13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 1376

THE STUDY ON A DISASTER PREVENTION/ MITIGATION BASIC PLAN IN ISTANBUL PART 1 - HAZARD AND DAMAGE ANALYSIS -

Shukyo SEGAWA[1], Osamu NISHII[2], Akio HAYASHI[3], Ali ISKENDEROĞLU[4], Mahmut BAŞ[5]

SUMMARY

Because of a phenomenon of large earthquake source regions migrating from the east to the west along the North Anatolian Fault (NAF), it is likely that a large earthquake will attack Istanbul in the near future. The authors had a chance to carry out seismic microzonation study in Istanbul [1]. This paper discusses about the implementation of hazard and damage analysis.

Many seismic microzonation studies are conducted systematically and the sophisticated methodology are used in Japan and California. But the high-grade techniques can't always be applied to many developing countries because of the poor basic information about the natural conditions and/or the social conditions. The easiness to understand the procedure of the analysis by the governmental people, who are person in charge of disaster management, is also important. The extent and methodology of the study should be decided based on the current conditions and future development of disaster management.

To calculate the hazard and damage is not the goal. It is proposed to be re-analysed according to the progress of the seismic mitigation measures. For this reason, the process of the seismic zonation analysis should be clear.

Based on this concept, the seismic microzonation study in Istanbul attached great importance on the joint work with the Istanbul governmental (IMM) people. The analysis provided tragic scenario with over 0.3g acceleration in city center, about 60,000 heavily damaged building and 90,000 human casualties in the worst case. The process of the Istanbul case study is applicable to other developing countries.

[1] OYO International Corporation, Tokyo, Japan. e-mail: segawa@oyointer.com
[2] OYO International Corporation, Tokyo, Japan. e-mail: nishii@oyointer.com
[3] Pacific Consultants International, Tokyo, Japan. e-mail: hayashia@pcitokyo.co.jp
[4] Istanbul Metropolitan Municipality, Istanbul, Turkey. e-mail: aiskenderoglu@ibb.gov.tr
[5] Istanbul Metropolitan Municipality, Istanbul, Turkey. e-mail: mbas@ibb.gov.tr

INTRODUCTION

Istanbul lies on an active seismic zone ranging from Java – Myanmar – Himalaya – Iran – Turkey and Greece, where many large earthquakes have occurred in the past. Based on world wide historical earthquake catalogues, Istanbul (Constantinople) has experienced earthquakes equal or greater than intensity 9 at least 14 times from 5th century. This means Istanbul has suffered damages due to earthquakes every 100 years, on average. About 1,000 people were killed by the 1999 Kocaeli Earthquake in Istanbul. This earthquake has occurred around the western end of the North Anatolian Fault (NAF), which is extending over 1500 km and across the Marmara Sea where Istanbul faces. The current earthquake cycle on the NAF shows general westward progression, therefore the next event on NAF is suspected to occur at just the west of the Kocaeli Earthquake, namely the south off of Istanbul in the north Marmara Sea [2]. Parsons et al. [3] has calculated the probability of strong shaking in Istanbul during the next 30 years as $62 \pm 15\%$.

The population of Istanbul counted around one million in the era of Constantinople in its heyday and it reached about nine million by census 2000. The population growth in these days is quite high, for example, the 60% of the buildings in Istanbul were constructed after 1980. Because the development of the city infrastructure which is commensurate with the population explosion was impossible, Istanbul implies the city problem with traffic, lifeline, environmental condition, etc.

If next huge earthquake may attack the city, it is easy to imagine the great tragedy in Istanbul. The authors had a chance to carry out seismic microzonation study in Istanbul during ”The Study on A Disaster Prevention/ Mitigation Basic Plan in Istanbul” [1]. This paper discusses about implementation of the hazard and damage analysis.

THE DIFFERNCES OF SEISMIC ZONATION BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

The recurrence interval of the damage by the earthquake is generally very long unlike the other natural hazards like typhoon or flood; although the scale of damage usually becomes very big. Therefore, only a few elder people have the experience of the last earthquake and the memory of earthquake damage has been faded in most earthquake prone cities. The specific image of the damage if earthquake may attack the city is the essential for person in charge of disaster management who seldom has the experiences of earthquake damage.

The seismic microzonation study is one of the solutions to this situation. It is conducted to know enemy (earthquake) and to know own (disaster and management). The estimation of the damage amounts and the distributions is indispensable to make appropriate earthquake disaster management plan. A lot of sophisticated researches are conducted systematically in Japan and California at great cost and labor. In California, the Hazard Maps are made based on the “Seismic Hazard Mapping Act” and it is compulsory to refer the map when dealing real estates. The Hazard Maps are revised at regular intervals and anyone can purchase the latest maps at low costs. In Japan, the Cabinet Board and the Ministry of Education and Science are making the seismic hazard maps of all over the country. Every local government has the obligation to make the earthquake disaster management plan. The seismic microzonation study was conducted by many local governments as the preconditions for the management plans and they are periodically revised in high risk area, for example, in Tokyo and Shizuoka. The state of the art technology and vast amount of precise data are used in these studies and enormous numerical calculations are conducted. The large earthquake damages, for example, 1989 Loma Prieta Earthquake, 1994 Northridge Earthquake, 1995 Kobe Earthquake, revealed the new challenges and technologies has progressed to solve them, unfortunately. Thus, the disaster managements of developed countries are not perfect but becoming better step by step.

On the contrary, the systematic disaster management activity is very rare in developing countries, where most of earthquake damages in the world are occurring especially in congested large city. It usually occurs that almost same structure of the city was rebuilt after large earthquake damage, and again same type of damage occurs by next large earthquake. It is important to take the possible action right now to cut this vicious cycle, even if the action is very small and primitive. The action may not be the best, it can be improved. It is important to reevaluate the plan/ action repeatedly.

The seismic microzonation and disaster management planning in developing countries are usually conducted with the technical and financial aid of other countries/ organizations. In many cases, the high-grade technologies can't always be applied. The insufficient basic information about natural and social conditions and infrastructures is one of the reasons. But the biggest reason is that the technology to be transferred to them should be sustained and developed by them. The seismic microzonation and disaster management planning should be checked and revised repeatedly. For this purpose, the easiness to understand the procedure of the analysis by the governmental people, who are in charge of disaster management, is important. The extent and methodology of the study should be decided based on the current conditions and future development of disaster management.

HAZARD ANALYSIS

Principle of Analysis

Based on the concept above, respecting the sustainability, future development and plain process, following procedures were adopted in hazard analysis. Also the hazard analysis attached great importance on the joint work with the Istanbul governmental (IMM) people.

Baserock Motion Analysis

- The empirical attenuation formula with focal distance and magnitude was used.
- One of the existing formulas was selected through the analysis based on the observed seismic records in Istanbul during the Kocaeli Earthquake.
- The attenuation formula can easily be replaced by their original formula referring local seismological and geotechnical conditions in the future if the observed seismic records will be accumulated.

Surface Soil Amplification

- The amplification factor in NEHRP [4] based on the average S-wave velocity over 30m from ground surface was adopted.
- The class D (stiff soil) was subdivided based on the local geotechnical condition of Istanbul.
- The ground classification of this study will be easily revised in the future if the S-wave velocity of the ground will be available.
- The numerical ground models of S-wave velocity and density from the ground surface to the engineering seismic baserock were also made. These models will be useful when Turkish side will conduct the response analysis. The geotechnical parameters were calibrated through the simulation of observed seismic records during the Kocaeli Earthquake.

Grid System

- The complicated ground distribution can be treated by GIS system; however it becomes difficult to revise the data. Therefore, the 500m grid system was selected as the analysis units in this study.

Scenario Earthquakes

The main trunk of the NAF enters through the Gulf of Izmit to the east, across the Marmara Sea and comes out at the north of Gelibolu peninsula, to the west. CNRS-INSU, ITU, TÜBİTAK [5] has conducted geophysical bathymetric survey of the northern part of the Marmara Sea and they obtained the precise fault location that is shown in Figure 1. The shortest distance from Istanbul to NAF is only 10km after this map. The epicenter of historical earthquakes by Ambraseys & Finkel [6] and the recent seismic activities around Istanbul by Boğaziçi University Kandilli Observatory are also shown in Figure 1. The seismic activity supports that this fault is active now.

Four scenario earthquakes models are made based on the submarine fault as shown in Figure 2. The eastern end of the fault within Figure 2 was broken during the 1999 Kocaeli Earthquake and the western end was broken during 1912 earthquake. The remaining recently un-broken part was modeled as scenario earthquakes considering the shape of the fault and the mechanism of small earthquakes along the fault. Model C suppose simultaneous break of the whole 170km section of NAF in the Marmara Sea and Models A, B, D suppose the partial break. The fault parameters are shown in Table 1.

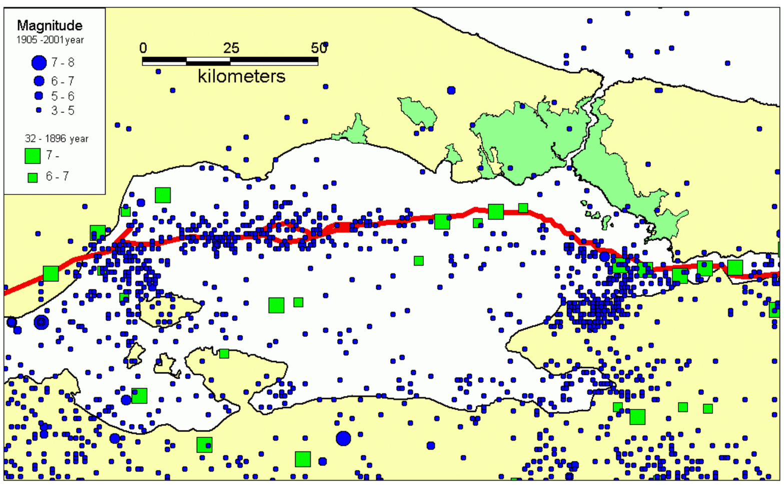

Figure 1 Seismicity around Istanbul and fault system in the Marmara Sea

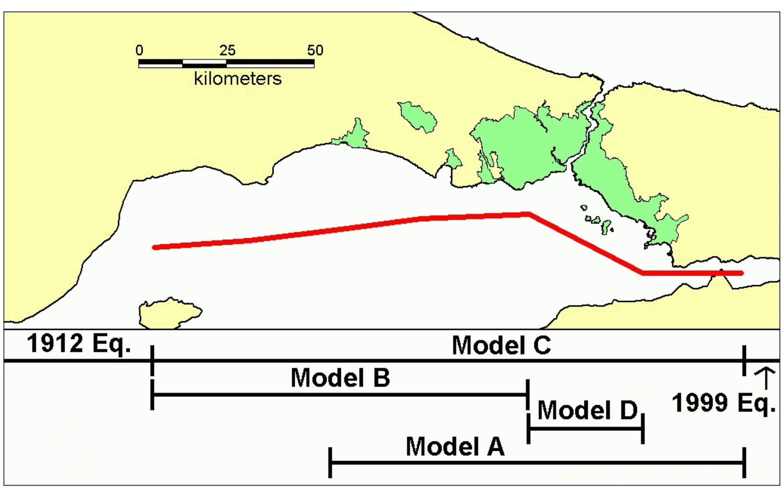

Figure 2 Fault models of scenario earthquakes

Table 1 Fault parameters

	Model A	Model B	Model C	Model D
Length (km)	119	108	174	37
Magnitude	7.5	7.4	7.7	6.9
Type	strike-slip	strike-slip	strike-slip	normal fault

Ground and Soil Analysis

IMM compiled 1:5,000 scale soil classification maps in most part of Istanbul for construction control purpose. The existing boring logs are for about 1,800 locations and the total length is about 38,000m. However the geotechnical data, especially the S-wave velocity was not sufficient. The on-site 48 drilling survey of totally 2,800m in length, including P- and S-wave velocity logging, were newly conducted to grasp the geotechnical properties of each soil layers. The ground classification was conducted based on these data.

At first, based on the existing 1:5,000 scale geological map by IMM, existing logging data and newly conducted boring data, geological N-S and W-E cross sections with 1km interval were delineated as shown in Figure 3. The all area of Istanbul was covered with 4,623 grids by 500m by 500m. Next, the soil layer from the ground surface to seismic engineering baserock (Vs=850m/sec) of each grid was modeled as shown in Figure 3. The ground classification for soil amplification analysis in this study was conducted based on NEHRP methodology and the average S-wave velocity over 30m from the ground surface (AVS30) was used. As mentioned before, the total soil layer model is applicable for the future analysis by Turkish side. The ground classification is shown in Figure 4. The class D was subdivided to 5 classes. Most part of Asian side (right in figure) is classified to class B and C. The northern hilly area of European side (left in figure) is classified to B and C. In the south of European side, class D distributes and class E distributes at the valley.

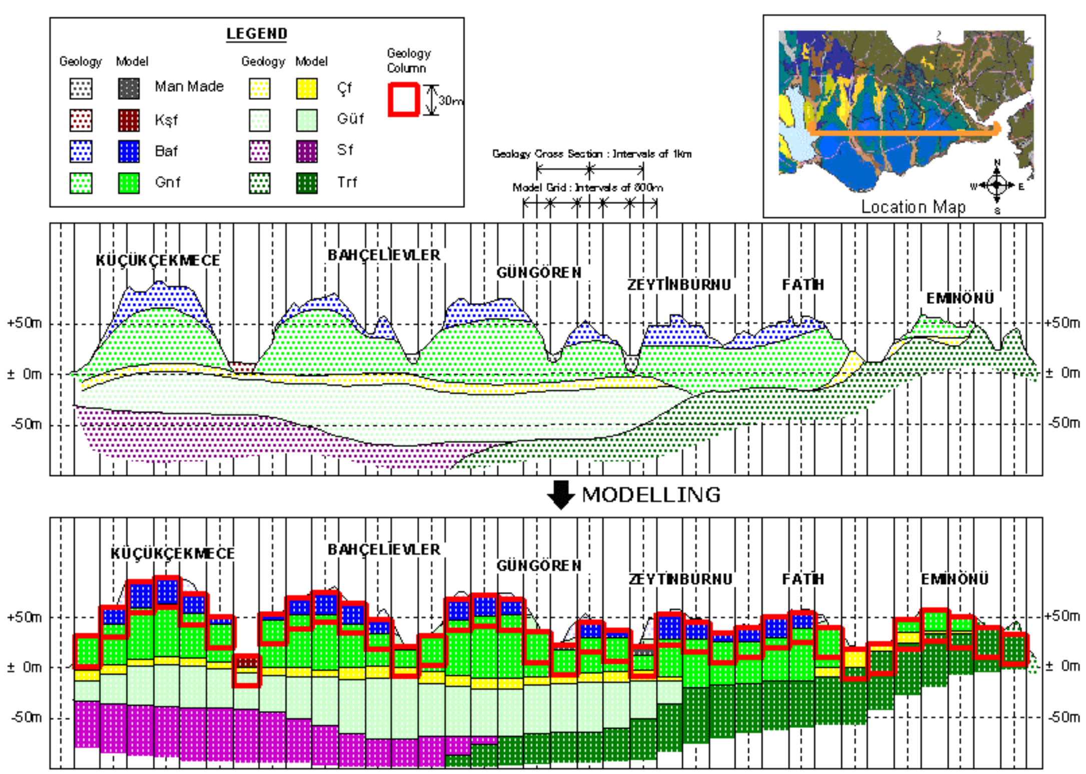

Figure 3 A sample of geological cross section and modelling by 500m grids

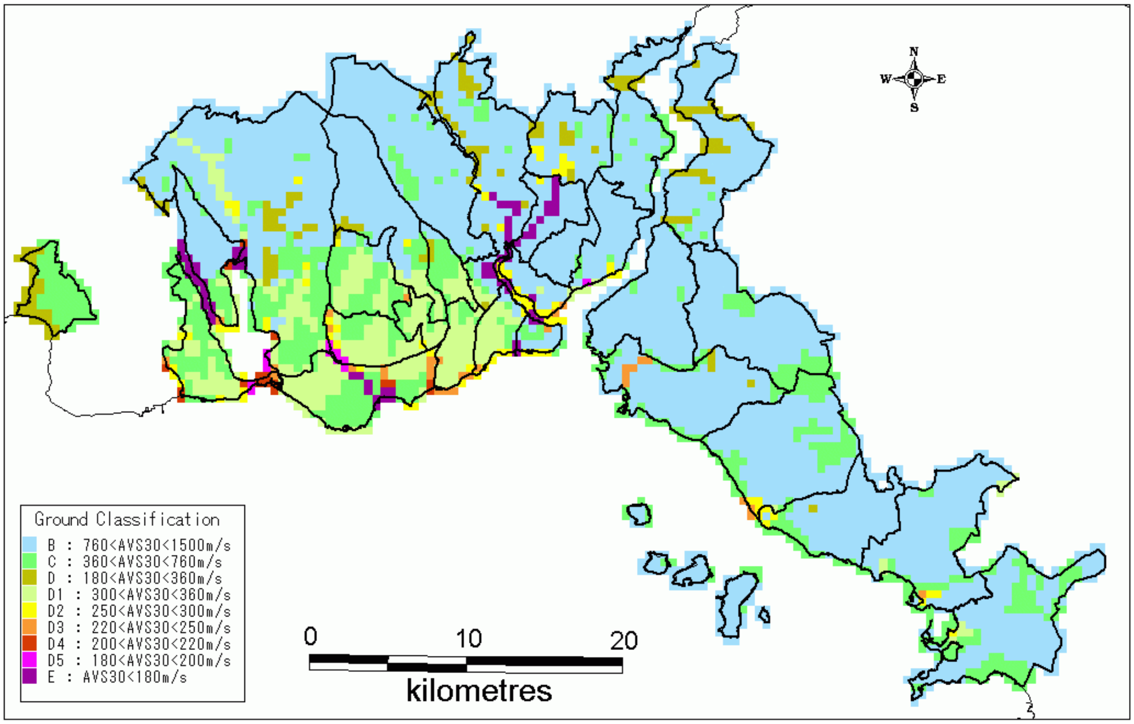

Figure 4 Ground classification

Seismic Motion Analysis

Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV) and Acceleration Response Spectrum (Sa, h=5%) at each grids are calculated. Figure 5 shows the PGA distribution for Model C scenario. The largest PGA is over 0.5g.

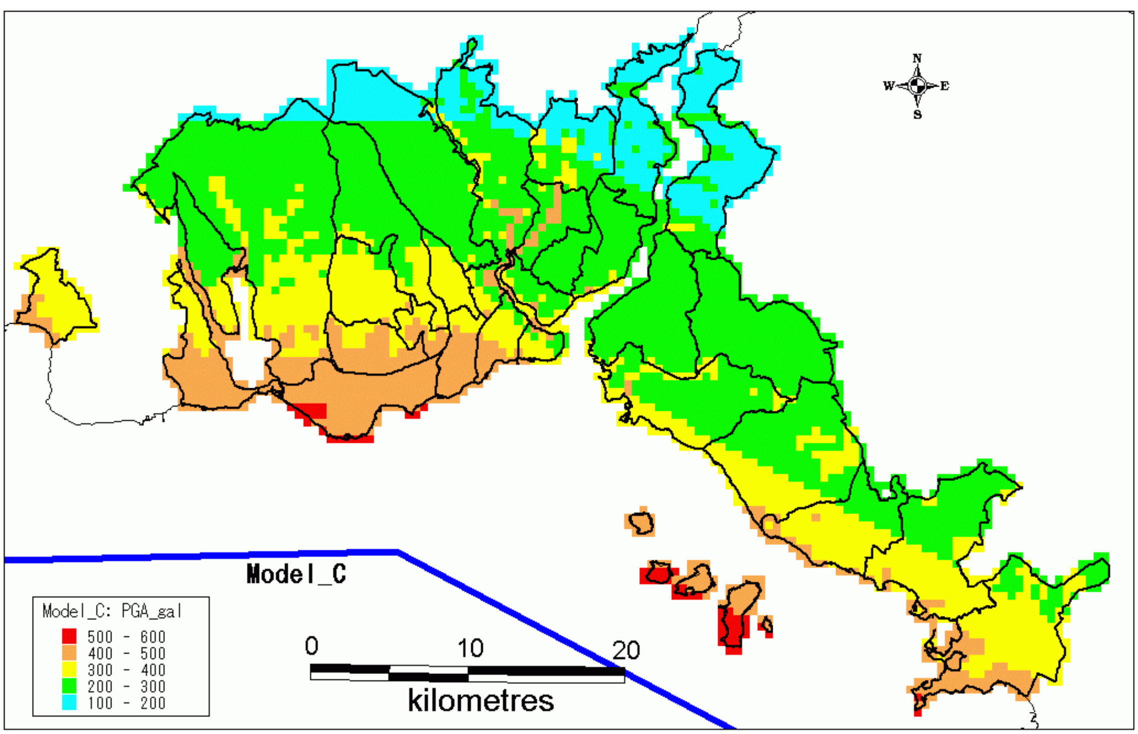

Figure 5 PGA distribution by Model C

DAMAGE ANALYSIS

Building Damage

Analysis Method

The building damage was estimated using the Capacity Spectrum method by NEHRP [4]. In Turkey, the building damage estimation has been conducted using Capacity Spectrum method in Izmir area [7]. The same methodology was adopted in this study respecting the sustainability and easiness of progression of building damage analysis by Turkish side. The specific parameters of buildings and the criteria of damage grade are modified by the calibration through the simulation analysis of the damage in Istanbul during the Kocaeli Earthquake and the damage by the 1992 Erzincan Earthquake.

Building Inventory

The Building Census 2000 was used to make building inventory database. All the buildings included in the census data are classified to 11 classes based on the structure, floor number and construction year. Figure 6 shows the classification by the structure. Over 75% buildings are classified to RC Frame with Brick Wall.

Estimated Damage

The building damages are calculated for scenario earthquakes Model A and Model C. Figure 7 shows the heavily damaged building number of each administrative division for Model C. The difference of building damage is mainly due to the ground condition because the building structure distribution is almost similar in Istanbul. The damage number in Asian side is less than European side. The summary of building damage is shown in Table 2. The total number of heavily damaged buildings for Model C is estimated as 59,000. This is 8% of the total buildings in Istanbul. The simulated damage for the Kocaeli Earthquake using the methodology of this study and the observed damage are also shown in Table 2.

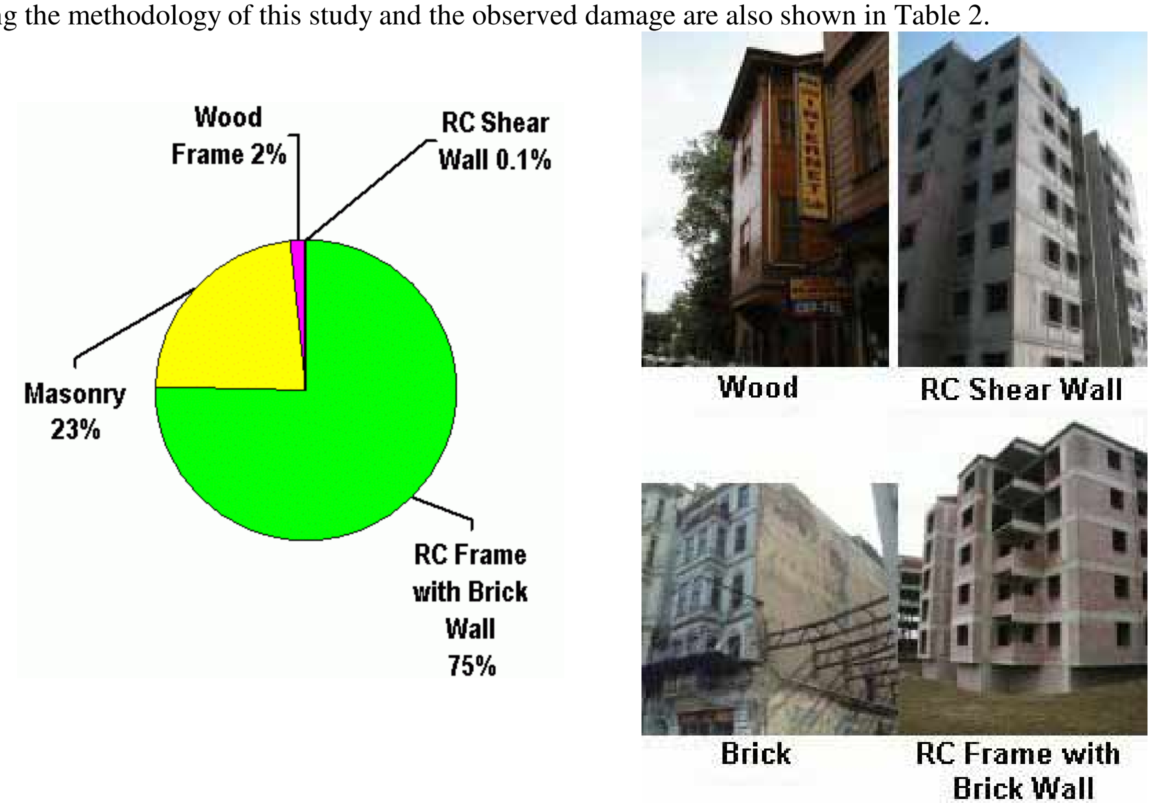

Figure 6 Structures of buildings and its ratio in Istanbul

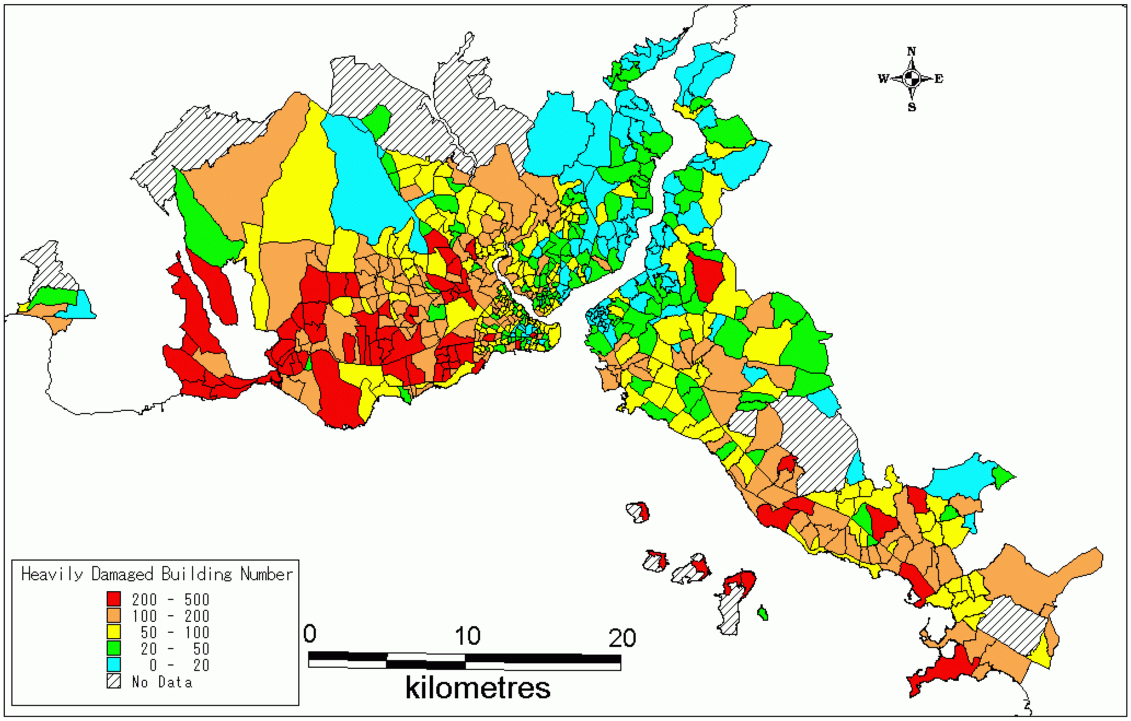

Figure 7 Number of heavily damaged buildings by Model C

Table 2 Summary of building damage

		Heavily	+ Heavily + Moderately	+ Heavily + Moderately + Partly
Model A		51,000 (7.1%)	114,000 (16%)	252,000 (35%)
Model C		59,000 (8.2%)	128,000 (18%)	300,000 (38%)
Kocaeli Eq.	Simulation	(0.15%)	(0.50%)	
	Observed	(0.06%)	(0.33%)	

Casualties

Damage Function

The death toll was estimated using the damage function that is shown in Figure 8, which was newly developed from the relation between the casualty damage and building damage by past earthquakes in Turkey. In the analysis, the number of housing unit was used instead of building number because the apartment houses, which have wide range of floor number, are popularly used in urban area. This casualty function can be upgraded if more data is collected and analysed; for example the specified time zone of the earthquake may be considered.

Estimated Damage

The estimated casualties for Model A and Model C are shown in Table 3. The death toll is estimated as 87,000 and the severely injured people reach to 135,000.

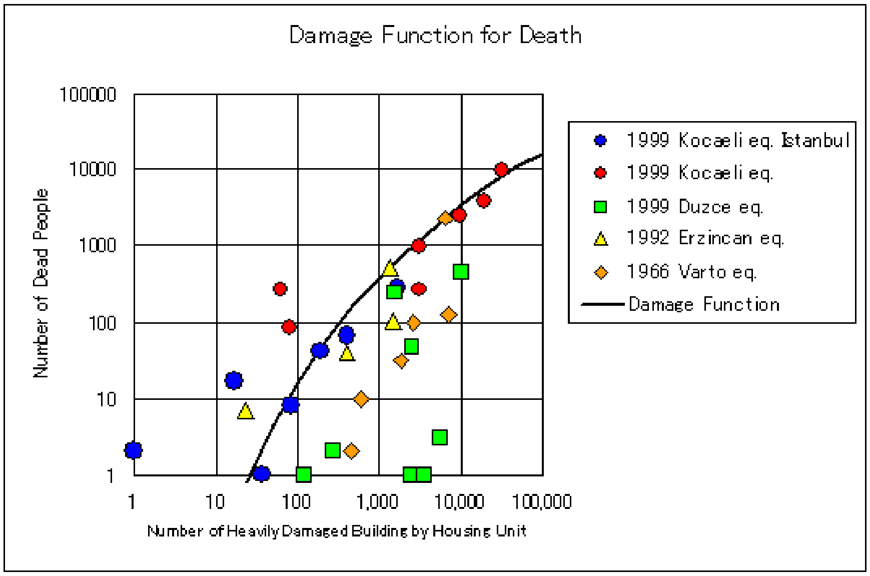

Figure 8 Empirical relation of building damage and death toll in Turkey and damage function

Table 3 Summary of Casualty Damage

		Death	Severely Injured
Model A		73,000 (0.8%)	120,000 (1.4%)
Model C		87,000 (1.0%)	135,000 (1.5%)
Kocaeli Eq.	Simulation	700	1,200
	Observed	418	1,838

PROPOSAL FOR ACTIONS IMPROVING BUILDING CAPACITY

It shows that if the suspected next large event along NAF may occurs, Istanbul will suffer devastating damage. It is also known that weak buildings are the main reason of the casualties. It is true that if all the weak buildings in Istanbul could be replaced, human loss will be minimized drastically. However it is impossible to realize such policy in large city with nine million populations. It is essential to start now from small and possible policy. Followings are the proposals towards improving seismic capacity of buildings in Istanbul.

Implementation of anti-earthquake reinforcement

It is impossible to reinforce all the existing buildings. Seismic capacity evaluation should be carried out to the buildings, where many people stay and reinforcement is effective, for example schools. If the reinforcement is possible, it should be implemented even if the perfect reinforcement may not be realized. Even if the reinforced building may not fulfill the latest seismic code, casualty will be reduced.

Establishment of the seismic capacity evaluation methodology and implementation

Seismic capacity evaluation of the buildings should be carried out based on the unique guideline to prioritize the anti-earthquake reinforcement. In many developing countries, each organizations uses different methodology from different country. The integrated guideline in local language should be documented and disseminated.

Education for building engineers

Many academic researchers in universities and institutes have high technology and enough knowledge; however the necessary information is not transferred to building engineers. The communication and technology transfer between researchers and engineers should be promoted.

Establishment of the effective building inspection/ permission system

The inspection and permission system for newly constructed buildings became merely a name. The licensing system of the impartial inspector should be established as well as the training of the inspection engineer.

CONCLUSIONS

Followings are concluded:

- The methodology of seismic microzonation study in Istanbul was established based on the current condition and the future sustainability of the disaster management.
- The ground classification was conducted in joint work with the Istanbul governmental people.
- The building damage by the worst case scenario (Model C) counts 59,000 and 87,000 people will be killed.
- The quantitative simulation and visualization of the hazard/ damage has great and effective impact to governmental people and the public.
- The actions to improve the capacity of the existing buildings against great earthquakes are proposed.

ACKNOWLEDGMENT

The authors were study team member and counterpart agency personnel in the "The Study on A Disaster Prevention/ Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey" supported by the Japanese Government through the Japan International Cooperation Agency's Development Study Program (JICA DSP). Authors wish to thank them for their support. Throughout the course of the Study, the authors held many discussions with JICA Advisory Committee members, Turkish Technical Advisory Committee members, Istanbul Metropolitan Municipality Government and also many local agencies. Their contributions to this paper have been great and the authors take special pleasure in acknowledging the important part played by them.

REFERENCES

1. Japan International Cooperation Agency (JICA). "The Study on A Disaster Prevention/ Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey". 2002.
2. Erdik, M., E. Durukal, Y. Biro, B. Siyahi and H. Akman. "Earthquake Risk to Buildings in Istanbul and a Proposal for its Mitigation". Boğaziçi University Kandilli Observatory and Earthquake Research Institute, Department of Earthquake Engineering. 2001: Department Report No:2001/16.
3. Parsons, T., S. Toda, R. S. Stein, A. Barka and J. H. Dieterich. "Heightened odds of large earthquakes near Istanbul : An Interaction-Based Probability Calculation". Science 2000; 288: 661-665.
4. Building Seismic Safety Council. "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures 1997 edition (FEMA 302)". 1997.
5. CNRS-INSU, ITU, TÜBİTAK. "Marmara Survey – Marmara Cruise, 2 Sept – 4 Oct 2000". http://www.geologie.ens.fr/marmara.
6. Ambraseys, N. N. and C. F. Finkel. "Long-term seismicity of Istanbul and the Marmara Sea region". 1991. Terra Nova; 3. 527-539.

7. Erdik, M., A. Ansal, N. Aydinoglu, O. Yüzügüllü, G. Birgoren, J. Swift, Y. Alpay and K. Sesetyan. "Development of Earthquake Master Plan for the Municipality of Izmir". 6th. International Conference on seismic Zoning. 2000. CD-ROM.