photo: Hernandez).
damage although service to Van was interrupted for approximately 3 hours due to downed power lines in the city. A new 380/154/33 kilovolt capacity electrical substation located approximately 20 km southwest of the October epicenter was under construction and scheduled to open in November 2011. The substation reportedly had no damage except some transformers that shifted during the earthquake. The opening of the substation was delayed until the transformers were repositioned.

Emergency Response

In the October quake, 604 people were killed, about 2,600 were injured, and 222 were rescued from collapsed structures during emergency response operations. During the November quake, 40 people lost their lives and 30 were rescued from collapsed structures near Van.

According to the Turkish Disaster and Emergency Management Directorate (AFAD), within hours of the October earthquake, nearly 500 search and rescue, emergency medical and Red Crescent personnel arrived at the disaster region. They were mobilized from 48 provinces and 39 agencies. As of mid-December, 5,267 search and rescue, 500 search and rescue, emergency medical and Red Crescent personnel arrived at the disaster region. They were mobilized from 48 provinces and 39 agencies. As of mid-December, 5,267 search and rescue, emergency medical and Red Crescent personnel arrived at the disaster region. They were mobilized from 48 provinces and 39 agencies.

As of mid-December, 73,679 tents (29,222 from abroad), 260 prefabricated housing units, 10,155 inhabitable containers, and 3,794 specially designed prefabricated houses were sent to the region. As winters are harsh in the disaster region, over 336,000 blankets, 7,192 sleeping bags, and 27,500 heaters were distributed. Approximately 20,000 people were living in 14 tent cities built in Van and Erciş. Nearly 3,500 tents were distributed in the countryside to shelter animals. Over 132,000 meals were being distributed daily in three central cafeterias and 35 schools in the region. At the end of January, 19,500 inhabitable containers were providing shelter to around 100,000 people (Uras, 2012). In Erciş, eight soup kitchens served 81,000 meals a day; in Van, three soup kitchens served 60,000 meals each day. Additionally, 72,000 meals were purchased daily by the state from private providers.

The domestic and international monetary aid is estimated to be TL 411 million (approximately US$ 220 million). Aid was received from Algeria, Armenia, Australia, Azerbaijan, Bahrain, Belgium, Bulgaria, Canada, Egypt, Finland, France, Germany, Iran, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kyrgyzstan, Malaysia, Netherlands, Norway, Pakistan, Qatar, Romania, Russia, South Korea, Spain, Sweden, Switzerland, Syria, Tunisia, Turkish Republic of Northern Cyprus, Ukraine, United Kingdom, the USA, and the UNHCR and OCHA.

Economic Impact and Long-term Recovery

Final damage surveys were carried out by 1,136 technical personnel between November 15th and December 22nd in Van, Erciş, and several other districts and villages in the province. As noted in Table 1, of the 103,478 buildings inspected, 33,016 buildings (31.9%) were either heavily damaged or collapsed, 4,755 buildings (4.6%) sustained medium-level damage, 35,545 buildings (34.4%) sustained light damage, and 30,162 building (29.1%) had no damage.

Of the 14,904 commercial units inspected, 2,440 (16.4%) were either heavily damaged or collapsed, 2,748 (18.4%) sustained medium damage, 6,307 (42.3%) sustained light damage, and 3,409
(22.9%) were not damaged (Table 2).

The total cost of this earthquake, including financial losses and reconstruction efforts, is expected to be US$ 500 million to 1 billion. To help with the recovery, over 2,250 permanent houses are expected to be completed by August 2012. Additionally, founda-
tions of 3,000 new housing units were laid with initial work started on additional 12,000 housing units, all supported by the government. Distribution of these residences is expected to start in August 2012.

Recommendations

Without doubt, Turkey has the structural engineers, seismic design code, and construction know-how to avoid earthquake disasters of this scale, but the damage clearly demonstrated that improvement is needed in pre-earthquake mitigation. Almost all of the damage and deaths were caused by the collapse of inade-
quately designed and constructed buildings, particularly buildings built during the last decade. Modern buildings should have had light damage, given that the shaking intensities were moderate, but they were not properly designed and/or not properly constructed. Obviously, an advanced building seismic design code does not guar-
antee good performance of build-
ings and their contents.

Design and construction. The building designs in seismic regions such as Van region should incor-
porate more and better distributed structural walls. Building lateral load resisting structural systems and the infill walls should be designed considering their possible interaction during earthquakes. In the current construction style the unreinforced infill walls are wedged between and flush with the struc-
tural elements. As a result, the infill walls are engaged in the structural response even though, at least on paper, they are supposed to be nonstructural elements. While these infill walls may sustain little damage at low-intensity shaking, during stronger shaking they are damaged, typically in the form of widespread cracking and even crushing. Crushing of the infill walls can cause development of cap-
tive column condition which often results in premature and brittle failure of the affected columns.

Given the observed high frequency of destructive earthquakes in Turkey, it would be worthwhile to revisit the code-specified drift ratio limit considered for the design level earthquake. It is possible that lowering this drift limit would provide long-term benefits that outweigh the short-term costs.

Several buildings inspected by the EERI team had improper designs. It could be that the code-enforce-
ment bodies, which are the local municipalities in the case of private buildings, are unable to provide competent reviews and/or enforce the seismic design code. If it is the latter, the state has to provide the necessary checks and balances of enforcement. However, if it is the former, the technical skills of the engineers reviewing the design need to be improved and a mini-

mum level needs to be established. A licensure process in engineering should be introduced to provide a formal and objective means to assess the competency of design engineers. This would result in establishment of engineering cadres that could protect the safety, well-being and other interests of the general public. Professional engi-
neering certification ensures that practicing engineers meet require-
ments for competency in their specific disciplines, and that engi-
neering designs are reviewed and accepted by qualified practicing engineers. Such a licensure pro-
cess is being developed, but there should be a higher level of licens-
ing required for essential facilities such as hospitals and schools. Those facilities should be designed only by experienced professional engineers specialized in structural and earthquake engineering. Industrial losses also were avoid-
able. Many of the losses were caused by equipment (tanks, ves-
sels, etc.) not properly anchored or braced to resist seismic loads. Such damage is well understood by professionals and can be miti-
gated at a modest cost.

Post-earthquake damage assessment. Given the frequency of large earthquakes affecting urban areas in Turkey, it behooves the Turkish government to orga-

nize teams of experts that could be called to duty on short notice to assist with the rapid inspection of the buildings. Such teams could be supported by professional civil engineering associations. It is not reasonable to expect that local engineers, who are very likely to be in crisis themselves, could bear the burden of inspecting buildings in their hometowns. Hospitals, emergency operations, and water and power distribution networks need continuity of operations after an earthquake, so these facilities should be surveyed and tagged right away. Instead, the inspec-
tion process was quite slow and apparently resulted in much confu-
sion. We visited several structures where the residents claimed that some people without official or technical credentials inspected their buildings, made statements, and gave ratings regarding the damage state and soundness of the structure. No documentation was left about those statements and ratings.

A post-earthquake building tagging system should be developed, and engineers trained in “rapid visual screening methods” should be dispatched to the field immedi-
ately after the earthquake to inform
building occupants whether it is necessary to evacuate their building or it is safe to go back inside. If the occupants of a damaged building are evacuated, it is also necessary to decide if and when emergency workers can enter the building for search-and-rescue or temporary shoring missions. Such a system is already in place in the USA, and has been used after many earthquakes with great success. Usually, the local government body responsible for enforcing the building safety code examines the affected structures and tags them as appropriate, but often they receive volunteer support from professional structural and earthquake engineering associations.

Hazard mitigation. To develop a program for seismic risk mitigation, the potential risks need to be quantified as accurately as possible. Compared to other earthquake vulnerabilities, buildings pose the largest risk to life, limb, property, and economic welfare. To determine vulnerable buildings, a countrywide building inventory needs to be prepared, starting from the heavily populated earthquake-prone city centers. This inventory should be prepared based on rapid engineering assessments for every building, so mitigation priorities can be set. Afterwards, an earthquake mitigation plan for the entire country should be prepared.

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