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SPECIFIED PROBLEMS ON WINTER EARTHQUAKE DISASTERS AT SNOWY COLD REGION IN JAPAN

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SUMMARY

Problems on winter earthquake disasters at snowy cold region in Japan are discussed in this paper. Northwestern part of Japan has much snowfall in winter and an occurrence of earthquake under the condition of much snow is anticipated with high probabilities. It might cause serious problems in an emergency response due to heavy snow and cold temperature. In this paper, past earthquake disasters in Japan under the snow conditions are surveyed through literatures. Then countermeasures to be considered are discussed referring present situation.

INTRODUCTION

Earthquake disaster under the condition of heavy snow and cold temperature causes serious problems in an emergency response. It is still fresh in our memory that the Kobe earthquake of 1995 took place in wintertime and homeless peoples were compelled to be exposed to a cold wind. In Japan half of her territory belongs to heavy snowfall region and many cities are surrounded by snow for one third of a year. For examples, Sapporo is a phenomenal snowy million city in the world which has more than 1 meter fallen snow deposit. Therefore countermeasures for earthquake disasters under the snowy cold conditions are indispensable in the northern part of Japan. However as for winter earthquake, main effort had been concentrated to snow load for building and an emergency response under snow is not considered in details. In this paper, problems are listed up through a survey on past damaging earthquakes in Japan. Then countermeasures to be considered are discussed referring present situations. At first, literature survey on damaging winter earthquakes occurred at the snowy cold region in Japan are made. Secondary, earthquake prevention planning prepared at local municipalities in snowy cold region are investigated through documents. A questionnaire survey of present situation are also performed to the whole 212 municipalities in Hokkaido, northernmost island. Then countermeasures to be considered in snowy cold regions are summarized from above considerations.

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SNOWY COLD REGIONS IN JAPAN

Japan Islands are located east side of Eurasian continent and separated by Japan Sea. In winter cold dry wind comes from Siberia to Japan crossing the Japan Sea and becomes wet getting humidity from the Tsushima warm current which flows from south to north along the islands. This wet wind is blocked by high mountain ridges and brings much snow to the Japan Sea side regions. Figure 1 shows the comparison among world cities in the cold region with average temperature and precipitation of January. Japanese cities show extremely high precipitation in spite of not so low temperature and this indicates that Japanese northern cities have much influence by snow.

Figure 2 shows a location map of Heavy Snowfall Area designated by the Special Countermeasure Law for Heavy Snowfall Area. Area where an average cumulative daily snow depth is more than 5,000 cm-day is defined as Heavy Snowfall Area and 967 municipalities are designated to this area which correspond to 52 percent of the whole area of Japan and 18% population is living. Among them Special Heavy Snow Region is designated to 280 municipalities.

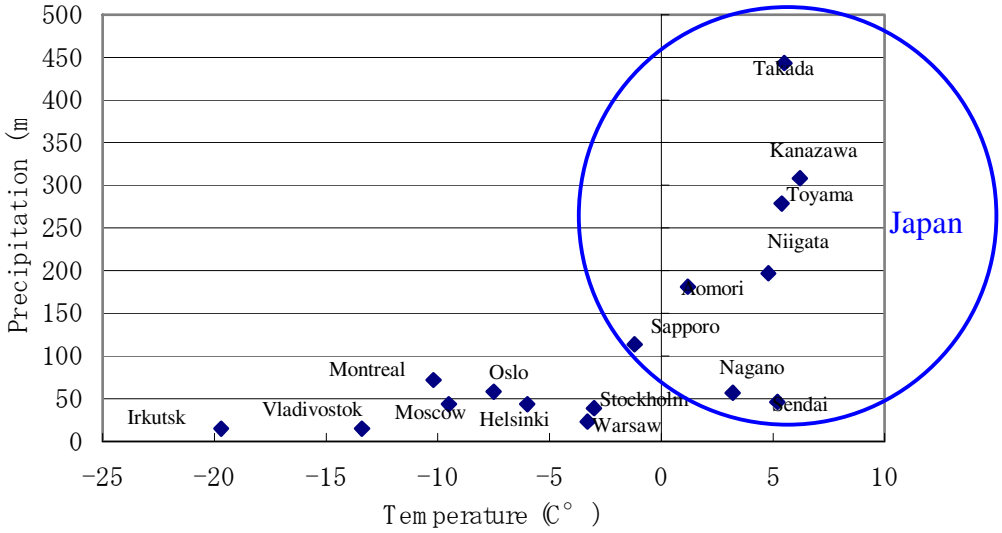

Figure 1. Comparison among world cities in the cold region with temperature and precipitation.

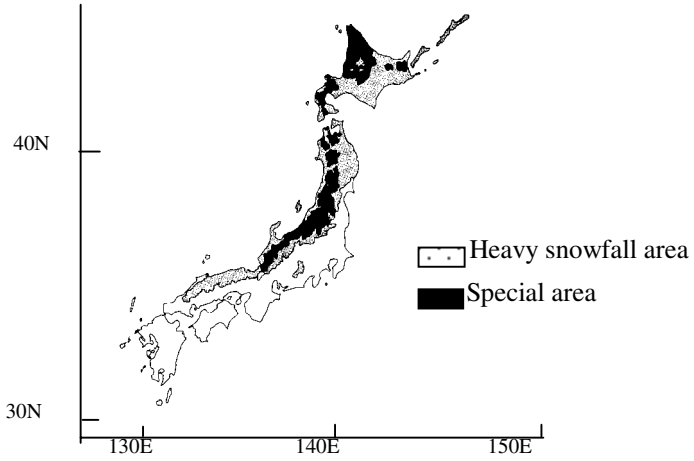

Figure 2. Location map of Heavy Snowfall Area in Japan

LITERATURE SURVEY ON WINTER EARTHQUAKE DISASTERS IN JAPAN

Disasters due to winter earthquakes occurred in the snowy regions are surveyed with earthquake reports and documents. At first winter earthquakes in snowy regions are chosen from the earthquake catalog compiled by Usami [1] and 21 events among 653 are listed in Table 1. In the Usami's catalogue description related to snow can be found in only three earthquakes of 1666, 1961 and 1971. Therefore detailed survey was carried out using "*Dainihon Jishin Shiryo* (Collected Literatures of Japanese Historical Earthquakes)" [2] and articles related to snow are picked out and filled on Table1. For recent earthquakes, reconnaissance reports, scientific papers and newspaper articles are also investigated. Epicenters of these earthquakes are plotted in Figure 3.

An outline of damage and descriptions on snow for each earthquake is as follows;

1) This earthquake is the oldest one occurred in wintertime and caused damage to Akita fortress but no description about snow is found.
2) Earthquake histories jumped to 16 Century reflecting the lack of earthquake history in Northern Japan. This earthquake hit Naoetsu city, western part of Niigata and killed many people but there is no description about snow.
3) This earthquake caused sever damage in Takada, southwestern Niigata, and death total was reached to 1,500 accompanying a big fire. There are many documents denoting heavy snow conditions. They say that snow depth was 1 *joh* and 5 *shaku* in old Japanese length unit, which is equivalent to 4.5 meters. This is the deepest snow deposit among historical earthquakes.
4) Magnitude 7.3 earthquake affected Aomori, northern most of Honsyu Island. This earthquake was also accompanied big fire and caused charred 283 bodies in addition to 989 victims due to building collapse. Multiple documents describ snow conditions and depth of snow is inferred as high as 50 cm to 1 meter. Refugees compelled to stay on temporal houses on the snow.
5) This earthquake also attacked Aomori and damage was concentrate in costal town Ajigasawa. At that time snowfall was recorded in wide area of Aomori district. Height of snow deposit is assumed to be around 50 cm.
6) This earthquake named as "Sanjoh Earthquake" from the place name of the most affected town in Niigata. It is denoted that it was heavy rain in spite of snowfall. No snow was appears in the picture book describing this earthquake disaster.
7) The magnitude of this earthquake is rather big as M=7.5 and affected area is spreading widely from Akita to Niigata but there is no records about snow.
8) This earthquake occurred at Ishikari near Sapporo city and damage to houses and sand blows due to liquefaction were recorded. Much snowfall might be existing from the occurrence date of February in this area but no explanation of sows were found in any documents.
9) This earthquake attacks Hirosaki, Aomori with minor damage and there is no record on snow.
10) This earthquake was occurred in 1872, just after the Meiji Revolution, and precise reconnaissance reports remained. According these reports the affected area had unusual heavy snow at that season and snow was remained in the mountainous area with 1 m.
11) This earthquake occurred in snowy inland but no snow was found in the photograph in reconnaissance reports.
12) This inland earthquake occurred at Tatango peninsula and clear surface faults were appeared. Heavy damage was found along the fault and more than 5,000 houses was collapsed and almost 8,000 were burnt by fires immediately after the earthquake. In that year there was heavy snowfall in this area and more than 1 meter snow was still remained even in early March. Farmer's houses were surrounded by snow deposit up to the eaves. It was fine at the day of occurrence and everybody were working for removing snow. The next day of the occurrence it began to rain and changed to sleet with heavy wind. This storm attacks refugees on the snow evacuated from earthquake fire. A few days later

melted snow made flood and caused additional damage. Newspapers at that time reported difficult situations under the deep snow. Headline of newspapers tell the following situations; “Evacuation from collapsed house digging snow”, “Cold temperature and hunger attack to the refugees in out doors”, “Stay up all night on the snow”, “Evacuation to neighboring village crossing a snowy pass having 2 to 3 meters snow”, and so on. Many photographs taken immediately after the occurrence show deep snow deposits. Photo 1 shows the most damaged Mineyama Town.

Photo 1. Damage in Mineyama town due to the Kita-Tango earthquake of 1927.
Collapsed house in snow (Left) and refugees on the snow (Right).
(after Mineyama Town Office [3])

13) Imaich, Tochigi earthquake of 1959 occurred at snowy inland in winter but no snow effect was reported. It was local earthquake and had 10 dead and 290 collapsed hopuses.
14) Off-Tokachi earthquake of 1952 was one of the largest inter-plate earthquake of magnitude 8.2 and hit wide area of southern part of Hokkaido at early March. Up to 50cm snows were covered at the affected area and outside temperature was 15 to 20 degrees below zero in centigrade. Outbreak of fires were limited in 9 cases in spite of the season that every houses were using stove of coal and firewood. However, burned injuries were dominated during the action of fire fighting. This earthquake accompanied large tsunami and attacked coastal area. At that season floating ices were moving from Okhotsk Sea to Pacific Ocean through Nemuro Channel and reached coastal area of southeastern Hokkaido. Tsunami wave attacked coastal area with floating ices and it caused fatal damage to houses. One of the most affected town was Kiritappu located on the sand dune connecting to a small island (Photo 2). It is one of the composite disasters should be considered in Hokkaido. In general, eastern Hokkaido area has no much snow but temperature is much lower in Hokkaido. Totally 370 temporal housing for 5 families were built in haste to protect homeless peoples from cold temperature of minus 20 degrees.

Photo 2. Tunami with floating ices at Kiritappu due to the Off Tokachi earthquake of 1952.
(after Hokkaido Prefecture [4])

15) Off Daishoji earthquake occurred at Ishikawa, snowy region, in March. However there was no snow was recorded.
16) Nagaoka earthquake of 1961 is well known as a typical earthquake occurred under the deep snow condition. This earthquake was attracted from a viewpoint how snow load on the roof of buildings effects to the building damage. At that time snow depth was almost 2 meters in the field and had 60 to 70 cm snow on the roof. Main concern of the reconnaissance at that time was concentrated to the snow load. Emergency response under deep snowfall was not mentioned in any reports. Details are discussed in the next chapter.
17) This earthquake occurred in Niigata and caused small damage including snow avalanches.
18) Off Urakawa earthquake of 1982 affected southern part of Hokkaido including Sapporo. In Urakawa, the epicentral area, there was no snow because of late March. There was no fire but many injuries were caused by heating devices. Minor but many damages were recognized in Sapporo City in spite of long epicentral distance of more than 200km. In Sapporo snow was still remained as high as 50 cm but no significant effect due to snow was reported. Leakages of oil from small tanks installed in backyard of dwelling houses were found.
19) Off Kushiro earthquake of 1993 took place at the most cold region in the midwinter and many lessons on the disasters due to the winter earthquake were learned. This earthquake occurred at night of January in the coldest region in Japan and outside temperature was minus 7 degree in centigrade. Every houses were using heating devices such as oil stove. In the Kushiro city there were 9 outbreaks of fire and typical causes of outbreak were overturning and fallen objects to heating devises. All the fires were extinguished by the residents before spreading. However, many were burned injury and scalded. The day of earthquake was national holiday and most peoples were stay in their houses and few was injured at outside from fallen objects. Ceilings of a gymnasium and halls fell but nobody was injured because these facilities were not in use. In this area surface ground freezes as deep as 70cm to 1m in wintertime and at the occurrence of this earthquake all the ground were frozen and might be suppressed liquefactions. However frozen ground made difficult for the restoration works of buried pipes of water and gas.
20) It was fine when the Off Noto-peninsula earthquake of 1993 took place and small amount of snow was left in the shade nevertheless in a snowy district. No effects due to snow was reported.
21) Far-Off Sanriku earthquake was interplate earthquake of M=7.5 and severe damage caused in Hachinohe city, Aomori Prefecture. Three were killed by building collapse and 50 houses were collapsed. It was slight snowfall but did not covered.

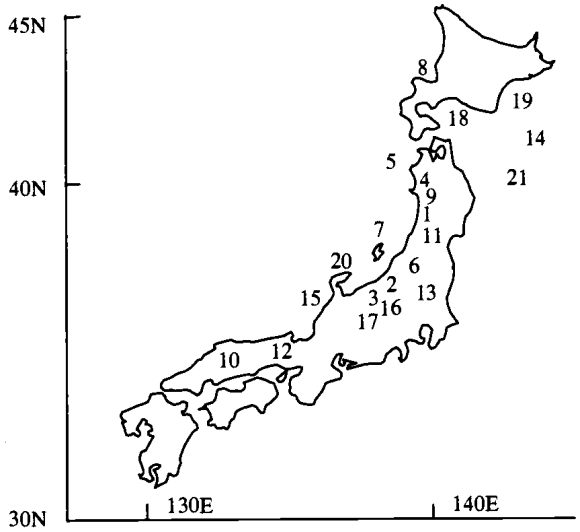

Figure 3. Locations of winter earthquakes listed in Table1.

Table 1 List of Damaging winter earthquakes occurred in snowy region

No.	Day/Mo/Yr	M	Name/Region	Damage	Snow depth
1	03/02/0830	7.5	Akita	To Akita fortress, Land break	-
2	28/01/1502	7.0	Southwest Niigata	Many died in Naoetsu	-
3	01/02/1666	6.3	West Niigata	Dead 1500	4.5m
4	08/03/1766	7.3	Aomori	Dead 989, Big fire	50cm
5	08/02/1793	6.9	West Aomori	Dead 12, Collapsed 154	50cm
6	18/12/1828	6.9	Sanjoh, Niigata	Dead 143, Collapsed 9,898	None, Rain
7	07/12/1833	7.5	Akita, Niigata	Sand blow	-
8	09/02/1834	6.4	Isikari, Hokkaido	Sand blow, Collapsed 23	-
9	13/01/1848	6.0	Hirosaki, Aomori	Minor damage	-
10	14/03/1872	7.1	Hamada, Shimane	Dead 804, Collapsed 5,796	1m
11	15/03/1914	7.1	Senboku, Akita	Dead 94, Collapsed 640	None
12	07/03/1927	7.3	Kita-Tango, Kyoto	Dead 2925, Burned 7,527 Collapsed 5,105,	1-2m
13	26/12/1949	6.4	Imaichi, Tochigi	Dead 10, Collapsed 290	-
14	04/03/1952	8.2	Tokachi-oki, Hokkaido	Dead 28, Collapsed 815	50cm
15	07/03/1952	6.5	Off Daisyouji, Ishikawa	Dead 7, Damaged 8	-
16	02/02/1961	5.2	Nagaoka, Niigata	Dead 5, Collapsed 220	2m
17	26/02/1971	5.5	South Niigata	Injured 13, Damaged 1	
18	21/03/1982	7.1	Off Urakawa, Hokkaido	Injured 167, Collapsed 9	50cm
19	15/01/1993	7.9	Off Kushiro, Hokkaido	Dead 2, Collapsed 12	10cm
20	07/02/1993	6.6	Off Noto, Ishikawa	Injured 1, Collapsed 1	Slight
21	28/12/1994	7.5	Off Sanriku, Aomori	Dead 3, Collapsed 55	Slight

DISASTER RESPONSE DURING THE NAGAOKA EARTHQUAKE OF 1961

As mentioned the previous chapter, the Nagaoka Earthquake of 1961 occurred under the condition of deep snow deposit as 2 meters. In this chapter, more detailed disaster due to this earthquake and emergency response are investigated through reconnaissance reports and newspaper articles at that time.

Heavy snowfall had been continued from the year-end of 1960 in the Niigata region and an inspection team for the heavy snowfall disasters was dispatched from the central government. Under this situation, this earthquake occurred. Magnitude of this earthquake was 5.2 and damaged area was limited in farm settlements of 3 km times 3 km area in Nagaoka City. Totally 220 houses were collapsed and 5 were killed by collapsed houses. At that time this area was covered by snow of 2 m depth and main concern was concentrated to clarify the relation between building collapse and snow load on the roof. Osawa and Yamamoto [5] pointed out that most of dwelling houses had 60 to 70 cm snow on the roof because of the usage of removing snow from roof in this district. In case of two storied houses, surrounding snow could support first story from tilting and reduced collapse rate. On the contrary, non residential buildings of barns and storages were not removed roof snow and many were destroyed.

In the reconnaissance reports there are no description about emergency response and restoration process under the snowy condition. Therefore, reproducing the response process is tried tracing newspaper articles at that time. Referring an archive of the Niigata-Nippoh, one of the main local paper, articles

related to this earthquake are listed in time series. Collapsed houses were buried by snow and rescuer operations were started from removing debris and snow. At first road clearance operations were carried out in priority dispatching snow removal teams from downtown Nagaoka. In the restoration process removal of snow from the main roads was continued. Disaster Relief Law was adopted to the affected area and Self Defense Force was dispatched to remove snows on the road. It is extensively reported that blankets were send and distributed from various organization as an important relief material. National Railway offered reduction and exemption of charge for relief goods.

Emergency response and restoration operations by each sector is listed in time series as shown in Table 2, compiling newspaper articles and official report of Niigata Prefecture [6]. Occurrence time was 03h39m in local time and 20 minute later emergency response were taken at City Fire Department and Nagaoka Police Station. At the Fire Department, headquarter for disaster management was setup and 3 rescue teams were dispatched. Assistance for Nagaoka branch office of Red-cross was also demanded. At the police office disaster inspection teams were dispatched quickly and headquarter was setup at 05h10m. Prefecture office assisted the city governments and at 07h30m Joint Headquarter was setup headed the Mayer of Nagaoka City. Self Defense Force was dispatched receiving the demand from the headquarter and engaged for cleanup road operations.

Construction of temporal houses decided to postpone untill spring because of an anxiety of destroying by an additional snow. Rise building cost and elongation of time limit for start until 40 days are requested to the central government and received. Operations of removing snow from roads were carried out as the most urgent and important countermeasure gathering the manpower and machines from the City, Prefecture, Self Defense Force and private sectors.

Table 2 Emergency response and restoration process by each sector
In case of the Nagaoka Earthquake of 1961

time	City Fire Department	Prefecture	Self Defense Force	Police
03h39m	Earthquake occurrence			
04h00m	Headquarter setup Dispatch 3 rescue teams Demand for Red-cross Emergency call for all staffs			Disaster inspection
04h30m				
05h00m				Call for staffs
05h10m				Headquarter setup
05h30m				Dispatch 89 staffs
07h30m	Joint Headquarter setup			
11h00m	Demand for Self Defense Force			
20h30m			Demand from City	
Next day			Dispatch 769 staffs Cleanup roads	
2-4days	Inspection to households with 150 staffs		Cleanup roads	

PROBLEMS ON WINTER EARTHQUAKES

In Japan 52 % of her territories are heavy snowfall area and one third of the year of December to March has a chance to suffer by snow. From simple calculation, one sixth of the earthquakes might relate to the snow. However, damaging earthquakes under the heavy snow conditions are not so frequent in Japanese long earthquake history. Deepest case was the Niigata earthquake of 1666 occurred in the condition of

deep snow as 4.5m. The second deepest case was the Nagaoka earthquake of 1961 having 2m snow deposit. Earthquakes occurred in the condition of 1m snow was Aomori of 1766 and 1793 and Kita-Tango of 1927. Off Tokachi of 1952, Off Urakawa of 1982 and Off Kushiro earthquakes, which were occurred in Hokkaido are took place in around 50cm snow deposit.

The most attentioned earthquake damage due to snow was roof snow load. In the case of Nagaoka earthquake many houses were destroyed and snow load was discussed. Big earthquake fires are also occurred in the1966, 1766 and 1927 earthquakes. Among them, in the case of 1927 Kita-Tango earthquake more than 7500 houses were burned and many peoples were compelled to exposed in cold outside refuge places. In the case of 1961 Nagaoka earthquake rescue and relief operations were disturbed by deep snow. In Table 3 major earthquakes with heavy snow and their problems are listed in order of snow depth.

Table 3. Problems on winter earthquakes disasters introduced from past earthquakes

Earthquake	Snow	Damage		Fire		Problems
Year Name	depth	dead	houses	dead	burned	
1966 Niigata	4.5m	-	many	large		Extremely high snow
1961 Nagaoka	1.7-2m	5	220	none		Snow load, Snow removal
1766 Aomori	1m	989	5308	308	252	Evacuation on snow
1793 Aomori	1m	12	154			
1927 Kita Tango	0.5-1m	2925	5105	many	7527	Evacuation on snow, Flood
1952 Off Tokachi	50cm	28	815	small		Temporal houses, Tsunami with ice
1982 Off Urakawa	30cm	0	9	none		Leakage of home oil tank
1993 Off Kushiro	10cm	2	12	small		Difficulty in restoration of buried pipe

COUNTERMEASURES IN LOCAL MUNICIPALITIES IN HOKKAIDO

In this chapter countermeasures for winter earthquakes are discussed taking a case of Hokkaido as an example. Hokkaido, northern most island, is the coldest district with much snow in Japan and belonging to single prefecture. In Hokkaido "Regional Countermeasure for Earthquake Disasters" are prepared as usual in other prefectures. Although there had been no description about winter earthquake in the Plan, a chapter of "Plan for Snow and Cold Countermeasure" was newly added from the 1997 edition. Items to be promoted are summarized in Table 4. In accordance with this edition, each municipality has been added such countermeasures about snow taking a chance of revision.

Table 4. Items on Plan for Snow and Cold Countermeasure

Article	Item	Category	Countermeasures
1	General provisions		Promotion of provision against snow disaster
2	Transportation	Road	Removing snow operation system
		Air transportation	Airport snow removing, Preparation of temporal heliport
3	Comunity planning	Housing safety	Snow load on roof, Management of roof snow
		Shelter	Keeping evacuation route
4	Countermeasure against low temperature	Shelter	Alternative heating device, Fuel, Power supply unit
		Refugee	Winter clothes, Blanket, Keeping long-term life
		Visitor for skiing	Safety of facilities, Snow avalanche

Postal questionnaire survey to the whole 212 local municipalities was performed in order to reveal the present situation about countermeasures to winter earthquakes and also snow removal operations. Totally 168 answers (79.2%) were collected. In the questionnaire, three questions about 1) Special countermeasures taken for winter earthquake, 2) System for snow removal operations and 3) Cooperation with snow removal operation, are prepared. At first, as for the actual correspondence to winter earthquake following countermeasures are indicate as listed in Table 5. Most concerned is how to setup and maintain shelter in snowy cold condition, and the second is on relief good for winter earthquake.

Table 5. List of countermeasures taken in local municipalities

Item	Countermeasures		Answers
Mobilization of staffs	Change of meeting place according to road interruption by snow Training in wintertime		8
Evacuation	Facilities for Shelter	Selection of shelter for winter considering heating convenience, snow avalanche risk, evacuation distance etc.	36
	Evacuation route	Priority snow removal from roads Snow removal of stares for evacuation from Tsunami	
	Setup Shelter	Maintenance of heating devices and stock of fuel Emergency power supply unit Supply hot foods Care for aged and handicapped	
	Training	Training in winter for setup of shelter	
Relief goods	Stock and transportation plan Keeping food not to freeze Support agreement with other organizations		11

Snow removal operation is indispensable in Hokkaido and most municipalities have own standing party for winter season. They are on standby in day and night to dispatch when snowfall reached to some amount. Criteria for dispatch is determined by each municipality and most of it is 10cm snowfall and more. In the case of winter earthquake emergency response has fatal disadvantages in cold and snowy conditions, such as difficulty of rescue and emergency transportation, refugees life in cold temperature and so on. However it will be an advantage if operation teams for snow removal can be diverted to earthquake response activity because they are on standby in day and night with much manpower and machines. In general earthquake emergency response and snow removal operation are charged by different sectors and cooperation in earthquake is expected. As for the question of "Cooperation between earthquake emergency response and snow removal operation is possible?", 114 municipalities answered possible among 138 effective reply and 7 are already taken into the countermeasure plan.

CONCLUDING REMARKS

In this paper specified problems on winter earthquake disasters at snowy cold region in Japan were discussed through documentation for historical earthquakes and actual situation survey. Following things can be pointed out.

1) In Japan, 21 winter earthquakes from 830 to 1994 can be listed occurred in snowy cold region.
2) Among them 8 are occurred in heavy snow conditions. Frequency of these earthquakes is not so high but disasters due to this type earthquake easy to enlarge by the influence of snow.

3) The 1666 Niigata earthquake took place in the heavy snow of 4.5 m depth, which is the deepest in our history. The second one is the 1961 Nagaoka earthquake of 2 m snowfall and this earthquake taught us many lessons on snow season earthquake.
4) Three earthquakes accompanied very large fires under the snowfall. In winter season heating devices have high risk for outbreak of fire and firefighting activities are also easy to disturbed. Nearest case is the 1927 Kita-Tango earthquake and refugees compelled to stay on the snow after the fire.
5) Problems during winter earthquakes in snowy regions have been started to consider in Disaster Countermeasure Plan of municipalities.
6) In an emergency response process snow removal operation is the most important and urgent task for rescuer and following relief activities.
7) How to setup and maintain shelter in snowy cold condition is the most important for the recovery process.
8) Snow removal operation is indispensable in northern Japan and working teams are on standby in day and night. It is expected to cooperate with earthquake emergency response.

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