Development of Promotion Systems for PP-Band Retrofitting of Non-Engineered Masonry Houses

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SUMMARY
Seismic retrofitting of vulnerable masonry houses is the key to reduce earthquake damage, especially casualties, in developing countries, however, retrofitting have not been promoted mainly due to lack of economic resources. In this paper, four seismic retrofitting promotion systems, making use of insurance and microfinance, were proposed and validated. Systems were proposed based on the correspondence analysis of 83 masonry house data, and were validated by using fragility function. Results showed the economic effect for the stakeholders in each promotion system, for 25 earthquake risk levels and five masonry structure types, which therefore can be used as an index for seismic retrofitting promotion.

Keywords: earthquake, masonry, PP-band, retrofitting, implementation, insurance, reinsurance, microfinance

1. INTRODUCTION

Seismic retrofitting of low earthquake resistant houses is essential to reduce both human and economic losses in earthquake disasters. However, in developing countries, lack of economic resources is a critical issue to promote seismic retrofitting. Therefore, a cheap and easy PP-band (polypropylene band normally used for packing) retrofitting method has been proposed in Meguro laboratory as a local acceptable and available solution (Mayorca and Meguro 2004, Mayorca and Meguro 2008, Sathiparan et al. 2008). With the proposed method, masonry walls are wrapped by PP-band meshes from the both sides and the meshes are connected by PP-strings or wires and embedded in cement or mud mortar overlay. The PP-band method can increase drastically the structure ductility and energy dissipation capacity and will reduce earthquake damage due to future earthquakes. The retrofitting cost is approximately 30 US$ per housing unit (73 m^2), if installed by the house owners. In case of hiring masons, still the cost will be no more than 5% of the total building cost. However, in many parts of the world, sometimes this amount of money is still unaffordable.

Previous studies have proposed a two-step incentive system for promoting PP-band retrofitting for masonry houses (Meguro 2008). The first step of this system is to provide materials for retrofitting and a subsidy, which is given after the house has been checked to be retrofitted properly. This subsidy is for preventing the house owners from selling the materials provided, and to give incentive to retrofit. The second step is to give compensations to those whose house was damaged due to earthquake, in spite of retrofitting. The validation showed if this two-step incentive system was implemented before the 2003 Bam, 2005 Kashmir and 2006 Java earthquakes, the expenditure of the government for housing reconstruction would have been decreased by 95.8%, 81.4% and 75.6%, respectively. However, in this system, the remaining problems were the funding source for the initial cost, and proper prioritization of the area and houses which this system is to be applied.

This study aims to propose a system to promote seismic retrofitting, focusing on the economic aspect of the stakeholders.

2. ANALYSIS OF MASONRY HOUSES

Masonry houses have been divided by its structural details in the previous studies. However, little attention has been paid on its social details. To promote retrofitting by making use of the cheapness and the simplicity of PP-band retrofitting method, the economic situation of the residents and the construction situation of the houses must be analyzed.
Data of the economic situation of the residents and the construction situation of the houses, for 83 masonry house samples, were collected from the World Housing Encyclopedia (Earthquake Engineering Research Institute and International Association for Earthquake Engineering 2009), and correspondence analysis was done. **Table 1** shows the categories for each sample. From the correspondence analysis, masonry houses were grouped into four groups, as shown in **Figure 1**.

Table 1. Categories of masonry houses

Housing condition	Building cost: annual income	Resident's financing	Construction process	Insurance
1. Single family	7. 5:1	11. Owner finance	17. Engineered	21. Insured
2. Multi family	8. 4:1	12. Personal saving	18. Non-engineered	22. Not insured
3. Urban	9. 3:1	13. Informal network	19. Code	
4. Rural	10. 1:1	14. Microfinance	20. No code	
5. With modification		15. Commercial bank		
6. Without modification		16. Government owned		

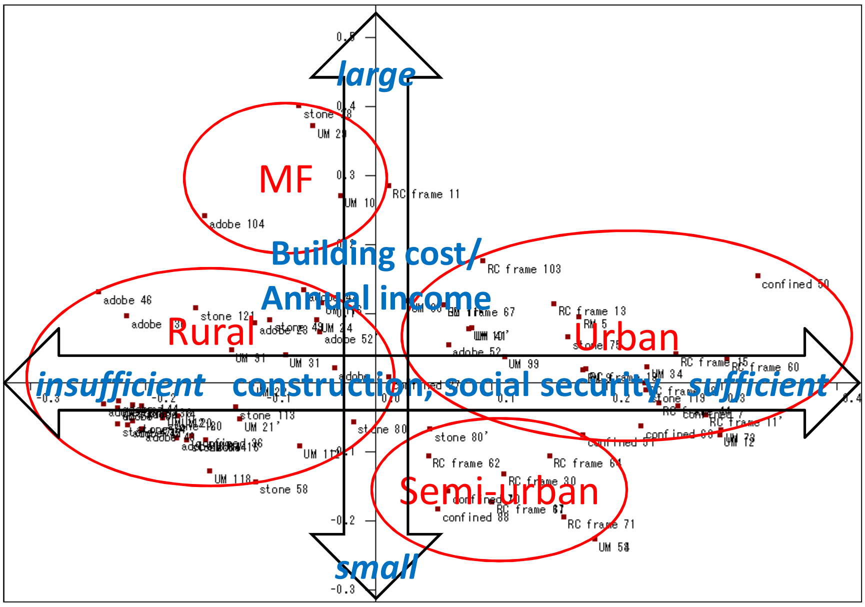


Figure 1. Grouping of masonry houses

Urban group has sufficient construction and economic situation, such as the role of engineer and architect during the construction, code enforcement and access to commercial banks or insurances. In addition, the ratio of building cost to annual income is about 5:1, which means they live in relatively expensive houses. On the other hand, Semi-urban group does not have access to insurances due to lack of economic resources. Their ratio of building cost to annual income is about 4:1. Rural group does not have sufficient construction or economic situation. Informal modifications of houses are seen, and residents usually do not have any access to commercial banks or insurances, so they rely on personal savings or owner financing. Their ratio of building cost to annual income is about 1:1. On the other hand, some of them are making use of microfinance (MF group). For the MF group, the ratio of building cost to annual income is about 5:1. However, this means their annual income is very low, which also explains the reason of using microfinance.

3. PROPOSAL OF SEISMIC RETROFITTING PROMOTION SYSTEM

Four promotion systems were proposed based on the analysis of masonry houses.

3.1. Micro Insurance System

Residents who have performed PP-band retrofitting will be insured, and when their houses are damaged due to earthquake, they will receive insurance money worth their house building cost. The premium will include the retrofitting cost and insurance money, but since PP-band retrofitting is cheap and the damage can be reduced drastically, the premium can be set at a low price. Insurance premium was estimated in validation.

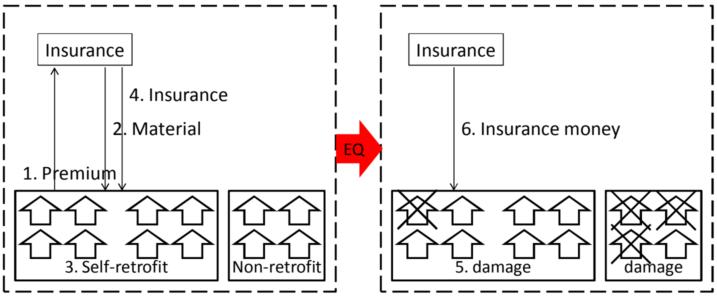


Figure 2. Micro Insurance System for Urban group

3.2. Government + Insurance System

Basically same as Micro Insurance System, but the premium will be lower because it will not include retrofitting cost. Insurance companies will bear the retrofitting cost at initial stage, and collect them when an earthquake occurs from the government. Insurance premium was estimated in validation.

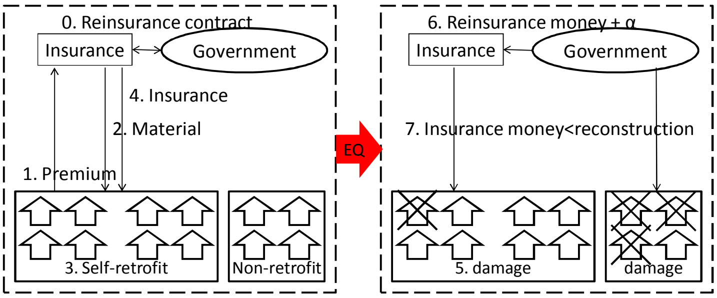


Figure 3. Government + Insurance System for Semi-urban group

3.3. Government Reinsurance System

Insurance companies will bear retrofitting cost, and the residents will be insured. Insurance companies will receive reinsurance money from the government, and collect retrofitting cost and insurance money for residents, together with their profit. Reinsurance money will be paid within the range of reduced amount of damage due to retrofitting, which can be considered as government's benefit. Insurance money for residents and profit for insurance companies were estimated in validation.

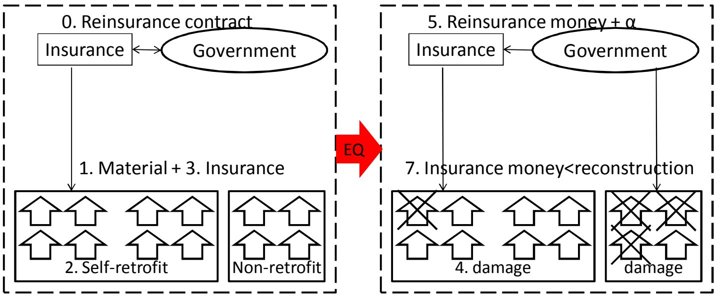


Figure 4. Government Reinsurance System for Rural group

3.4. Micro Credit System

MFIs (Microfinance Institutes) will collect retrofitting cost through investment, and perform retrofitting. Residents who have performed retrofitting will receive micro credit loan as an incentive. MFIs will collect insurance money from the government, and collect outstanding loan balance, and also give return to the investors. For the investors, this extra dividend will be an incentive to invest, as well as the clear social contribution in terms of earthquake disaster mitigation. The expected amount of collection on outstanding loan balance for MFIs, and ROI (rate of return) per investment (=retrofitting cost) were estimated in validation.

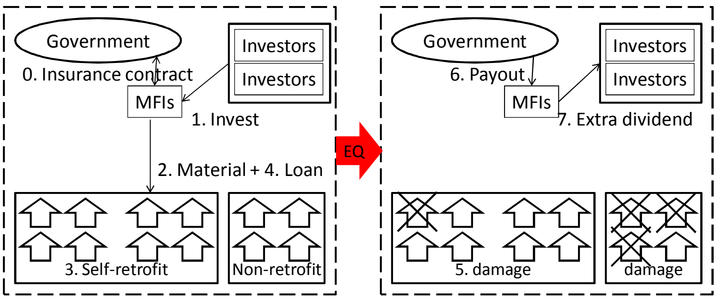


Figure 5. Micro Credit System for MF group

4. VALIDATION OF THE PROPOSED SYSTEM

Validation focused on the economic aspects of the stakeholders in each system. First, earthquake risk was defined in 25 levels as shown in **Figure 6**.

JMA	PGV [cm/s]	50 years exceedance probability (return period)				
		2% (2745 yrs)	5% (975 yrs)	10% (475 yrs)	39% (100 yrs)	62% (50 yrs)
4	8.1					
5-	16			Kashmir		
5+	31			Java		
6-	60		Kashiwazaki	Tokyo		
6+	116				Shizuoka	

Figure 6. Earthquake risk

Second, fragility functions were used to estimate the earthquake damage for each earthquake risk. Fragility functions of 1) adobe and/or mud, 2) brick and/or stone, 3) brick 1-2F, 4) brick 3F and 5) concrete block were used for comparative study among different structures. For PP-band retrofitted structures, 1) self-retrofit (retrofitted by house owners), 2) engineer-retrofit (retrofitted by engineers) and 3) license-retrofit (retrofitted by PP-band specialized engineers) were used, considering upper (+) and lower (-) bound.

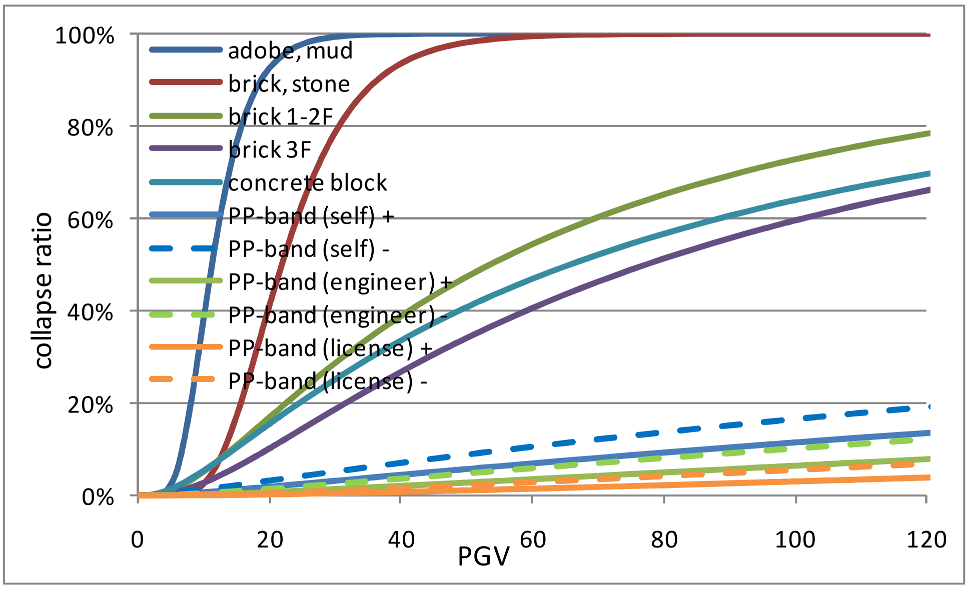
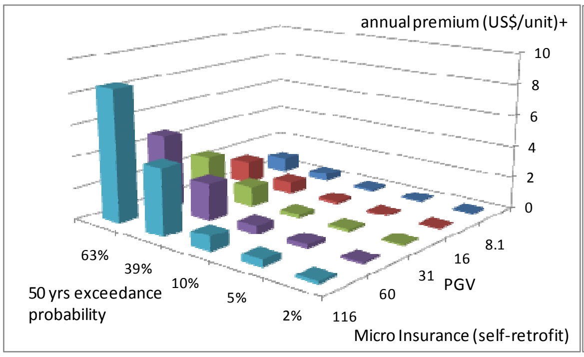


Figure 7. Fragility functions (JICA 2005, JICA and IMM 2002, and MIE 2008)

Finally, the economic effects for the stakeholders were estimated for each system. The results shown below are for each structure types, of self-retrofit.

Table 2. Costs used for analysis

Building cost (US$)	Retrofitting cost (US$)		
	Self-retrofit	Employment	License
3,000	30	150	270



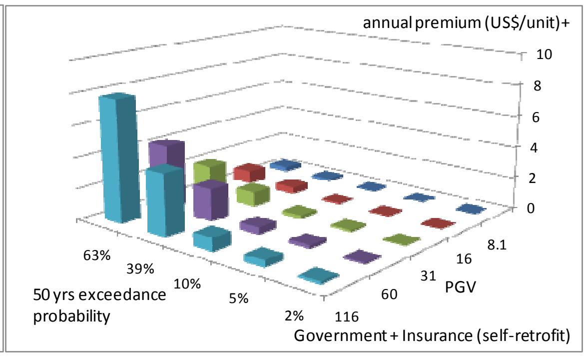


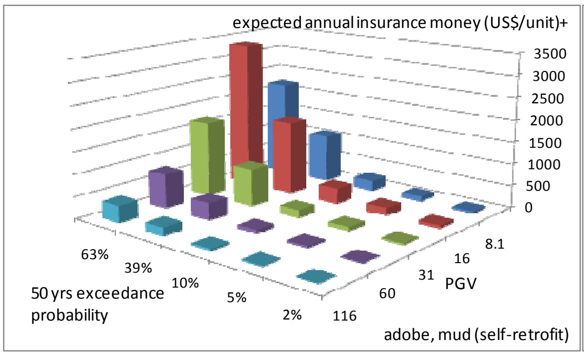
Figure 8. Premium for Micro Insurance

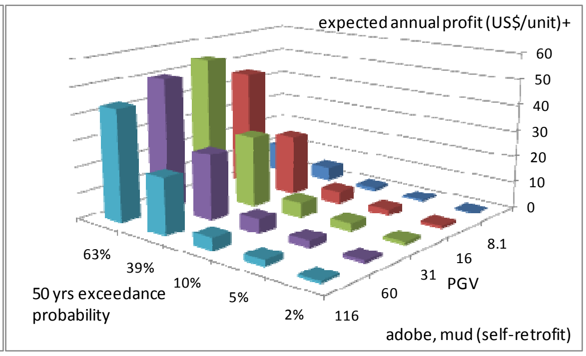
Figure 9. Premium for Gov. + Insurance

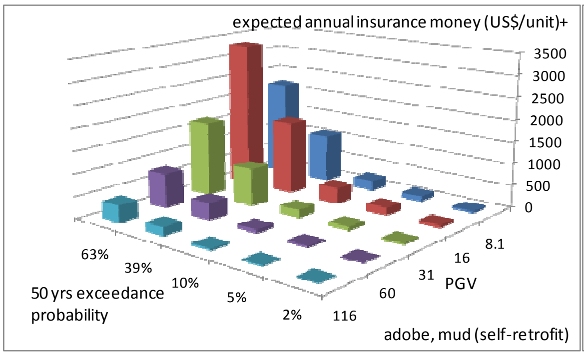
The annual premium was estimated to be less than 10US$ at all 25 earthquake risk levels, under the condition that residents will receive insurance money worth building cost. Compared to the other earthquake insurances in the world, as shown in **Table 3**, this system is valuable to the residents.

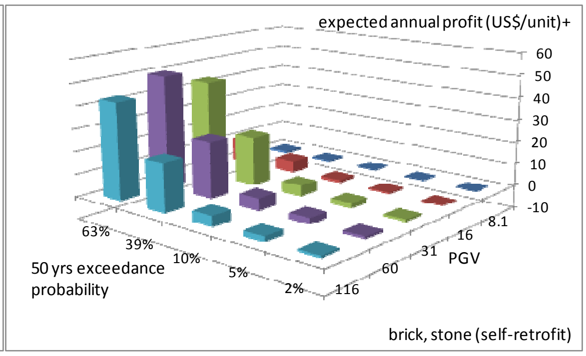
Table 3. Comparison of the earthquake insurance

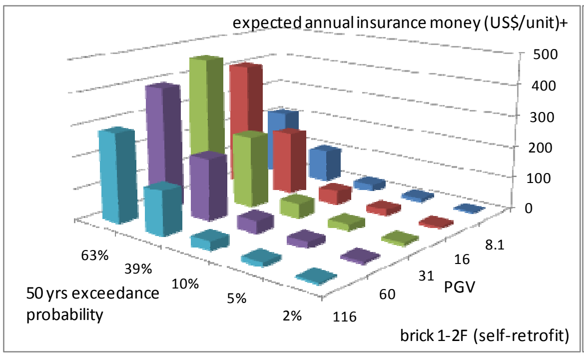
	Japan	California	New Zealand
Premium rate (%)	0.50-3.15	0.46-8.05	0.50
Insurance money limit (US$)	550,000	100,000	61,000

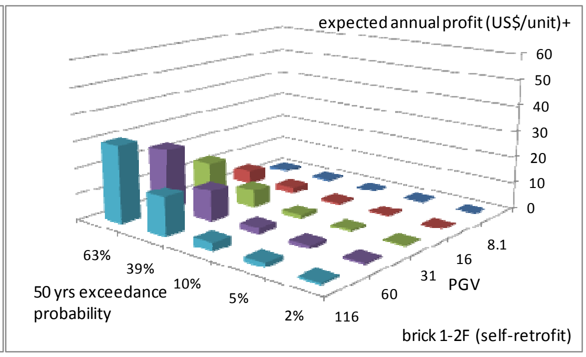












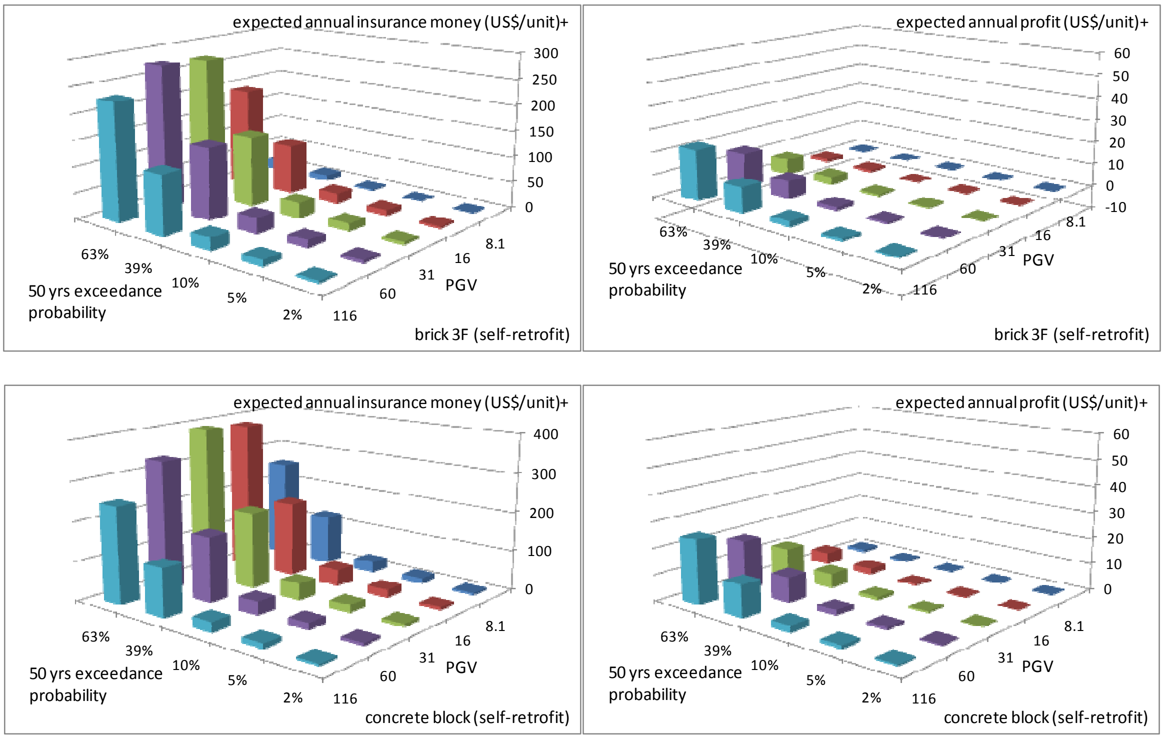
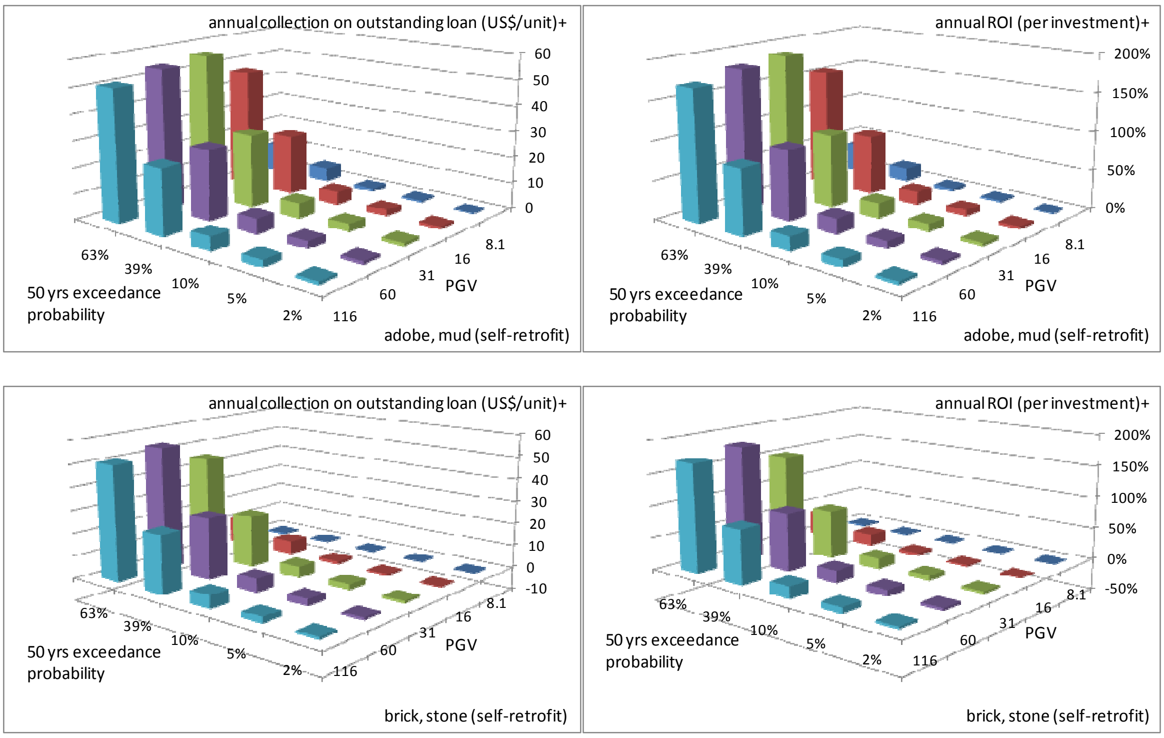


Figure 10. Government Reinsurance (left: insurance money, right: profit)

Insurance money for residents was more than 2,000 US$ per year, at high earthquake risk levels. If the contract is made for 10 years, insurance money will be 20,000US$, which is sufficient for rebuilding a house. For insurance companies, annual profit by reinsurance money was estimated, which was plus at all earthquake risk levels. This means that this system has an incentive to both the residents and the insurance companies. Furthermore, insurance companies have a chance to spread insurance to the low income people by this system.



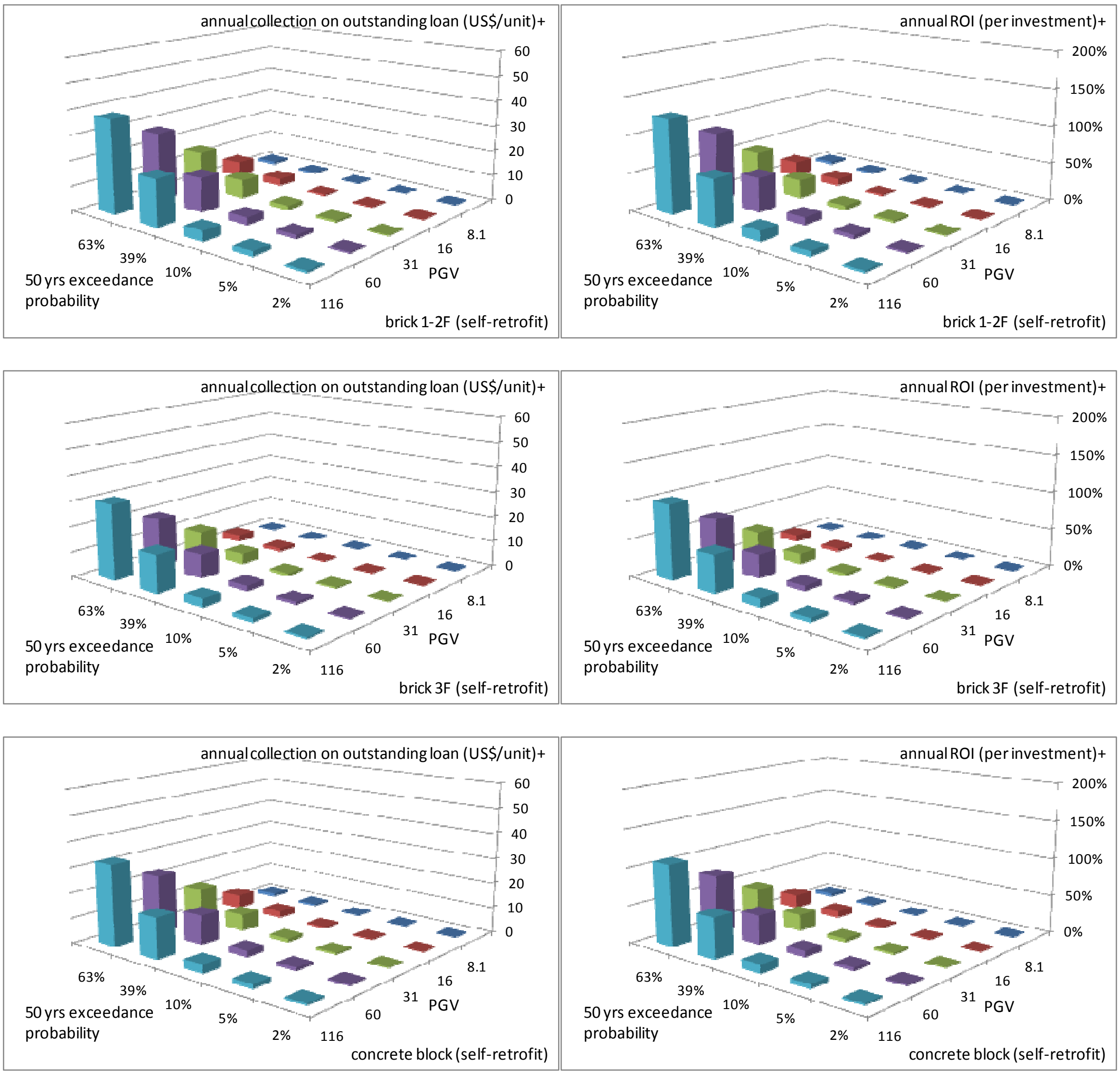


Figure 11. Micro Credit (left: collection on outstanding loan, right: ROI)

Amount of collection on outstanding loan balance for MFIs were estimated, which was plus at all earthquake risk levels. In addition, ROI (rate of return on investment) per investment (=retrofitting cost) was estimated, which was plus at all earthquake risk levels. For the MFIs, this means they have chance to collect their outstanding loans within less than 10 years in most cases, as shown in **Table 4**.

Table 4. Amount of the outstanding loan (Microfinance Information Exchange 2008)

US$	2005	2006	2007
Africa	174	241	325
Asia	120	139	164
ECA	1,127	1,404	1,931
LAC	642	684	848
MENA	241	264	345

5. CONCLUSIONS

Four promotion systems for seismic retrofitting implementation were proposed, and validated for their economic effects. For Micro Insurance Model and Government + Insurance Model, the annual premium was estimated to be no more than 10US$ per unit, at 25 different earthquake risk levels. For Government Reinsurance System, insurance money was enough to rebuild a house, at relatively high earthquake risk levels. In addition, profit for insurance companies was estimated, under the condition that residents will receive insurance money sufficient for reconstruction. For Micro Credit Model, amount of collection on outstanding loan for MFIs, and ROI for investors were estimated, both of which proved to be plus. Furthermore, validation was done for five different structures and three different retrofitting conditions, which enables to consider the implementation in the area with combined structures. Thus we conclude this study have proposed an effective promotion systems, together with the index for implementation.

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