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SEISMIC RISK ESTIMATION FOR PRINCIPAL CITIES IN TURKEY

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SUMMARY

A large earthquake with a moment magnitude of 7.4 hit the northwestern part of Turkey on 17th August, 1999, causing serious and extensive damage in the area. The Duzce earthquake was occurred successively on 12th November, 1999 along the North Anatolian fault. In this area, it has been continuously concerned about the earthquakes that frequently occur. The main objective of this study is to estimate the seismic risks for principal cities in Turkey.
In this study, damage to structures was calculated based on a vulnerability function, which is a relationship between the ground-motion intensity and the damage probability. Damage to human was measured as a function of building damage. The function was constructed based on the past earthquake damage to human in Turkey. The economic losses were evaluated from the physical loss and production losses. Following results were obtained as the conclusions. (1) If a large earthquake strikes Istanbul, the occurrence of huge damage is predicted and the impact of such damage on Turkish economy is serious. It affects the Turkish economy and finance seriously. (2) The retrofitting of building is effective to reduce the casualties and the economic losses, since it prevents buildings from causing heavy damages.

INTRODUCTION

The earthquake occurred in Marmara region on 17th August 1999 with a moment magnitude of 7.4 caused serious and extensive damage in the area. It is called the 1999 Marmara earthquake. There existed seventeen thousand and over deaths and forty four thousand casualties [1]. About sixty to one hundred thousand buildings were collapsed or incurred major damage [1]. In response, the government of Turkey has implemented progressive earthquake recovery programs and activities. The Marmara earthquake was followed by the Duzce earthquake occurred on 12th November, 1999 along the North Anatolian fault. This area has been paid continuous attention in relation to the frequent occurrence of seismic hazards especially due to the location of the largest city of Istanbul is in this hazard zone. The total damage cost affected by the 1999 Marmara earthquake was estimated at 3.1 billion to 6.5 billion US dollars by the World Bank [2]. It is equivalent to the 2.4 to 5.1 per cent of Turkish GDP, which is a significant portion of

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the country's domestic production and the damage seriously affected the economy and finance of the country. If the large earthquake strikes Istanbul, the occurrence of huge damage is predicted.

Since Turkey has not only Anatolian fault but also numerous active faults, other cities are also in high earthquake risk. For the earthquake prone countries like Turkey, it is important to estimate the seismic risks for the major cities and to prepare it are important.

The main objective of this study is to estimate the seismic risks for principal cities in Turkey. The seismic risk of each city was evaluated through the physical and economic loss analysis. In the damage estimation, the calculation method was calibrated by the actual damage data of the 1999 Marmara earthquake.

METHODOLOGY

Basic Data

Objective areas for the earthquake damage estimation are listed in Table 1. As shown in Table 1, these four provinces are the largest cities in Turkey with respect to population and economy. Moreover, Kocaeli province is selected for the verification of the damage estimation of the Marmara earthquake on 17th August, 1999.

Five scenario earthquakes listed in Table 2 are considered for the target provinces. Each fault is selected as the highest hazardous seismic source to the corresponding province. For Istanbul, two faults, which are given in the JICA study [3], are applied. Each fault is displayed in Figure 1.

Table 1 Basic data of objective areas

Province	Ankara	Istanbul	Izmir	Kocaeli	Turkey
Area (km^2)	25,401	5,312	12,016	3,625	783,577
Population (2000)	4,007,860	10,033,478	3,370,866	1,206,085	62,865,574 *)
GDP (1999) (Mil. US$)	9,857	27,133	8,753	5,237	124,182
＜Share＞	7.9%	21.8%	7.0%	4.2%	100%
＜Growth＞	62.1%	49.4%	52.7%	39.9%	48.2%
Number of District	24	32	28	7	-

*) Population Census (1997)

Table 2 Scenario earthquakes for this study

No.	Province	Mw	Location	Note
1	Ankara	7.6	19km north from Ankara	North Anatolia fault
2	Istanbul	7.5	South offshore 7km from Istanbul	JICA Model A [3]
3	Istanbul	7.7	ditto	JICA Model C [3]
4	Izmir	6.5	Right under Izmir	Bogazici Univ. [4]
5	Kocaeli	7.6	Izmit bay	1999 Marmara earthquake

Mw means moment magnitude.

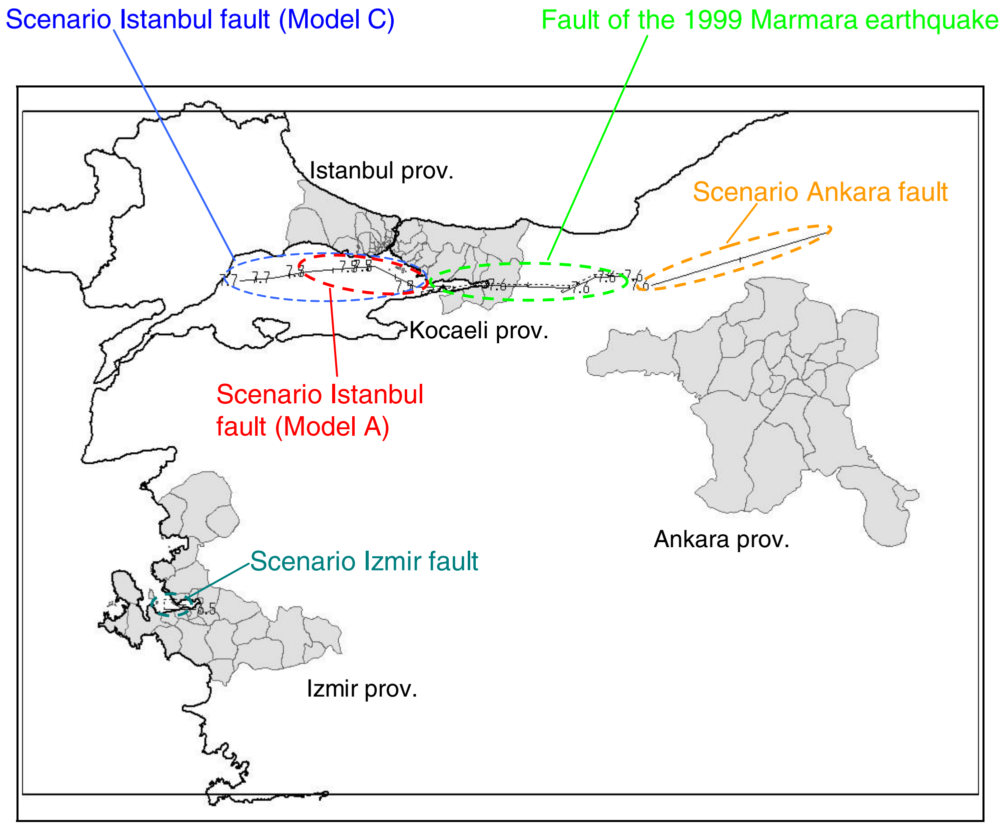


Figure 1 Objective areas and scenario earthquakes

Damage Estimation Model

Flow of damage estimation is shown in Figure 2. At first, scenario earthquakes were identified based on the distribution of active fault and the seismicity. MSK seismic intensity of each site was calculated from ground-motion attenuation relationship taking ground condition into consideration. Attenuation relation was formulated from the distribution of seismic intensity data on the Marmara earthquake [5]. Damage to structures was calculated based on a vulnerability function, which is a relationship between the ground-motion intensity and the damage probability. Damage to human was considered as a function of building damage. The function was constructed based on the past earthquake damage to human in Turkey. Statistics obtained from national censuses [6]-[10] and authors' field survey were employed as the input data for damage estimation model.

Economic loss due to earthquake damage was estimated based on the experience in Kocaeli on the Marmara earthquake. At first, building damage costs in each district were calculated by using the building assets. Thus, the building damage costs estimated in this study are calculated as the costs to restore the buildings to its original state [8],[9]. Building damage costs were classified by the usage. Average fixed assets value in the Kocaeli industries [11] was applied to estimate the industrial material loss. Production loss was presumed using the relationship between the material loss and production loss. Total damage costs were given as a summation of all material loss and production loss.

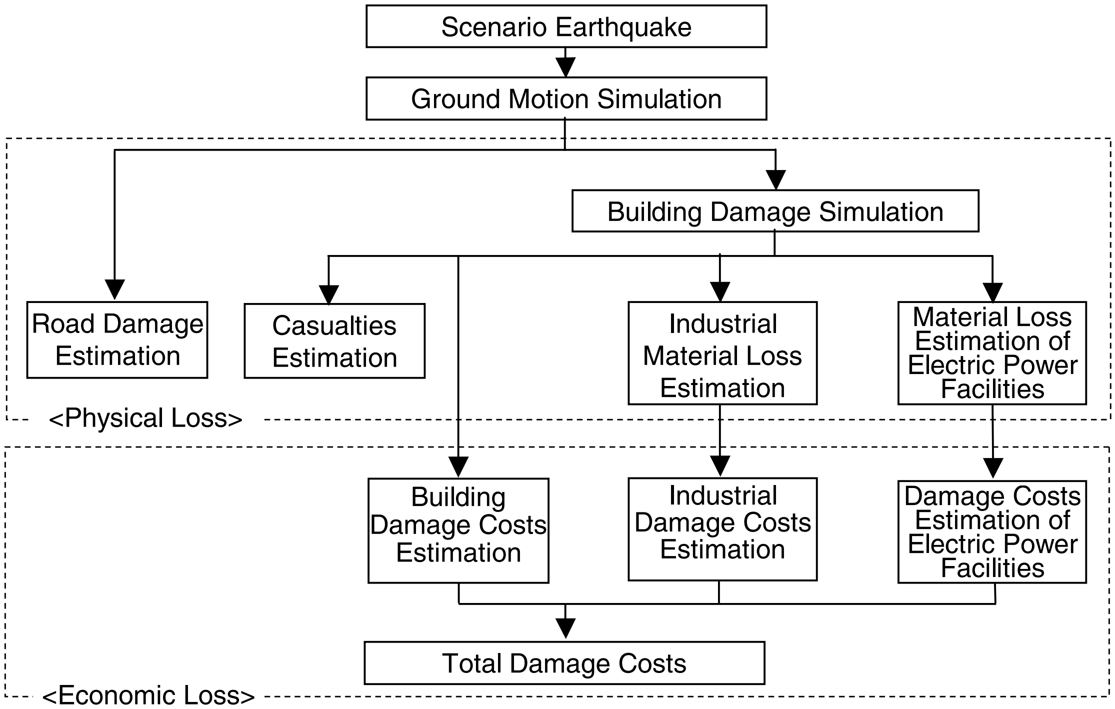


Figure 2 Flow of Damage Estimation

Verification of Estimation Accuracy

Figure 3 exhibits the comparison between the actual damage statistics [12] and estimated value. The comparison with respect to building damage shows good results. Therefore, it can be concluded that using these functions can perform acceptable simulation.

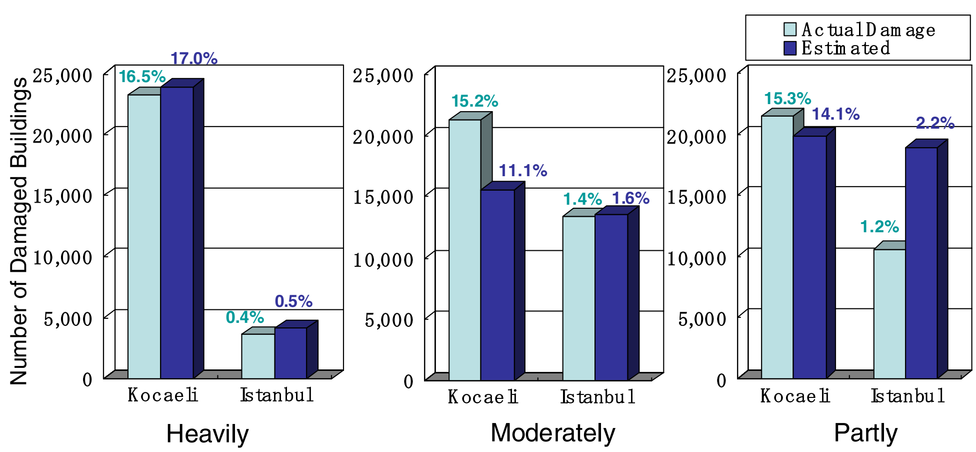


Figure 3 Comparison between the actual building damage and estimated value
- Simulation of the 1999 Marmara earthquake -

PHYSICAL LOSS

The estimated damage in each province is listed in Table 3. In this table, the results of JICA study were quoted for Istanbul. The results for Ankara and Izmir were obtained by using the above-mentioned method. The predicted damage in Istanbul is huge, while Ankara is slight. The damage to Izmir is in between. The difference between the scenario earthquake Model A and Model C is not significant.

Table 3 Estimated Earthquake Damage

Province		Ankara	Istanbul*)		Izmir
Scenario Earthquake		-	Model A	Model C	-
Population (2000)		4,007,860	9,040,059	9,040,059	3,370,866
Casualties	Dead	35	73,487	87,273	18,247
	Severe Injured	64	119,609	135,169	29,490
Total Number of Building		384,489	724,623	724,623	753,690
Building Damage	Heavily	130	51,447	59,176	13,672
	Heavily + Moderately	1,062	113,535	128,047	37,252
	Heavily + Moderately + Partly	2,329	252,370	272,953	70,157
Electric Power Distribution Facilities	MV Trans.	107	206	206	48
	LV Trans.	8815	12733	12733	9662
	MV Line (km)	10265.4	11493.3	11493.3	8767.8
	LV Line (km)	22819.4	29180.8	29180.8	13253.3
Damage of Electric Power Distribution Facilities	MV Trans.	0	21	51	0
	LV Trans.	27	899	1165	250
	MV Line (km)	13.6	198.1	262.9	92.0
	LV Line (km)	12.0	619.9	810.1	94.7
Total Length of Highways (km)		195.17	229.87	229.87	189.0
Num. of Highway Damage		4	28	36	14

*) Istanbul Metropolitan Municipality area

ECONOMIC LOSS

Estimated damage costs for each province are listed in Table 4. The amount of the building damage costs represents the largest of all damages, though some differences can be seen in each province. Damage costs in Istanbul are extremely large. The total damage cost on the 1999 Marmara earthquake was estimated about 3.1 to 6.5 billion dollars by World Bank [2]. The damage cost in Izmir is similar to the Marmara earthquake case.

Damage costs in Istanbul are about ten times bigger than the same in the Marmara earthquake. Furthermore, it affects the Turkish economy and finance severely, because the total loss is over 20 per cent of Turkish GDP.

Table 4 Damage Costs

(Unit: Million US$)

Province			Ankara	Istanbul		Izmir
Scenario Earthquake			-	Model A	Model C	-
Building	Residence		142.2	9,977.4	11,335.9	1,938.9
	Commercial		25.3	7,770.6	8,714.3	600.5
	Other		22.0	768.9	864.3	117.7
Industries	Material Loss	Building	7.9	1,353.5	1,543.0	286.9
		Land	5.5	941.5	1,073.3	199.6
		Vehicles	1.3	222.9	254.1	47.2
		Machinery & Equipment	15.0	2,567.9	2,927.4	544.3
	Production Loss		39.6	6,781.1	7,730.3	1,437.4
Electric Power Distribution Facilities			0.6	14.9	20.5	4.7
Total			259.4	30,398.7	34,463.1	5,177.2
Compared with GDP (%)			0.2	24.5	27.8	4.2

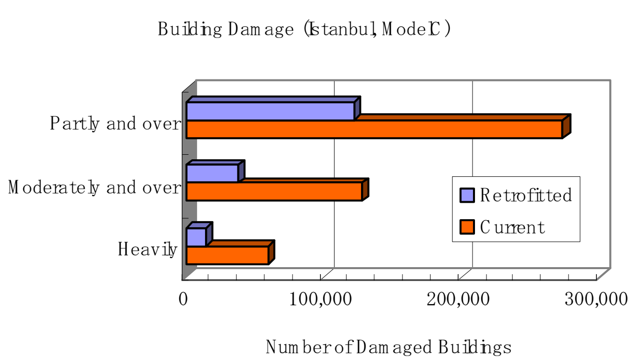
EFFECT OF SEISMIC RETROFITTING ON LOSS

Effect of Seismic Retrofitting on Physical Loss

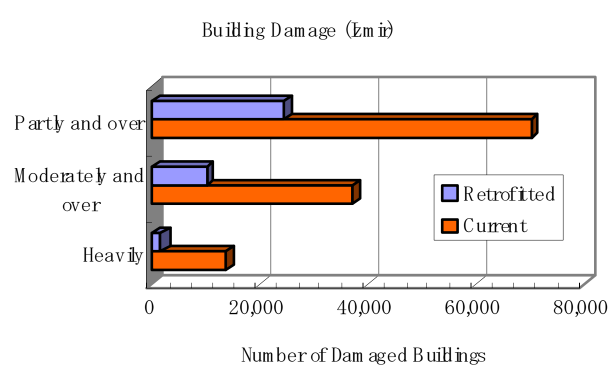
Provisional estimations to evaluate the effect of retrofitting on earthquake damage were carried out. Comparison between the "with" and "without" retrofitting are shown in Figures 4 and 5. In these figures, "Current" means estimation for the existing situations and "Retrofitted" means another condition case considering retrofitted building. In the case of retrofitting, all kinds of damage functions for buildings are modified. It is assumed that all buildings in the object area are retrofitted and the performance is adequate enough to meet the provisions of the existing building standards of Turkey.

The retrofitting produces extreme effects on the reduction of casualties by decreasing number of heavily damaged buildings. Total deaths are reduced by almost 80 per cent.

From this trial, it is concluded that the retrofitting is efficient to reduce the earthquake damage.

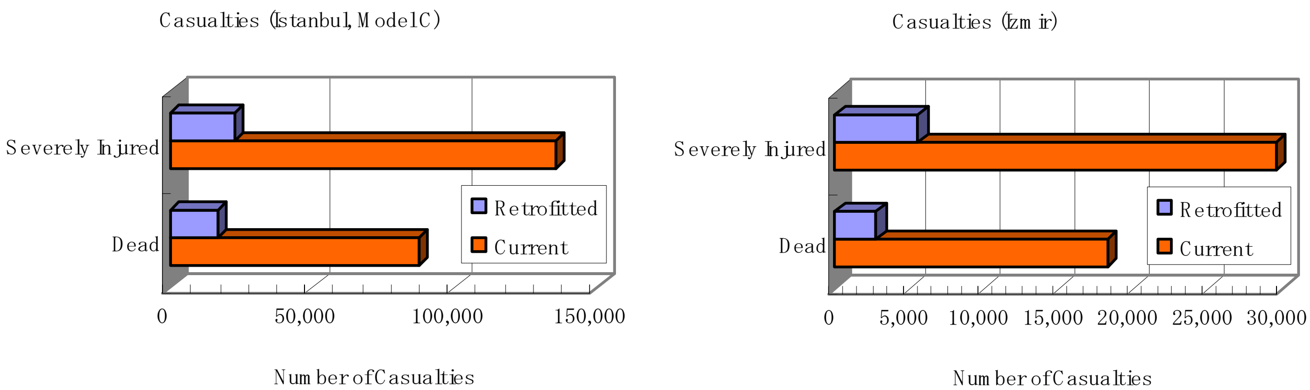


(1) Istanbul (Model C)



(2) Izmir

Figure 4 Effect of retrofitting on building damage



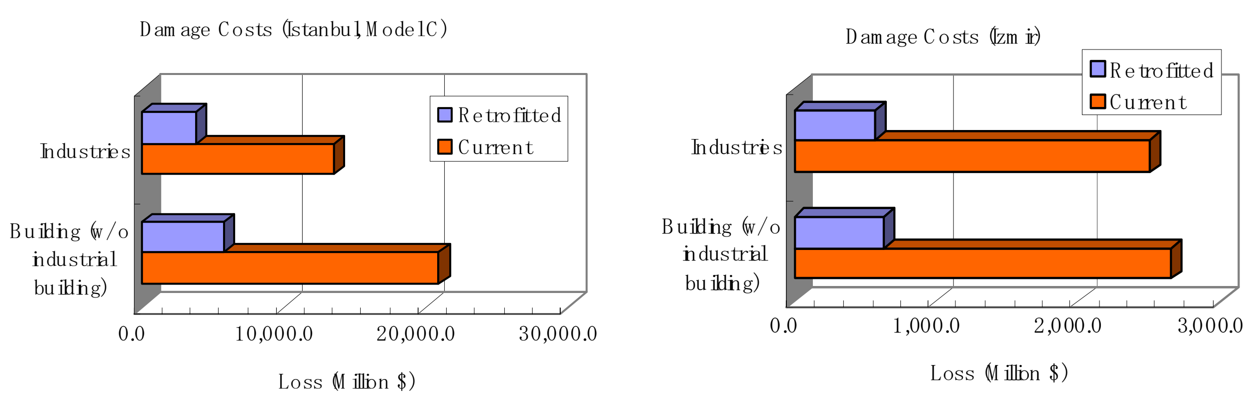
(1) Istanbul (Model C) **(2) Izmir**

Figure 5 Effect of retrofitting on casualties

Effect of Seismic Retrofitting on Economic Loss

Figure 6 shows the provisional estimation to evaluate the effect of retrofitting on economic loss. The condition of retrofitting is the same as the physical loss estimation. The results of damage costs estimation in Figure 6 are based on the building damage in Figure 4. Therefore, this is a tentative calculation to investigate the validity of retrofitting.

The retrofitting contributes reducing economic losses to a greater extent. The ratios are decreased by more than 70 per cent. The estimated economic losses, in case of retrofitted buildings, correspond to about 7 per cent of the Turkish GDP. The reduced economic losses in Istanbul draw near to the damage costs on the Marmara earthquake.



(1) Istanbul (Model C) **(2) Izmir**

Figure 6 Effect of retrofitting on economic loss

Discussion

The analysis mentioned above revealed that, the seismic retrofitting is effective to reduce the physical and economic losses. However, the cost for retrofitting against the initial cost of building construction is high in Turkey compare to Japan. Figure 7 shows cost for retrofitting in each province. Following the survey of Yoshimura and Meguro [13], unit cost listed in Table 5 was employed to estimate for retrofitting costs. It was assumed that retrofitting was carried out targeting vulnerable buildings, which were classified to moderate and over damaged in the damage estimation. In this figure, costs for retrofitting are compared to building damages obtained in the economic loss estimation. The costs for retrofitting are comparable to 30 to 50 per cent of building damages. It is suggested that the retrofitting to the existing vulnerable buildings is high investment for citizens, business organizations and government. At present, the benefit cost ratio of retrofitting is small, since the cost for retrofitting is expensive.

A significant need for the development of new low-cost retrofitting techniques is emphasized by the analysis.

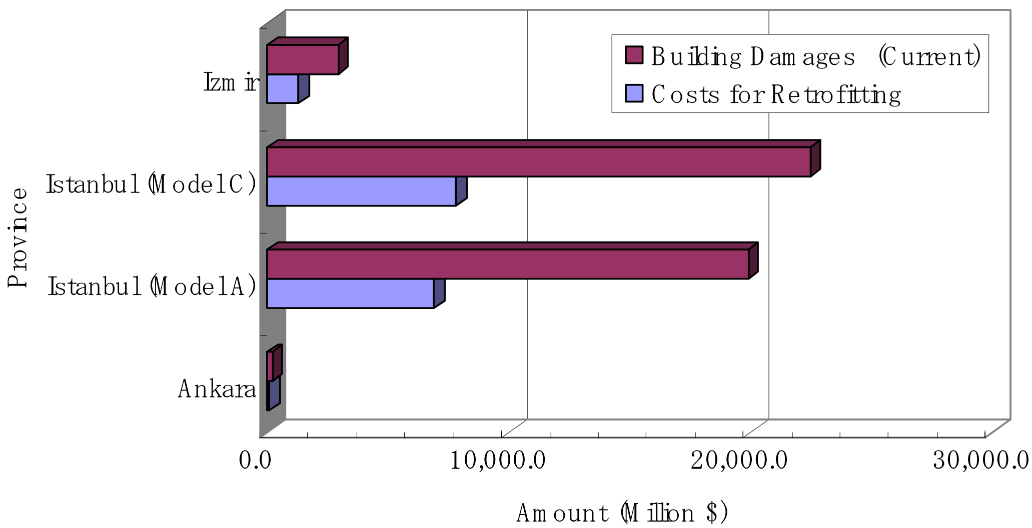


Figure 7 Costs for retrofitting in each province

Table 5 Unit costs for retrofitting

Type of Structure	Unit costs for retrofitting (US$/m^2)
RC Frame	60
Masonry	30

CONCLUSIONS

Investigation results and the implications of this study are summarized as follows.

1) Although Turkey has admirable building standards, it is not adhered under the present situation. The majority of the existing buildings inadequately meet the specifications of the building standards. In some cases, members in structural frame are cut out to improve the livability and

functionality. Many civilians have little interest in the building strength of their residence.

2) If a large earthquake strikes Istanbul, the occurrence of huge damage is predicted. The total loss is predicted over 20 per cent of Turkish GDP. It is about ten times to the damage by the Marmara earthquake. It might cripple the Turkish economy seriously.

3) The retrofitting of building is effective to reduce the casualties, since it drastically reduce damages to buildings. It also reduces the immeasurable economic losses, which are predicted on the present conditions.

4) In Turkey, the retrofitting cost is high against the initial cost of building construction. This is a key factor that keeps people away from the retrofitting.

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