DAMAGES TO GENERAL PROPERTIES DUE TO A STORM SURGE IN JAPAN

Fuminori Kato[1] and Ken-ichi Torii[2]

Abstract: In cost/benefit analysis of shore protection works against storm surges in Japan, the effects of prevention from flood are computed as benefits. In this computation, flooding without the works is assumed and the reduced values of properties in the flooded area are obtained taking the loss ratios into account. The loss ratios used in Japan are based on the results of river disaster studies because little data on the damages from storm surges is available. The storm surge due to Typhoon No. 9918 that struck Japan in September, 1999 caused a storm surge in the Yatsushiro and Suo seas, and damage from flooding over wide coastal areas. The loss ratios for general properties due to storm surges from Typhoon No. 9918 were measured in Shiranui Town and Ube City.

INTRODUCTION

In September 1999, Typhoon No. 9918 struck the Kyushu and Chugoku districts in Japan. It caused a storm surge in both the Yatsushiro and Suo sea areas, leading to serious flooding of large coastal areas. In the Matsuai area (Shiranui Town, Kumamoto Prefecture) facing the north of the Sea of Yatsushiro, 12 lives were lost due to the flood. Although several typhoons around 1960 caused catastrophic damage by flooding due to storm surges, the occurrence of such damage has decreased in Japan due to the improvement of embankments and revetments as well as the establishment of warning notice and evacuation systems. The serious damage caused by Typhoon No. 9918 prompted us to review the prevention planning for storm surges.

In Japan, loss ratios for general properties, which are set for each flooding level, are used for calculating general asset damage due to flooding when evaluating the benefits of shore protection works against storm surges. These loss ratios were developed by examining damages in river disaster because there is little data related to storm

1 Research Engineer, Coast Division, National Institute for Land and Infrastructure Management, Asahi 1, Tsukuba 305-0804, Japan, katou-f92fr@nilim.go.jp

2 Head, Coast Division, National Institute for Land and Infrastructure Management, Asahi 1, Tsukuba 305-0804, Japan, torii-k92fr@nilim.go.jp

surges. To evaluate the benefits more accurately, further cumulative data from examinations is needed.

With this background, this study compiled the damages due to storm surges caused by Typhoon No. 9918, and calculated loss ratios for general properties due to the storm surge.

Summary of Damages due to Typhoon No. 9918

As shown in Figure 1, on September 24, 1999, Typhoon No. 9918 landed near Ushibuka City (Kumamoto Prefecture) at 4:00 a.m. (central atmospheric pressure: 945 hPa), passed almost longitudinally along the west side of the Sea of Yatsushiro at 40 km/hour, and reached the Shimabara Peninsula at 5:00 a.m. (950 hPa) and Ohmuta City (Kumamoto Prefecture) at 6:00 a.m. (950 hPa). At 5:00 a.m., when the typhoon most closely approached the Sea of Yatsushiro, the atmospheric pressure dropped to 955 hPa in Yatsushiro City, 15 km south of Shiranui. Then the typhoon traversed the Sea of Suo, landed again near Ube City (Yamaguchi Prefecture) and passed over the west part of the Chugoku district and into the Sea of Japan.

On September 24, a spring tide came and the peak of the astronomical tide was observed in the Sea of Yatsushiro and the Sea of Suo at about 8:00 a.m. The values measured at the tide station in the Port of Yatsushiro indicated T.P. (Tokyo Bay mean sea level) +2.7 m, a peak tide level, at 6:03 a.m. According to Takikawa (2000), the tide anomaly was 1.8 m at this point. The tide level reached its peak point again at 8:20 a.m. This observation data clarified that the actual peaks of tide levels occurred one or two hours before the astronomic peaks.

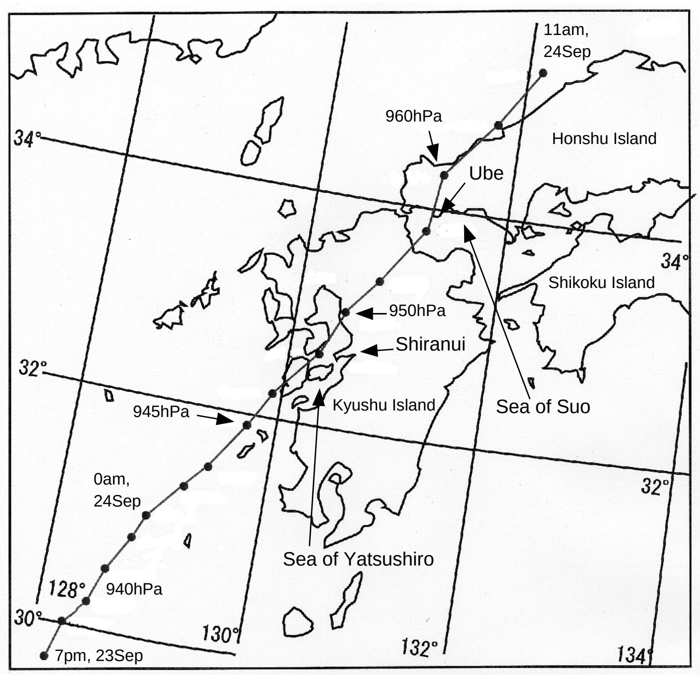

Figure 1 Typhoon No.9918 path

At the Port of Shimonoseki, 30 km west of Ube, the peak tide level reached T.P. +4.1 m, 1.6 m higher than the maximum peak level so far, at 8:00 a.m. The tide anomaly was 2.2 m at this time. On the other hand, at the Port of Ube, the peak tide level reached T.P. +3.5 m, 1.3 m higher than the maximum peak level so far, at 8:00 a.m. After that, no more measurements were taken. The tide anomaly was 2.0 m at that time.

Damage from Typhoon No. 9918 was reported in 12 prefectures throughout Japan, particularly in Kumamoto Prefecture and Yamaguchi Prefecture in the Kyushu and Chugoku districts. Regarding coastal areas, Suo and Yatsushiro were worst hit by storm surges, and the following damages were reported.

At Shiranui Town (and Matsubase Town, south of Shiranui Town) in the coastal area of the Sea of Yatsushiro, 12 lives were lost, 47 (1) houses were completely destroyed, 27 (31) houses were half destroyed, 738 (592) houses were partially destroyed, 165 (241) were flooded above floor level, and 101 (91) houses were flooded under floor level. Note that floor levels in most houses in Japan are roughly 50 cm higher than ground levels around their houses. This indicates that the northeast area of the Sea of Yatsushiro was worst hit by storm surges. On the other hand, with respect to the Sea of Suo, in Ube City (and Shimonoseki City), 13 (4) houses were completely destroyed, 568 (33) houses were half destroyed, 5,769 (519) houses were partially destroyed, 286 (650) houses were flooded above floor level, and 3,408 (1,300) houses were flooded under floor level, which means that the damage was severe in the west area of Yamaguchi.

Figure 2 shows the flooded areas in the northeast coast of the Sea of Yatsushiro. As seen from the figure, the flood hit the reclaimed land situated on the left bank of the mouth of the Ohno River. The flood covered Shiranui Town in the center of the Matsuai area, where many lives were lost, and the left bank of the mouth of the Ohno River.

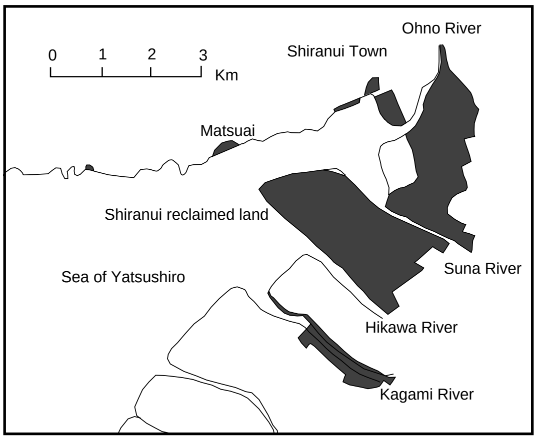

Figure 2 Flooded area in the northern part of Sea of Yatsushiro

Photo 1 Flooding in Matsubase Town, south of Shiranui Town

Photo 2 A destroyed house due to flood in Shiranui Town

Photo 3 A room after flood in Matsubase Town

Photos 1 to 3 show flooding and its impacts on houses in Matsubase and Shiranui towns.

Cost-benefit analysis of shore protection works

In the analysis of the cost-benefit of shore protection works, the benefits of the projects can be broadly classified into the following three groups:

1) Benefits of flood prevention

Benefits from prevention of flooding of properties in the region due to storm surges, high waves, or tsunamis

2) Benefits of erosion prevention

Benefits from prevention or reduction of loss of land and damage to properties due to coastal erosion

3) Benefits of use of seaside and coastal environment maintenance

Benefits from promoting use, and improved and maintained natural/living environments through shore protection works and improvement works for coastal environment.

Among them, with respect to flood-prevention benefits, general properties, agricultural products, and public works facilities and public projects are evaluated, and the reduced values due to flood are computed by an alternative method taking the loss ratios into account.

Method for computing loss ratios

The loss ratios for general properties are computed as follows using the formula of Kuriki et al. (1995).

(1) House

$$\text{Loss ratio} = \sum_i \left\{ \sum_j \left(Db_{ij} \times Lb_{ij} \right) \times Pb_i \right\} \tag{1}$$

where Db_{ij} = the partial count of damages for each level of severity (1 for applicable, 0

for not applicable); Lb_{ij} = the partial attrition rate for each level of severity; Pb_i = the partial value composition ratio; i = parts of the house (foundation, external walls, floors, etc); and j = the damage level. For the partial attrition rate for each level of severity and the partial value composition ratio, the results of the studies by Kuriki et al. (1995) were applied. For the partial value composition ratio, different average values were used depending on whether or not the houses were wooden.

(2) Household items

Loss ratio = amount of loss / value of assets

$$= \sum_i \left\{ \sum_j \left(Df_{ij} \times Lf_{ij} \right) \times Pf_i \times Rf_i \right\} \div \sum_i \left(Tf_i \times Pf_i \times Rf_i \right) \qquad (2)$$

where Df_{ij} = the by-item count of damages for flood severity; Lf_{ij} = the by-item attrition rate for each level of flood severity; Pf_i = the re-procurement value; Rf_i = the remaining-value ratio over time; Tf_i = the by-item count of holdings; i = the item, and j = the flood severity. With respect to the by-item attrition rates for each level of flood severity and re-procurement value, the results of the studies by Kuriki et al. (1995) and the same remaining-value ratio over time of 0.75 were applied.

Investigation method

A questionnaire was conducted concerning the damage to homes and household items caused by storm surges in Shiranui Town and Ube City, both of which were severely damaged by Typhoon No. 9918. The survey was conducted from June 2 to 6, 2000. In selecting the respondents, those households where any family member had died or whose house was lost were excluded. In the site investigation, requests for participation in the survey were sent to prospective respondents and the surveyors visited them and asked for their cooperation. They then distributed the questionnaires to the respondents and collected them a few days later.

In the survey, the form developed by Kuriki et al. (1995) was used without change. In this form, the targets to be surveyed are grouped into the categories shown in the following list.

(1) Houses

After asking the respondents about the type of house, years since construction, flood depth, sediment deposit depth, flooding time, and the presence of parts washed away, respondents were asked to select applicable answer(s) from the classified parts such as roof and external wall, which were ranked into 4 to 6 levels. Two types of forms were prepared, one for wooden housing including mortar houses, and the other

for non-wooden houses.

(2) Household items

Respondents were asked to fill in information about 28 types of furniture and electric appliances, the number of items with the lower half flooded, the number of completely flooded items, and the number of lost or scrapped items in the questionnaires. With respect to cars, motorcycles and scooters, the number of holdings, the number of items with 50 cm flooded, the number of items with 100 cm flooded, the numbers of fully-flooded items, and the number of lost or scrapped items had to be filled in as well. For 26 types of clothing, excluding that for infants and elementary school boys and girls, the number of holdings, the number of flooded items, and the number of lost or scrapped items were filled in.

Status of collected responses

Responses were collected from 70 households in Shiranui and 143 in Ube. The following information was obtained from collected data.

1) The most common occupation of the head of household was “Other”, most of them being unemployed, in both the Shiranui and Ube areas. In Ube, the percentage of office workers was high, while in Shiranui the percentage of farmers and self-employed workers was relatively high.

2) Most of the houses in both the Shiranui and Ube areas are made of wood.

3) About two-thirds of houses in Shiranui and about half in Ube are two-story and all the remaining ones are one-story.

4) Almost no houses in both areas have a basement.

5) All the houses in Shiranui and most of the houses in Ube are detached.

6) Most of the houses are dedicated dwelling type in both areas.

7) For half of the houses, the floor space and total floor area are 100-200 m^2 in both areas. Note that more than half gave no answer or responded as unknown in Shiranui.

8) Regarding years since construction, the largest percentage is 30 years or more in Shiranui and 20-30 years in Ube.

9) Many respondents did not give an estimated value of their house. The most common figure was 10-20 million yen in both areas.

Damages to houses

Figure 3 lists the flood depths of houses. About half of the houses in both areas for which information was collected were flooded 0-50 cm above floor level. In Shiranui, about 40% of houses were flooded 50 cm above floor level and in Ube, the more houses were flooded under floor level than above floor level. Note that 60-70% of the houses for which information was collected were flooded for six hours or less while some were flooded for 24-74 hours in both areas.

Figure 4 lists the sediment deposit depths in the houses. In Shiranui, sediment of

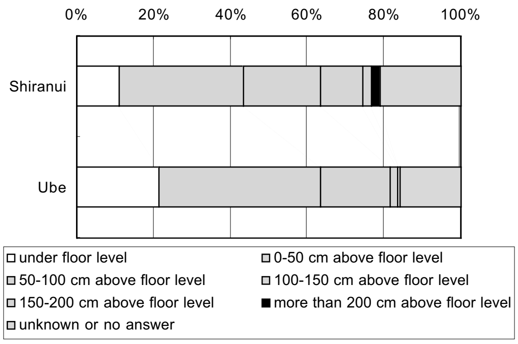

Figure 3 Flood depths of houses

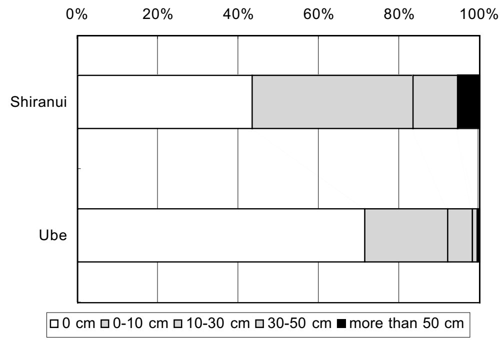

Figure 4 Sediment depths of houses

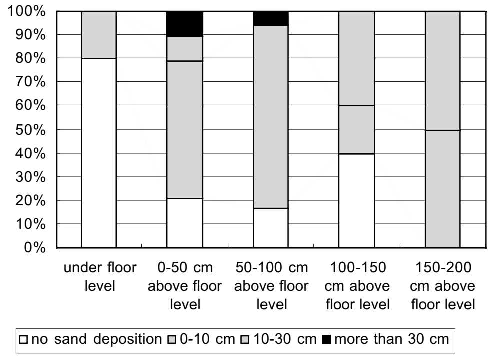

Figure 5 Sediment depths in houses for each flood depth (Shiranui)

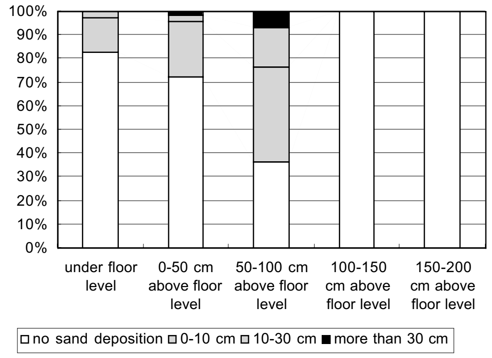

Figure 6 Sediment depths in houses for each flood depth (Ube)

less than 10 cm thick was deposited in about 40% of the houses for which information was collected, and sediment of 50 cm or more in thickness was deposited in 6%. In Ube, sediment was deposited in about 30% of the houses, 30 cm or less in most cases.

Figures 5 and 6 summarize the deposited sediment depths in the houses for each flood depth in Shiranui and Ube. In both areas, sediment was deposited in about 20% of the houses flooded under floor level. For the houses flooded above floor level, sediment was deposited in 80% of the houses flooded 50 cm or less above floor level in Shiranui. In Ube, fewer houses flooded 100 cm above floor level, for which the ratio of respondents was large, had sediment deposit than in Shiranui. Note that there was almost no difference in the percentage of houses in which sediment was deposited between the flooding times “six hours or less” and “24-72 hours” in both areas.

Thus, although no significant difference was observed in the flooding time, the flood depth and the deposited sediment depth in the houses flooded above floor level were larger in Shiranui than in Ube.

Damages to household items

Figures 7 to 9 summarize the household items for each flooding depth classified into furniture/electrical appliances, car/motorcycle/scooter, and clothes in Shiranui and Ube.

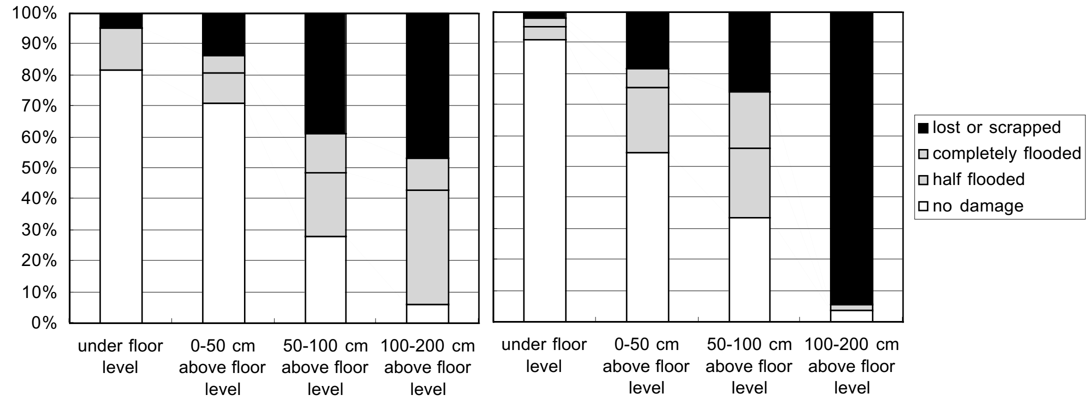

Figure 7 Damages to furnitures and electrical appliances (Left: Shiranui; Right: Ube)

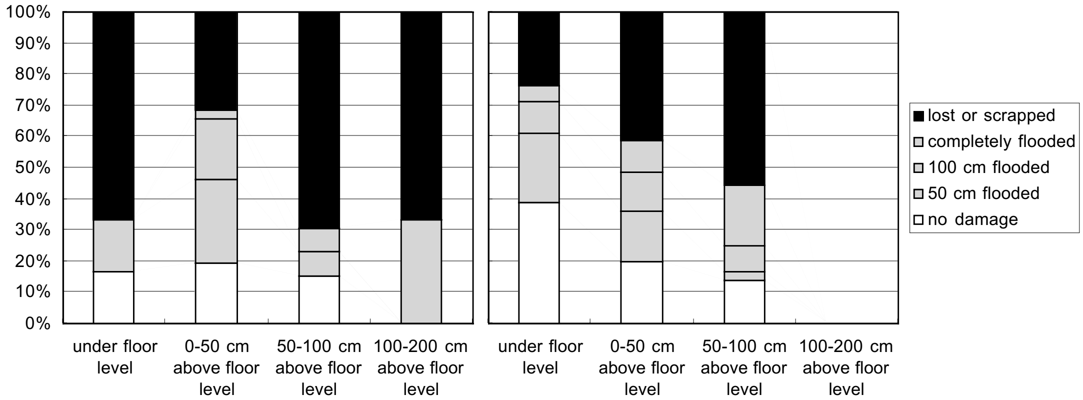

Figure 8 Damages to cars, motorcycles and scooters (Left: Shiranui; Right: Ube)

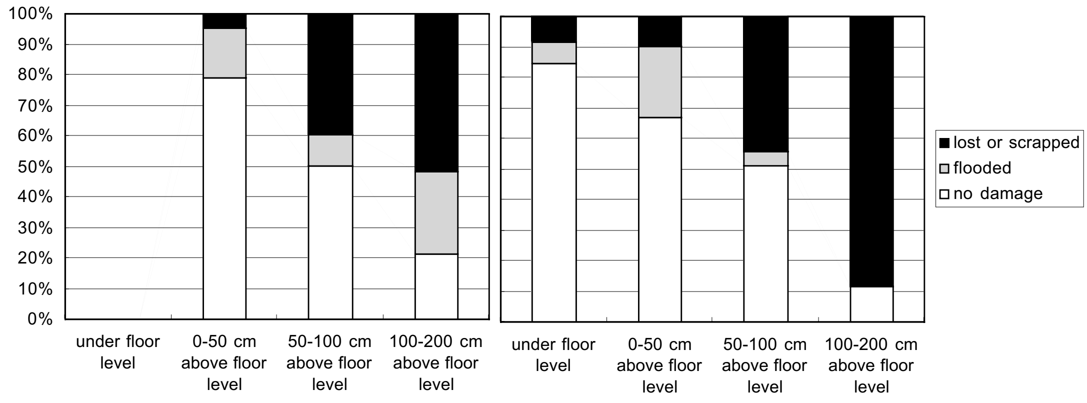

Figure 9 Damages to clothing (Left: Shiranui; Right: Ube)

Furniture and electrical appliances were damaged in only 10-20% of the houses flooded under floor level, in 30-50% of houses flooded 50 cm above floor level, in about 70% of houses flooded 50-100 cm above floor level, and in most of the houses flooded 100-200 cm above floor level. As the flood depth increases, the percentage of damaged houses increases. The percentages of lost and scrapped items significantly increased for the houses flooded above floor level. The percentage of damage in the houses flooded under floor level was larger in Shiranui than that in Ube. Most items were lost or scrapped in the houses that were flooded 100 cm above floor level in Ube.

In Shiranui, more than 80% of motor vehicles were damaged for the houses flooded under floor level, and most of these were lost or scrapped. On the other hand, about 60% were damaged in Ube. The percentage of flooded, lost, or scrapped items was not dependent on the flood depth in Shiranui but the percentage increased with flood depth in Ube.

Only 15% of clothes were damaged in the houses flooded under floor level in Ube, 20-30% in the houses flooded 50 cm or less above floor level, 50% in the houses flooded 50-100 cm above floor level, and 80-90 % in the houses flooded 100-200 cm above floor level. The percentage increased with flood depth. The percentages of lost and scrapped items significantly increased in the houses flooded 50 cm or more above floor level.

Thus, it is clear that motor vehicles were damaged in the houses flooded under floor level while the percentage of damaged furniture and electrical appliances in the houses flooded above floor level significantly increased with flood depth. In the houses flooded 50 cm above floor level, the percentages of lost and scrapped clothes were significantly higher than that in the houses flooded less than 50 cm above floor level.

Results of computing loss ratios

(1) Comparison with existing loss ratios

Figures 10 and 11 show the loss ratios obtained from this investigation of actual conditions with those used in evaluating river and shore protection works. The loss ratios for houses in case of a river disaster are grouped into three types depending on the slope of the ground. Here, we indicate the average values. The obtained loss ratios for the houses were somewhat higher for those flooded under floor level than those used in the existing computation. For the houses flooded 200 cm or less above floor level, for which the rate of respondents was relatively large, the obtained loss ratios were higher than those used for the existing computation for shore protection works and were the same as those for river works. On the other hand, the obtained loss ratios for household items in both the houses flooded above and under floor levels were far larger than those used in the existing computation for river and shore protection works.

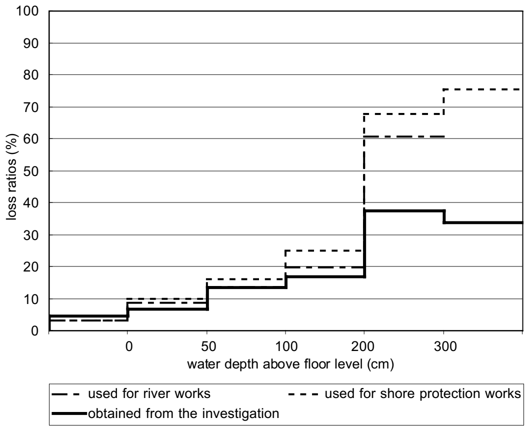

Figure 10 Loss ratios for houses

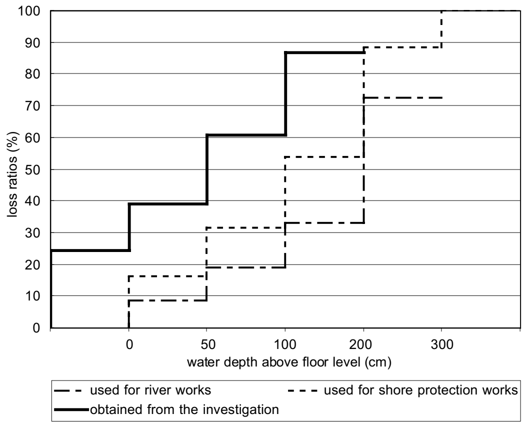

Figure 11 Loss ratios for household items

As shown in Figure 12, the loss ratios for household items were computed for each of the categories of: furniture/electrical appliances, car/motorcycle/scooter, and clothes. The damage to the furniture/electrical appliances and clothes became more severe as the flood depth increased. On the other hand, cars were damaged even for the houses flooded under floor level, irrespective of flood depth. This might be one of the reasons why the computed loss ratios for household items were higher than those used for shore protection works.

(2) Comparison between areas

Figure 13 compares the loss ratios for the houses and the household items between Shiranui and Ube. Excluding the houses flooded 200 cm or more above floor level, for which information was not collected in Ube, almost no difference was observed in the loss ratios for the houses flooded under and above floor levels. For the loss ratios for household items, there was no significant difference for the houses flooded 0-50 cm and 50-100 cm above floor level, for which much information was collected. Note that those were somewhat higher in Ube than in Shiranui. The loss ratios for household items for the houses flooded under floor level were significantly higher in Shiranui than in Ube. This was due to a difference in the precision of the computations because the number of target households was 2 in Shiranui and 31 in Ube. Thus, it is considered that for houses flooded up to the same level, there was no significant difference in the loss ratios for the houses and the household items between Shiranui and Ube.

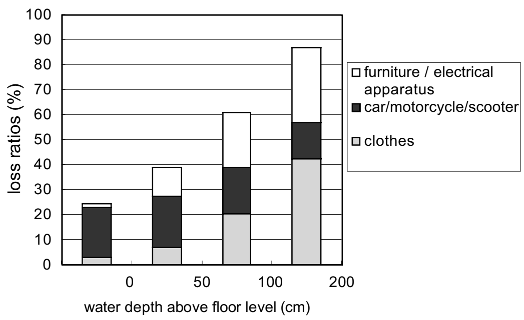

Figure 12 Loss ratios for each category of household items

(3) Comparison with river disaster cases

Figure 14 compares the computed loss ratios for houses and household items with those for river disasters computed by Kuriki et al. (1995). These river disasters include the floods occurring in Saitama Prefecture and Tokyo Metropolis from Typhoon No. 11 (August, 1993), in Yamaguchi Prefecture from heavy rain (August, 1993), and in Kagoshima Prefecture from heavy rain (August and September, 1993). For the houses flooded under floor level, loss ratios for the houses were 0% in the river disasters but about 5% in the storm surge. For the houses flooded above floor level excluding those flooded 200 cm or more above floor level, for which less information was collected,

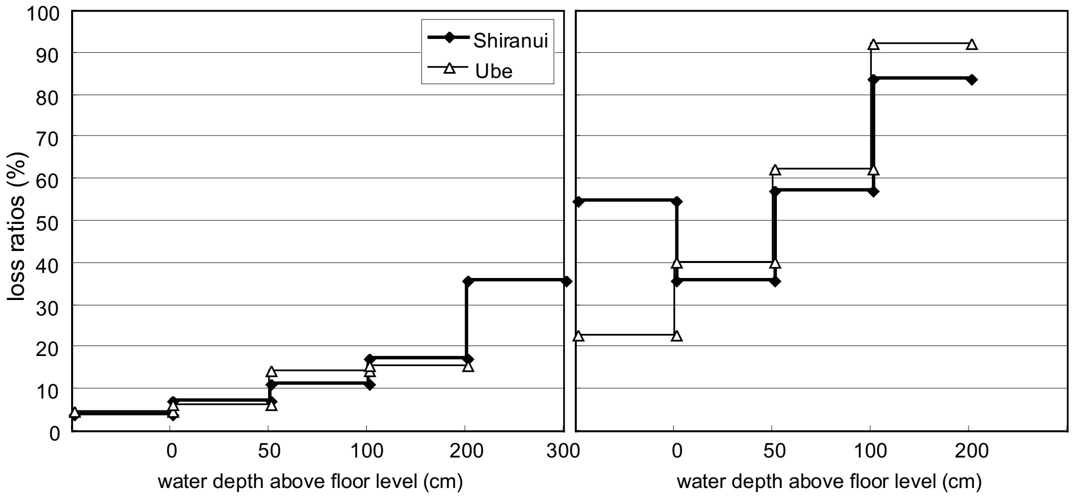

Figure 13 Comparison of loss ratios between Shiranui and Ube (Left: houses; Right: household items)

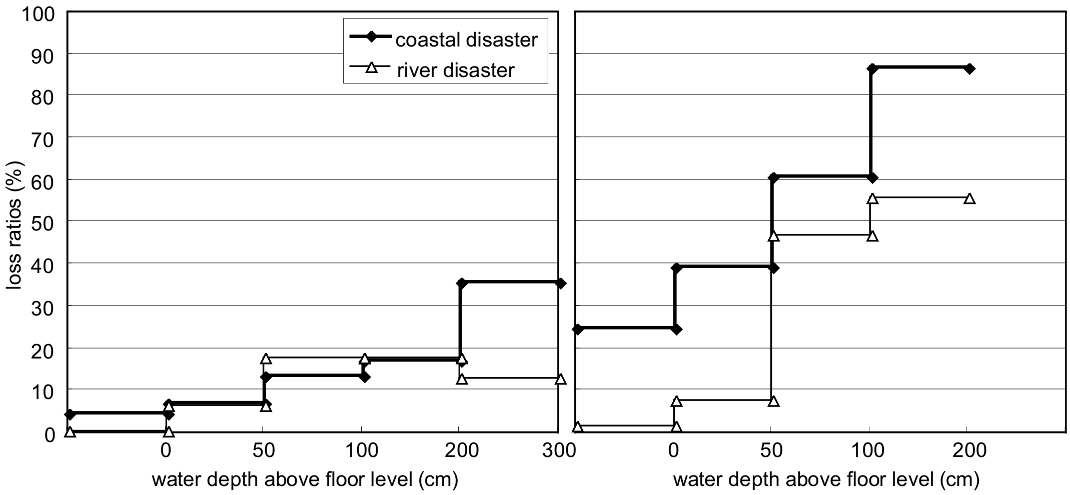

Figure 14 Comparison of loss ratios between coastal disaster and river disaster (Left: houses; Right: household items)

the loss ratios were almost the same between both types of disasters. On the other hand, with respect to household items, the loss ratios were higher for both the houses under and above floor levels in case of the storm surge than in case of the river disasters. This may be one of the reasons why the flood depth suddenly increased in case of the storm surge, resulting in no time to move household items. This is apparent from the fact that 34% of houses could move them in case of the river disasters while only 17% could do so in case of the storm surge. Since the effects of salt were not considered in the attrition ratios for houses and household items used in computing the loss ratios, further examination on this issue is needed.

CONCLUSIONS

We conducted interviews on the damages to houses and household items caused by storm surges in Shiranui Town and Ube City. The loss ratios were computed for each category of assets and the relationship was deduced between the actual states of flooding and the damages to houses and household items. The following key findings were obtained.

(1) The flood depths were higher and the deposited sediment depths were also higher for the houses flooded up to the same level in Shiranui than in Ube.
(2) Regarding household items, motor vehicles were damaged for the houses flooded under floor level, the damage to furniture and electrical appliances significantly increased for the houses flooded above floor level as the flood depth became larger, and the percentage of lost and scrapped clothes remarkably increased for the houses flooded 50 cm or more above floor level.
(3) For the houses flooded under floor level, the computed loss ratios for houses were slightly higher than the existing ones while for the houses flooded 200 cm or less above floor level, the computed loss ratios were lower.
(4) The computed loss ratios for household items were significantly higher than the existing ones for all levels of flooding. The damage to the furniture/electrical appliances and clothes became more severe as the flood depth increased but damage to vehicles did not depend on the flood depth.
(5) Compared with the damages from river disasters occurring in Saitama Prefecture, Tokyo Metropolis, Yamaguchi Prefecture, and Kagoshima Prefecture in 1993, the computed loss ratios for houses were slightly higher for the houses flooded under floor level and almost the same for the houses flooded 200cm or less above floor level. The loss ratios for household items were higher in case of the storm surge than in case of the river disasters for both the houses flooded under and above floor levels.

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