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Damaging and Restoring Process in a Rural Town due to the 1983 Central Japan Sea Earthquake

—— As for Elucidating Long-term Earthquake Effects ——

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Abstract

This paper presents a study conducted on the elucidation as to how the local people have restored their houses and associated facilities so as to recover from seriously affected situations by a great earthquake attack. Surveyed was a typical rural town of Wakami, Akita prefecture, in the 1983 Central Japan Sea earthquake (M=7.7). As an extended study of damage investigation immediately after the earthquake, a special field survey for investigating the restoring processes was performed 6 months later by means of both questionnaire and interview, and through an analysis of these data time-sequential restoration processes were figured out in relation to controlling factors. A simulation model for tracing such restoration processes was constructed, and actually executed for the purpose to explore better post-earthquake countermeasures in a private sector.

1. Introduction

Investigations on the damaging process due to destructive earthquakes have frequently been carried out and therefore their reports are too numerous to be referred. On the contrary, investigations on its restoration process has been started only in the recent few years. As a pioneering study, the report of Geipel can be cited which investigated the process of reconstruction after the Friuli, North Italy earthquake of 1976[1]. Total understanding of the processes from damaging to restoring is quite necessary in order to promote earthquake prevention studies. During restoration processes, a household is designated as a basic and minimum unit. Therefore, focusing our main research intention on the restoration process in a household unit, a field survey was performed and succeeding statistical and simulation analyses were attempted.

Department of Architectural Engineering

2. Surveyed Area

At the Central Japan Sea earthquake of May 26, 1983 (M=7.7) dwellings and agricultural damages, caused by ground failure such as sand soil liquefaction, were dominant[2]. A typical rural town in the severely damaged area, Wakami town, Akita prefecture, was selected as for the test field in this study. This town is located at 139.92° E, 39.92° N, between Hachirogata lagoon and Japan Sea. It extends 20 km in length to a north-south direction, 2 km wide, and it is composed of 18 villages along the main road from north to south. The town is mainly agricultural with area 39.87 km^2, 9,135 population and 2,198 households (by 1983 census). Primary, secondary and tertiary industries share 44%, 25% and 31% respectively.

Figure 1 shows the location of the town and seismic intensity distribution. Average intensity determined by our questionnaire survey is 5.5, a lower limit of VI in JMA scale (around IX in MSK scale). The amount of loss are listed in Table 1. Total loss is ¥5.4 billion, which corresponds to 2.4 times of town's yearly income. Agriculture, public facilities and dwellings are major items of monetary losses. Among this total, ¥2.9 billion comes directly from the private sector of households. Average loss per household amounts to ¥1.33 million.

In order to clarify the damage extent and recovery processes, a door-to-door questionnaire survey was performed in the December, after waiting for 6 months from the earthquake. The questionnaire contains 66 questions, among which 14 are on attributes of a

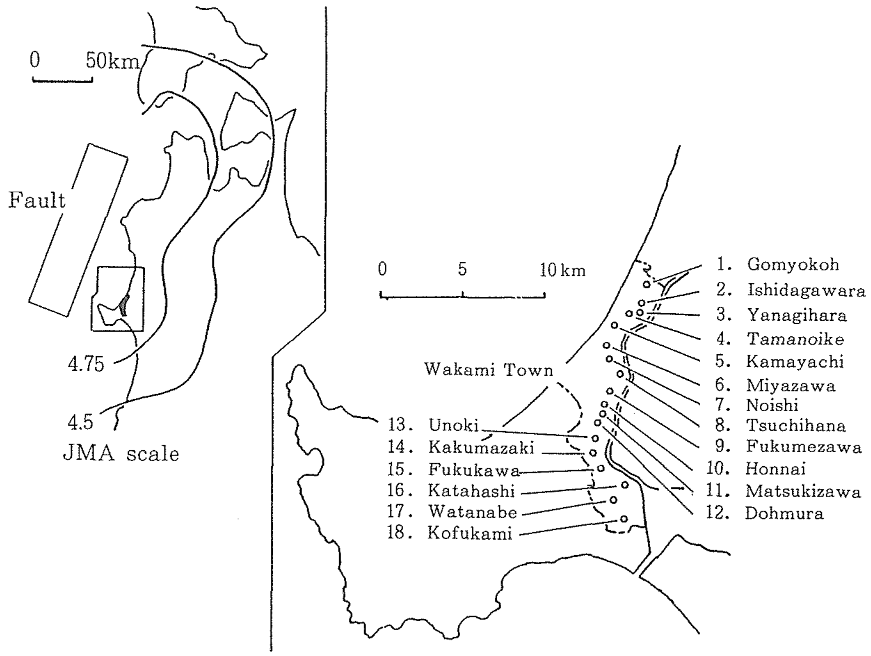

Fig. 1 Location of Wakami town with 18 villages and seismic intensity distribution of the 1983 Central Japan Sea earthquake.

Table 1 Total loss of Wakami town due to the 1983 Central Japan Sea earthquake

Item		Loss
Public facilities	Educational	3,300
	Agricultural, Fishery	1,560,000
	Civil engineering	868,983
	Others	112,250
	Sum	2,544,533
Private	Agricultural	275,760
	Fishery	202,106
	Business	410,000
	Dwellings	1,715,575
	Others	289,657
	Sum	2,893,098
	(per household)	1,330
Total sum		5,437,631
General accounts in 1982		2,265,700
Ratio to general accounts		2.4 times

unit=¥thousand

household and a dwelling damage, 8 on damage to farming, fishing and business, 5 on daily life after the shock, 5 on economic impact and 23 on seismic intensity evaluation. The municipal authorities cooperated to distribute questionnaires to all the 2,198 households in the December and to collect 52%.

Since villages in northern part, numbered 1-4 in Figure 1, with 161 households suffered the most extensive damage, an interview survey was performed additionally in a more thorough manner. Each interview took 0.5-1 hour and 146 cases were obtained by 5 interviewers.

3. Damaging Process

3.1. Dwelling house

Local houses are mostly single story timber-framed structures built on concrete or reinforced concrete foundations. The outer wall is covered with either metal siding or cement mortar and roof is of zinc.

Since houses were damaged by ground failure such as cracks and unequal subsidence due to sand soil liquefaction, foundations are the most affected and upper frames are deformed conspicuously and even houses judged officially as 'collapsed' kept standing. Nobody in the town was killed and very few were injured. Based upon questionnaire data, Figure 2 indicates how foundations and outer walls were damaged. Prefectural Association of Architects conducted an intensive field survey in a week after the earthquake and classified damages into the 4 categories of Heavy, Moderate, Little and No damage.

Changes of damage rate along the north-to-south road (Figure 3) seems to correspond

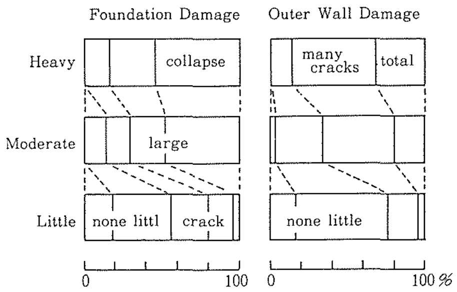

Fig. 2 Foundation and outer wall damage.

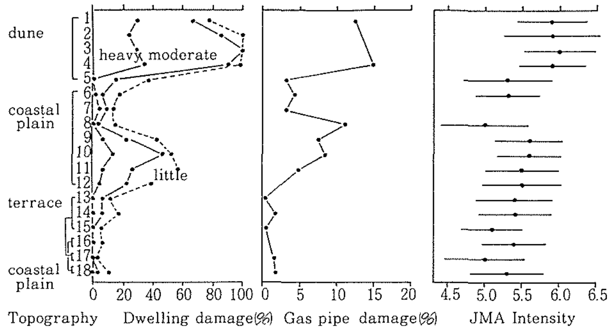

Fig. 3 Damage and intensity distribution along the north to south road.

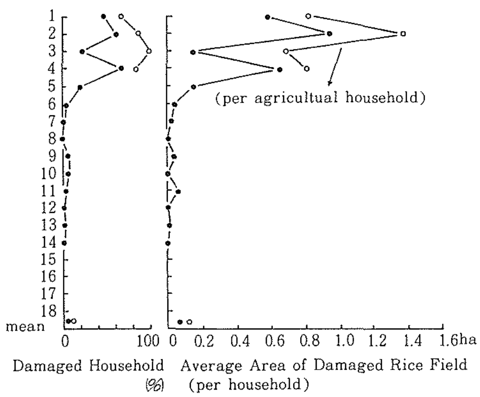

Fig. 4 Distribution of rice field damage along the north to south road.

with soil conditions. It is the largest in the northern end 4 villages which are situated on sand dunes, and it has the second peak in the central part (9-12) of the town. Rates of gas pipe damage show a similar tendency and correlate well with those of heavily damaged dwellings. Seismic intensity estimated from the questionnaire differs more than 0.5 between the northern and southern parts.

3.2. Agricultural Damage

Farming households number 1,227, and total land under cultivation amounts to 2,613 ha (1980) in Wakami town. In the northern part, Vinyl sheets are usually spread beneath 1 meter of rice paddy field to maintain indispensable water to the growth of young rice plants, and in 30 ha of it the sheets suffered considerable damage as being treated or exposed. Added with other damages of upheaval and subsidence, rice fields which were unable of attain planting amount to 145 ha in all, affecting 151 farmers family (12%). These damages to farm land and watering facilities also reduced the harvest in autumn. A distribution curve of rice field damage is shown in Figure 4. In the northern area from village 1 to 4 the severest impact such as seen in dwellings was observed. Damage was hardly recognized in further south area.

4. Restoring Process

4.1. Public Sector

Table 2 summarizes time-sequentially major responses of the municipality (town office) in the emergency and restoration period. The town organized the disaster relief headquarters immediately after the quake, and performed quick field surveys of dwelling damage within 1 week and of agricultural damage within 2 weeks. Such surveys was relayed to those by Ministries of Construction and of Agriculture and Fishery, central government of Japan, the objective of which is to evaluate necessary restoration works and their necessary expenditures. Meanwhile it opened a counsel office for inhabitants and assisted applications to the governmental loans for disaster relief. It was a few months later when inhabitants obtained actually relief and cash in public loans. The town office played a dominant role in agricultural restoration works in 1984 winter to reduce the farmers' monetary burden.

There was no electric power cut. Slight damage to the water supply system was

Table 2 Emergency response and recovery process of Wakami town

Date		Days	Aftershock	Local government	Life lines
May	26	1	Main shock III(JMA)	Anti-disaster headquarters established Damage survey Disaster Relief Law applied	Water supply in villages 14-18
	27	2		Damage survey by personnels Survey by agricultural body Main N-S road passable oneway	Help for gas repair arrlved Water supply in south
	28	3		Governor's visit	
	29	4	III	Damaged day nursery moves	
	30	5	III	Start to construct 27 temporary housing Explain disaster loan	
	31	6		7 houses endangered by landslides in Matsukizawa (11)	Gas supply in south
June	1	7	III	2 days survey by 24 architects Agricultural body meeting	Gas supply in 12-8
	2	8		Consulting for inhabitants for 3 days	Gas supply in 13-5
	6	12		Meet damaged farmers	Help for gas repair leaved
	9	15	IV, IV, III III	Emergency call for personnels Field survey	
	12	18		: : Distribute information	Replace gas pape in 4-1 till June 23
	19	25	III	: and relief goods	
	21	27	III	:	
	23	29		Survey by Ministry of Agriculture till July 29	Gas supply in 4-1
	28	34		Survey by Ministry of Construction till July 1	
July	1	37		Assign a personnel for restoration Announce as national disaster	
	2	28	III	Close headquarters Final damage report	
	15	51		Meet fishermen's cooperative	

Number means village

repaired in the same day. Gas supply was totally interrupted and its recovery was started from the less damaged southern villages (Figure 3). In the northern villages, low pressure gas tubes were destroyed at the joints and invaded with sands. It took almost one month to renew all the tubes for restoration.

4.2. Private Sector

Periods necessary to return to daily life is compared taking several indexes such as absence from jobs, resettlement and recovery to normal living conditions, gas supply and repair of dwellings (Figure 5). The derived diagram has the largest peak near to the northern end and a small peak in the central villages and shows a similar pattern to dwelling damages. Method of repair for dwellings can be classified into a) reconstruction, b)replacement of foundation - to raise up a house, make a new concrete foundation and resettle the upper part, and c) small repair. Figure 6 shows the relation between the degree of damage and mode of repair in the northern villages. There are considerable cases where only small repairs have been conducted in spite of heavy damage.

Figure 7 indicates by a cumulative frequency curve when repair works were started

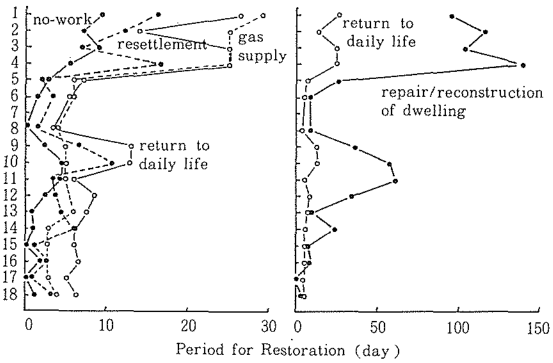

Fig. 5 Distributions of period for recovery along the north to south road.

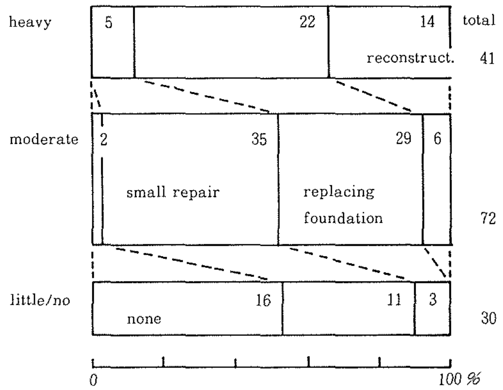

Fig. 6 Relation between degree of damage and repairing method in the northern villages.

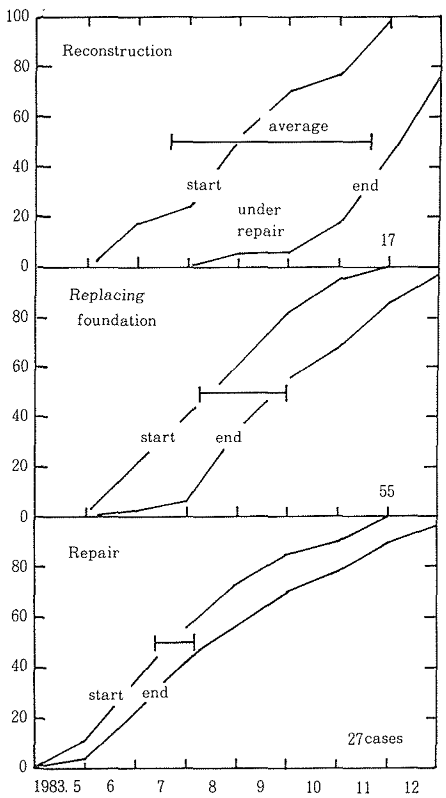

Fig. 7 Period for dwelling restoration.

and finished. Small repair starts earliest, and replacement of foundation and reconstruction follow with a delay time of about 1 month. The repair work seem to be prolonged and scattered from June, shortly after the shock, to December when it starts to snow in the area, because local carpenters are very busy, farmers works and field restoration are more urgent, and also it takes time to find the financial source for repair. Almost 90% of families whose houses necessitate reconstruction were obliged to spend an average of 110 days in temporary housing. It was possible to stay in the house while the foundation is replaced, however, in 25% of the families preferred to live in temporary dwellings for an average of 70 days. Based upon the Disaster Relief Law, 27 prefabricated temporary houses (plan area : 23.1-33.0 m^2) were built in the town for 2 years free rent. It seems to have eased the difficulties during the restoration period that the post-disaster period happened to be in the summer season and farmer family usually has a barn together with spacious residential land.

The necessary cost for dwelling restoration is investigated to evaluate the economic loss (Figure 8). Higher cost than the average seems owing to a large plan area of the farmer's house. Partial repair is mostly done within the available limit of public disaster relief loan which is provided at low interest rates. Expenses for the heavily damaged cases amount to ¥6.7 million on an average, of which 40% is covered by building insurance, while those of the moderately damaged cases amount to ¥3.0 million and 30% of it is covered by insurance. The important governmental loan systems prepared for disaster relief are Special Funds for Building Restoration by Housing Loan Corporation with an annual interest of 5.05% and Disaster Relief Fund with an annual interest of 3% for 10 years.

Various causes of monetary loss and financial sources for restoration are depicted in Figure 9 in comparison with the annual income. Young rice plants were floated and covered by mud in 1/3 area which resulted in 20% decrease of the crop. Altogether the harvest is estimated to have decreased by 30-40%. Since the governmental loan offers a farmer with land at most ¥1.50 million with annual interest of 4.6% for 20 years, additional assistance by municipal government is expected for restoration of field. Fishermen, although they are few in Wakami town, lost fishing facilities such as boats, nets and huts so that their income may be seriously affected for the coming years.

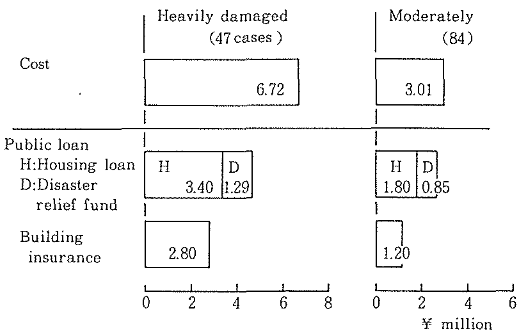

Fig. 8 Necessary cost and fund for dwelling restoration.

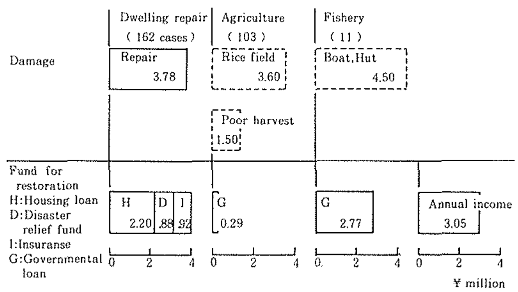

Fig. 9 Monetary loss and financial sources for restoration.

5. Simulation of Restoration Process

In order to understand the restoration process in a somewhat quantitative manner an approach by simulation analysis was introduced with special attention to the damaged dwelling houses.

5.1. Restoration Frame and Related Factors

The restoration process of wooden houses can be schematized in a time-series flow chart as shown in Figure 10. Related items and factors are explained successively. First, we recall that the degree of damages to dwelling houses are determined by the vulnerability relations as a function of seismic input motions. Vulnerability relations vary with structural types, number of stories, amount of walls, quality of work, building age and so on. As mentioned in the previous chapter, methods of repair for damaged houses are classified into reconstruction, replacement of foundation, and small repairs. But, the actual selection of the method is decided taking into account numerous factors. The principal factors are as follows. a) Degree of damage : As shown in Figure 6, this factor is most influential, but far from sufficient. b) Monetary source for repairing : This factor seems to have a certain priority to determine the manner of repairs . Expected monetary sources are, in addition to private funds, building insurance and public loans. c) Building age : The life span of usual Japanese wooden house is 30-50 years. This factor acts in a complex way. In case of old houses, some are, in spite of a slight damage, rebuilt taking the unexpected opportunity, and some are abondaned to repaire because of fatal damage. In case of very new houses, some are compelled to be satisfied with small repairs because of the debt at the previous construction. d) Family occupation : For farmers and fishermen, restorations of agricultural and fishery damages are sometimes more important and urgent. Family occupation is also influential to the decision-making for the housing restoration.

The next major item to be examined is time-dependent characteristics on the restoration processes. It takes a certain number of days to plaee an order for repairs. This period is controlled by the following factors ; a)

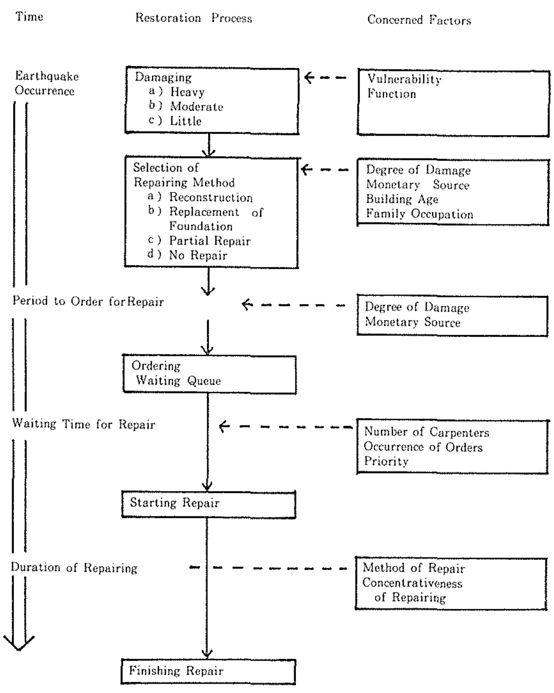

Fig. 10 A time series flow chart of the restoration process of wooden houses.

Degree of damage, b) Monetary source for repairing.

Repairing does not necessarily begin immediately after the ordering and a waiting time, delay is inevitable because of the number of local carpenters and technicians is limited and they cannot reply to a rush of orders. This situation is simulated by use of the well-known Queuing Theory. When the total number of orders exceeds the capacity of carpenters, it causes the forming of a so-called waiting queue.

5.2. Simulation Model

Taking into account of these factors in a simplified form, a simulation model was constructed. In this simulation, a closed area is selecled and no interaction with surrounding areas are considered. That is, the total numbers of damaged houses and carpenters were fixed as a constant. A carpenter can repair only one house at the same time, and starts repairing one by one according to the normal order of queuing row.

Calculation for simulation are performed step by step in a time-domain. First, for each house, parameters of damage degree, repairing method, period until ordering and necessary time of repairing are given by proper probability functions. At each time step, it is checked to see if an order was made or not, house by house. If ordered, that house must queue at the last position of waiting line. For each carpenter, if he is busy or not is checked. If free, the carpenter starts to repair the house from the head of the waiting queue. For a busy carpenter, whether he is still on the job or not is checked after a certain time. When the repair was completed, his status changes from busy to free. These procedures are repeated step by step until the entire damaged houses are repaired. At each step, percentages of houses which have already been started and repaired are calculated, and cumulative frequency curves are drawn.

5.3. Execution of Simulation

Using the data obtained in the northern part of Wakami town, the trial executions were carried out in order to reproduce and analyze actual restoration processes. The characteristics of individual households were given by probability functions. Total number of damaged houses, to be repaired and considered in the simulation, is 143. The degree of damage to houses was classified into three categories of partial (28.7%), half (50.3%) and total (21.0%) so as to maintain the obtained percentages in Wakami town. Time lengths until ordering were also given by normal distribution. As there were no surveyed data, the average period and its standard deviation were taken as the initial values of 80 and 52 days for all the methods of repairing.

The total number of available carpenters were fixed as 40. From the field survey data, distribution of necessary periods for restoration were approximated by the normal distribution regardless of methods of repair. Mean values are 25 days for small repair, 50 days for replacement of foundation and 120 days for total reconstruction, respectively.

Using the above parameters, a simulation was performed and the results are shown in Figures 11 with a pair of cumulative curves of the onset and completion of repair in comparison with the surveyed ones. In case of the total reconstruction and replacement of

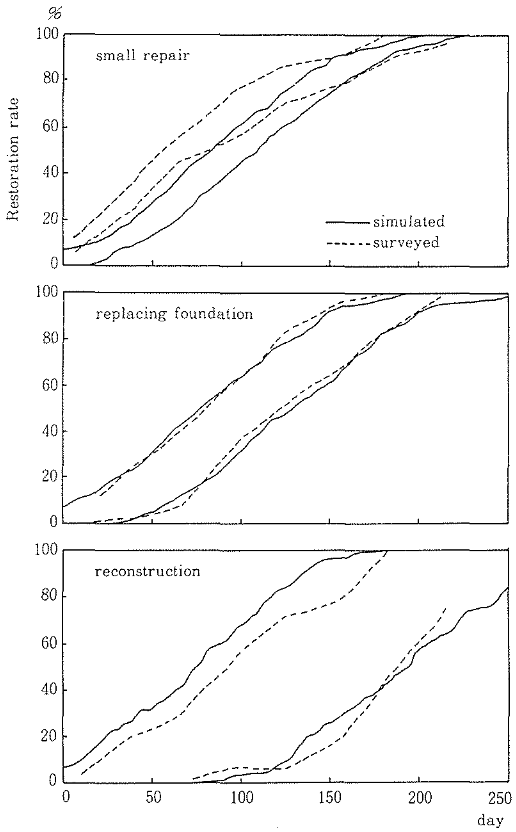

Fig. 11 Simulated restoration process of houses for initial model.

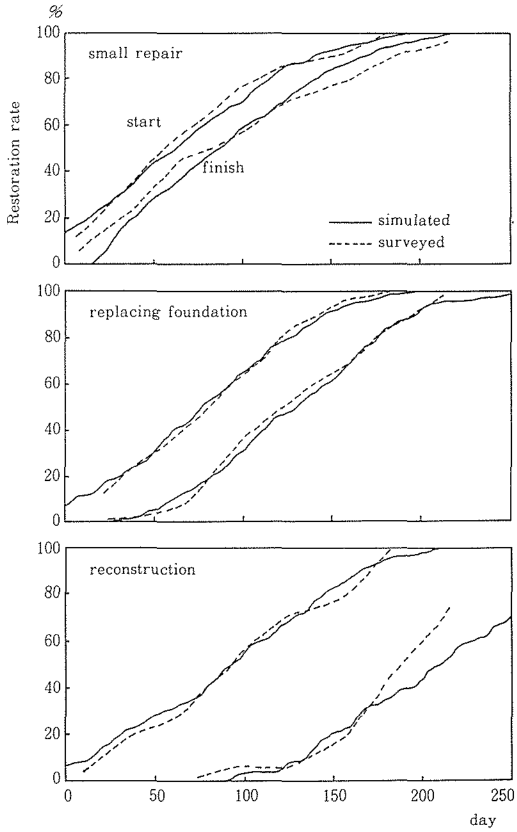

Fig. 12 Simulated restoration process of houses for revised model.

foundation, the simulated results are in agreement with the observed curves. As for small repairs, simulated results show a slight time-delay. In actual case there is evidence that simple repairs were made immediately after the quake and these repairs were counted as small repairs. The time lengths until ordering were changing parametric, several cases of simulations were carried out in order to find the optimal factors. The simulated results can be fitted to that of the observed as shown in Figure 12. Obtained average time lengths until ordering are 60 days for small repairs, 80days for replacing foundation and 120 days for reconstruction respectively. The standard deviation in case of small repairs is 1.5 times larger than that of others and it reflects that the category of small repairs contained various kinds of from small but urgent repair to considerable ones.

6. Concluding Remarks

This report has introduced damaging and restoring process surveyed in a rural town with a population of slightly less than 10 thousand. In spite of the limited nature of a case study, there are many facts that were revealed from the field survey and simulation analysis.
1. Aftereffects to households have various aspects which last for a considerable length of

time.

2. Agricultural area as situated, restoration of farming land as a major source of family income is as important as dwelling repair.

3. The period necessary to recover a somewhat steady daily life is determined by the restoration time of life line systems. Though there were no much damage in the surveyed town, but in case of huge cities, life line services must play a crucial role.

4. Method of repair for damaged dwelling is statistically well correlated with the degree of damage, but it is far from one-to-one correspondence. Importance of other factors of available monetary sources, building age and family occupation were also recognized.

5. A simulation model for tracing restoration processes of dwelling houses was constructed and by this model observed processes were well reproduced.

Since we believe that an improvement of restoration process is one of the desirable ways to relieve the problems in earthquake disasters, we intend to continue similar case studies not only in Japan but in other earthquake countries.

Acknowledgment

This field survey was performed with the entire cooperations of Wakami Town, Akita Prefecture. The authors express their sincere thanks to the staff of the town office, local communities and the whole inhabitants who answered the questionnaires and complied to interviews.

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