NEW RETROFITTING PROMOTION SYSTEM FOR LOW EARTHQUAKE-RESISTANT STRUCTURES IN EARTHQUAKE PRONE COUNTRIES -CASE STUDY IN ISTANBUL, TURKEY-

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ABSTRACT

Recent damaging earthquakes have clearly revealed that retrofitting low earthquake-resistant structures is the key issue for earthquake disaster reduction. In this paper, a new system and policies that could serve as driving forces for the promotion of retrofitting of weaker structures are proposed. The main concept of the Retrofitting Promotion System (RPS) is that the government guarantees a portion of the building repair and reconstruction expenses if retrofitting is implemented by the owner following guidelines before the earthquake and in spite of this, the structure is damaged. The effect of applying the RPS to Istanbul in Turkey was investigated on the basis of the recovery activity data after the 1999 Kocaeli earthquake, Istanbul building stock data, and a hypothetical earthquake ground motion. The effectiveness of the RPS was verified and several advantages for both governmental and citizen sides were identified.

1. INTRODUCTION

Seismic retrofitting not only reduces the damage to buildings during earthquakes, but also the costs of rescue and first aid activities, rubble removal, temporary residence building, and permanent residence reconstruction to re-establish normal daily life. Furthermore, considering the fact that it can also sharply reduce the number of dead and injured immediately after an earthquake and the various disaster response activities carried out later, a system that could effectively contribute to encouraging seismic retrofitting could be the most important to provide earthquake protection. Although such a system could mainly provide financial assistance, if it effectively contributes to the encouragement of seismic retrofitting, it can prove highly beneficial. To achieve the above goals, the authors have proposed the new Retrofitting Promotion System (RPS) —a system under which the government guarantees a portion of the building repair and rebuilding expenses if retrofitting is implemented by the owner following the guidelines before the earthquake and in spite of this, the structure is damaged—.

The RPS is hypothetically applied to Istanbul in Turkey and its effectiveness is evaluated on the basis of the recovery activity data during 1999 Kocaeli earthquake, Istanbul building stock data and hypothetical earthquake ground motion. The first step is to identify problems with the existing system by estimating the extent of damage that an earthquake can cause. Next, the effects of applying the RPS to 10,000 residences under different hypothetical earthquake ground motions in Istanbul were verified according to the degree of the system acceptance.

2. IDENTIFICATION OF CURRENT SYSTEM PROBLEMS

2.1 Hypothetical Earthquake Ground Motion and Building Distribution

Hypothetical Earthquake Ground Motion and Building Distribution according to JICA and IMM (2002), considers four scenario earthquakes at Istanbul. This section discusses the case, whose fault model is a 120 kilometer section running from the west side of the fault where the 1999 Kocaeli Earthquake occurred in to Silivli as shown in Fig.1. This was chosen because the earthquake activity along the Northern Anatolia Fault is advancing westward and therefore an earthquake with this type of fault rupture is very likely. The moment magnitude (Mw) for this case is estimated as 7.5 and the corresponding Hypothetical Peak Ground Velocity (PGV) distribution is shown in Fig. 2. 543,622 RC frame brick infill residences and 168,100 masonry residences account for 75% and 23.2% of the total, respectively. Figure 3 shows the distribution of buildings according to the building types, the number of stories, and the hypothesized earthquake ground motion at the building location. It can be seen that many buildings are located in the regions with PGV ranging from 20 to 80 kines (cm/s).

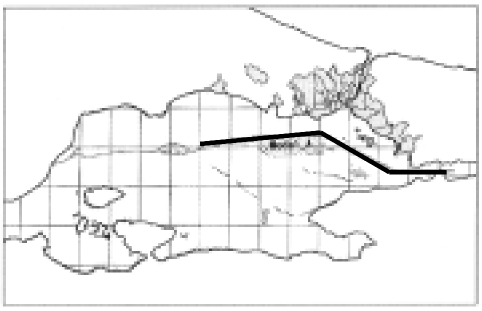


Figure 1: Fault Model

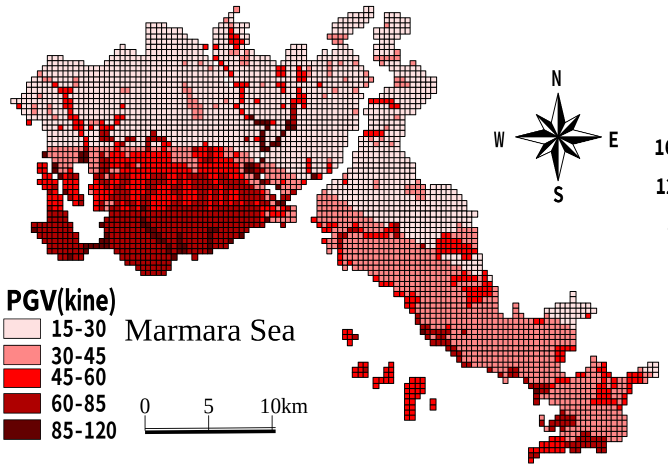


Figure 2: Hypothetical PGV in Istanbul

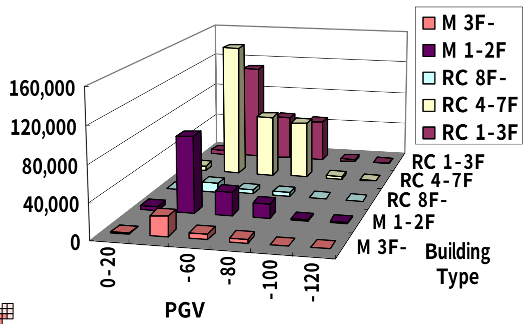


Figure 3: Distribution of Buildings According to Building Types, the Number of Stories, and the Hypothesized Ground Motion

2.2 Building Code and Building Strength

The first set of explicit legal provision for earthquake resistance in Turkey appeared in 1944. This was in reaction to a series of severe earthquakes that started with the Erzincan Erarthquake in 1939 with the magnitude 7.9. Buildings were regulated with a set of construction requirements and a map defining the different seismic regions. The most recent earthquake code went into effect in 1998. Between 1944 and 1998, the building code was revised in 1961, 1968 and 1973.

Figure 4 shows the fragility curves by JICA•IMM (2002). The damage ratio is represented by a logarithmic normal distribution. These are the fragility curves of RC frame brick infill residences with 1 to 3 floors and masonry residences with 1 to 2 floors constructed before 1970.

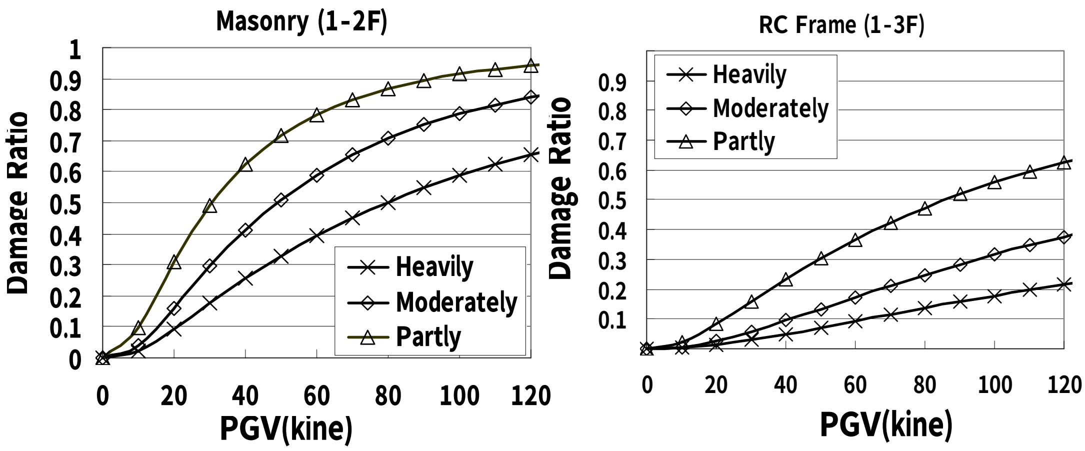


Figure 4: Building Damage Fragility Curves

2.3 Retrofitting Cost

The interview survey revealed that the cost of seismic retrofitting buildings in Turkey is extremely high because the current building strength is very low. The US$30/m2 cost for seismic retrofitting is equal to 3/4 of the US $40m2 cost of constructing the structure of a new masonry building. The situation is Japan is quite different. The costs of retrofitting wooden and RC buildings are 1/10 and 1/8 of the cost of constructing a new house. The high cost of seismic retrofitting in Turkey discourages people to retrofit. Therefore, it is necessary to lower the retrofitting cost by improving retrofitting technologies and adopting a system of government support for retrofitting.

2.4 Public Systems

Whenever an earthquake occurred in Turkey, the support that the government provided to the owners of damaged residences during the emergency recovery phase included setting up of tents, constructing temporary residences, and cleaning up rubble. The cost for supplying temporary residences was calculated referring to the provision of temporary residences following the 1999 Kocaeli Earthquake and is equal to US$4,717 per dwelling. On the other hand, the cost of cleaning rubbles after Kocaeli

Earthquake was US$28,758,170 for 60,503 demolished houses or approximately US$1,163 per building. During the recovery and restoration phase, new permanent residences are constructed, and house owners of heavily damaged residences can obtain those residences with long-term low interest loans. Following the Kocaeli Earthquake, permanent residences were constructed by the government at a cost of US$42,000 (including the cost of utility connections and other infrastructure) and provided to the people at a price of US$12,000. The government provides financing for purchasing permanent residences and those money are repaid within 20 years at an extremely low interest rate and no payments during the first two years1). However, considering an economy in Turkey with a high inflation rate, these conditions resemble more a donation than a loan.

The government expenditures after residences are damaged include the cost of temporary residences, the rubble removal, and permanent housing construction. The estimated numbers of buildings heavily, moderately and partly damaged when a hypothetical earthquake described in section 2.1 occur were 51,477, 113,535 and 252,370, respectively. According to the study by JBIC (2002), the total economic damage following the building damage is US$30.4 billion that corresponds to 15.2% of Turkey's US$199.9 billion GDP for 2000. Moreover, the total government expenditure after residential damage is estimated to be US$7.3 billion, which amounts to 3.6% of Turkey's GDP. This shows that it is not realistically possible for the Government of Turkey to provide this level of assistance to disaster victims following an earthquake. It is essential to improve the seismic performance of buildings in advance and to review the existing system.

3. PROPOSAL OF RETROFITTING PROMOTION SYSTEM (RPS)

This section proposes the Retrofitting Promotion System (RPS) as a new system that can resolve the problems described above. Under this system, the government bears a portion of the building repair and rebuilding expenses, if retrofitting is implemented by the owner following the guidelines before an earthquake and in spite of this, the structure is damaged. A large part of the government expenditure calculated in the previous section is obtained from public funds that would not be necessary if buildings were not damaged. The RPS creates an environment that encourages retrofitting by providing incentives to citizens to retrofit in advance so that the building damage and casualties are reduced. When this system is fully operational, it will be necessary to establish an autonomous body to judge whether buildings have been adequately retrofitted according to appropriate building strengthening standards.

4. ANALYSIS OF THE EFFECTIVENESS OF RPS APPLIED TO 10,000 RESIDENCES

The effects of applying the RPS to 10,000 residences under different hypothetical earthquake ground motions in Istanbul were verified according to the degree of the system acceptance. As pointed out in the study of the conditions resulting from a hypothetical earthquake, the present system of supplying permanent residences gives house owners no incentive to retrofit their own houses. It also forces the government to bear a heavy burden when earthquakes occur in the future. One way of resolving these two problems is the abolition of supplying permanent residences. However, because the current system is beneficial for citizens, they will surely oppose the abolition of the current system. Taking this into consideration, as a first step, the effectiveness of the RPS while maintaining the current system was studied. Then, an ideal RPS was explored.

4.1 Change in the Cost Burdens for Both the Government and Citizens

Table 1 summarizes the changes in the cost burdens for both the government and citizens after the introduction of the RPS based on current system. In order to offer greater incentives to citizens, money will be given to cover a part of the cost of repairing buildings moderately or partly damaged. As for demolished buildings, providing permanent residences in the past will be expanded to include incentive money to cover part of the cost of re-establishing their lives. This is an extremely generous system that will, in turn, encourage the public to seismically retrofit their buildings.

The incentive money paid for a home that was destroyed even though it had been retrofitted was set at twice the cost required for seismic retrofitting. It was also assumed that the incentive money paid for a moderately damaged home and a partly damaged home is equivalent to half and 1/3 of the amount paid for a destroyed home. Table 2 shows the payment of incentive money in case of a masonry residence with 1 to 2 floors based on the cost for retrofitting obtained by the interview survey.

Table 1: Changes in the Cost Burdens under the RPS Based on Current System

Before Introduction of RPS	Various Costs	After Introduction of RPS
House owners	Seismic retrofitting	House owners
House owners	Structural and equipment damage	House owners
Government	Cost of removing rubble	Government
Governments	Constructing temporary residences	Government
House owners	Repairing moderately and partly damaged residences	House owners + Government (Incentive money)
Government (Permanent residences)	Reconstructing demolished residences	Government (Permanent residences + Incentive money)

Table 2: Incentive Money in case of a masonry residence with 1 to 2

Various Cost	Unit	Cost According to the Damage Type		
		Demolished	Moderately	Moderately
Floor Area	m²	200		
Seismic Retrofitting	\$/m²	30		
Constraction of Structural Part	\$/m²	40		
Constraction of Equipment Part	\$/m²	60		
Repair of Damage	\$/m²		13	8
Incentive Money				
Based on Current System	\$	12,000	6,000	4,000
Under Ideal System	\$	20,000	6,000	4,000

Under the ideal RPS, supplying permanent residences is abolished as shown in Table 3. Instead of this, the incentive money for the owners of heavily damaged residences is set at the amount that enables the owners to construct a new house (Table 2).

Table 3: Changes in the Cost Burdens Following Introduction of the Ideal RPS

Before Introduction of RPS	Various Costs	After Introduction of RPS
House owners	Seismic retrofitting	House owners
House owners	Structural and equipment damage	House owners
Government	Cost of removing rubble	Government
Governments	Constructing temporary residences	Government
House owners	Repairing moderately and partly damaged residences	House owners + Government (Incentive money)
Home owners	Reconstructing demolished residences	Government (Incentive money)

4.2 Building Strength after Retrofitting

The improvement of seismic performance of buildings through retrofitting is represented by changes in the shape of fragility curves. Specifically, on the fragility curves, retrofitting increases the mean value of logarithmic normal distribution to a degree equal only to the standard deviation. Figure 5 shows the fragility curve of masonry residences with 1 to 2 floors before (described as thick lines) and after (thin lines) retrofitting. The building strength improvement by retrofitting was determined from the interview survey with the experts in Turkey and the difference between the fragility curves of pre and current building –code in Japan.

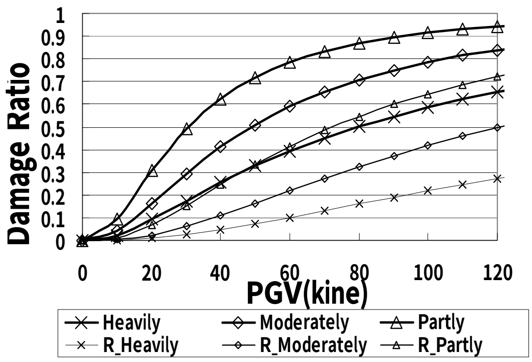


Figure 5: Fragility Curves Before and After Retrofitting

4.3 RPS Effectiveness Based on Current System

The effect of applying the RPS based on current system was investigated from the viewpoint of both government and citizens. Here, a case in which 10,000 masonry residences with 1 to 2 floors located in different regions and therefore exposed to different hypothetical earthquake motions is introduced. This is the building type with the lowest earthquake-resistance among the building types shown in Figure 3. Figure 6 shows how the number of demolished residences changes according to PGV and the acceptance of the RPS. In case that the citizens bear the cost of retrofitting, in regions where the earthquake motion is 60 kine or less, the more retrofitting is performed, the higher the overall burden on citizens is (Figure 7-a). The arrow on the figure shows the trends as the RPS spread. This trend is because the increase in the cost of retrofitting resulting from the spread of the RPS will exceed the reduction in the citizens' burden in case that the citizens bear the total retrofitting cost. Considering that 87% of the masonry residences with 1 to 2 floors are in the region with the PGV less than 60 kine, bearing the full cost of seismic retrofitting will not provide an incentive to all the citizens under the present circumstances. Then, the citizens' profit by obtaining permanent residences is taken into account for estimating the cost burden on citizens. The higher the earthquake ground motion is, the more profit the citizens gain instead of losing their asset, because the obtained asset value exceeds the expenditure due to an earthquake (Figure 7-b). This clearly reveals that the current system that promises providing a permanent residence to the owner of a destroyed home eliminates incentives for ordinary citizens to retrofit their own buildings.

If the retrofitting cost is assumed to be US$7.5/m2 that is 1/8 the cost of constructing the building structure, as it is in Japan, the cost burden on citizens falls in the region with the PGV more than 10 kine as the system spreads (Figure 7-c). Considering that all the masonry residences with 1 to 2 floors are in the region with the PGV more than 10 kine, this shows that all the citizens will benefit from the RPS if new low cost retrofit techniques are available. It is extremely important to support the improvement of the retrofitting technology to enhance the effectiveness of the RPS.

Focusing on the government's cost burden, in case that the citizens bear the entire cost of retrofitting, the greater the RPS acceptance, the lower the cost burden on the government is (Figure 8). This shows that because the costs of temporary residences, permanent residences, and rubble removal are all sharply reduced due to the building strengthening, the total cost burden will be reduced even if incentive money is paid to owners of damaged residences. The reduction in cost burden proves to be the advantage of introducing the RPS for the government.

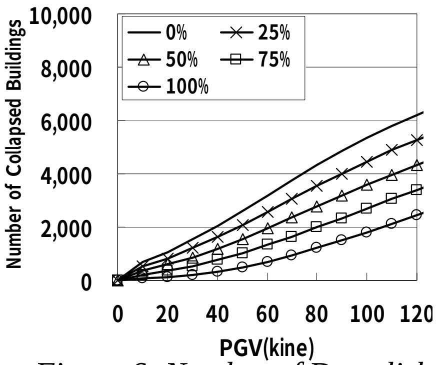


Figure 6: Number of Demolished Residences

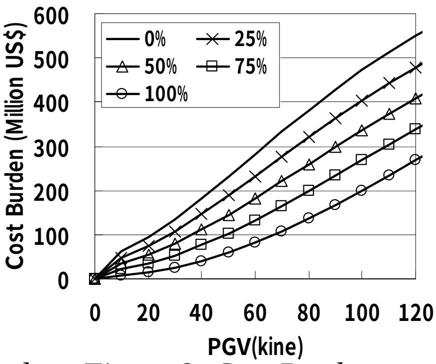
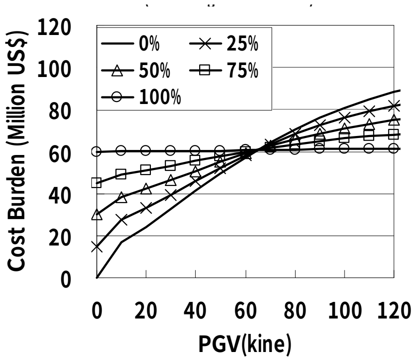
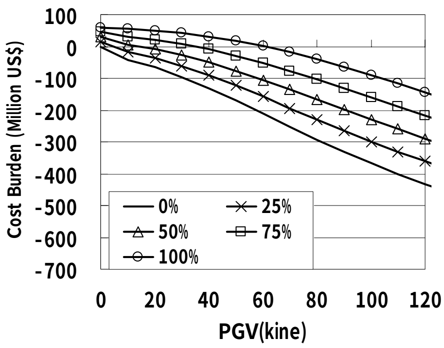


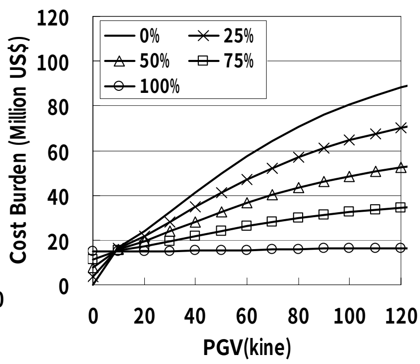
Figure 8: Cost Burden on Government



(a) Cost Burden on Citizens



(b) Cost Burden on Citizens (Including Obtained Profit by Permanent Residences)



(c) Cost Burden on Citizens (Low-cost Retrofitting)

Figure 6: Cost Burden on Citizens in Case the RPS Based on the Current System

4.4 Effectiveness of the Ideal RPS

Next, the effect of applying the ideal RPS to 10,000 masonry residences with 1 to 2 floors located in different regions was investigated. The government's burden increases with the system spread, because high incentive money for demolished residences imposes huge expenditures on the government (Figures 9). However, comparing the government cost burden under the system based on the current system and under the ideal RPS, it can be observed that its cost is drastically reduced due to the abolishment of the system of supplying permanent residences. This ideal system is strongly recommended in order to prevent the bankruptcy of the Turkish Government due to the excessive burden that the government should bear to supply permanent residences to the citizens that lost their houses.

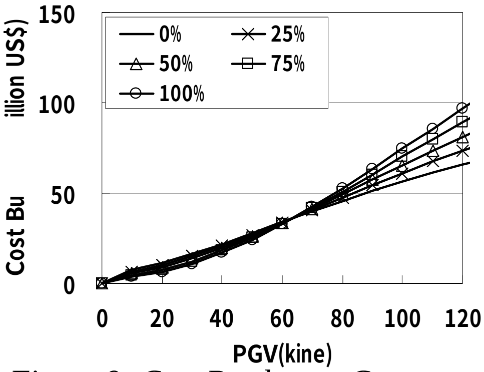


Figure 9: Cost Burden on Government in Case of the Ideal RPS

5. CONCLUSIONS

In this paper, we propose new Retrofitting Promotion System (RPS) that could serve as driving forces for the promotion of retrofitting of weaker structures. The RPS was hypothetically applied to Istanbul in Turkey and its effectiveness was evaluated on the basis of the recovery activity data during the 1999 Kocaeli earthquake, Istanbul building stock data and hypothetical earthquake ground motion. The analysis confirmed the advantages of the RPS for both governmental and citizen sides. The RPS will be more effective if new low cost retrofit techniques are available. In order to effectively apply the RPS, not only its introduction and presentation through educational campaigns are necessary, but also the study of methods to improve seismic retrofitting techniques.

REFERENCES

Nakabayashi, I., 2000. Reports on Urban Reconstructing after the 1999 Earthquake in Turkey and Taiwan. *City Planning*, 72-75, Japan.

Japan International Cooperation Agency, Istanbul Metropolitan Municipality, 2002. *The Study on A Disaster Prevention /Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey.*

Japan Bank for International Cooperation, 2002. *JBIC Special Assistance for Project Implementation for Emergency Earthquake Recovery Loan*, Japan.

Earthquake Engineering Research Institute, 2002. World Housing Encyclopedia Report –Turkey-.

Murao O., Yamazaki F., 2000. "Development of Fragility Curves for Buildings Based on Damage Survey Data of a Local Government

After the 1995 Hyogoken-Nanbu Earthquake."Journal of Structural Construction Engineering, AIJ, No.527, 189-196, Japan.