Chapter 6. Concluding Remarks

Herein this EDM report, a reconnaissance report on the earthquake source, ground motions and structural and geological damages has been briefly reviewed and summarized. The results of analytical researches utilizing data obtained during the reconnaissance tour and through satellites in space have been examined and discussed as well. We would like to place our endeavor on analytical researches making this report as a research report on the Kocaeli, Turkey earthquake of August 17, 1999.

Discussion on each research item has been summarized within each topic included herein. In the following, we would like to compile the concluding remarks described in each topic in the previous sections for making an overall review on the report.

Chapter 2. Earthquake and Damage

2.1 Source Characteristics and Ground Motion

A fault model that is so-called the kinematic model for the earthquake is reviewed. With in the model proposed, the importance of the forward directivity effect radiated from the main asperities is shown from a preliminary observation of the recordings at the vicinity of the fault. This directivity effect coupled with the site amplification at Golcuk city can explain the heavy damage observed within the region.

Introduced, herein, is the so-named hybrid simulation procedure for the broadband estimation of ground motion based on the kinematic model of the source.

Further studies are needed to determine the ground motion at the heavily damaged zone of Golcuk during the quake. We would like to extend our research to evaluate the ground motions at Golcuk utilizing the proposed hybrid technique to explain the contribution of the source to the ground motion. The generated ground motions can be utilized for the damage analysis on the buildings discussed in the Chapter 5 in the following.

2.2 Building Damage

Reconnaissance tour Survey on building damage has been performed in the damaged areas in Avcilar, Istanbul, Yarimca, Derince, Izmit, Yalova, Degirmendere, Gölcük, Adapazari and Sapanca. The observation on the damage leads to the remarks as follows:

1) Most of the building damage seems to be due to the poor structural configuration and poor detail of structural elements, rather than the strong motion characteristics;
2) Poor construction practice also gave rise to poor performance of structure. As for the middle and small-scale residence building, quality of material and construction seemed worse than large one;
3) A large number of buildings suffered serious damage that was constructed in improper site, such as on active faults and in areas of high liquefaction potential; and
4) Structural performance described in the 1975 code was not insufficient for the earthquake. However, earthquake-resistive details and design philosophies in the code did not accompany construction practice.

2.3 Ground Failure

Investigation on ground failure has been performed in the Kavakli district in Golcuk, the southern shore area of Lake Sapanca, and the central area of Adapazari, to examine structural damage to buildings due to fault scarp and/or soil liquefaction. The results of investigation on the above three districts can be summarized as follows:

1) In Golcuk, most of structures on the lower side of the fault scarp and ground depressions were undamaged or damaged slightly, although even several structures on the upper side of those were collapsed;

2) A gymnasium located on the fault scarp in Golcuk was damaged on the head part of pile-foundation only;
3) Ground failures observed in Sapanca might be caused due to either or all of liquefaction and lateral spreading of subsurface soils, and the fault scarp on ground;
4) The extent of the submerged area changed after seven months after the main shock;
5) Adapazari was damaged heavily due to soil liquefaction, which could be observed concentrically at several local sites;
6) Spatial variations of ground failures were indistinct at several sites in Adapazari, so it might be hard to distinguish clearly between liquefied and nonliquefied areas. Therefore, it is suggested that both our and the JGS results should be inspected and be re-compiled based on further detailed survey in future; and
7) Source and path of seismic motion, sedimentary basin structure, subsurface soil condition, and building and foundation information could be all quite important in order to understand mechanism of damage to soils and foundations.

Chapter 3. Disaster Management

3.1 Damaged Area Estimation Based on DMSP/OLS Nighttime Imagery

A method of the damaged area estimation is proposed utilizing the nightlight imagery taken by the satellite, and applied to the case produced by the 1999 Kocaeli Earthquake. It is revealed that the estimation is considerably accurate at least in case that the cloud influence is of less significance and the observational interval is short, but further examinations are needed to devise a robust and reliable estimation method under various conditions.

In our analysis, it took three weeks since the onset of disaster to disseminate the final results, including one week to acquire the relevant DMSP/OLS images from NOAA/NGDC. The entire process should be reduced to shorter than 24 hours since the onset of the disaster by establishing a proper procedure of analysis and dissemination processes.

3.2 Disaster Response after Marmara Earthquake Disaster

The progress of damages for both human causalities and building losses is described. The final reported numbers of deaths and injured during the quake are increased to 17,127 and 43,953, respectively. The direct economic loss is reported as well.

Within the report, the development/transition of disaster management system in Turkey is briefly reviewed. In the regulation established in 1988 with amendment in 1993, the Ministry of Public Works, Turkish Government should be primarily in charge of disaster management. Provided that a disaster would be catastrophic, an organization established directly under the Prime Minister should be responsible for the disaster management against the event. The case for the Kocaeli earthquake corresponded to the latter case. The disaster response such as that of sheltering tent settlement is summarized.

3.3 Experience Sharing and International Cooperation

The EDM experiences shared with the so-named Hyogo-Kobe Mission, which has been dispatched to support the recovery process from the quake under a JICA Disaster Relief Team, have been summarized. The activities of the Mission are reviewed and self-evaluated. The Mission has held two seminars making discussion on the recovery process based upon the experience from the 1995 Hanshin-Awaji earthquake disaster. A couple of proposals are considered and itemized for future occasions for a mission to make its relief activities, emergency responses and others to a disaster fruitful on an international cooperation basis.

Chapter 4. Damage Detection from the Space

4.1 Recognition of Damaged Areas Using Optical Images

Landsat images before and after the earthquake were investigated. The analyzed region of interest showed different types of damage (i.e. fire, subsidence and various levels of building damage). The analysis of the near infrared band (band 4 in case of Landsat/TM 5 satellite) gives a good approach to detect the flooding. The ratio of the *NDVI* of the images before and after the earthquake gives some trend that conveys some relationship between the different levels of damage. Although the results are in good agreement with the field survey, there is still a high variability in these indices and a further study using other bands and data from other areas will be needed.

4.2 Interferometric Satellite SAR for Damage Detection

A quantitative evaluation on the backscattering properties of SAR images was demonstrated, such as the difference of intensities, intensity correlation and complex coherence between different acquisitions for the areas hit by the earthquake. ERS/SAR images taken before and after the event and detailed field survey data were employed to examine the possibility of capturing the damage distribution. The building damage ratio for city blocks obtained by the field survey and the backscattering properties derived from the SAR images were compared.

In the areas of heavy building damage, the backscattered intensity and the intensity correlation between the pre- and post-event images were found to become low. The degree of complex coherence was found to be useful to classify small damage levels. The estimated damage distribution from the SAR images almost corresponded to the results by the field survey. In spite of these results regarding the mean characteristics of the SAR images, a large degree of randomness exists in the backscattering properties for each damage classification. Further study is suggested for a general statement for the earthquake damage survey in urban areas using satellite SAR is made.

Chapter 5. Ground and Building Motion Simulation in Golcuk

During this earthquake, a large number of buildings were heavily damaged. Observation on spatial damage distribution reveals the fact that the damages have been concentrated on and within the specific areas. The “local site effect” can be pointed out to be a possible reason for the damage concentration. Herein the study, utilizing the date obtained from microtremor measurement performed at Golcuk, the local subsoil condition at the damaged and non-damaged areas have been determined. The S-wave velocity profiles have been evaluated by employing the so-called H/V spectral method, with which one can determine the S-wave profiles with ease without detailed borehole data.

Using the estimated S-wave velocity profiles at five spots in Golcuk with an assumption that the bedrock motion in Golcuk can be well estimated by the motion recorded at the Yarimca strong motion observation station, the ground motions at the spots in Golcuk have been evaluated. The spatial distribution of both the peak ground acceleration (PGA) and velocity (PGV) are obtained along the north-south observation line crossing the heavily damaged zone and lightly or non-damaged zone. With the analysis on the microtremor measurement on the damaged and undamaged masonry buildings, the following two remarks can be pointed out:

1) Strong ground motions in the town of Golcuk, heavily damaged during the earthquake, have been simulated based on the estimated S-wave velocity profiles evaluated from the microtremor measurement at the spot. The peak acceleration and velocity on ground were obtained. The results of the evaluated PGA and PGV were compared with the damage distribution of buildings obtained from an inventory reconnaissance survey by the AIJ research group. It is concluded that the simulated spatial distribution of the PGA well corresponds to the observed spatial distribution

of damaged buildings.

2) Strength demand spectra for a response of building not to exceed the specified ductility demand have been evaluated, employing an inelastic response analysis on a building represented by a single-degree-of-freedom oscillating system. The estimated ground motion at Golcuk is utilized. The evaluated strength demand spectra show the tendency consistent with the damage reconnaissance inventory. When compared the evaluated strength demand spectra with the observed damage, the lateral strength of medium-rise masonry buildings within the damaged areas could be greater than 0.4 in the shear coefficient

The EDM strongly wishes that this technical research report would be of interest and much use for research and practical activities before/during and after a hazardous earthquake. The analytical results included in the report could be utilized to earthquake disaster mitigation through damage detection, damage evaluation and assessment, and disaster management described herein.

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