# PROPOSAL OF RETROFITTING PROMOTION SYSTEM FOR LOW EARTHQUAKE-RESISTANT STRUCTURES 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.

**Key Words**: Retrofitting, Turkey, Kocaeli earthquake, Disaster Mitigation

## 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. Figure 1 shows the overall flow of the study. The first step is to identify problems with the existing system by estimating the extent of damage that an earthquake can cause. Next, the effectiveness of introducing the RPS is analysed. The existing system has been extremely beneficial for ordinary citizens so far. However, it will not be surely functional in case a big

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earthquake predicted to happen in near future attacks Istanbul. But because a drastic revision of the existing system would be extremely difficult to carry out, it is assumed that the present system is gradually changed and different levels of RPS acceptance are considered. The effects of the proposed system on both the government and citizens are explored. Finally, an ideal RPS is studied.

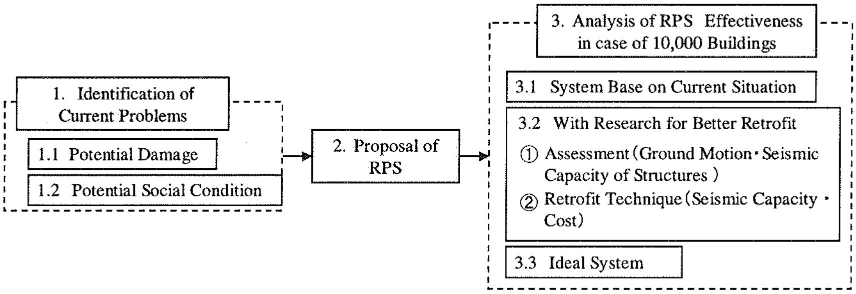



**Figure 1.** Proposal Procedure

## IDENTIFICATION OF CURRENT SYSTEM PROBLEMS

### *Hypothetical Earthquake Ground Motion and Building Distribution*

Reference 2, from the JICA•IMM, 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. 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 Figure 2.

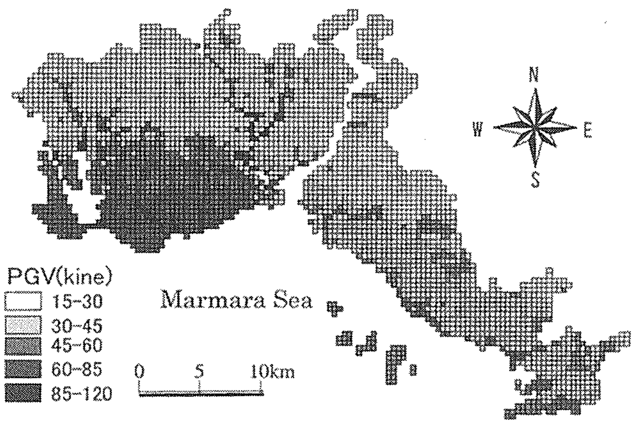



**Figure 2.** Hypothetical Peak Ground Velocity (PGV) in Istanbul

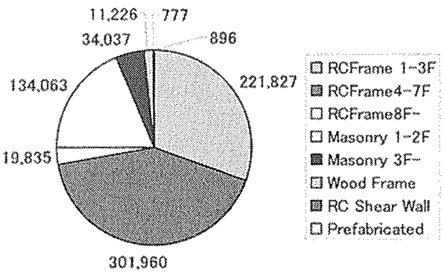



**Figure 3.** Classification of Buildings According to the Building Types and the Number of Stories

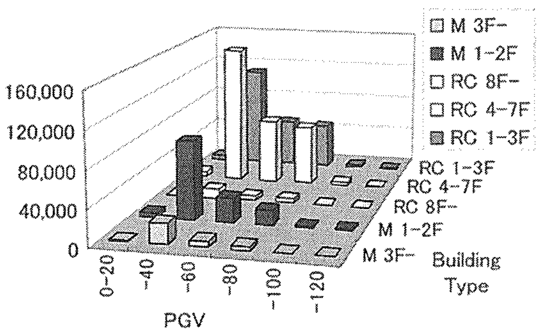



**Figure 4.** Distribution of Buildings According to the Building Types, the Number of Stories, and the Hypothesized Earthquake Ground Motion

Figure 3 shows the classification of building in Istanbul according to the building types and the number of stories. 543,622 RC frame brick infill residences and 168,100 masonry residences account for 75% and 23.2% of the total, respectively. Figure 4 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).

*Aggregation of Potential Building Damage*

Damage to all buildings in Istanbul was estimated in order to clarify the social conditions resulting from the occurrence of an earthquake. The building damage ratio was evaluated using the fragility curves by JICA•IMM (Reference 2). The damage ratio is represented by a logarithmic normal distribution. Figure 5 shows 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. The estimated numbers of buildings heavily, moderately and partly damaged were 51,477, 113,535 and 252,370, respectively.

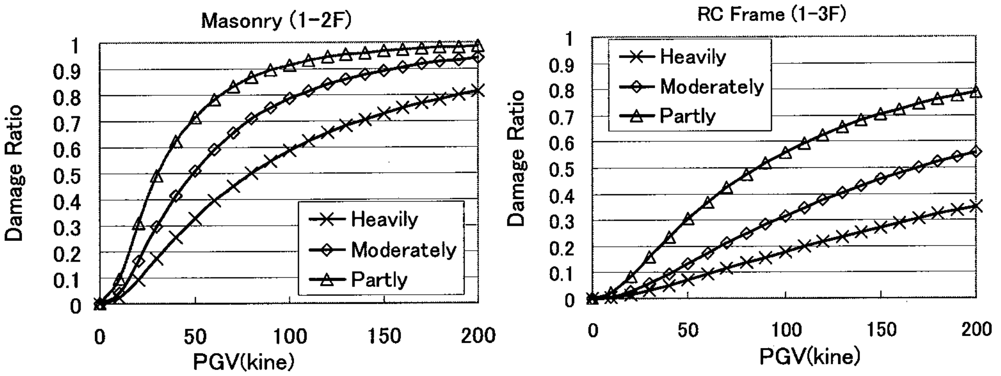



**Figure 5.** Building Damage Fragility Curves

*Social Conditions Resulting from Building Damage*

In this part of the study, problems with the present system were clarified by foreseeing the social situation in case an earthquake occurs under the present system.

*(a)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. Supplying temporary residences requires funding to cover the land rental and infrastructure provision cost in addition to the construction cost. This cost was calculated referring to the provision of temporary residences following the 1999 Kocaeli Earthquake and is equal to US$1,928 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 approximatelyUS$475 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 (floor area for each household = 100 $m^2$) 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 years[1]. However, considering an economy in Turkey with a high inflation rate, these conditions resemble more a donation than a loan.

***(b)Calculation of Expenditures by the Government of Istanbul***

The government expenditures after residences are damaged include the cost of temporary residences, the rubble removal, and permanent housing construction. According to the study by JBIC (2002), the total damage due to the hypothetical earthquake is estimated to be US$30.4 billion that corresponds to 24.5% of Turkey's US$124 billion GDP for 2000. Considering the fragility curves described above (Figure 5) and the building stock data, the government expenditures when an earthquake occur are obtained as shown in Table 6. The total government expenditure is US$4.6billion, which amounts to 4% 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.

**Table 1.** Expenditures by the Government and Citizens after the Earthquake

| Government | | | | Citizens | | | |
|---|---|---|---|---|---|---|---|
| Expenditures (US $ million) | | | | Expenditures (US $ million) | | | Profit (US $ million) |
| Temporary Residences | Permanent Residences | Removal of Rubble | Total | Structural Damage | Equipment Damage | Repairing | Permanent Residences |
| 523 | 4,064 | 24 | 4,611 | 3,253 | 4,629 | 1,866 | 4,064 |

***(c)Calculation of Expenditures by the Citizens in Istanbul***

Following an earthquake, the expenditures assumed by the citizens include the cost of damage to the structure of their residences and home equipment, and the cost of repairing moderately or partially damaged residences. According to the interview survey, the cost of constructing a new house including the structural parts, utility connections and other equipment is shown in Table 2. Assuming that the new construction cost is the assessed asset value of a new building, the cost of structural and equipment damage is estimated considering that the property will depreciate by a half in 30 years (annual rage of decline of 2.3%.) The cost of repairing moderately and partly damaged residences is assumed to be equal to 1/3 and 1/5 of the cost of constructing a new home. In case that a citizen whose residence is demolished can get a permanent housing from the government, the US$42,000 asset value obtained is considered as the citizens' profit. The sum of all the citizens' profit obtained in this fashion is equivalent to 42% of the citizen expenditures, which means that the current aid for the owners of damaged residences is excessive. Moreover, this system acts as a force that discourages ordinary citizens to retrofit their buildings.

**Table 2.** Costs for Construction, Repairing and Retrofitting Residences per Floor Area

| Cost per 1 m² Floor ($/m²) | RC Frame | Masonry |
|---|---|---|
| Constraction of Structural Part | 80 | 40 |
| Constraction of Equipment Part | 120 | 60 |
| Repair of moderately Damage | 27 | 13 |
| Repair of Partly Damage | 16 | 8 |
| Seismic Retrofitting | 60 | 30 |

***(d)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$60/m$^2$ cost for seismic retrofitting is equal to 3/4 of the US $80/m$^2$ cost of constructing the structure of a new RC frame building. Approximately US$6,000 is required to cover the cost of each household. 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.

## 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.

## 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.

### *Change in the Cost Burdens for Both the Government and Citizens*

Table 3 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. According to the statistical data in Reference 2, it was assumed that in the studied region, the number of households inhabiting masonry residences with 1 to 2 stories, 3 stories or more are 2 and 4 households, respectively. It is also assumed that the floor area per household is 100 m2. Table 4 shows the incentive money that should be paid for masonry buildings with various kinds of damage types and number of stories.

**Table 3.** 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 4.** Amount of Incentive Money Paid

| Damage type | Incentive Money (US$) | | | |
|---|---|---|---|---|
| | Base on Current System | | Under Ideal System | |
| | 1-2F | 3F- | 1-2F | 3F- |
| Demolished | 12,000 | 24,000 | 20,000 | 40,000 |
| Moderately damaged | 6,000 | 12,000 | 6,000 | 12,000 |
| Partly damaged | 4,000 | 8,000 | 4,000 | 8,000 |

**Table 5.** 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) |

Under the ideal RPS, supplying permanent residences is abolished as shown in Table 5. 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. The incentive money paid for a moderately damaged home and a partly damaged home is same as in the case based on the current system (Table 4).

***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 6 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 –seismic code in Japan.

***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

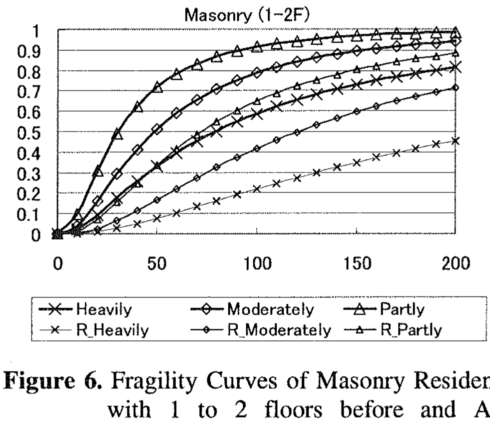



**Figure 6.** Fragility Curves of Masonry Residences with 1 to 2 floors before and After Retrofitting

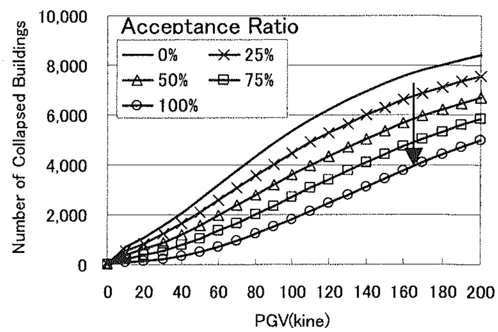
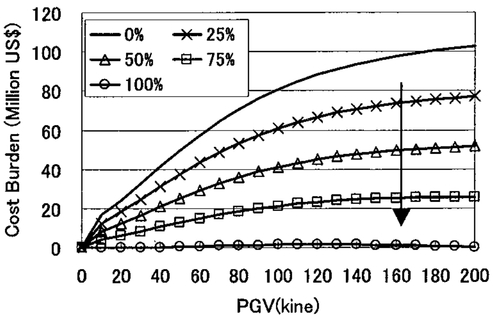
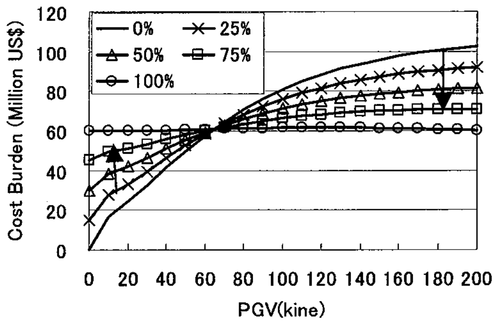



**Figure 7.** Number of Demolished Residences

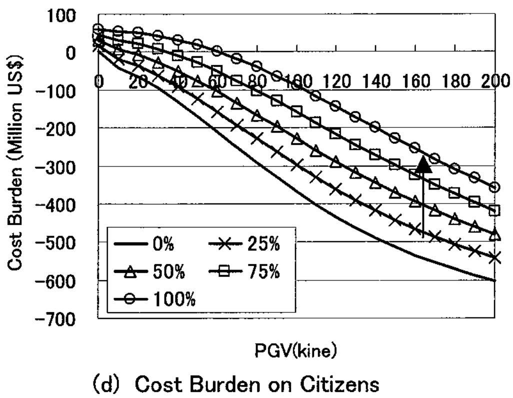
in different regions and therefore exposed to different hypothetical earthquake motions is introduced. This is the building type with the lowest earthquake-resistance among the building types shown in Figure 3. The study included earthquake motions stronger than the motions that are expected in the region (from 0 to 200 kine) to emphasize the trend of the effect. Figure 7 shows how the number of demolished residences changes according to PGV and the acceptance of the RPS. The cost burden on citizens, without including the retrofitting costs, will reduce with the spread of the RPS (Figure 8-a). This is because the cost of structural and equipment damage and the cost of repairing residences reduced and because the incentive money provided through the RPS offsets the total cost burden. The arrow on the figure shows the trends as the RPS spread. However, in case that the cost of retrofitting is included, 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 8-b). 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, as shown in Figure. 4, 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. 8-c). 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.



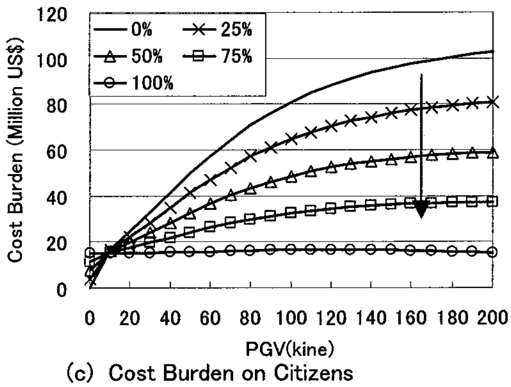

(b) Cost Burden on Citizens
(Excluding Retrofit Cost)




(a) Cost Burden on Citizens
(Including Retrofit Cost)




(d) Cost Burden on Citizens
(Including Retrofit Cost and Obtained Profit by Permanent Residences)




(c) Cost Burden on Citizens
(Including Retrofit Cost with Technological Improvement)

**Figure 8.** Cost Burden on Citizens in Case the RPS Based on the Current System is Implemented for Different Acceptance Ratios and Ground Motions (Case study: 10,000 Masonry Buildings with 1 to 2 Floors)

If the retrofitting cost is assumed to be US$7.5/m$^2$ 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 8-d). 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 9-a). 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. As shown in Figure 9-b, even if the cost of the seismic retrofitting is completely borne by the government, the spread of the system reduces the cost burden in the region with the PGV more than 10 kine.

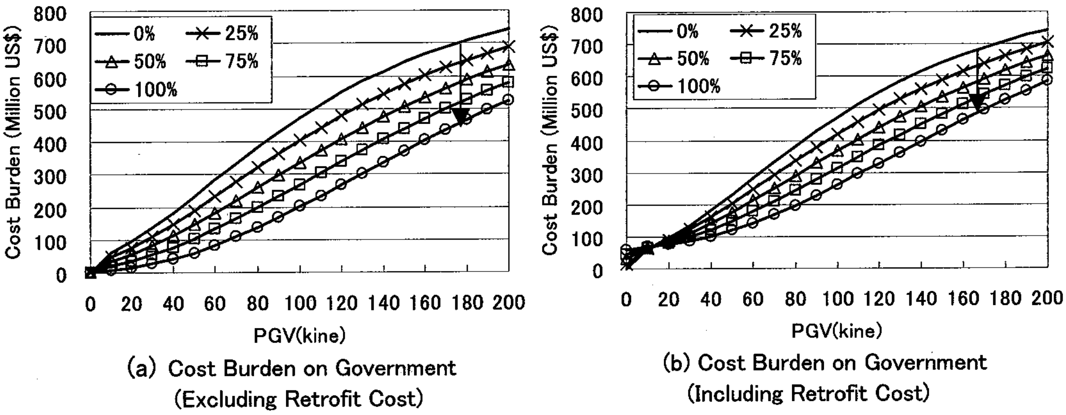
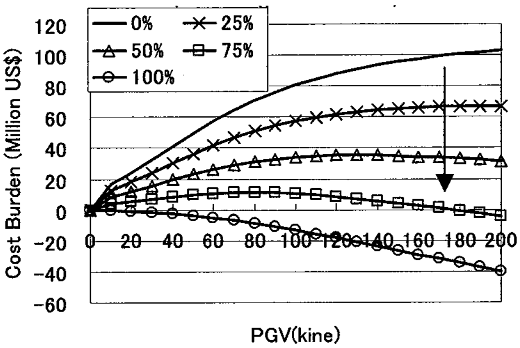



**Figure 9.** Cost Burden on Government in Case the RPS Based on the Current System is Implemented for Different Acceptance Ratios and Ground Motions (Case Study: 10,000 Masonry Buildings with 1 to 2 Floors)

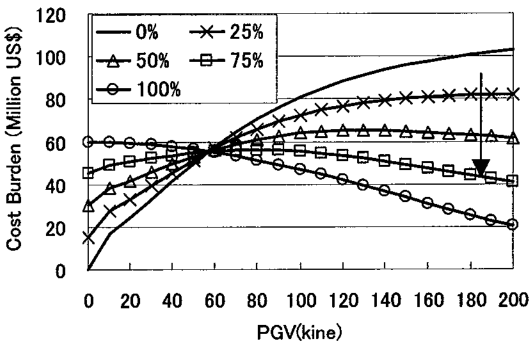
### *Effectiveness of the Ideal RPS*

Next, the effect of applying the ideal RPS to 10,000 masonry residences with 1 to 2 floors located in different regions was investigated. Focusing on the cost burden on citizens, without including the retrofitting costs, the greater the RPS acceptance is, the lower the total cost is. Especially, the citizens gain the profit instead of losing their asset at the acceptance of 75% and 100%, because the obtained incentive money exceeds the expenditure due to an earthquake (Figure 10-a). In case that the cost of retrofitting is included, 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 10-b). However, if the retrofitting cost decreases to the same level as in Japan, the cost burden on citizens falls in the regions where the PGV is less than 10 kine as the system spreads (Figure 10-c). It is verified that all the citizens can have advantages of the RPS if new low cost retrofit techniques are available under the ideal RPS.

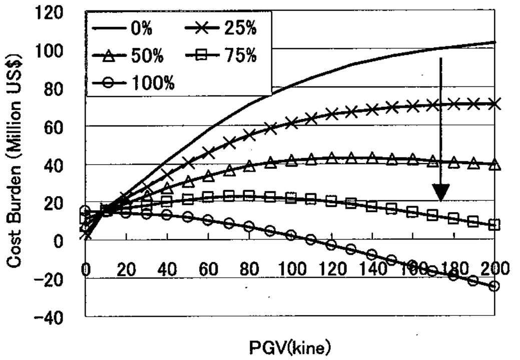
The government's burden increases with the system spread, because high incentive money for demolished residences imposes huge expenditures on the government (Figures 11-a and 11-b). However, comparing the government cost burden under the system based on the current system and under the ideal RPS, it 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.




(a) Cost Burden on Citizens
(Excluding Retrofit Cost)

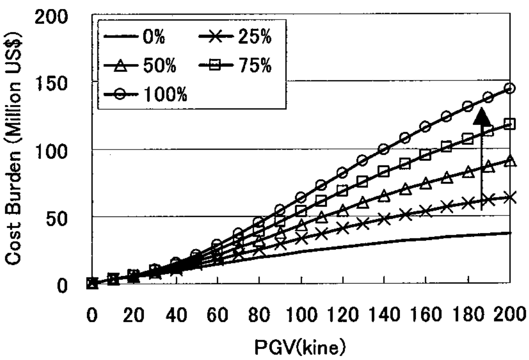



(b) Cost Burden on Citizens
(Including Retrofit Cost)

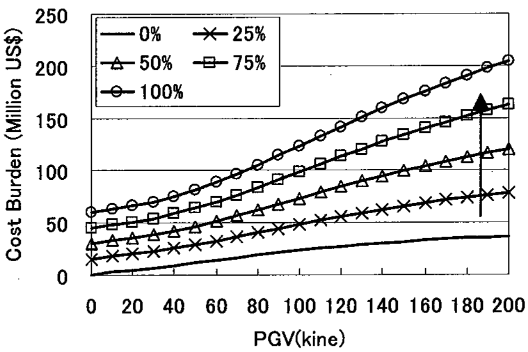



(c) Cost Burden on Citizens (Including Retrofit
Cost with Technological Improvement)

**Figure 10.** Cost Burden on Citizens in Case the Ideal RPS is Implemented
for Different Acceptance Ratios and Ground Motions
(Case study: 10,000 Masonry Buildings with 1 to 2 Floors)




(a) Cost Burden on Government
(Excluding Retrofit Cost)




(b) Cost Burden on Government
(Including Retrofit Cost)

**Figure 11.** Cost Burden on Government in Case the Ideal RPS is Implemented
for Different Acceptance Ratios and Ground Motions
(Case Study: 10,000 Masonry Buildings with 1 to 2 Floors)

## CONCLUSIONS

With the current Turkish system for earthquake disaster relief, a house owner that loses his/her house due to an earthquake will get a new house from the government. This system presents two problems: a) House owners do not have any incentive to retrofit their houses and thus future earthquake damage is not reduced; b) The Turkish government cannot realistically support this relief system because the amount of seismic damage and the cost of new residence construction is huge. In this paper, we propose a new system and policy that could serve as driving forces for the promotion of retrofitting of weaker structures. Under the proposed Retrofitting Promotion System (RPS), the government guarantees a portion of the repair and rebuilding expenses if retrofitting is implemented by the owner following the guidelines before an earthquake occurs and in spite of this, the structure is damaged. With the RPS, the government does not need to prepare a large amount of funds before the disaster for promoting retrofitting. Moreover, by the spread of retrofitting, the total damage including structural damage and human casualties due to earthquake drastically reduces. Contrarily to the earthquake insurance system, which is not directly connected with minimizing damage immediately after an earthquake, the RPS is directly linked with mitigating earthquake damage. 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.

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