Encl. 1

Nordic Course on
"Seismic Hazard and Earthquake Engineering"
Regional Background Document

Seismic Hazard in Izmir and its Surroundings

Background

The Anatolian microplate, bounded by the North and East Anatolian Fault Zones, moves westward with a velocity of ca. 2.0 cm/year due to the plate tectonic convergence between the African and Eurasian plates. This continuous motion towards west combined with the subduction of the Mediterranean oceanic lithosphere along the Hellenic arc (south of the islands of Crete and Rhodes in southern Aegean) results in N-S oriented extension over the entire Aegean Sea. As a result of this development, western Anatolia (western part of Turkey along the Aegean coast) has been dominated by crustal deformation distributed over several E-W oriented graben structures and the associated faults. The earthquake activity along these faults outlines clearly the active deformation in the area (Fig. 1). In addition, block rotations occur, activating the N-S and NE-SW oriented oblique-slip faults (Fig. 2). These faults have been active during the time period from Miocene to Holocene, especially since Pliocene, due to the development of the North Anatolian Fault Zone (NAFZ), giving rise to the westward escape of the Anatolian microplate.

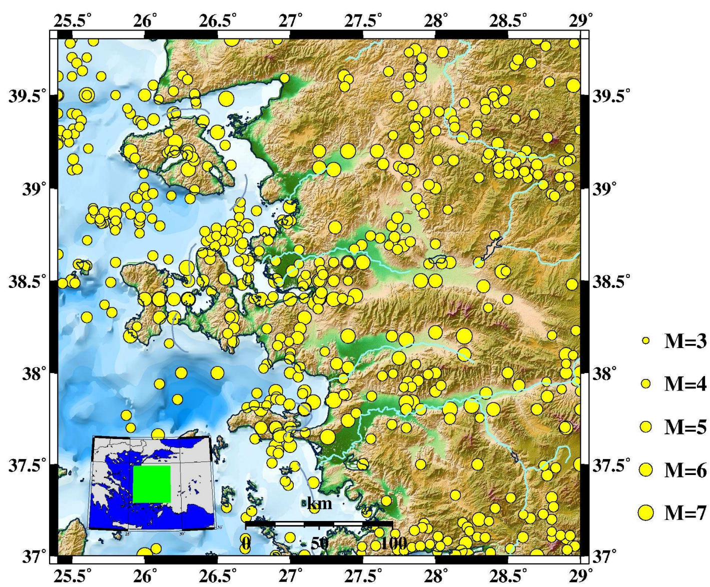


Figure 1. Seismicity of Western Anatolia and Eastern Aegean. Data is from Kandilli Observatory and Earthquake Research Institute (KOERI) covering the historical and instrumental time periods. The city of Izmir is located ca. 38.43°N and 27.13°E

Throughout the historical times there have been several large earthquakes in the region with catastrophic consequences in Izmir. The most significant of these was the earthquake that occurred on July 10, 1688, where 2/3 of the city was completely destroyed. Fifty years later, another large earthquake occurred in 1739, where the northern part of the city (Foça area) was mostly destroyed. In 1788, again approximately fifty years later, there was yet another destructive earthquake which destroyed most of the city. The historical earthquake activity show clear examples of significant destruction during earthquakes along various structures in the region and there is little doubt that there is a considerable risk in the main population centers, especially in Izmir, the third largest city in Turkey with almost 4 million inhabitants.

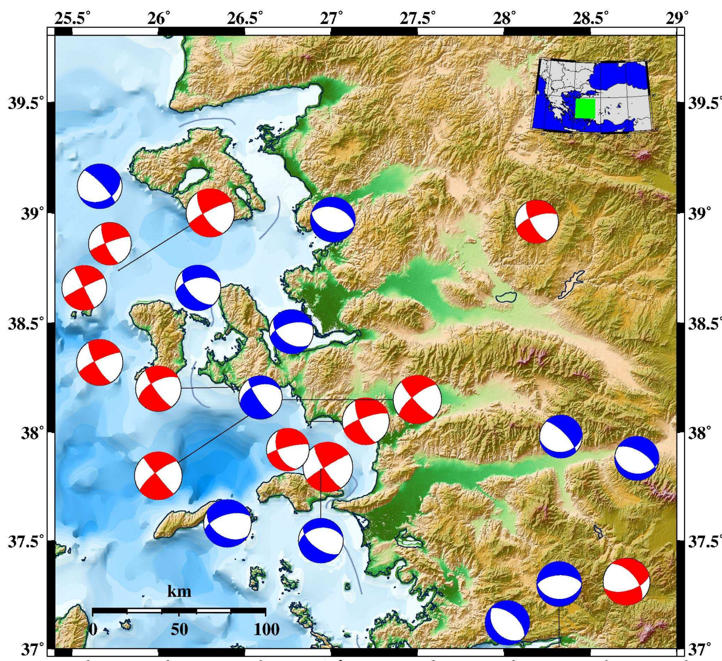


Figure 2. Focal mechanisms of major events (from Harvard moment tensor catalogue). The red solutions indicate dominantly strike-slip, whereas the blue show dominantly normal faulting.

Choosing the city of Izmir and its surroundings, as the location for the Nordic course on "Seismic Hazard and Earthquake Engineering" provides an optimum scale for illustrating the broad spectrum of scientific problems associated with seismic hazard and earthquake engineering.

Main scientific challenges in the region

There are a number of scientific challenges within the entire spectrum of problems from the upstream towards the downstream end. Many of these are being addressed through the ongoing and planned projects in the region.

In connection with these efforts the earthquake potential along main active faults in the area are investigated in detail. The most significant of these is the Izmir Fault with an E-W orientation extending underneath the city of Izmir (Fig. 3).

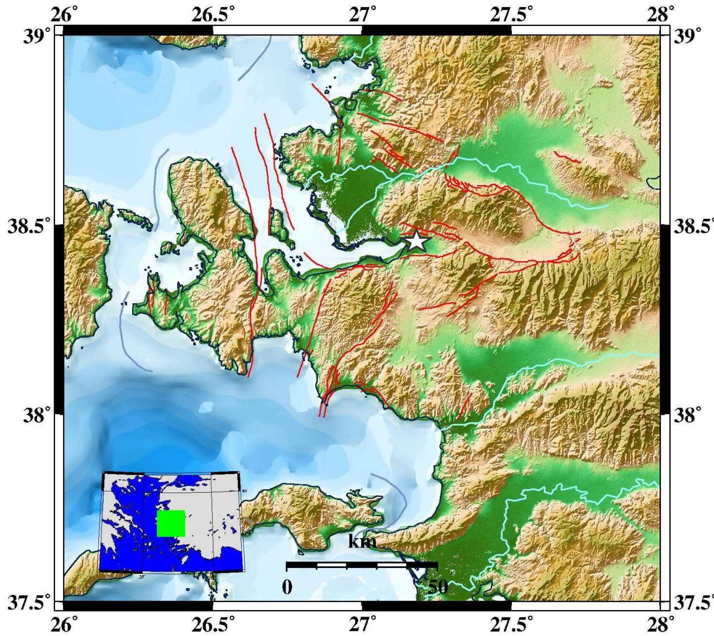


Figure 3. The main active faults (shown in red) in Izmir and its surroundings (interpretations based on MTA's recent work). White star indicates the location of Izmir.

Understanding the earthquake potential of this specific fault, as well as the N-S and NE-SW oriented faults surrounding the area are considered as one of the key elements of the seismic hazard in the area. There are other challenging aspects which are associated with the interaction between these three main fault systems acting in the area. The earthquake swarm of last year with several hundred's of earthquakes within a month (three above M>5.8) are the latest manifestations of the activity along the NS trending fault (Fig. 4). The recent GPS studies show significant block rotations in the area of study which imply that the earthquake recurrence on the each of the bounding faults is probably controlled by the interaction between these. Such fault interactions results in earthquake clusters in time separated by long quiescence. The city of Izmir has been destroyed almost completely three times in the history by large earthquakes in 1688, 1739 and 1788. The occurrence of these three earthquakes approximately 50 years apart, followed by a quiescence of more than 200 years (i.e. no damaging earthquakes Izmir during the last 228 years), clearly illustrates this problem.

In a case where the hazard is mainly controlled by the nearby faults capable of generating significant earthquakes, assessing the earthquake hazard cannot be only based on standard probabilistic approaches. State-of-the-art methodologies such as hybrid ground motion simulations based on earthquake scenarios are being applied in the area. An example of the results from these is shown in Figure 5. The model assumes a simple earthquake rupture scenario along the E-W oriented fault under the city of Izmir. These preliminary results clearly indicate that there is significant hazard associated with a possible earthquake of a moderate magnitude (i.e. 6-7). The maximum acceleration values reach 0.3 g, while maximum velocities are in the range 30-40 cm/sec.

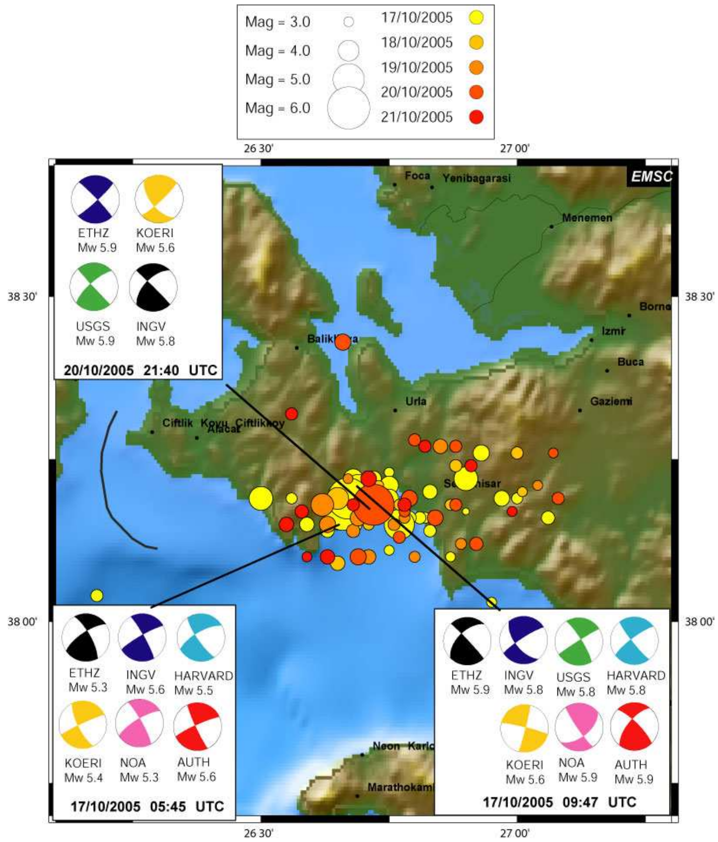


Figure 4. The recent earthquake swarm which occurred along the N-S trending fault that is located along the eastern coast of the Karaburun peninsula and its continuation across the Urla area to the Seferihisar-Ovacik bay in the south. The figure is from the European Mediterranean Seismological Centre (EMSC) and shows the epicenters and the focal mechanisms of the most significant events. Note that the match between the NNW-SSE oriented fault with left-lateral strike slip motion and one of the nodal planes in the solutions.

Since these computations are conducted for bedrock conditions, additional effect of the local site conditions will probably enhance the level of hazard to very high values capable of causing significant destruction in the metropolitan area. Expected nature of faulting along the modeled fault is predominantly normal, with hanging-wall block on the northern part of the city. This results in high values of the ground motion around the bay, especially in the northern part of the city. Considering that the site effects constitute a critical issue there, the hazard in this area is a major concern.

The northern and the eastern parts of the city are built on soft sediments (the northern part is an old delta) and the local site amplifications and liquefaction are major problems (Fig. 6). In addition, along the coastal strip within the Izmir bay there are artificially filled areas which are used both for new residential areas as well as main transport routes. Moreover, there are potential areas where landslides along the mountain slope as well as submarine slides within the bay area may occur, which in turn give rise to an increased tsunami threat from the bay area.

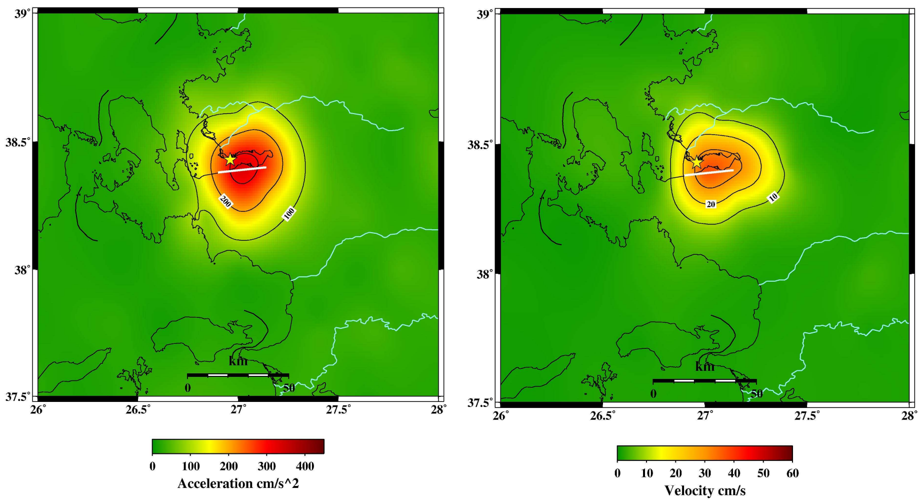
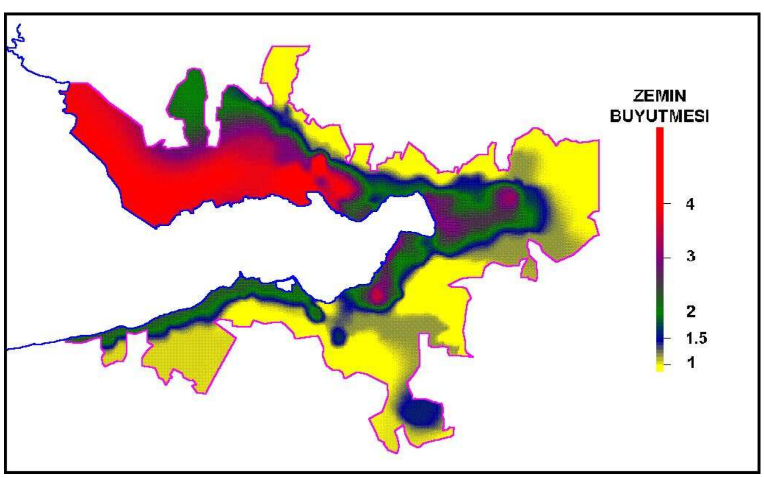


Figure 5. Hybrid ground motion simulations, based on a simple scenario earthquake rupture along the E-W oriented fault underneath the city of Izmir. The computations clearly show the significant hazard in the area. The left figure shows the ground motion in acceleration (cm/sec^2) and right figure in velocity (cm/sec). Note that the modeled fault corresponds to the western segment of the Izmir Fault.

The tightly spaced building stock of the densely populated areas of Izmir poses serious challenges. In spite of a conservative seismic design code, the poor constructional practices observed during the 1999 Izmit and Düzce earthquakes demonstrated the disastrous consequences of this problem. Regrettably, there is no reason to believe that these conditions are any better in Izmir.

Izmir and its surroundings provide an excellent opportunity to exemplify the problems associated with the seismic hazard and earthquake engineering. It is therefore proposed that the planned Nordic course is held in Izmir at Dokuz Eylül University at Kaynaklar-Buca Campus. It is hoped that the planned field-trips in nearby locations will help understanding the content of the course better.



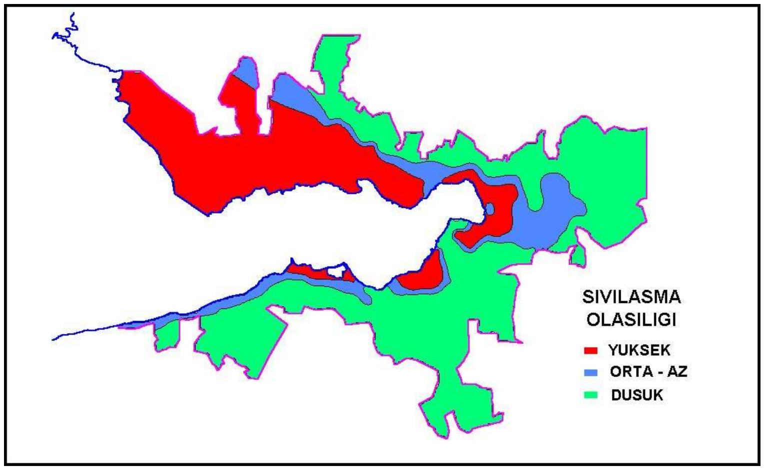


Figure 6. Soil amplification factors (top) and liquefaction potential (bottom) in Izmir. Soil amplification factor is shown by the color code indicating the amplification factors. Liquefaction potential is expressed as three categories where high (red), intermediate (blue) and low (green). Both figures are from the Izmir Earthquake Master Plan, prepared by Bogazici University, KOERI. Note the high susceptibility to both soil amplification and liquefaction in northern and eastern parts of the city.