Sabo works in Wakayama Prefecture
- Historical disasters and Sabo -

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Sediment-related disasters occur every year in Wakayama prefecture whose territory is covered by rugged and fragile mountains and is affected by typhoon. It is said that the beginning point of sabo works in the prefectural government is hillside works that were carried out in 1908 and the Sabo has been evolved by the innovation of technologies about sediment-related disasters prevention through past historical disaster events. In order to reduce disaster damages, especially aim to prevent loss of human lives, various countermeasures combining both 'Structural' and 'Non-Structural' are carried out in recent years. This study introduces examples of the disaster prevention countermeasures and considerations about the prefectural government's activities in the future.

Key words: natural factors, historical disasters, sabo

1. INTRODUCTION

Wakayama is a prefecture that is located in the south-western part of the Kii-Peninsula, which is the largest peninsula of Japan, and about 80% of its 4724km^2 land area is covered by mountains and hills which have steep and fragile slope. Also, the mountainous area in the southern part of the prefecture is nationally renowned for having heavy rainfall and being vulnerable to typhoon threats. Every year, an inhabitant suffers damages from sediment-related disasters. In recent years, the occurrence of a mega earthquake called as 'Nankai trough great earthquake' is being forecasted and there are signs of worries that its subsequent sediment-related disasters may severely interfere with various restoration processes.

This study shows firstly the outline of the relevant natural factors that the prefecture has in regards to sediment-related disasters and the past catastrophe that the prefecture have experienced, and secondary will introduce examples of various countermeasures against disasters.

2. NATURAL FACTORS RELATED TO SEDIMENT-RELATED DISASTERS

2.1 Geomorphological feature

Geomorphological feature of the Wakayama region is shown in Fig.1. The mountainous area, which stretches across from east-north-east to west-south-west of the prefecture's land, is above 1000m from the sea-level. And most of the rivers, which eventually flow its way to the sea, originate from these mountains. The erosive action of these rivers is harsh since its outflowing routes are short and are simultaneously accompanied by heavily steep slope. Hence the hill-slopes have characteristics of being extremely steep. On the other hand, the plain area is being developed along the Kino-River, which penetrates the northern part of the prefecture from east to west, and at the mouth of the other rivers. Most of the prefecture's population is concentrated in these plain areas but communities are also formed in the valley plain areas that are located in the meso-mountainous region.

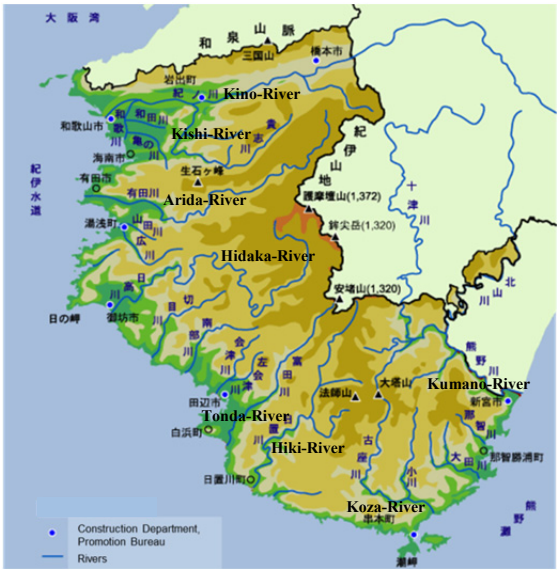

Fig.1 Geomorphological map

2.2 Geological feature

The geological condition layout is shown in Fig.2. The geological condition of the prefecture can be observed into two parts as the Median Tectonic Line (MTL) that crosses the northern part of the land area from east to west makes the division. The southern part of the MTL is composed of the Pre-Tertiary accretionary zone sediments such as sandstone, mudstone, chert, and serpentine that have been formed throughout the Paleozoic era to Cenozoic era. Tectonic lines and faults, however, still exist within these geological zones. Therefore the geological conditions of these mountains are extremely fragile. Furthermore, in the southern part of the prefecture, volcanic rocks derived from volcanic activities in the Neogene period are distributed.

Fig.2 Geological map [1)]

2.3 Precipitation

The annual precipitation figures are shown in Fig.3. The climate of the prefecture is generally regarded as warm except for the mountainous region. The concentration of rainfall occurs in summer and autumn, especially in June, July and September. The annual precipitation of the northern part and also the coast that flows through the northern to the middle part of the area is approximately 1500-2000mm, the southern part is estimated to be more than 2000mm and with the south-eastern part of the mountainous region exceeding 3500mm, the figures suggest that the prefecture is one of the rainiest regions in the country.

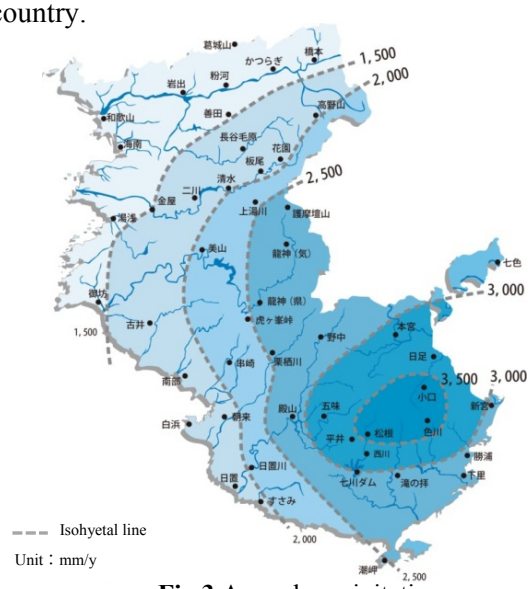

Fig.3 Annual precipitation

3. HISTORICAL DISASTERS IN THE WAKAYAMA PREFECTURE

3.1 The Arida-River disaster of 1953

On July 1953, a heavy rainfall by seasonal rain front in early summer caused a remarkable catastrophe in the catchment area of the Arida-River, Hidaka-River, and Kishi-River that has never been witnessed before. Particularly in upper-stream of the Arida-River, there have been a lot of landslides and the formation of subsequent landslide dams. The landslides occurred in upper-stream of the Arida-River is shown in Table.1 and Fig.4 and the subsequent landslide dam is shown in Fig.5.

Table.1 The data of landslide in Arida-River[2)]

Number of landslides	2,272
Total area of landslides	3,840,000m^2
Total volume of collapsed soil	20,900,000m^3
Number of blocked river	8

Fig.4 Landslide in Arida-River[3)]

Fig.5 Landslide dam in Arida-River[4)]

The size of the landslide dam recorded 100m in height, 600m in width, reservoir area of $8.4\times10^5 m^2$ and the reservoir capacity of $1.7\times10^7 m^3$. This reservoir capacity figure still remains as the largest scale in Japan since the Second World War. The so-called natural dam was broken down by the Typhoon No.13's rainfall on the 25th of September, 1953. And this event has derived severe loss and damages to the lower-stream of the valley. Apart from this, the upper-stream of the Arida-River had 7 sites that were troubled by landslide dams. In this calamity, approximately $1.8\times10^7 m^3$ of sediment have flowed towards the lower reaches of the rivers and the riverbed level of mid-lower river has risen from 5 to 20 meters. This catastrophe brought 615 casualties, 431 people missing, 8,600 housings completely destroyed or washed away and the total of over 262,000 residents were known to be affected by the disaster.

3.2 The disaster caused by the Typhoon TALAS of 2011

The Typhoon TALAS has recorded a remarkable amount of rainfall that dreadfully focused on the mountainous areas of the Kii-peninsula. In this calamity, widespread of continuous rainfall of more than 1000mm through the period from the 29th of August to 4th of September was observed and the Ohsugi rain gauging station eventually estimated a record-breaking rainfall figure of 1998mm. The statistics of rainfall that was derived from Typhoon TALAS is indicated in Table.2 and Fig.6.

This typhoon caused large-scale deep-seated landslides, and stimulated the occurrence of debris flow in the southern part of the prefecture. The damage of the disasters brought total of 37 casualties and missing as well as collapsing of 59 housings units. An example of disaster damages is shown in Fig.7.

Table.2 The record of rainfall

	Observatory	Place	Recoed level	Record length
total amount of the precipitation	Ohsugi	Shimokawashimo, Tanabe-shi	1,998mm	8/29 21:00 ～9/4 24:00
hourly precipitation	Takada	Takada, Shingu-shi	132mm	9/3 2:00 ～3:00
maximum precipitation in 24 hours	Takada	Takada, Shingu-shi	1,064mm	9/3 6:00 ～9/4 6:00
maximum precipitation in 48 hourss	Ohsugi	Shimokawashimo, Tanabe-shi	1,607mm	9/2 9:00 ～9/4 9:00

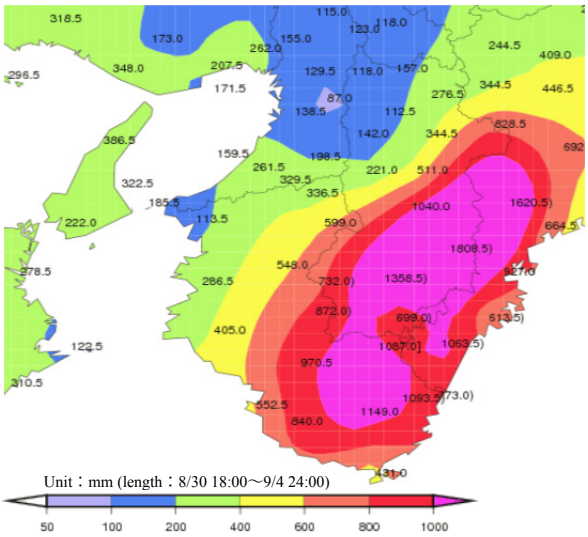

Fig.6 Rainfall distribution map

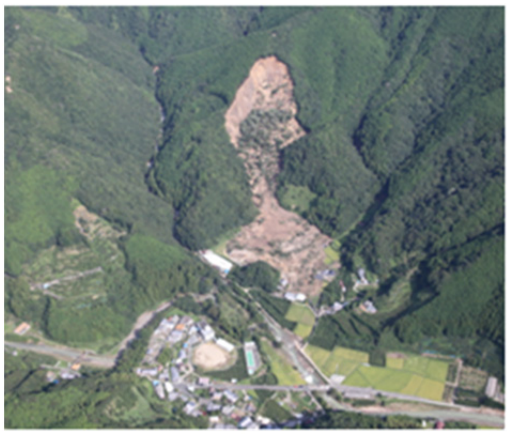

Fig.7 Landslide disaster in Tanabe-city

Particularly, in the Iyagawa village (Tanabe city) where a landslide dam was formed and was one of the most severely affected areas, the potential damage that may be caused by the collapse of the

landslide dam was under apprehensiveness and stimulated urgent circumstances.

As for the Nachikatsu-ura town, its river area was affected by the debris flows, which occurred at many branch torrents in the Nachi-River basin, and widespread flood damages that are accompanied by the debris flow sediments. The damage situation of Iyagawa village and Nachikatsu-ura town is shown in Fig.8.

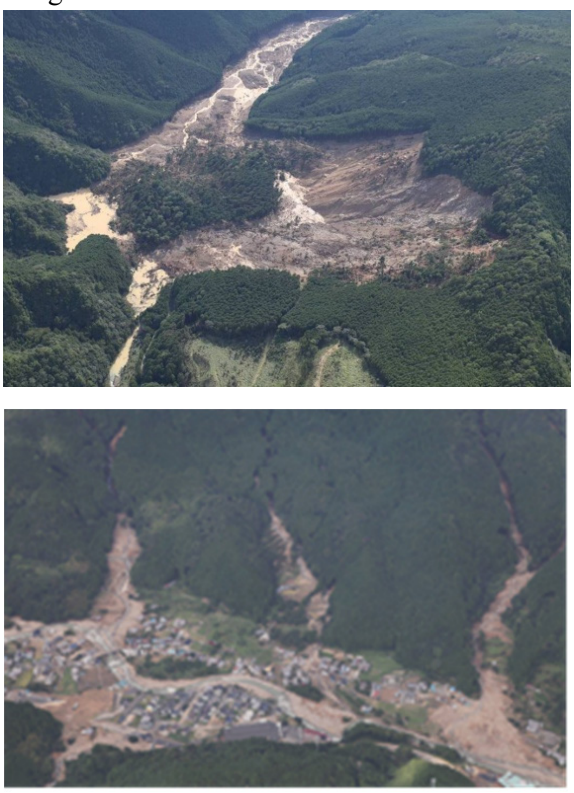

Fig.8 The damage situation
(above : Iyagawa village, below : Nachikatu-ura town)

4. COUNTERMEASURES AGAINST SEDIMENT-RELATED DISASTERS

Referring to the prefecture's natural factors as mentioned above, there are approximately 18,500 places or sites and more than 90,000 housing units that are exposed to the danger of sediment-related disasters in the prefecture. The prefectural government is operating the so-called 'Structural' and 'Non-Structural' measures against sediment-related disasters in which underscores protection of human beings as its primary objective.

4.1 'Structural' measures

The prefectural government is conducting a construction of facilities for sediment-related disasters prevention that prioritizes hazardous ratings on disastrous potential and importance of asset to be conserved against the disasters. The flow chart of the priority system is shown in Fig.9.

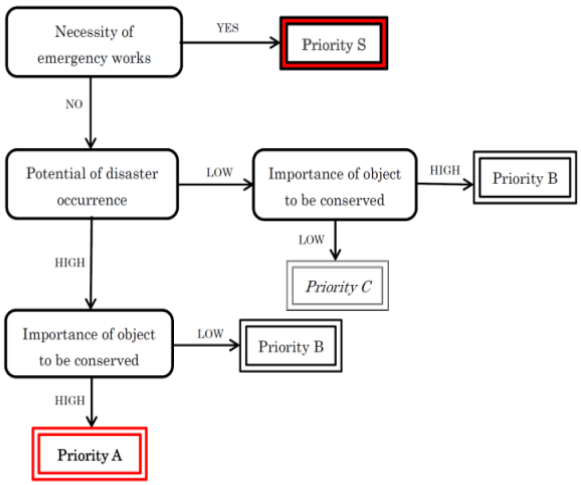

Fig.9 Flow chart of priority system

The future tasks such as accuracy of risk evaluation on disaster occurrence, target residents' understanding on importance of asset to be conserved, etc. are involved in this method. Therefore, it is necessary to develop objective skills on risk evaluation and to promote partnership on prioritization between the prefectural government and target residents. An example of facility arrangement based on the priority is shown in Fig.10.

Fig.10 Construction facility

In southern part of the prefecture where steep mountains come in contact with coastline, residents are always exposed to danger of slope failure and it is forecasted that the Tsunami accompanied by the 'Nankai trough great earthquake' causes severe damages.

The prefectural government is collaborating with its town on implementing a project that is intended for protection of human lives against slope failure and for creation of evacuation space against Tsunami. An example is shown in Fig.11.

Fig.11 An example evacuation place in Taiji town

Fig.12 Sediment-related disaster map

4.2 'Non-Structural' measures

Despite the prefecture's investment on constructing facilities that aims to protect residents' lives and their property, the percentage of the areas, where sediment-related disasters prevention facilities have been constructed of the total dangerous areas, only remains at an extremely low rate of 20%. There are severe sediment-related disasters happening nationally due to the influence of recent years' climate change i.e. the record-breaking local guerilla rainfall and heavy rainfall triggered by Typhoon TALAS in 2011. Establishing facilities at all dangerous areas requires enormous budget and long term period. In this condition, it is indispensable to promote 'Non-Structural' measures such as the establishment of warning and evacuation system, etc. still more in the future and the prefectural government is implementing various programs in order to reduce disaster impacts efficiently.

4.2.1 The information on places influenced by disasters

It is necessary for residents to recognize the significance on the disaster prevention policy, "one protects one's own life", and to understand the information on damaged places. In order to achieve this, the prefectural government publicly notifies the information on dangerous spots for sediment-related disasters through the website to the residents.

Furthermore, the prefectural government discloses appropriate information on areas that they designated based on the 'sediment-related disaster prevention law' in order to promote 'Non-Structural' measures such as the establishment of warning and evacuation system. This public notification is shown in Fig.12.

4.2.2 The information of time

Since 1994, the prefectural government has installed rainfall gauging stations and developed equipment for sending and processing rainfall information. Currently the prefectural government is observing rainfall information collected by their 182 rainfall gauging stations installed within the prefecture in real-time and concurrently provides rainfall information through not only the website but also digital TV broadcast and mobile phone SMS (mailing) services. Moreover the prefectural government, in cooperation with the local meteorological observatory, has been issuing 'sediment-related disaster warning information' since 2007 on behalf of promoting warning and evacuation activities by municipalities and residents. Furthermore, based on a lesson from 2011 catastrophe, a criterion of sediment-related disaster warning information, which is called as 'sediment-related disaster warning division figure' is also publicly informed through the local digital data broadcasting system in order to acknowledge the public with more easily understandable information. An example of publication is shown in Fig.13.

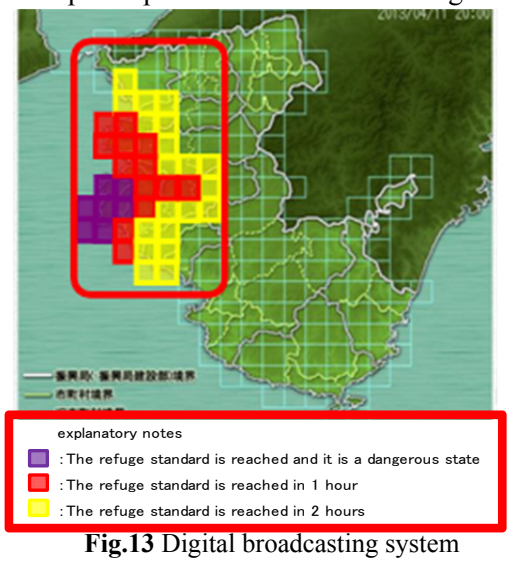

Fig.13 Digital broadcasting system

4.2.3 Training and advocacy to enhance residents' awareness on disaster prevention

The prefectural government is operating warning and evacuation trainings in which municipalities and residents participate during the national sediment-related disaster prevention month and holding seminars in order to provide appropriate knowledge about sediment-related disaster prevention. The training is illustrated in Fig.14.

Fig.14 warning and evacuation training

In addition, in response to requests from elementary schools, the prefectural government is also holding lessons about sediment-related disaster prevention and simultaneously provides effective advices to school teachers in relations to the disaster-prevention education.

5. CONCLUSION

We explained the historical disasters and the general countermeasures against sediment-related disasters in the prefecture. It is forecasted that the disasters due to the influence of climate change such as the gigantic typhoon affected in Philippines in 2013 and the record-breaking localized torrential rainfall will cause more severe damage. In order to protect the residents' lives from sediment-related disaster events, it is necessary that the prefectural government promotes the present programs and implements countermeasures as follows.

- To support community-based disaster prevention planned by municipalities
- To provide more easily understandable information for warning and evacuation activities
- To reduce disaster impact through adding a viewpoint of disaster prevention to land utilization plans in meso-mountainous regions
- To contribute to disaster prevention education and folklore of disaster remembrance

REFERENCES

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[2,3,4)] Erosion and sediment control division, Wakayama Prefecture