General evaluation on the seismicity of Turkey and Japan.

VISITING RESEARCHER 2019A, TERM OF AUGUST 26- NOVEMBER 21, 2019

Ozgur Tuna OZMEN
Geophysical Engineer
Ministry of Interior
Disaster and Emergency Management Presidency
Republic of Turkey

DISCLAIMER

Contents of this research paper is prepared by Mr. Ozgur Tuna OZMEN, Visiting Researcher of 2019 term (August-November) Batch A, for the Asian Disaster Reduction Center, Kobe, japan.

This report was compiled by an ADRC visiting researcher (VR) from ADRC member countries. The views expressed in the report do not necessarily reflect the views of the ADRC. The boundaries and names shown and the designations used on the maps in the report also do not imply official endorsement or acceptance by the ADRC.

CONTENTS

ACRONYMS	
ACKNOWLEDGEMENTS	
Chapter 1	
○ Introduction	06
○ Risk Profile of Turkey	08
Chapter 2	
○ Recent Major Earthquakes in Turkey	11
○ National Strong-Motion Network of Turkey (TR-NSMN)	26
○ Local Networks	30
Chapter 3	
○ Recent Major Earthquakes in Japan	32
○ Strong Earthquake Motion Observation in Japan	38
The Japan Meteorological Agency (JMA) Seismic Intensity Network	38
K-Net and Kik-net	40
Seismic Intensity Information Network of Local Governments	40
Other National Research Institutes and Public Bodies	41
Public Works Research Institute, Ministry of Construction	41
Port and Harbour Research Institute, Ministry of Transport	42
Earthquake Research Institute (ERI), University of Tokyo	42
Tokyo Gas Co. Ltd.	42
Yokohama City	43
Building Research Institute (BRI)	43
Nationwide Strong Motion Network of BRI	43
Dense strong-motion instrument array in Sendai	44
Strong-motion instrument network in the Metropolitan Area	45
Strong-motion observation at Urban Disaster Prevention Research Center	45
Chapter 4	
○ Conclusion and Recommendation	47
○ Reference	48

ACRONYMS

AFAD	Disaster and Emergency Management Presidency
ADRC	Asian Disaster Risk Reduction
BRI	Building Research Institute
EAFZ	East Anatolian Fault Zone
ERI	Earthquake Research Institute
GHAE	Great Hanshin-Awaji Earthquake
GEJE	Great East Japan Earthquake
JMA	The Japan Meteorological Agency
MoI	Ministry of Interior
NAFZ	North Anatolian Fault Zone
NIED	National Research Institute for Earth Science and Disaster Prevention
TR_NSMN	National Strong Motion of Turkey
YGF	The Yenice-Gonen Fault

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to the governments of both Japan and Turkey in giving me the tremendous opportunity to participate in this program.

Especially my thanks and best regards to all of those who devoted their time and efforts to education and training in the field of disaster management.

And finally, I would like to express my appreciation to the ADRC staff, who made my time in Japan an experience that has far surpassed my every expectation.

CHAPTER 1

Introduction

Turkey between 35-42 north latitude, and 25-44 east longitude covers 779,452 sq km and has borders with Bulgaria, Greece, Georgia, Armenia, Iran, Iraq and Syria. The road distance from Edirne on the Bulgarian border to Kars on the Armenian one is over 1700 km. The coastlines along the Black, Aegean and Mediterranean Seas total almost 8400 km. The country is geographically diverse, with snow-capped mountains, rolling steep broad rivers, long rocky shorelines and rich agricultural valleys. Going from west to east the climate changes from Mediterranean climate (sub-tropic) to hot and dry in summer and very cold in winter. Rainfall along the Black Sea coast where the mountains come right down to the sea is two to three times the national average.

Turkey is a bridge between east and west geographically and have a socially, economically, and strategically vital role in the region. Turkey has a population approaching 70 million. Since 1980's the population growth rate has been decreasing from almost 3% to 2%. The most of the population (67%) lives in cities. Two-thirds of the population is under 25 years old.

GDP per capita 6.700 US$ (2003 estimation) Sectoral distribution of GDP, for agriculture 11.7%, industry 29.8%

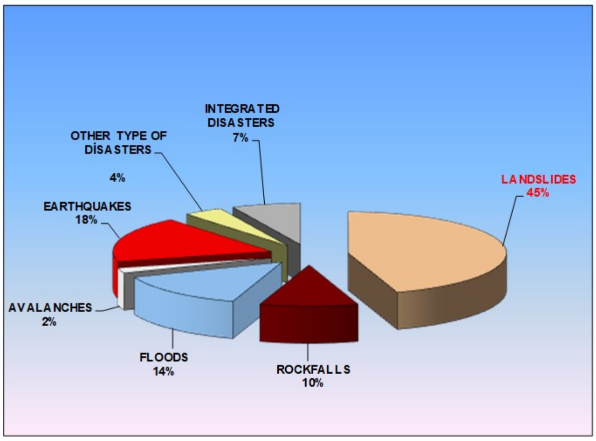
Turkey is progressing to overcome its present difficulties. Its economy through many respects prosperous and dynamic, is saddled with a heavy burden of debt and deficit, inflation and unemployment. Turkey has embarked on some ambitious projects in recent years. There is a host of new roads, bridges, tunnels, dams, factories and universities. Due to globalization and new economic policies Turkey approached to open market economy. The foreign trade capacity reached to US$ 86 billion in 2002. The highest proportion in GDP is the industrial sector that has a proportion increased to 28%, the agricultural sector's proportion reached to 12% in 2003.

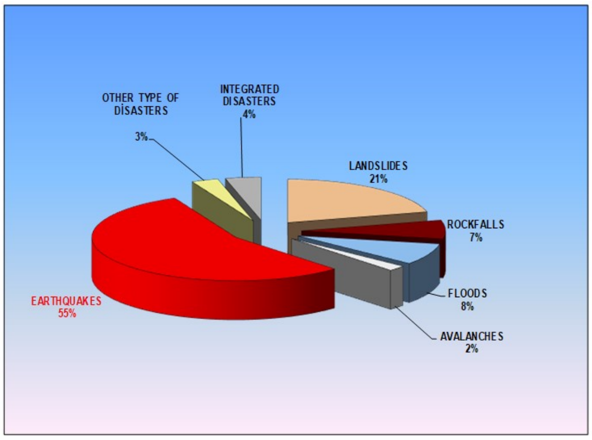
There are 81 city provinces, 850 towns and 36,527 villages in Turkey. Almost 30% of total population lives in the three-metropolitan cities (Istanbul, Ankara, Izmir). The dual organization of local administration in Turkey, with appointed governors and elected municipal officials (mayors), establishes the basis for their distinguished role in disaster management. Provincial governors are agents of the central authority, therefore they conduct pro-active role in managing emergency situations as it stated in the Disaster Law-7269. The mayor and municipal organizations stay under the authority of the governor in the emergency. On the other hand, according to the Development Law-3194 land-use planning and building constructions are administrated by the municipalities. The current compulsory earthquake insurance system, Turkish Catastrophe Insurance Pool (TCIP) is running by an insurance administration (DASK) which is also considered for leadership in mitigation activities to reduce losses, is relatively small, however, it has been growing rapidly in recent years.

All of Turkey's big cities are now ringed with settlements –gecekondu- inhabited by migrants from the countryside who come looking for work. Many are escaping from the south-east Turkey where a burital terrorism and also wars in the Gulf occurred. The absence of a public housing program, cheaply built, illegal housing and the country's poor inspection system contribute the problem in the major cities. For Istanbul another most important and complex issue in mitigation is the retrofit of existing buildings.

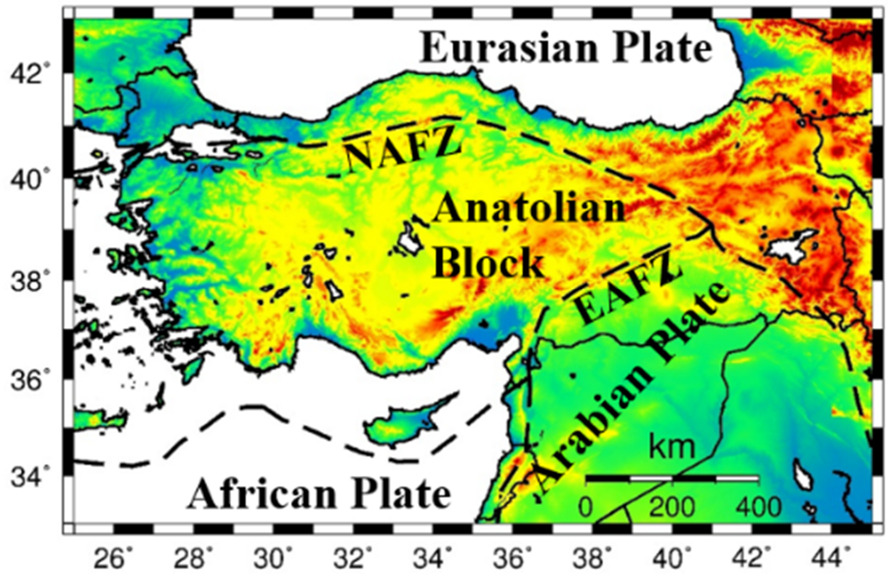
Risk Profile of Turkey

More than 95% of the country lies in one of the most active earthquake and landslide regions in the world. Large earthquakes can occur anytime along the North Anatolian Fault Zone (NAFZ) which crosses the entire country. The ratios of events (left) and Affected Structures according to disaster types are shown below.





There are 2 different major fault systems tectonically control Anatolia from east to west. the 1500-km long North Anatolian Fault Zone (NAFZ) and the 550-km long East Anatolian Fault Zone (EAFZ).



- 70% of the population lives in areas highly vulnerable to earthquakes.
- 66% of the country is located on active fault zones.
- 75% of damaged buildings and %64 of total disaster losses in the last century are due to earthquakes.

Population growth continues to increase development pressures that in turn lead to mostly uninsured residential, commercial, and industrial poor construction in the alluvial plains (soft soil) along the NAFZ. The resulting potential for social, economic, and devastation has been demonstrated time and again – e.i. the 1999 Earthquakes.

The greatest landslide risk is within the Black Sea region. Due to climatic changes cities which are along the rivers are at greatest risk from floods and landslides. Unfortunately, these regions are expose to floods every year.

- Mostly in coastal plains and exacerbated by deforestation, erosion and ignorant development.
- 15% of total disaster losses are due to floods.
- Annual average losses exceed 100 million US$

Most landslides are secondary hazards of earthquakes and floods.

- 25% of country area is exposed to landslide hazard.
- 11% of total population is located in landslide areas.
- 16 % of total disaster losses are due to landslides.

In the last thirty years Turkey faced heavy natural disasters: e.g Erzincan Earthquake (1992), Flood in Black Sea Region (1998), Adana-Ceyhan Earthquake (1998), Marmara Earthquake (1999), Hakkari Earthquake (2004), Sivas Landslide (2005) and Van Earthquake (2011).

Direct economic losses due to natural disasters is expected 1% of GDP ever year. The losses like down in the market, production losses and unemployment are even more greater. The probabilty of economic losses exceeding 11.4 billion US$ in one year is about 0.5 percent. This is about 6% of the country's GDP. The probability of annual losses exceeding 3.5 billion US$ is about 5%.

For Istanbul, a worse-case scenario for earthquake of 7,5 is assume to take place along the Main Marmara Fault of NAFZ. Probability of occurrence of a large earthquake in the next 30 years is greater than 65%, in next 10 years is greater than 20%. Approximately 70 thousand dead people, 120 thousand heavily injured people, 400 thousand injured, direct economic losses is 30 billion US$ (Erdik, 2003). Secondary impacts may be triggered by a large earthquake, liquefaction and subsidence of soil, landslides along the coastal areas damaging transportation lines, infrastructure, fires from particularly natural gas pipeline ruptures.

CHAPTER 2

Recent Major Earthquakes in Turkey

December 26, 1939 Erzincan Earthquake

The 1939 Erzincan Earthquake (M = 7.8), occurred on the NAFZ, was one of the most active strike-slip faults in the world, and created a 360-km-long surface rupture. The 1939 Erzincan earthquake struck eastern Turkey at 1:57:23 a.m. on 27 December local time with a moment magnitude of 7.8 and a maximum Mercalli intensity of XII (Extreme). This was one of the largest in a sequence of violent shocks to affect Turkey along the NAFZ between 1939 and 1999.

Almost 33,000 had died due to the earthquakes and to blizzard conditions, followed by heavy rains that caused floods. So extensive was the damage to Erzincan city that its old site was entirely abandoned and a new settlement was founded a little further to the north.

December 20, 1942 Erbaa Earthquake

Two devastating earthquakes occurred between Erzincan (39.75N, 39.49E) and Erbaa, Tokat (40.70N, 36.58E) just three years one after another in 1939 and 1942. While 1939 Erzincan earthquake (M=7.8) ruptured nearly 360 km, 1942 Erbaa-Niksar earthquake (M=7.1) has a length of 50 km surface rupture.

The 1942 Niksar–Erbaa earthquake in Turkey occurred at 16:03 local time on 20 December. It had an estimated surface wave magnitude of 7.0 and a maximum felt intensity of IX (Violent) on the Mercalli intensity scale, causing 3,000 casualties.

November 26, 1943 Tosya-Ladik Earthquake

The 1943 Tosya–Ladik earthquake occurred at 00:20 local time on 27 November, near Tosya, Kastamonu Province, in northern Turkey.

The earthquake had an estimated moment magnitude of 7.5 and a maximum felt intensity of between IX–X (Violent to Extreme) on the Mercalli intensity scale. It caused 2,824 deaths, 1250 injuries and about 75 percent of houses are destroyed or damaged in the Ladik-Vezirkopru area. The Earthquake produced 280 km long surface rupture in the Tosya-Ladik segment of the NAFZ.

<u>February 1, 1944 Bolu-Gerede Earthquake</u>

The 1944 Bolu–Gerede earthquake occurred at 05:22 local time on 1 February. The earthquake had an estimated surface wave magnitude of 7.2 and a maximum felt intensity of IX–X (Violent–Extreme) on the Mercalli intensity scale. 2,790 people are killed and 50,000 houses destroyed or heavily damaged in the NAFZ from Bolu through Gerede to Kursunlu.

<u>May 31, 1946 Varto-Hinis Earthquake</u>

The 1946 Varto–Hınıs earthquake occurred at 05:12 local time on 31 May. The earthquake had an estimated magnitude of 5.9 and a maximum felt intensity of VIII (Severe) on the Mercalli intensity scale, causing between 800 and 1300 casualties.

March 18, 1953 Yenice-Gonen Earthquake

The tectonics of northern and eastern Turkey are dominated by the two strike-slip fault zones that accommodate the west to southwestward movement of the Anatolian Plate relative to the Eurasian Plate and the Arabian Plate as it is effectively being squeezed out by convergence between them. The quake occurred along the Yenice–Gönen Fault (YGF), which is a southern extension of the North Anatolian Fault Zone.

The YGF is located in the central part of the Biga Peninsula between Gönen and Yenice and is a right-lateral strike-slip active fault with general trending N65°E. On 18 March 1953 there was an earthquake on the YGF that died 263 people (Ms=7.3) and a 70 km surface rupture developed during this earthquake.

The quake had a surface wave magnitude of 7.3 and it killed at least 1070; 998 of those deaths were in Yenice, with another 50 in Gönen, 20 in Çan, and 3 in Manyas. The cost of repair was estimated at US$3,570,000. Several thousand buildings were affected in the Can-Yenice-Gonen area. Damage of intensity VI occurred at Sakarya (Adapazari), Bursa, Edirne, Istanbul and Izmir.

The quake was felt throughout the Aegean Islands and in much of mainland Greece, with damage occurring as far away as Crete. Shaking was also recorded in Bulgaria. Although officials predicted the earthquake would cause only 265 deaths, it multiplied with a death toll seven times the number as expected.

The damage caused by this earthquake led to a new national reconstruction law in Turkey. In Greece the damage was severe enough that new building codes were introduced.

<u>August 19, 1966 Varto Earthquake</u>

The 1966 Varto earthquake occurred on 19 August with a magnitude of 6.8 a maximum Mercalli intensity of IX (Violent). At least 2,394 were killed and up to 1,500 people were injured in the town of Varto in the Muş Province of eastern Turkey.

The earthquake devastated all the structures in Varto. This disaster was preceded by an earthquake of magnitude 5.6 that hit Varto on 7 March 1966 killing 14 and wounding 75 people.

19 August 1966 Varto earthquake (Ms = 6.8) was an extra ordinary event at the 40 km east of junction between NAFS and EAFS which are two seismogenic system and active structures shaping the tectonics of Turkey. This earthquake sourced from Varto fault zone which are approximately 4 km width and 43 km length. It consists of faults which have parallel to sub-parallel, closely-spaced, north and south-dipping up to 85°-88° dip amount. Although this event has 6.8 (Ms)

magnitude that is big enough to create a surface rupture, there was no clear surface deformation had been detected. This creates the controversial issue about the source fault and the mechanism of the earthquake.

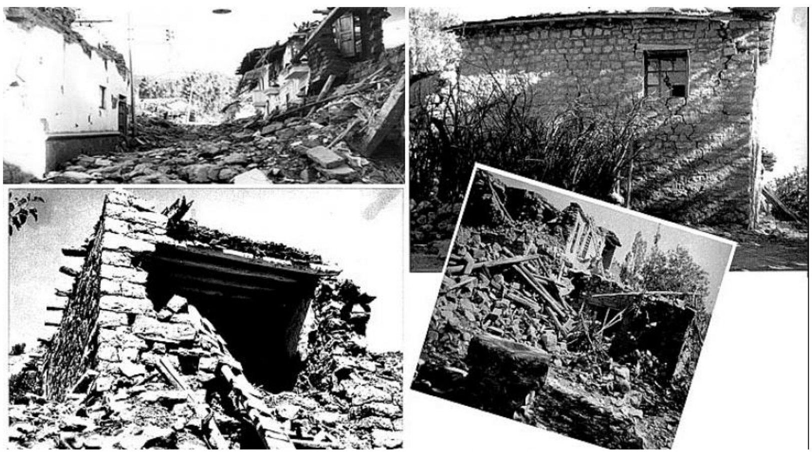
March 28, 1970 Kutahya-Gediz Earthquake

The 1970 Gediz earthquake (also known as the 1970 Kütahya-Gediz earthquake) struck western Turkey on 28 March at about 23:02 local time, with an estimated magnitude of 7.2 on the Ms scale. The event killed 1,086 people, injured 1,260 people, and left many thousands homeless in Gediz. A district of Kütahya Province situated 98 km southeast of Kütahya. Many people were burned alive as fires broke out from overturned stoves, and 9,452 buildings in the region were severely damaged or destroyed.

The town of Gediz, home to repeated natural disasters like earthquakes and floods, was relocated following a government resolution soon after the destruction to a new place 7 km away on the road to Uşak under the name "Yeni Gediz" (literally: New Gediz). The residents moved in their newly built, earthquake-resistant homes. Neighboring towns and villages were also rebuilt at places with relative minimum earthquake risk. Other major earthquakes occurred in Gediz in 1866 and 1896, and on June 25, 1944, at 07:20 local time, a magnitude 6.0 earthquake occurred in Gediz, killing 20 people and damaging around 3,500 buildings.

May 22, 1971 Bingol Earthquake

The 1971 Bingöl earthquake occurred at 18:44:02 local time on 22 May. It had a moment magnitude of 6.9 and a maximum intensity of VIII (Severe) on the Mercalli intensity scale, killing at least 755 people.



September 6, 1975 Lice Earthquake

The 1975 Lice earthquake struck the Turkish district of Lice at 12:20 local time (09:20 UTC) on 6 September. The epicenter of the Ms 6.7 shock was located near the town of Lice and the maximum felt intensity was VIII (Severe) on the Mercalli intensity scale. More than 2,300 people were killed.

The tectonics of Turkey are dominated by the effects of the continuing collision between the African Plate and the Eurasian Plate. The main result of this collision is the southwestward escape of the Anatolian Plate by displacement along the EAFZ and EAFZ. To the east of these faults, the plate boundary is a zone of orthogonal collision, with the relative displacement spread out over a wide zone, continuing as far north as the Greater Caucasus. The largest fault within the plate boundary zone is the west-east trending Bitlis frontal thrust and the 1975 earthquake is thought to have been caused by movement on this structure.

The earthquake occurred near midday without any warning. The shaking continued for about 20–24 seconds. The main shock was followed by aftershocks that continued for more than a month. The focal mechanism for the earthquake suggests that it was associated with dominantly reverse movement on a fault plane dipping at 45° to the northwest with a significant sinoatrial (left lateral) component.

The main area of damage was located near the towns of Hani, Lice and Kulp. In Lice 12 out of the 13 mahalles (sections) of the town were completely destroyed. 6 schools, 6 mosques and 132 commercial buildings were damaged. In the 188 villages surrounding Lice that were affected, 5,555 houses suffered either severe damage or total destruction.

November 24, 1976 Van-Caldiran Earthquake

The 1976 Çaldıran–Muradiye earthquake occurred at 14:22 local time (12:22 UTC) on 24 November. The epicenter was located near Çaldıran, 20 km northeast of Muradiye, in the Van Province of eastern Turkey. The earthquake had a magnitude of 7.3 with a maximum intensity of X on the Mercalli intensity scale. The area of severe damage, where over 80% of the buildings were destroyed, covered an area of 2,000 square kilometers. There were between 4,000 and 5,000 casualties.

The easternmost part of Turkey lies within the complex zone of continuing continental collision between the Arabian Plate and the Eurasian Plate. The overall shortening that affects this area is accommodate partly by thrusting along the Bitlis-Zagros fold and thrust belt and partly by a mixture of sinistral strike-slip on SW-NE trending faults and dextral strike-slip on NW-SE trending faults. The earthquake was caused by movement on the Çaldıran Fault, one of the dextral faults, which had not been recognised before the earthquake. No earthquakes with magnitudes of 6 or greater were recorded within 100 km of Çaldıran in the preceding 74 years, possibly explaining why it was considered an area of only intermediate seismic risk (zone 3 out of the five zone system of seismic risking used in Turkey at the time, with zone 1 being the highest).

The earthquake was associated with a 50–55 km zone of surface faulting, extending from three kilometres west of Sarikök in the west to just west of Baydoğan in the east. A maximum dextral offset of 3.5 m was recorded. The rupture width was estimated at 24 km and the fault zone was found to dip at 78° to the south. The duration of strong ground shaking is estimated at six seconds.

In Çaldıran 95% of the houses were destroyed with all the others damaged to some extent and 615 of the 3,304 inhabitants were killed.[4] In the villages around Çaldıran over 80% of the houses were destroyed and most of the rest were damaged; 2,313 of the 27,587 inhabitants were killed. In Muradiye almost all the houses were either completely collapsed or damaged and 159 of the 6,753 inhabitants were killed.

Most of the buildings in the epicentral area were constructed of thick walls made from rubble masonry cemented with mud mortar. The structures were typically finished with a heavy earth roof with wooden supports. The very low resistance to lateral loads of these structures explains why almost all the buildings in Çaldıran collapsed in the earthquake, causing most of the deaths. Reinforced concrete structures generally performed well, with none suffering complete collapse. The performance of brick or stone masonry structures was mixed, with some collapsing and others being apparently unaffected.

52. One-Storey Officers' Housing, Çaldıran

October 30, 1983 Erzurum earthquake

The 1983 Erzurum earthquake occurred on 30 October 1983 at 07:12 local time (04:12 UTC). It was an Ms 6.9 earthquake. About 1,340 people are killed and 530 injured when an earthquake hits the Turkish city of Erzurum in the northeast. Measuring 6.9, 50 villages are destroyed in the provinces of Erzurum and Kars.

August 17, 1999 Izmit Earthquake

The 1999 İzmit earthquake (also known as the Kocaeli, Gölcük, or Marmara earthquake) occurred on 17 August at 03:01:40 local time in northwestern Turkey. The shock had a moment magnitude of 7.6 and a maximum Mercalli intensity of IX (Violent). The event lasted for 37 seconds, killing around 17,000 people and left more than 250,000 people homeless. The nearby city of İzmit was severely damaged.

The earthquake occurred along the western portion of the NAFZ. The Anatolian Plate, which consists primarily of Turkey, is being pushed west about 2–2.5 cm (0.8–1.0 in) a year, as it is squeezed between the Eurasian Plate to the north and the Arabian Plate to the south. Major earthquakes in Turkey result mainly from slip along the NAFZ or the EAFZ.

The Izmit earthquake had a rupture length of 150 kilometers (93 mi) extending from the city of Düzce all the way into the Sea of Marmara along the Gulf of İzmit. Offsets along the rupture were as large as 5.7 meters. From the timing of P-wave and S-wave arrivals at seismometers there is strong evidence that the rupture propagated eastwards from the epicentre at speeds in excess of the S-wave velocity, making this a supershear earthquake.

Destruction in Istanbul was concentrated in the Avcılar district to the west of the city. Avcılar was built on relatively weak ground mainly composed of poorly consolidated Cenozoic sedimentary rocks, which makes this district vulnerable to any earthquake.

The earthquake was heavily felt in this industrialized and densely populated urban area of the country, including oil refineries, several automotive plants, and the Turkish navy headquarters and arsenal in Gölcük, increasing the severity of the loss of life and property. The earthquake also caused considerable damage in Istanbul, about 70 kilometers away from the earthquake's epicenter.

Totally at 17,127 killed and 43,959 injured, but many sources suggest the actual figure may have been closer to 45,000 dead and a similar number injured. Reports from September 1999 show that 120,000 poorly engineered houses were damaged beyond repair[citation needed] and approximately 20,000 buildings collapsed, resulting in more than 250,000 people becoming homeless after the earthquake.

There was extensive damage to several bridges and other structures on the Trans-European Motorway (European route E80), including 20 viaducts, 5 tunnels, and some overpasses. Damage ranged from spalling concrete to total deck collapse.

The earthquake sparked a disastrous fire at the Tüpraş petroleum refinery. The fire began at a state-owned tank farm and was initiated by naphtha that had sloshed out of a holding tank. Breakage in water pipelines, results of the quake, nullified attempts at extinguishing the fire. Aircraft were called in to douse the flames with foam. The fire spread over the next few days, warranting the evacuation of the area within three miles of the refinery. The fire was declared under control five days later after claiming at least seventeen tanks and untold amounts of complex piping. The earthquake caused a tsunami in the Sea of Marmara that was about 2.5 meters high. The tsunami caused the deaths of 155 people.

Oct 23, 2011 Van Earthquake

The 2011 Van earthquakes occurred in eastern Turkey near the city of Van. The first earthquake happened on 23 October at 13:41 local time. The shock had a Mw magnitude of 7.2 and a maximum Mercalli intensity of VIII (Severe). It occurred at a shallow depth, causing heavy shaking across much of eastern Turkey and lighter tremors across neighboring parts of the South Caucasus and Levant. According to Disaster and Emergency Management Presidency on 30 October, the earthquake killed 604 and injured 4,152. At least 11,232 buildings sustained damage in the region, 6,017 of which were found to be uninhabitable. The uninhabitable homes left as much as 8,321 households with an average household population of around 7.6 homeless in the province; this could mean that at least around 60,000 people were left homeless. The other 5,215 have been damaged but are habitable. A separate earthquake within the same earthquake system happened on 9 November at 21:23 local time (19:23 UTC). 40 people were killed and 260 people were injured in the 9 November earthquake.

The magnitude 7.2 (Mw) Eastern Highlands earthquake occurred inland on 23 October 2011 at 13:41 local time (EEST), centered about 16 kilometers north-northeast of Van, Turkey and at an estimated focal depth of 7.2 kilometers. Its focal region and much of easternmost Turkey lie towards the southern boundary of the complex zone of continental collision between the Arabian Plate and the Eurasian Plate, beyond the eastern extent of the Armenian and Asia Minor fault zones. Part of the convergence between these two plates takes place along the Bitlis-Zagros fold and thrust belt. The earthquake's focal mechanism indicates oblique thrust faulting, consistent with the expected tectonics in the region of the Bitlis-Zagros Fault Zone, where thrust mechanisms dominate.

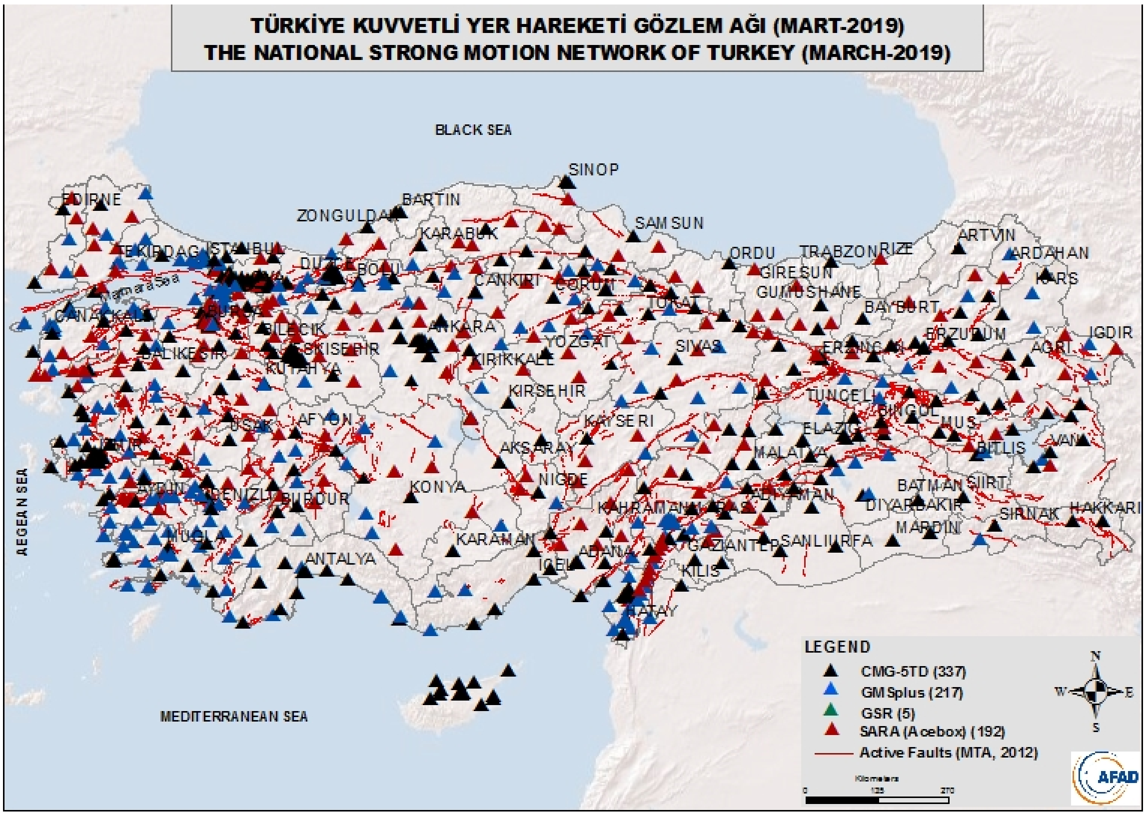
The size of the rupture has been estimated as 60 km x 20 km, consistent with the observed distribution of aftershocks, on a WSW-ENE orientated fault plane with a dip of about 35°. An offset of about 2 meters has been estimated at 10–15 kilometers depth but there is no visible rupture of the ground surface. The rupture lasted for about 50 seconds.

There have been 1,561 aftershocks above magnitude 2.0 as of 30 October. The highest magnitude aftershock came at 11:45 pm Local on 23 October, with a Ml 5.7 and Mw 6.0. The number of aftershocks reported in ranges as follows: 556 ranging from magnitude 2 to 3; 832 ranging from magnitude 3 to 4; 108

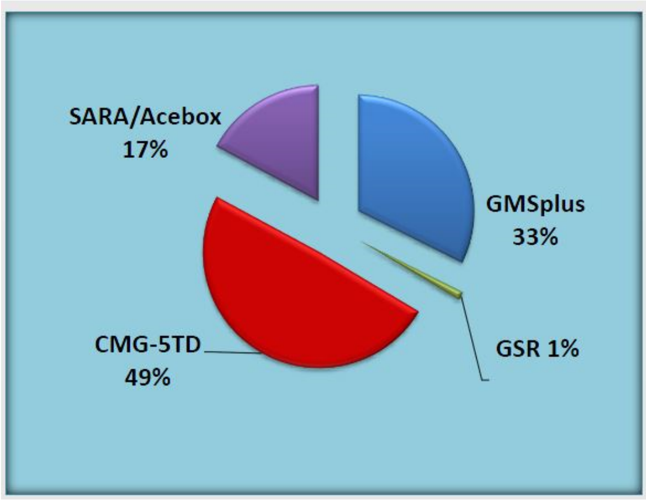
ranging from magnitude 4 to 5; and 7 ranging from magnitude 5 to 6. In the first five months there were 9,367 aftershocks with magnitudes in the range 1.5 to 5.8.

National Strong-Motion Network of Turkey (TR-NSMN)

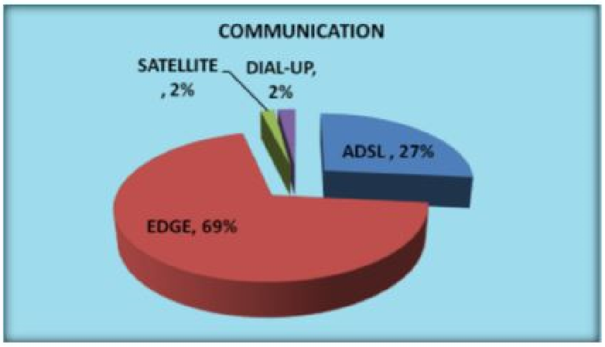
National Strong-Motion Network of Turkey (TR-NSMN) was established in 1973 with 67 analog recorders and recorded the first strong-ground motion record in 1976. Digital accelerometer devices have been installed since 1993. In 2014, TR-NSMN started to record data in a real-time (online) mode under a national Turkish Earthquake Data Center Project (TDVM-2013) conducted by Disaster and Emergency Management Authority (AFAD).



Recently, TR-NSMN with 678 stations in total consists of 3 different digital tri-axial force-balance accelerometers of CMG-5TD (24 bit) at 338 stations), SARA (24 bit) at 115 stations, GSR (16/18 bit) at 8 stations, and GMSplus (24 bit) at 217 stations.

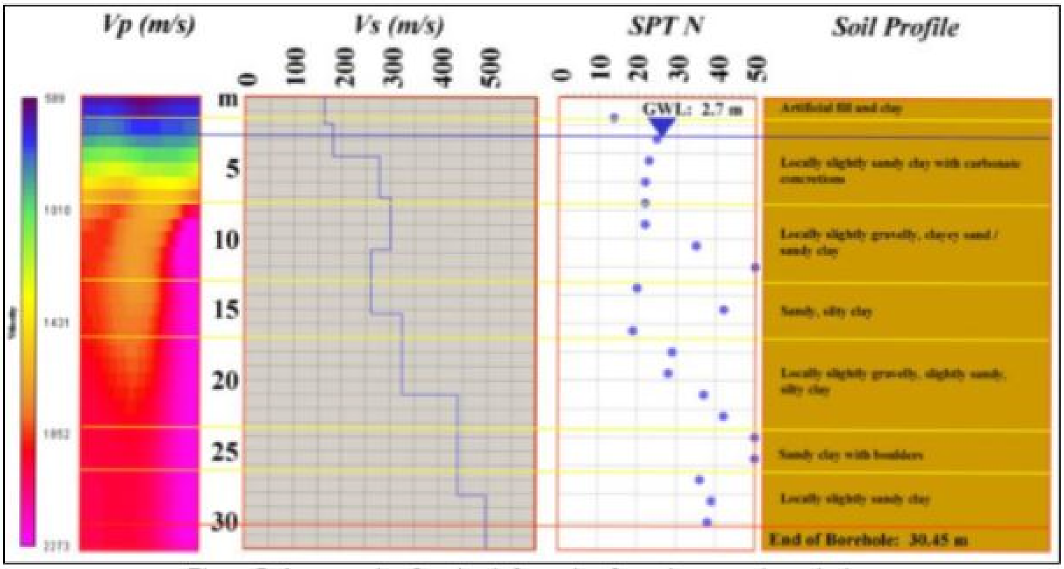


All the accelerographs are located on the free surface in densely populated cities in active regions such as NAFZ, EAFZ and the Aegean Graben Systems. Data transmission is provided via dial-up, ADSL, GPRS EDGE (mostly) and satellite. All the records are stored in an ASCII format including N-S (north-south), E-W (east-west) and U-D (up-down) components and there isn't any process implemented on the acceleration data, except for a base-line correction.



The data coming from field are transmitted to the data center by means of Dial-Up, ADSL, GPRS and Satellite. Data transferring is mostly provided via GPRS (EDGE).

As site conditions of the strong-ground motion stations, shallow S-wave velocity structures (for the first 30 meters) were obtained at many of the stations (Akkar et al., 2010; Sandıkkaya et al., 2010; Yılmaz et al., 2008). Additional S-wave data at some of the stations were available in geophysical explorations, such as microtremors (e.g., Özmen et al., 2017b; Yamanaka et al., 2018).



Since the establishment of TR-NSMN data center (1973), it is possible to access to all accelerograms on the web site (www.deprem.gov.tr).

File names are generated and saved as in this example:

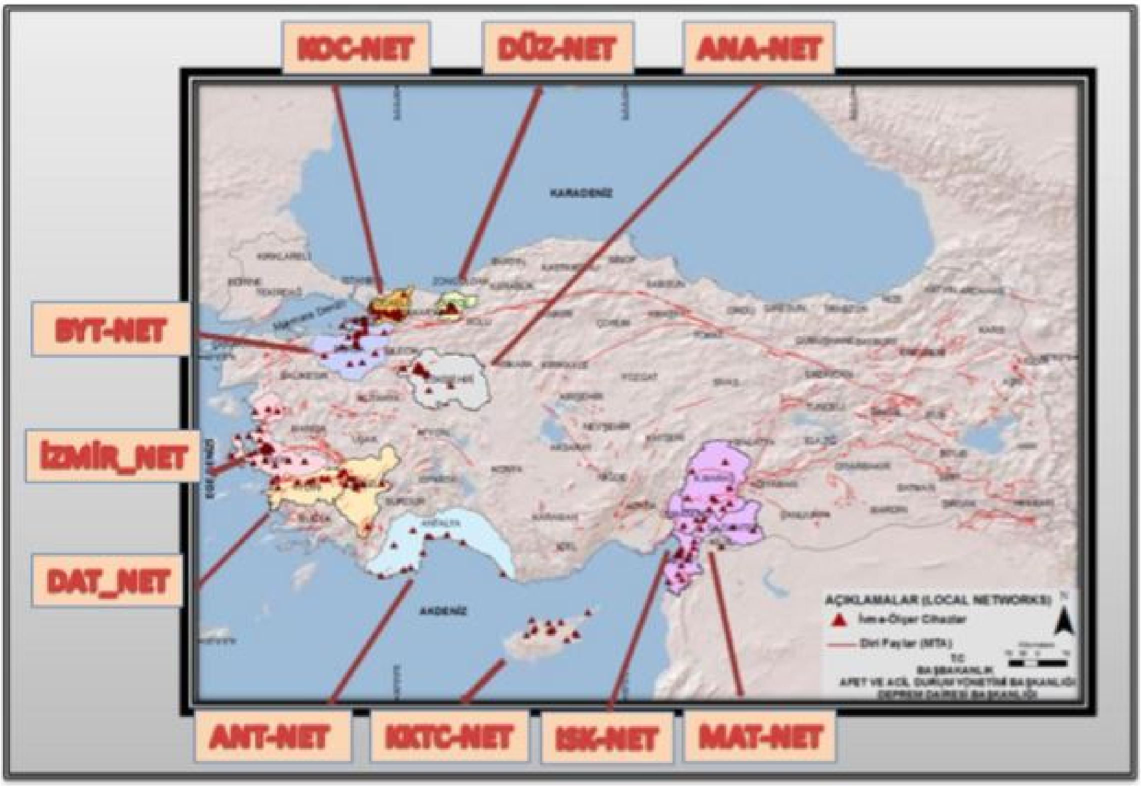
Date (yyyymmdd)+time(hhmmss)+abbreviation of the station (1201)(ex.20030501002704_1201).

```
STRONG GROUND MOTION RECORDS OF TURKIYE
PLACE                      : DENIZLI MERKEZ METEOROLOJI MUDURLUGU
EARTHQUAKE DATE            : 19/08/1976 01:12:39 (GMT)
EPICENTER COORDINATES      : 37.71000N-29.00000E
EARTHQUAKE DEPTH (km)      : 20
EARTHQUAKE MAGNITUDE       : 5.0ML
STATION ID                 : 2001
STATION COORDINATES        : 37.76219N-29.09222E
STATION ALTITUDE (m)       : 427
RECORDER TYPE              : SMA-1
RECORDER SERIAL NO         : 986
RECORD TIME                : 19/08/1976 01:12:40 (GMT)
NUMBER OF DATA             : 1601
SAMPLING INTERVAL (sec)    : 0.01000000
RAW PGA VALUES (gal)       : (N-S) 348.5268 (E-W) 290.3560 (U-D) 173.2901
Copyright EARTHQUAKE RESEARCH DEPARTMENT
GENERAL DIRECTORATE OF DISASTER AFFAIRS
       N-S           E-W           U-D
   -13.107400    -47.950600    -18.514590
   -13.104980    -47.952520    -27.176980
   -12.865700    -46.140580    -22.777830
   -11.157570    -41.740460      6.933893
        ...           ...           ...
        ...           ...           ...
```

All records are created as ASCII format as seen in Figure 9. Beneath the header information there are three components of acceleration data like; N-S (North-South), E-W (East-West) and U-D (Up-Down). Besides, sample interval value for each record can be found in the header information. There isn't any process implemented on acceleration data, except for base-line correction, in the other words, records on the web page are entirely raw data and unit of PGA values is cm/sn2 (gal).

Local Networks

Local networks have also been operated within the framework of the different projects or cooperation. These are deployed with specific geometrical arrays on active fault systems in order to observe seismic activity closely. Currently, with different regions and arrays, 10 local- scale networks around the populated cities located very close to active faults have been operated under the TR-NSMN. The first one is, supported by the NATO Science for Peace Program (SFP977484) in 2001, procured with 20 instruments around two arrays (Gülkan et al. 2007). One of these array has already been positioned between Yalova and Bursa (BYT-NET: 27) region in north-western and the other one is between Aydin and Denizli (DATNET: 18) region in western of Turkey. In addition to these, between Hatay and K.Maras region (MAT-NET: 55), in Eskişehir (ANA-NET: 15), in Kocaeli (KOC-NET: 25), in Antalya (ANT-NET: 14) and in Düzce (DUZ-NET: 8) provinces are the others. Another important local array, İZMİR-NET, which consist of 32 stations installed in İzmir province with TUBİTAK support (Polat et al. 2009). The last of these arrays, KKTC-NET (13) and Iskenderun (ISK-NET: 10) have been connected to the national network in 2012. Locations of the local networks are shown in Figure 8. In time, all local networks have been enhanced in terms of both number and instrument quality.



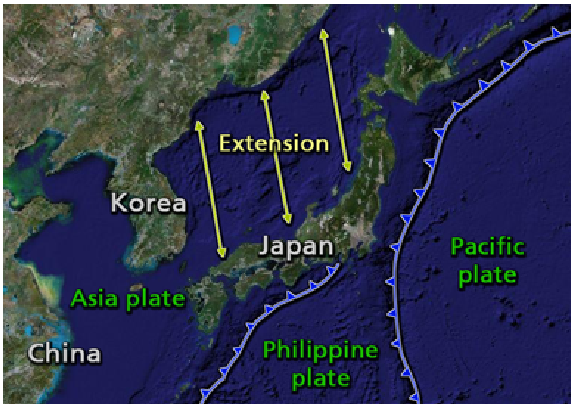
Apart from local networks, within the framework of the AFAD RED Project (Rapid Loss Estimation Project) 20 accelerometers have been installed both K.Maraş and Hatay provinces in 2013. While installing it, conditions such as density of buildings and population, different sites and geological units etc. were primarily taken into consideration. Initiated for a specific purpose, scope of this project will be extended and will be implemented at the various regions in 2014 as well.

CHAPTER 3

Recent Major Earthquakes in Japan

Japan has a notorious earthquake history. About 1,500 earthquakes strike the island nation every year. Minor tremors occur on a nearly daily basis. Deadly quakes are a tragic part of the nation's past.

Japan has such a large potential for earthquakes and disaster because the nation sits atop four huge slabs of the Earth's crust, called tectonic plates. These plates mash and grind together and trigger deadly earthquakes, like the 9.0-magnitude quake that struck on March 11.



September 1, 1923 Great Kanto Earthquake

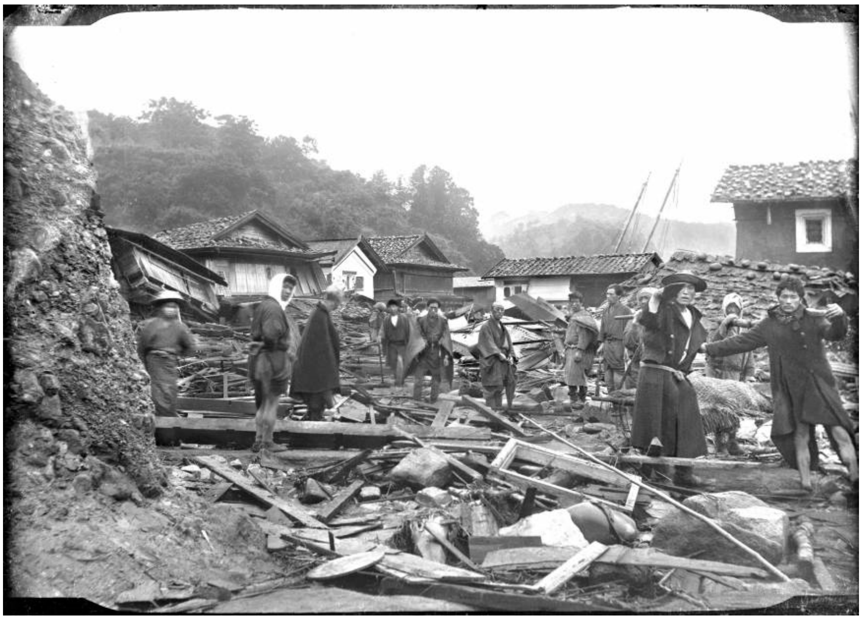
In 1923, a magnitude 7.9 earthquake struck the Kanto plain on the island of Honshu on the morning of Sept. 1. The shaking lasted up to 10 minutes in some places. The quake devastated Tokyo, then home to about 2 million people, and caused widespread damage throughout the Kanto region.

The earthquake triggered massive fires (people were cooking lunch on gas stoves when the quake hit). The after-fires claimed far more lives than the earthquake itself. The quake killed 142,800, making it one of the deadliest of all time.

In remembrance of the earthquake, September 1st is Disaster Prevention Day in Japan.

March 2, 1933 Sanriku Earthquake

The 1933 Sanriku earthquake occurred on the Sanriku coast of the Tōhoku region of Honshū, Japan on March 2 with a moment magnitude of 8.4. The associated tsunami caused widespread damage to towns on the Sanriku coast of the Tohoku region of Honshu, killing more than 3,000.



Although little damage was produced from the shock, the tsunami, which was recorded to reach the height of 28.7 metres at Ōfunato, Iwate, caused extensive damage, and destroyed many homes and caused numerous casualties. The tsunami destroyed over 7,000 homes along the northern Japanese coastline, of which over 4,885 were washed away. The tsunami was also recorded in Hawaii with a height of 9.5 feet, and also resulted in slight damage. The death toll came to 1,522 people confirmed dead, 1,542 missing, and 12,053 injured. Hardest hit was the town of Tarō, Iwate (now part of Miyako city), with 98% of its houses destroyed and 42% of its population killed.

December 20, 1946 Nankaido Earthquake

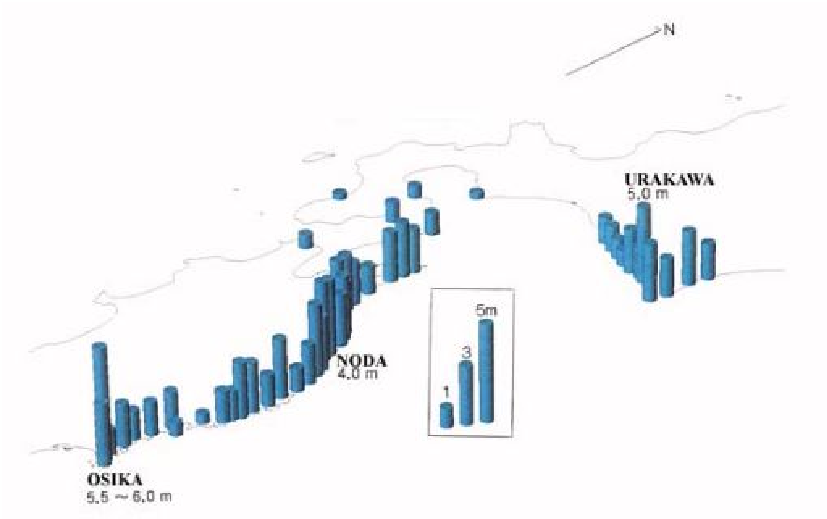
A magnitude 8.1 earthquake struck Nankaido, Japan, on Dec. 20, 1946. The earthquake was felt from Northern Honshu Japan's largest island and home to about 100 million people to the southernmost island of Kyushu. The quake killed 1,362 people.

This quake ruptured in the Nankai Trough, a subduction zone where one tectonic plate slides below another. Earthquakes have been rupturing here every 100 to 200 years since the 7th century.

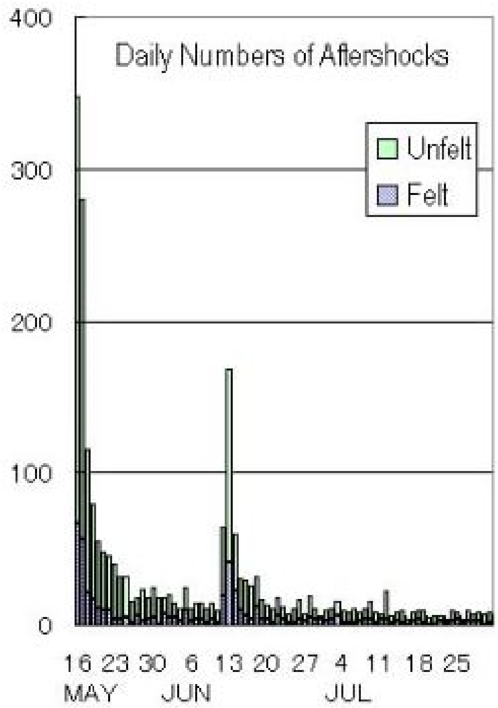
May 16, 1968 Tokachi Earthquake

The 1968 Tokachi earthquake occurred on May 16 at 0:49 UTC (09:49 local time) in the area offshore Aomori and Hokkaido. The magnitude of this earthquake was put at Mw 8.3. The intensity of the earthquake reached shindo 5 in Aomori, Aomori and Hakodate, Hokkaido.

The source region of this interplate earthquake covered a broad stretch in the open sea east of Aomori Prefecture. Strong ground motion was felt over a wide area, primarily in the northern Tohoku region and southern Hokkaido. In the Tohoku region, this earthquake registered a seismic intensity of 5 in JMA scale in Aomori City and Hachinohe (Hatinohe) City. This earthquake also generated a tsunami that was around 6 m at its highest point. The tsunami arrived at low tide, however, so only slight damage resulted.



The earthquake was responsible for a total of 52 fatalities, 47 of which were in Aomori Prefecture. The primary damage included landslides and the collapse of cliffs and houses. Damage was extensive in areas with soft ground, including hilly areas comprised of volcanic deposit, reclaimed land, and low marshy areas. Another factor thought to have contributed to the damage was the soft ground caused by more than 200 mm of rainfall in three days prior to the event in eastern Aomori Prefecture.



The largest aftershock (M 7.5) occurred about 12 hours after the main shock on May 16 and the M 7.2 aftershock occurred on June 12. Seismic intensity 4 in JMA scale was observed over a wide area from the northern Tohoku region to southern Hokkaido. The largest aftershock, which occurred on May 16, registered a seismic intensity of 5 in JMA scale in Urakawa and Hiroo in southern Hokkaido. The frequency of aftershocks increased for a time on June 12, but gradually diminished .

The 1952 Earthquake off the Coast of Tokachi (M 8.2) occurred in the area adjoining the northeast side of the site of the 1968 Earthquake off the Coast of Tokachi.

January 17, 1995 Great Hanshin-Awaji Earthquake

The Great Hanshin earthquake occurred on Tuesday, January 17, 1995, at 05:46 JST (January 16 at 20:46 UTC) in the southern part of Hyogo Prefecture, Japan. It measured 6.8 on the moment magnitude scale (USGS) and Mj7.3 (adjusted from 7.2) on JMA magnitude scale. The tremors lasted for approximately 20 seconds. The focus of the earthquake was located 16 km beneath its epicenter on the northern end of Awaji Island, 20 km away from the city of Kobe.

It killed 6,434 people; injured 43,792; destroyed 104,906 houses; half destroyed 144,274 houses; and partially destroyed 390,506 houses. The fires that broke out because of the earthquake burned down an area of 835,858 square meters.

November 15, 2006 Kuril Islands Earthquake

The 2006 Kuril Islands earthquake occurred on November 15 at 8:14:16 pm JST with a Mw magnitude of 8.3 and a maximum Mercalli intensity of IV (Light). This megathrust earthquake was the largest event in the central Kuril Islands since 1915 and generated a small tsunami that affected the northern Japanese coast. The tsunami crossed the Pacific Ocean and damaged the harbor at Crescent City, California. Post-tsunami surveys indicate that the local tsunami in the central Kuril Islands reached run-up of 15 meters or more. This earthquake is considered a doublet of the 2007 Kuril Islands earthquake that hit the same area on January 13, 2007.

March 11, 2011 Great East Japan Earthquake

The 2011 earthquake off the Pacific coast of Tohoku, also known as the 2011 Tohoku earthquake or the Great East Japan Earthquake, was a magnitude 9.0 (Mw) undersea megathrust earthquake off the coast of Japan that occurred at 14:46 JST (05:46 UTC) on Friday, 11 March 2011, with the epicenter approximately 70 kilometers (43 mi) east of the Oshika Peninsula of Tohoku and the hypocenter at an underwater depth of approximately 30 km (19 mi).

It was the most powerful known earthquake ever to have hit Japan, and one of the five most powerful earthquakes in the world overall since modern record-keeping began in 1900. The earthquake triggered powerful tsunami waves, which reached heights of up to 40.5 meters (133 ft) in Miyako in Tōhoku's Iwate Prefecture, and which in the Sendai area travelled up to 10 km (6 mi) inland. In addition to loss of life and destruction of infrastructure, the tsunami caused a number of nuclear accidents, primarily the ongoing level 7 meltdowns at three reactors in the Fukushima I Nuclear Power Plant complex, and the associated evacuation zones affecting hundreds of thousands of residents.

Strong Earthquake Motion Observation in Japan

In the light of the tragic disaster of the 1995 Hyogo-ken-nanbu (Kobe) Earthquake, the Special Measure Law on Earthquake Disaster Prevention (implemented on July 18, 1995) was passed to protect the people's lives and properties from disasters caused by earthquakes. According to the law, the Headquarters for Earthquake Research Promotion was established under the Prime Minister's Office for unified promotion of earthquake research.

The Headquarters is comprised of the Director (Minister of State for Science and Technology) and its staff (Vice-Ministers of relevant Ministries and Agencies). Under the Headquarters, there are two subsidiary committees, each is comprised of the staffs of relevant Ministries and those of people of experience or academic standing, who are conducting the following mandate concerning to earthquake research.

- Planning comprehensive and basic policies,
- Coordinating administrative works such as budgets for relevant bodies,
- Formulating comprehensive survey and observation plans,
- Collection, arrangement, analysis and comprehensive evaluation of the results of surveys by relevant administrative bodies and universities,
- Public relations based on the comprehensive evaluations.

On the other hand, the situation of strong motion observation also underwent drastic changes. Several projects were planned and conducted in order to reinforce the strong motion network. Japan Meteorological Agency (JMA) deployed about 600 seismic intensity meters throughout Japan. National Research Institute for Earth Science and Disaster Prevention (NIED) established the nationwide network "K-Net" with 1,000 observation sites. NIED is also constructing another strong motion instrument network "KiK-Net". Every prefecture equipped the seismic intensity information network system to concentrate data from all containing municipalities. About 2,600 seismic intensity meters were newly installed in municipalities that have neither JMA station nor K-Net station. Those up-to-date networks can gather and announce the seismic information rapidly.

The Japan Meteorological Agency (JMA) Seismic Intensity Network

The Japan Meteorological Agency (JMA) is a unique national agency that is responsible for tsunami forecasts, short-term prediction of a large earthquake, and information service on earthquakes, tsunamis and volcanic activities. JMA is operating a network made up of about 180 seismographs for continuous earthquake monitoring and 600 seismic intensity meters covering the whole of Japan as shown in Figure.

The Earthquake Phenomena Observation System (EPOS) at the headquarters of JMA in Tokyo and the Earthquake and Tsunami Observation System (ETOS) at six District Meteorological Observatories collect the observational data.

After an earthquake occurs, JMA immediately processes the observational data and quickly announces information on epicenter, magnitude and the distribution of seismic intensity to the public through the media as well as to the disaster prevention organizations. Information from 2,000 seismic intensity meters, which are set up by local governments, is also compiled together.

The JMA seismic intensity scale was originally assessed by the human feeling and the damage examination. In 1996, JMA introduced the new seismic intensity scale, which can be calculated from acceleration records, and developed the seismic intensity meter for prompt estimation of the instrumental seismic intensity. Table provides situation and damage caused by earthquakes correspondent to the JMA seismic intensity scales. Acceleration data files are distributed by Japan Meteorological Business Support Center at cost later on.

JMA Seismic Intensity Scale	*Explanation*
7	In most buildings, wall tiles and windowpanes are damaged and fall. In some cases, reinforced concrete-block walls collapse.
6+ (upper)	In many buildings, wall tiles and windowpanes are damaged and fall. Most unreinforced concrete-block walls collapse.
6- (lower)	In some buildings, wall tiles and windowpanes are damaged and fall.
5+ (upper)	In many cases, unreinforced concrete-block walls collapse and tombstones overturn. Many automobiles stop due to difficulty to drive. Occasionally, poorly installed vending machines fall.
5- (lower)	Most people try to escape from a danger. Some people find it difficult to move.
4	Many people are frightened. Some people try to escape from a danger. Most sleeping people awake.
3	Felt by most people in the building. Some people are frightened.
2	Felt by many people in the building. Some sleeping people awake.
1	Felt by only some people in the building.
0	Imperceptible to people.

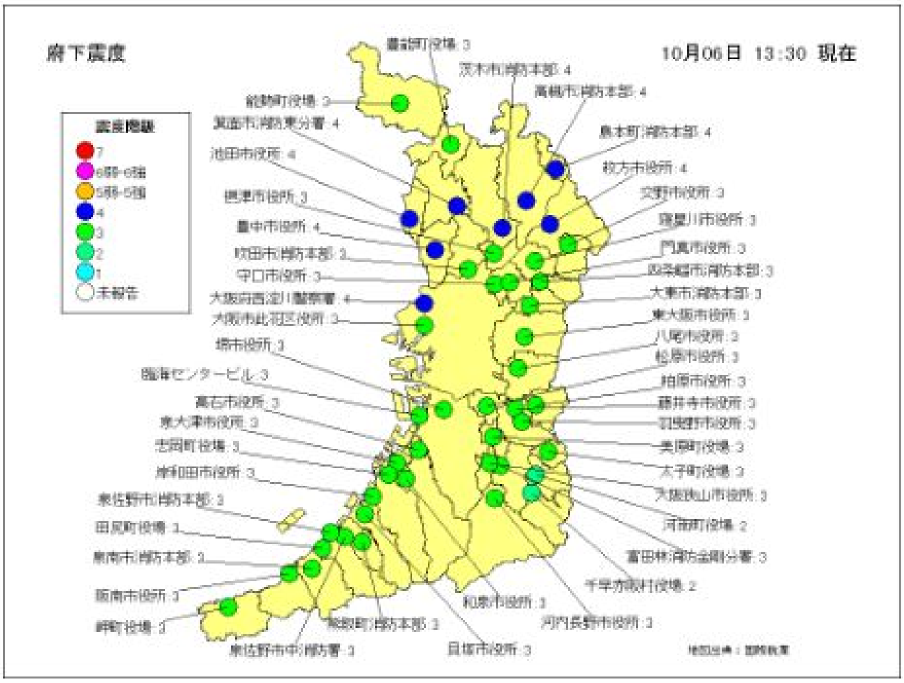
K-Net and KiK-net

National Research Institute for Earth Science and Disaster Prevention (NIED), Science and Technology Agency, constructed a large network, which is called K-Net e), of strong motion instruments in 1996. K-NET consists of 1,000 observation stations that were deployed all over Japan with spaces of about 25 km. Each station has a digital strong-motion instrument with a broad frequency-band and a wide dynamic range on the free field and connects with the control center in NIED, Tsukuba, through the Integrated Services Digital Network (ISDN) line. After the occurrence of an earthquake, the distribution of peak ground accelerations is quickly reported by facsimile and e-mail. Digital acceleration records are posted on the web site within a few days.

NIED is also deploying the high sensitivity seismograph (Hi-net) and the digital strong-motion seismograph (KiK-net) across the all of Japan, as part of the activities of the Headquarters for Earthquake Research Promotion. A high sensitivity seismograph and an acceleration sensor are installed on the firm bedrock at the bottom of a well. An additional acceleration sensor is placed on the ground surface. The project plans to construct a network of more than 500 stations, and about 450 installations have been completed at present. Strong earthquake motion data are opened on the Internet web server.

Seismic Intensity Information Network of Local Governments

The Fire Defense Agency, Ministry of Home Affairs, subsidized local governments to construct the network system that gathers information on seismic intensity promptly. The system assists emergency measures and disaster relief activities by transmitting the information to organizations concerned with disaster measures. A seismic intensity meter is installed in every municipality and each local government collects seismic intensities from containing municipalities. All information finally concentrates at the Fire Defense Agency. About 200 JMA stations and 500 K-Net stations have been already placed on the premises of municipal offices. Therefore, 2,600 seismic intensity meters were newly installed at remaining municipalities. Forty-seven local governments (prefectures) and about 3,300 municipalities (cities, towns and villages) are enrolled in this huge network in total. Seismic intensity scales at a large part of the stations are included in the JMA announcement.



Other National Research Institutes and Public Bodies

Public Works Research Institute, Ministry of Construction

Public Works Research Institute (PWRI), Ministry of Construction, is a national institute in the field of civil engineering. PWRI developed an essential tool for grasping damage outline immediately after an earthquake by providing rough estimation on damage of road facilities. The tool, which is called Seismic Assessment Tool for Urgent Response and Notification (SATURN), consists of about 700 strong motion instruments placed along highways and rivers with an interval of 20 to 40 kilometers 3). Peak ground accelerations and spectrum intensities are transmitted to the headquarters in real-time, and are used to estimate liquefaction possibilities and damage of highway bridges.

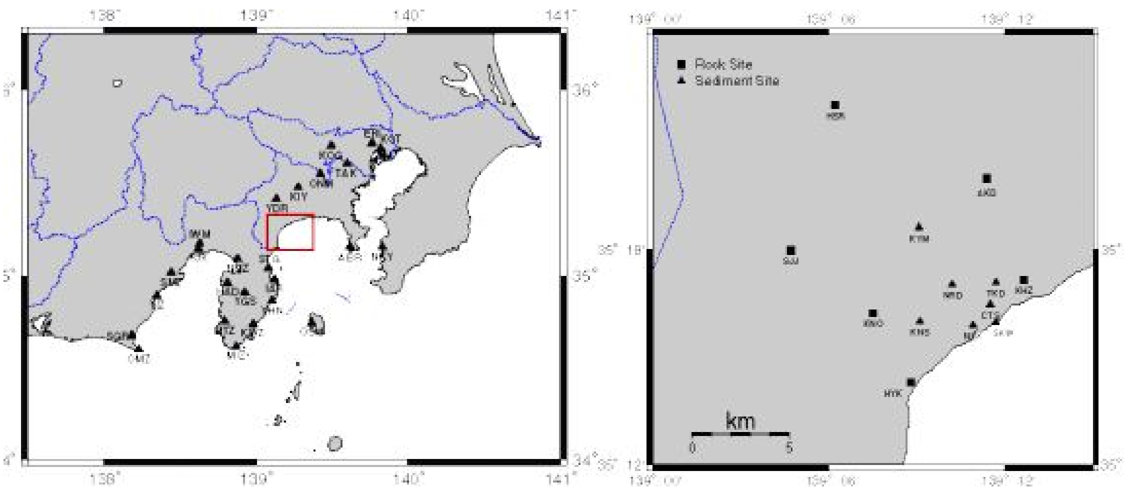
On the other hand, PWRI is operating the Dense Instrument Arrays for Strong Motion Monitoring in nine sites. In order to investigate the seismic effect of geological and topographical conditions, many accelerometers are three-dimensionally arrayed at each site. PWRI is also maintaining traditional strong motion observation sites. The network possesses 1672 instruments at 361 sites and targets dynamic behavior of bridges, river embankments and dams.

Port and Harbour Research Institute, Ministry of Transport

Port and Harbour Research Institute (PHRI), Ministry of Transport, is committed to researching on broad range of themes concerning ports and harbors as well as airports by tying-up closely with the bureaus of the ministry in charge of constructing ports and airports. Strong motion observation of PHRI has been carried out since 1963, and nowadays observation stations reach 57 ports including high-density earthquake observation network using seismic meter distributed intensively in the Haneda Airport and the Kushiro Airport 6). The results of the observation are periodically reported as the annual reports and widely used for seismic design and study on earthquake disaster prevention measures.

Earthquake Research Institute (ERI), University of Tokyo

Earthquake Research Institute (ERI), University of Tokyo was a member institute of the Strong Motion Accelerometer Committee that developed the original Japanese strong motion instruments, and has long history of strong motion observation. ERI has deployed strong motion observation stations from southern Kanto area to Suruga Bay, and densely arranged instruments in the Ashigara Plain as shown in Figure. Observational records are provided on the Internet web site.



Tokyo Gas Co. Ltd.

Tokyo Gas Co. Ltd. supplies gas to customers in the Tokyo metropolitan area. Tokyo Gas launched development of the Seismic Information Gathering and Network Alert System (SIGNAL) in 1986 and put it into operation with 331 SI (Housner's Spectral Intensity) sensors in 1994. In addition, Tokyo Gas commenced preparation of the most extensive ultra-high-density real-time seismic motion monitoring and disaster mitigation system in 1998. The system, which is called Super-Dense Real-Time Monitoring of Earthquakes (SUPREME), will install 3,600 new SI sensors.

Yokohama City

Yokohama City, the second largest city in Japan, founded the Dense Strong Motion Network as a part of the READY (Real-time Assessment of Earthquake Disasters in Yokohama) system. The network consists of 150 ground surface stations and nine borehole stations distributed at an average interval of 1.7 kilometers. Information on earthquake ground motions, e.g. peak ground acceleration and JMA seismic intensity, is transmitted to three centers through the ISDN line within three minutes.

The seismic information is reported to organs concerned disaster countermeasures and is utilized for damage estimation by READY. Distribution of seismic intensity is also uploaded to the web site of Yokohama City.

Building Research Institute (BRI)

Building Research Institute (BRI), Ministry of Construction, is a national institute engaging in researches on architecture and building engineering. BRI has started the installation of strong motion instruments more than 40 years ago and is now in charge of three networks. The aim of the observation is contribution to the enhancement of earthquake-resistant design technology by means of experimental investigation of strong ground motion characteristics and building seismic response. Dynamic soil-structure interaction is also the essential target of observation. Our three networks and the intensive strong motion installation at BRI are outlined hereinafter.

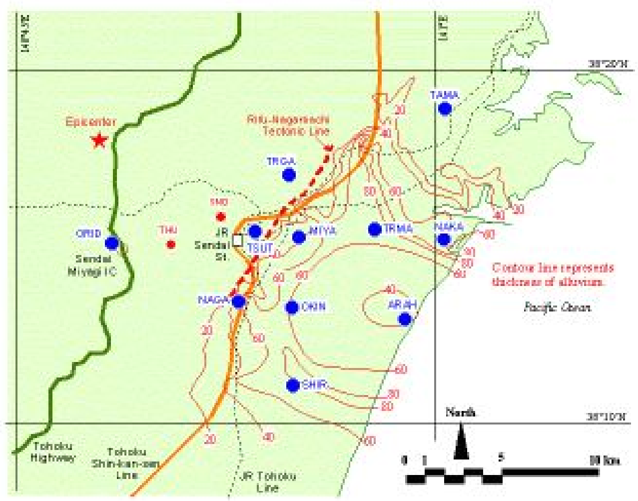
Nationwide Strong Motion Network

The nationwide strong motion network, which has the longest history, has observation sites in major cities throughout Japan. Forty-seven observation sites are equipped with digital strong-motion instruments as shown in Figure , and connected to BRI through the telephone line. The objects of observation are mainly buildings, and acceleration sensors are usually placed both at the top floor and at the basement floor of the building. In addition, a sensor is also set up on the ground surface at the newly equipped sites.

The network has obtained a number of noteworthy records. For example, in the 1964 Niigata Earthquake, the change in the characteristics of the seismic motion caused by liquefaction was clearly recorded in the building next to the collapsed apartment house in Kawagishi-cho. Also, in the 1978 Miyagi-ken-oki (Off Miyagi Pref.) Earthquake, acceleration of more than 1,000 cm/s2 was recorded at the top floor of the nine-story school buildings of Tohoku University. Recently, the peak ground acceleration of 711 cm/s2 was recorded at the Kushiro Local Meteorological Observatory by the 1993 Kushiro-oki (Off Kushiro) Earthquake. In addition, in the 1994 Sanriku-haruka-oki (Far Off Sanriku) Earthquake, an enormous acceleration record was obtained in the building next to the severely damaged old Hachinohe city hall building.

Dense strong-motion instrument array in Sendai

It has been considered that the sub-surface layer especially influences characteristics of the seismic motion acting upon buildings. From 1984 to 1989, eleven observation stations were established on grounds with various conditions in the Sendai area, under the name of joint research by governmental and private bodies. Each observation station holds three accelerometers, placed on the ground surface, in the base rock, and in the intermediate layer. Figure shows configuration of observation stations.



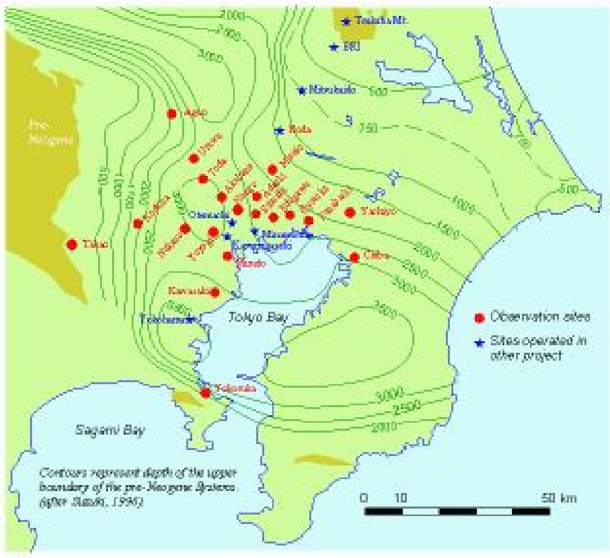
The observation systems of all stations are collectively controlled by the control center in Sendai City. An NTT exclusive line connects the observation stations with the control center, and an NTT public line connects the control center to BRI in

Tsukuba. The information on the earthquake records and the change of instrumental conditions will be sent immediately.

The project as joint research with private bodies has been completed in 1999. BRI reduced the network and updated recording equipment in order to continue the operation.

Strong-motion instrument network in the Metropolitan Area

The 1995 Hyogo-ken-nanbu (Kobe) Earthquake awakened us again to the importance of disaster prevention measures for large-scale urban areas. It is important to predict the probability of a future earthquake and its impact, and make as many preparations as possible in anticipation of such an event. It is also very essential to grasp the damage situation immediately to put in effect the necessary countermeasures.

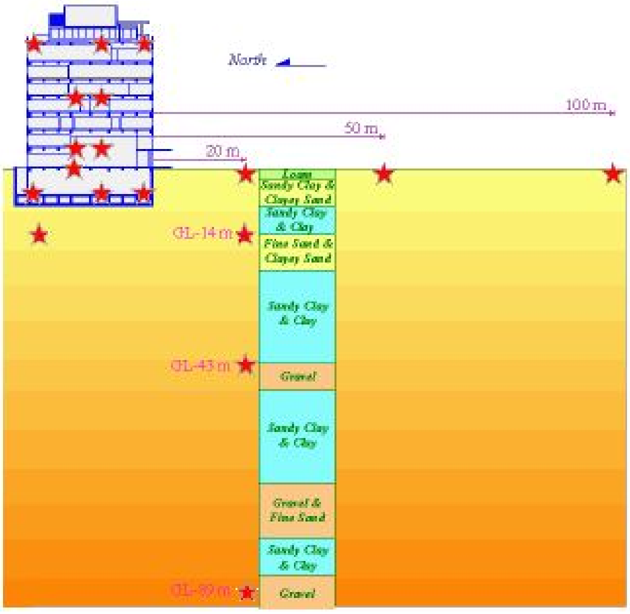


In 1996, BRI established eighteen new observation sites that are deployed radially in the Tokyo metropolitan area as shown in Figure. Tokyo stands on the extremely thick sediment at the center of the Kanto Plan, which is the largest on in Japan. Therefore, the site configuration was planed in consideration of the effect of the sedimental layers and the influence of extensive Kanto Plain on seismic motions. At typical sites, two or three accelerometers are installed in a building. The system immediately collects information on the seismic intensities through the telephone line at the time of an earthquake occurrence.

Strong-motion observation at Urban Disaster Prevention Research Center, BRI

The project to observe the complicated behavior of the building and the effect of the soil-structure interaction during earthquakes was drafted with the construction of the Urban Disaster Prevention Research Center building of Building Research Institute, Tsukuba. The installation was completed in 1998, and the observation is now under way.

The annex building has eight stories with single basement floor and supported by the mat foundation on the clayey layer of 8.2 meters below. The observation system has eleven sensors in the annex building, seven sensors in the surrounding ground, and four sensors in the main office building. The farthest sensor



on the ground is placed 100 meters away from the annex building, and the deepest sensor is set up 89 meters in depth.

The amplification process by the ground surface layers and the three-dimensional behavior of the buildings are recorded using twenty-two sensors in total. All sensors are connected to the recording equipment in the observation room in the annex. The system has 24-bit A-D converters, high-performance digital signal processors and 40 MB flash memory storage.

CHAPTER 4

Conclusion an Recommendations

History of strong motion observation reaches a half of a century in Turkey. The instrumentation technology has been steeply improved and the observation density has been extremely getting higher. Especially the 1999 Izmit Earthquake accelerated installation of strong motion instruments as a principal part of the real-time disaster information system

On the other hand as in the case of Japan; information on the intensity of earthquake motions is gathered primarily. Peak ground accelerations, JMA seismic intensity scales and/or SI values are adopted as values representing the ground motion intensity. Acceleration wave data will be afterwards collected. Characteristics of recent strong motion instruments and observation work in Japan can be summarized as follows:

- High reliability and broad dynamic range of instruments,
- Calculation and display of seismic intensity scale and/or spectral intensity,
- Prompt transmittance and announcement of seismic information,
- Mutual use of seismic information between different networks,
- Rapid publication of digital acceleration data,
- Utilization of Internet

In the light of this information; it is suggested that TR-NSMN should be developed as in the case of Japan.

However, as is known the most of strong motion instruments which were expanded after the 1999 Izmit Earthquake are placed on the ground surface.

On the other hand, strong motion observation for structures is also essential to rationalization of seismic design. More reinforcement of the strong motion observation targeted at building structures is earnestly expected.

References

Ambraseys, N. N., Tchalenko, J. S. (1970). *The Gediz (Turkey) Earthquake of March 28, 1970*. Nature, Volume 227, Issue 5258, pp. 592-593, 10.1038/227592a0.

Ammon, Charles J.; Kanamori, Hiroo; Lay, Thorne (2008). *A great earthquake doublet and seismic stress transfer cycle in the central Kuril islands, Nature,* 451 (7178): 561–5.

Barka, A.; Reilinger (1997). *Active tectonics of the Eastern Mediterranean region: deduced from GPS, neotectonic and seismicity data*. Annali di Geofisica. 40 (3): 588–592.

Bayrak, Y.; Öztürk S.; Çınar H.; Kalafat D.; Tsapanos T.M.; Koravos Ch. & Leventakis G.-A. (2009). *Estimating earthquake hazard parameters from instrumental data for different regions in and around* Turkey. Engineering Geology. 105 (3–4): 200–210. doi:10.1016/j.enggeo.2009.02.004.

Corkill, E. (2011). *Heights of survival*. Japan Times, 12 June 2011, pp. 9–10.

Gurbaga, S. (2013). *New Field Observations About 19 August 1966 Varto earthquake, Eastern Turkey*. American Geophysical Union, Fall Meeting 2013, abstract id. T23C-2611

Gülkan, P.; Gürpinar, A.; Celebi, M.; Arpat E. & Gencoğlu (1978). *Engineering report on the Muradiye-Çaldiran, Turkey, earthquake of 24 November 1976*. National Academies. pp. 5–25.

Gürsoy, H., Tatar, O., Akpınar, Z., Polat, A., Mesci, L., Tunçer, D. (2013). *New observations on the 1939 Erzincan Earthquake surface rupture on the Kelkit Valley segment of the North Anatolian Fault Zone, Turkey*. Journal of Geodynamics, volume 65, 259-271, https://doi.org/10.1016/j.jog.2012.06.002.

Historical Earthquakes:The 1933 Sanriku Earthquake. United States Geological Survey. 14 March 2008. Archived from the original on 2008-07-24. Retrieved 2008-07-16.

Junji Kiyono (2008). Earthquake and lifeline damage. Archived from the original (PDF) *on 2013-06-12*. Retrieved 2014-09-12*.*

Kashima, T. *Strong Earthquake Motion Observation in Japan*. *https://iisee.kenken.go.jp/staff/kashima.*

MacInnes, B.T., Bourgeois, J., Pinegina, T.K., Kravchunovskays, E., (2009). *Tsunami geomorphology: erosion and deposition from the 15 November 2006 Kuril Island tsunami*. Geology, v. 37, p. 995–998.

Masaya Hirosawa; Tomoaki Akiyama; Tatsuya Kondo & Jiandong Zhou (1999). *Damages to Beam-to-Column Joint Panels Of R/C Buildings Caused By The 1995 Hyogo-Ken Nanbu Earthquake And The Analysis*.

Masayuki Nakao. *The Great Meiji Sanriku Tsunami*. Association For The Study Of Failure.

Nilgün OKAY. (2005). *The Risk Profile and Disaster Management System of Turkey* (PDF), https://www.researchgate.net/publication/242126867_THE_RISK_PROFILE_AND_DISASTER_MANAGEMENT_SYSTEM_OF_TURKEY.

Ohta, Y.; Goto N.; Satoh K.; Ergünnay O. & Tabban A. (1980). *An engineering seismological study on the 1976 Çaldiran earthquake in Turkey*. Proceedings of the seventh world conference on Earthquake Engineering, Istanbul, Turkey. pp. 399–406.

Tepeuğur, E., Çeken, U., Kuru, T., Apak, A., Kökbudak, D., Özsaraç, V., Sezer, S., Tekin, K., Ateş, E., and Şahin, C. (2014*). National strong motion network of Turkey*. Second European Conference on Earthquake Engineering and Seismology, Istanbul, August 25-29, 2014.

Tepeuğur, E., Kuru, T., Apak, A., Kökbudak, D., Tekin, K., Ateş, E., Sezer, S., Kaplan, M., Eravcı, B., Yalçın, D., Baykal, B., Çetin, C., and Şahin, C. (2017). *Recent developments on AFAD strong motion observation systems*. 4th International Conference on Earthquake Engineering and Seismology, 11-13 October 2017, Anadolu University, Eskişehir.

Toksöz, M.N.; Arpat E. & Şaroğlu F. (1977). *East Anatolian earthquake of 24 November 1976*. Nature. 270 (5636): 423–425. Bibcode:1977Natur.270..423T. doi:10.1038/270423b0.