FRAGILITY CURVES FOR WOODEN HOUSES CONSIDERING AGED DETERIORATION OF THE EARTHQUAKE RESISTANCE

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ABSTRACT :

In 1995 Hyogo-ken Nanbu Earthquake, there is a sharp contrast between the damage ratio of new wooden houses and aged wooden houses. Saratani et al. said that it is caused that building's earthquake resistance is associated with a performance decrement of deformation by aged deterioration. We built fragility curves for wooden houses considering aged deterioration of the earthquake resistance based on ratio of damage of buildings in 1995 Hyogo-ken Nanbu Earthquake and its strong motion distribution. We set the parameters (index of strong motion) for fragility curves as below. Choose 4 periodical band, 0.5-2.0 [sec], 0.5-3.0 [sec], 1.0-2.0 [sec], and 1.0-3.0 [sec]. Calculate Peak ground velocity, Maximum velocity response, and Average velocity response for each periodical band. As a result of parametric study, we have best correlation coefficient by the case choosing 1.0-3.0 [sec] periodical band and Average velocity response.

KEYWORDS: Wooden Houses, Fragility, Aged Deterioration, Maintenance, 1995 Hyogo-ken Nanbu Earthquake.

1. INTRODUCTION

In 1995 Hyogo-ken Nanbu Earthquake, the difference by the architecture age was clear on the damage ratio of the wooden houses. The knowledge that the lowering of the deformability by the aged deterioration of the building is dominant has been obtained this. Here, fragility curve of the wooden houses considering the aged deterioration of earthquake resistance performance is constructed on the basis of damage ratio (suffering investigation data) and simulated earthquake motion distribution of the 1995 Hyogo-ken Nanbu Earthquake.

2. AGED DETERIORATION OF WOODEN HOUSES

In Japan, we analogize the earthquake performance of the general building have greatly changes in 1981, 1971, (and 1959, 1950 in wooden houses) when the earthquake proof design code of the building was greatly changed. However, it tends to be dependent on years, after the correspondence building is built further than the difference between the earthquake proof design code in the wooden houses, though the tendency is observed in RC structure building and Steel structure building, when Fig.1-3 is seen which plotted the building damage rate (result of judging a complete collapse by the suffering proof) in the strong earthquake area in Hyogo-ken Nanbu Earthquake in the architecture age independent. On the building which is older than about 30 years, the dispersion by the age becomes any approximately fixed damage ratio of the thing.

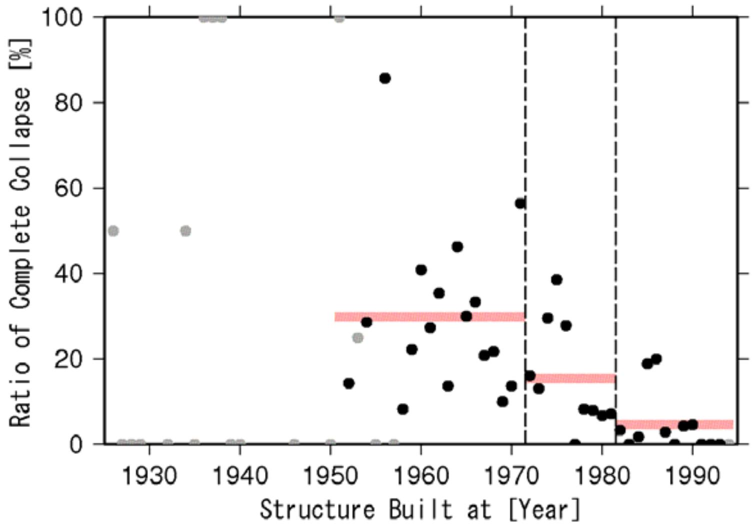


Figure 1 Damage ratio of RC structure buildings in 1995 Hyogo-ken Nanbu Earthquake.

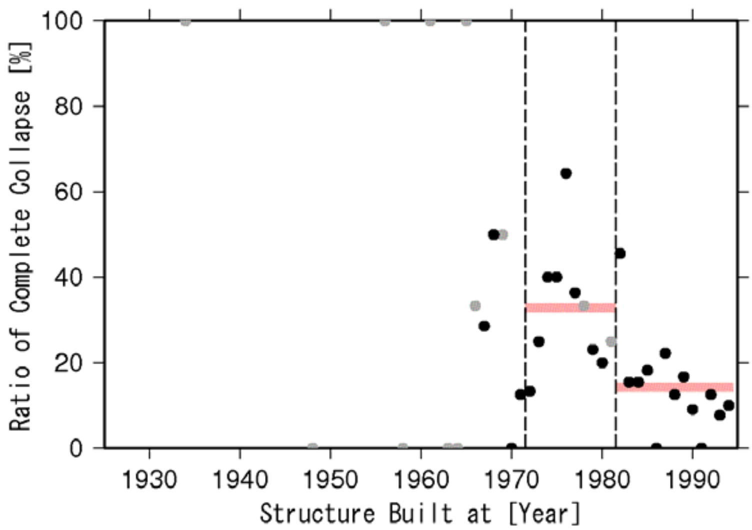


Figure 2 Damage ratio of steel structure buildings in 1995 Hyogo-ken Nanbu Earthquake.

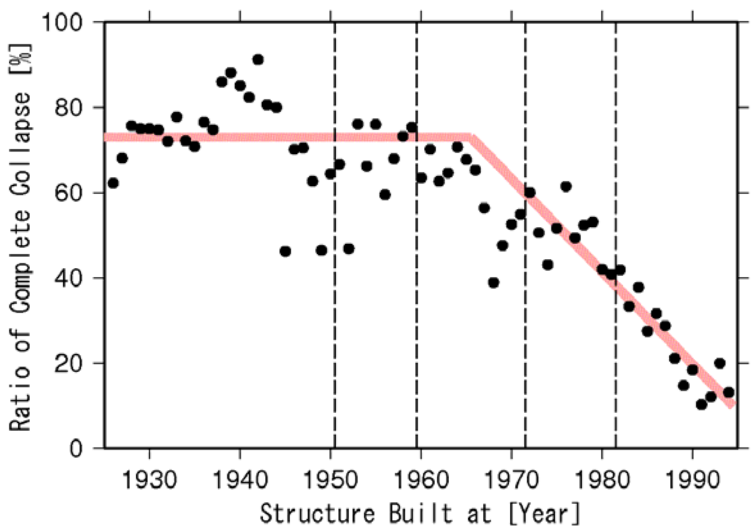


Figure 3 Damage ratio of wooden houses in 1995 Hyogo-ken Nanbu Earthquake.

It is assumed that the deformability lowers by the aging degradation in Saratani et al.(2005) valley and other in the wooden construction building, and aging degradation curve shown in equation (1), fig.4 has been constructed.

$$f(T) = \max\left\{\exp\left(-\alpha\cdot\left(\frac{T}{\beta T_0}\right)^2\right) \quad , \quad \gamma\right\} \tag{1}$$

$f(T)$: The aging deterioration curve.
T : After construction passed years.
T_0 : Estimation service life of the wooden houses.
β : The extra coefficient by building maintenance, etc..
α : The constant which determines the deterioration speed.
(α =0.7 in Hyogo-ken Nanbu Earthquake's result of analysis.)
γ : The lower limit of the aging deterioration curve.
(γ =0.5 in Hyogo-ken Nanbu Earthquake's result of analysis.)

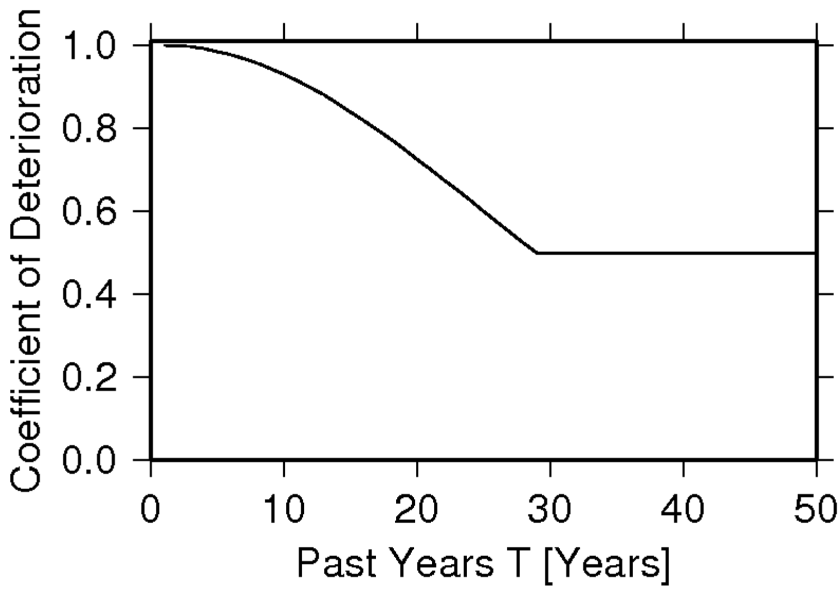


Figure 4 Aged deterioration curve for wooden houses.

3. FRAGILITY CURVES

By assuming that the damage ratio of the wooden houses follows logarithmic normal distribution, the damage ratio curve is given by equation (2-3). Equation (2) has shown the logarithmic normal distribution. Equation (3) has shown the decreasing rate of λ by aged deterioration. Aged deterioration curve of the wooden houses around Kobe is given like Fig.4. This aged deterioration curve is changing by the region, and improving the building maintenance. By giving the fragility curve in doing like this, the curve in which the damage ratio increases yearly which it passes through after construction is obtained, until the aged deterioration coefficient becomes a lower limit. By introducing aged deterioration coefficient like this into the fragility curve, it becomes an equation which also estimates the effect of earthquake-proof improvement (or the earthquake-proof lowering inhibition) by the building maintenance.

$$F(X)=\int_{-\infty}^{X}\frac{1}{\sqrt{2\pi}\cdot\zeta\cdot X}\cdot\exp\left\{\frac{-(\ln X-\lambda)^2}{2\zeta^2}\right\} \tag{2}$$

$$\lambda(T)=\lambda(0)\cdot f(T)^{\delta} \tag{3}$$

$F(X)$: Cumulative frequency function.
X : Index-value as a quadrature axis.
Average : $E(X)=\exp\left(\lambda+\zeta^2/2\right)$
Variance : $V(X)=\exp(2\lambda+\zeta^2)\{\exp(\zeta^2)-1\}$
δ : Dependence for $f(T)$

3.1. Data of Damage Ratio of Wooden Houses

As a building damage data, we used the suffering investigation data (suffering proof) by the municipality in Hyogo-ken Nanbu Earthquake. Attention is necessary for difference between the structural damage imaged from the word in 'complete collapse' and 'half collapse', and suffering proof. Damage fragility curve constructed here removed the damage of the region which generated the liquefaction near the coast, since it is made to be an equation only of the effect by strong motion.

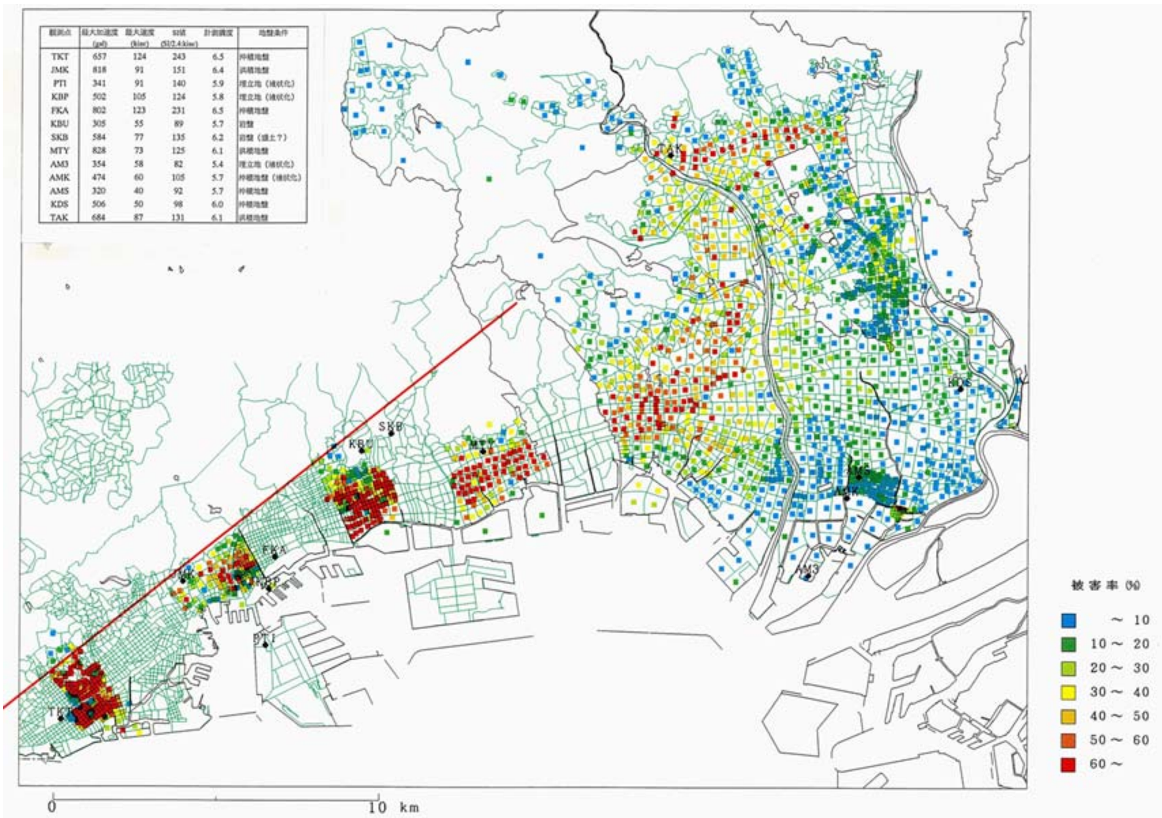


figure 5 Damage ratio of wooden houses of each blocks in 1995 Hyogo-ken Nanbu Earthquake.

3.2. Data of Distribution of Strong Motion

We obtained distribution of index-value X of fragility curve, using earthquake motion distribution by simulation of Matsushima and Kawase (2000). This earthquake motion distribution is simulated for the surface subsoil (about Vs=400m/s).

We used the equation of Midorikawa et al.(1994) as an equation for doing the rough calculation of the ground amplified. We substituted AVS30 in equation (4-6), and amplification factor R for the engineering basement (Vs=400m/s) was required. We show an example of distribution of index-value X (1.0-3.0[sec] average velocity response) in Fig.6.

$$\log R_S = 1.83 - 0.66 \log AVS_{30} \tag{4}$$
$$\log R_{400} = 1.83 - 0.66 \log(400) \tag{5}$$
$$R = R_S / R_{400} \tag{6}$$

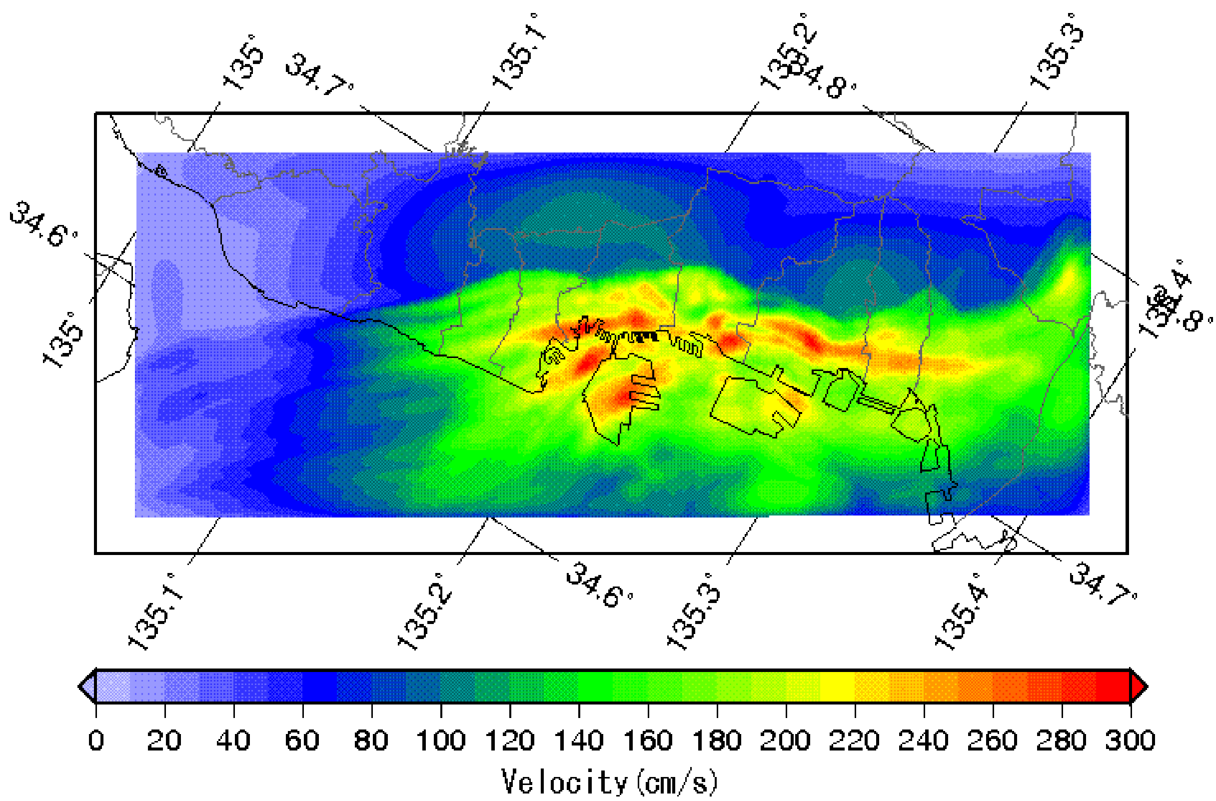


Figure 6 Distribution of average velocity response. (1.0-3.0[sec])

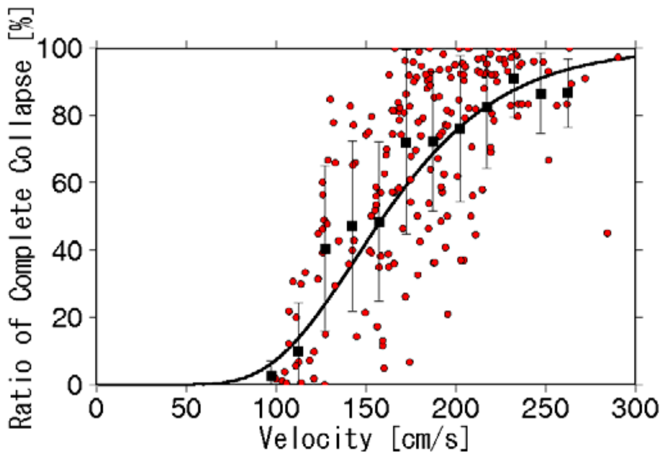
3.2. Data Fitting and Comparing Correlation Coefficient

We obtained distribution of 24 kinds of mean value as index-value X, Maximum value of velocity, Maximum value of relative velocity response(h=5%), Average value of relative velocity response(sampling intervals are equal on the logarithmic axis)(h=5%,10%,15%,20%), from above-mentioned earthquake motion waveform for 4 periodic bands in the 0.5-2.0[sec],0.5-3.0[sec],1.0-2.0[sec],and・1.0-3.0[sec].We plotted these index value X and damage ratio. We plotted index value and damage ratio (in the every constant-breadth of the index-value, it was calculated as a Total number of damage building / Total number of building in the range of calculation). We obtained optimum parameter fitting by the least squares method, weighting by standard deviation. The damage ratio is classified based on Seismic design code in the age, and the fitting is carried out.

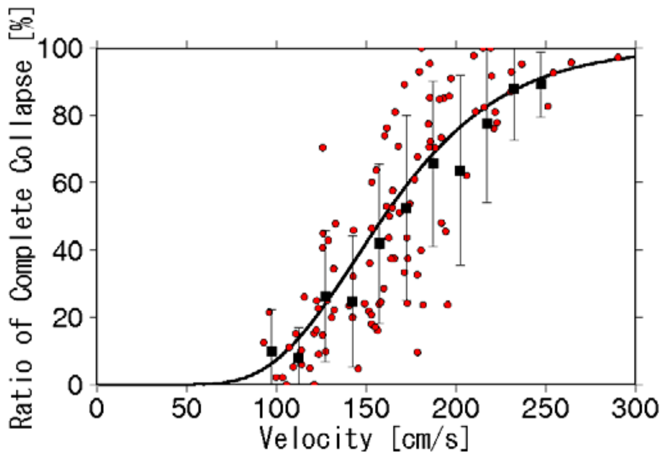
For the evaluation for the dispersion of the raw (not averaged) damage of Fragility curve, we plotted the damage ratio even in each blocks, and calculated correlation coefficient for fragility curve. We show correlation coefficients in Table 1.We show an example, fitting result and aged deterioration of fragility curve (complete collapse rate) in Fig.7-8, using 1.0-3.0[sec] average relative velocity response for index value X.

Table.1 Correlation coefficient of averaged and raw damage ratio and fragility curves.

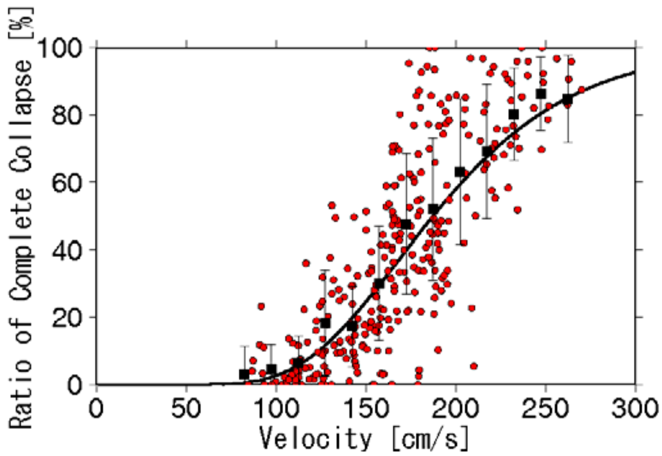
		Complete Collapse		Half Collapse	
		Whole Area	Each Blocks	Whole Area	Each Blocks
Vel-Max	0.5-2.0	0.978	0.851	0.983	0.851
	0.5-3.0	0.973	0.846	0.980	0.848
	1.0-2.0	0.971	0.826	0.953	0.813
	1.0-3.0	0.964	0.828	0.927	0.811
Resp-Max h=5%	0.5-2.0	0.959	0.776	0.968	0.807
	0.5-3.0	0.968	0.792	0.971	0.764
	1.0-2.0	0.972	0.792	0.961	0.821
	1.0-3.0	0.967	0.802	0.960	0.773
Resp-Ave h=5%	0.5-2.0	0.897	0.717	0.933	0.765
	0.5-3.0	0.971	0.809	0.973	0.817
	1.0-2.0	0.931	0.759	0.968	0.816
	1.0-3.0	0.985	0.848	0.988	0.845
Resp-Ave h=10%	0.5-2.0	0.921	0.727	0.944	0.764
	0.5-3.0	0.966	0.797	0.970	0.806
	1.0-2.0	0.944	0.757	0.967	0.805
	1.0-3.0	0.982	0.828	0.975	0.832
Resp-Ave h=15%	0.5-2.0	0.928	0.727	0.932	0.750
	0.5-3.0	0.968	0.785	0.981	0.798
	1.0-2.0	0.950	0.754	0.968	0.794
	1.0-3.0	0.975	0.813	0.971	0.823
Resp-Ave h=20%	0.5-2.0	0.938	0.719	0.963	0.748
	0.5-3.0	0.964	0.771	0.969	0.793
	1.0-2.0	0.940	0.745	0.961	0.787
	1.0-3.0	0.984	0.803	0.986	0.817



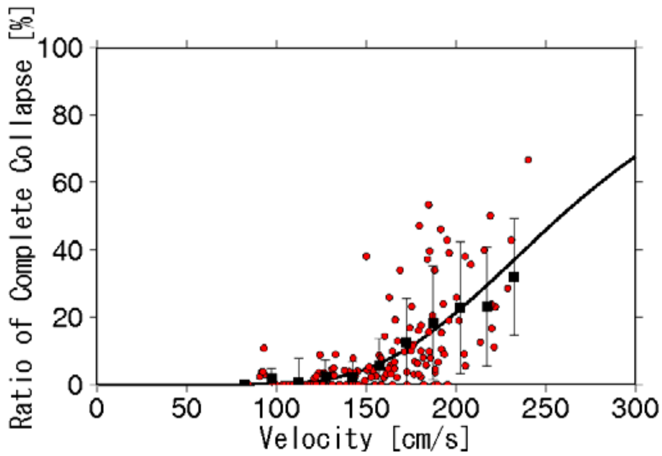
-1950



1951-1959



1960-1981



1982-1994

Figure 7 Result of fitting of averaged (black dot) and raw (red dot) damage ratio and fragility curves.

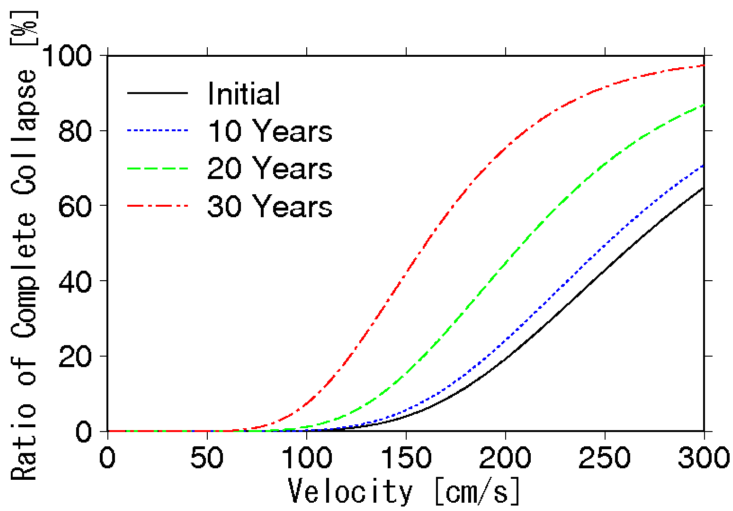


Figure 8 Aged deterioration of fragility curve.

4. CONCLUSION

We obtained most large correlation coefficient using 1.0-3.0[sec] average relative velocity response for index value X, when damage ratio plotted at damage ratio calculated from the whole analysis area, and from each blocks. We obtained large correlation coefficient using Maximum velocity for index value X. Fragility curves we got here, will be used seismic damage prediction with synthesis strong motion waveform. Some specific periods may be excellent over the actual phenomenon on the synthesis waveform. In such case, It is higher the robustness of mean value than the maximum value as an index.

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