

Emergency Recovery Cooperation between Local Governments and Construction Contractors after 2016 Kumamoto Earthquake

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A set of interview surveys was conducted on emergency restoration activities by staffs of municipalities and construction contractors in the district severely damaged by the 2016 Kumamoto earthquake. The aim of the interviews was to determine the real picture of their activities and co-operation and to find out how they achieved emergency restoration of power in the area. Although the investigation is ongoing, the following were noted as important: 1) Big differences among the disaster response performance of the municipalities, 2) Practical preparation and drills in preparation for a big earthquake, 3) Efficient personnel allocation by separating emergency restoration work from refugee support work, 4) Building good relationships between municipalities and local construction contractors, 5) Preparedness for receiving support from outside and explanation to local construction contractors about support received, 6) Clear division of support operations based on disaster agreement from works based on maintenance contracts, 7) Improvement of disaster agreement by adding clauses regarding automatic enforcement, compensation for cost and for injuries resulting from restoration work, 8) Utilization of voluntary disaster prevention activities in small settlements, and 9) Development of user-oriented disaster management IT system.

Key Words: 2018 Kumamoto Earthquake, local government, local construction contractor, emergency cooperation, infrastructure recovery

1. INTRODUCTION

In the event of a major earthquake that damages social infrastructure facilities, it is important not only to help the affected people, but also to restore facilities in affected areas very quickly. Therefore, support from national organizations is necessary, but in the emergency restoration phase, the municipality of the affected area must cooperate with local construction contractors to maximize the recovery ability of the area. To this end, the authors set up a subcommittee “Study on the Emergency Response of Construction Engineers in the 2016 Kumamoto Earthquake” to the Earthquake Engineering Committee of JSCE, and interviewed the staffs of municipalities and construction contractors in affected area about their emergency responses and problems in their cooperation after the earthquake.

Table 1 Abbreviation for earthquake and organization described in this paper

GEJE	2011 Great East Japan Earthquake	KACC	Kumamoto Association of Construction Contractors
KE	2016 Kumamoto Earthquake	MLIT	Ministry of Land, Infrastructure, Transport and Tourism
JMA	Japan Meteorological Agency	NILIM	National Institute of Land and Infrastructure Management
JSCE	Japan Society of Civil Engineers	RDB	Regional Development Bureau
JWWA	Japan Water Works Association	SDF	Self Defense Force
JSWA	Japan Sewage Works Association	Tech-Force	Technical Emergency Control Force of MLIT

2. PREVIOUS RESEARCHES

Goto, et al.¹⁾ interviewed 49 civil engineers who were in charge of emergency restoration works after the 1993 Hokkaido-nanseioki Earthquake, the 1995 Great Kobe Earthquake, the 2003 Tokachi-oki Earthquake, the 2004 Niigata-ken Chuetsu Earthquake, the 2007 Noto-Peninsula Earthquake and the 2007 Niigata-ken Chuetsu-oki Earthquake, and discussed the importance of cooperation between facility maintenance organizations and local construction contractors. Toyozawa, et al.²⁾ investigated injuries during the restoration work after the 1995 Great Hanshin-Awaji Earthquake, the 2004 Niigata-ken Chuetsu Earthquake, the 2007 Niigata-ken Chuetsu-oki Earthquake, and GEJE, and recommended the implementation of risk assessment at the time of emergency restoration considering special risk factors. NILIM³⁾ conducted a questionnaire survey on the contribution of construction contractors to restoration work after the 2007 Niigata-ken Chuetsu-oki earthquake, and reported that the first response was carried out within two hours of the earthquake and municipalities considered that the role played by construction contractors was significant.

Regarding emergency restoration in GEJE, the Disaster Response Management Sub-committee⁴⁾ of JSCE GEJE Follow-up Committee discussed the effectiveness of autonomous activities of local construction contractors by advance response planning and training. Mori et al.⁵⁾ reported research on the activities of construction companies and discussed the importance of "local self-responsiveness" required immediately after a disaster and a "wide-area continuous cooperation system until restoration in the case of a large area disaster". Morizane et al.⁶⁾ discussed the need to review existing disaster agreements between administration and construction contractors based on lessons learned in GEJE, and proposed that a contract should be automatically entered into according to the JMA seismic intensity information, that compensation for workers injured during emergency restoration work should be equivalent to cases where the governor issues an order, and that expenses for disaster emergency response related works should be borne by the administration.

About the KE, Kumamoto-prefecture⁷⁾, Kumamoto-city⁸⁾, and Mashiki-town⁹⁾ published verification reports for their earthquake disaster correspondence based on questionnaires to their staff, and KACC¹⁰⁾ also compiled the results of interviews with the main member companies in a booklet named "Toward the Future, - A Trace of Emergency Recovery Activity". As academic researches, Inoue and Nakano¹¹⁾ interviewed people concerning the disaster responses of local construction contractors and discussed information transmission and sharing, a disaster response management system, cooperation with municipalities, cooperation among multiple institutions, and compensation for labor accidents. Numata, et al.¹²⁾, using questionnaires and work time records, investigated the disaster responses of the staffs of Ishinomaki-city and Yabuki-town of Fukushima at GEJE, Kumamoto-city at KE and Joso-city during the Kanto-Tohoku heavy rain. They developed a framework classified into 48 types of operations and showed its applicability for estimating overall disaster response workloads and prioritizing the limited human resources. Kakimoto and Yoshida¹³⁾ analyzed the process of decreasing the number of evacuees, as a large number of evacuees were generated by KE and became a burden on the staff involved in recovery and reconstruction of the municipalities. Their numerical model showed effects such as the service level of shelter, recovery of water supply, and reduction of the effects of aftershocks.

3. ORIGINALITY OF THIS RESEARCH

The above-mentioned past researches have investigated subjects concerning earthquakes before KE^{1) to 6)}, or summarized problems from the viewpoint of either local government or construction contractors^{7) to 12)}, or analyzed factors regarding the number of evacuees¹³⁾. This research was intended to study the emergency responses of municipalities and local construction contractors for the restoration of damaged local infrastructures just after the KE disaster. To this end, we interviewed the staffs of both sides and discussed the issues from both perspectives to maximize the recovery power of the area, focusing on the overall picture of emergency responses and their cooperation.

4. TARGET AREAS AND BASIC INFORMATION

The interview covered emergency recovery activities from the KE foreshock of April 14th until the end of May, 2016. The target areas were Minamiaso-village, Nishihara-village, Mashiki-town, Kashima-town and Kumamoto-city, as shown in Figure 1. Table 2 shows basic information of the target municipalities. Table 3 is a list of offices where the hearings were carried out with staff involved in the restoration of infrastructure

facilities. Figure 2 shows the flow of the alignment and cooperation among organizations during the emergency restoration. The organizations colored pink and green were the targets of this study.



Using satellite image data and national city boundaries provided by ESRI, and numerical maps issued by the Geographical Survey Institute

Fig. 1 Studied municipalities (Kumamoto-city, Kashima-town, Mashiki-town, Nishihara-village, Minamiaso-village)

Table 2 Basic information and disaster situation of the surveyed municipalities

	Area (m ²)	Population *1	Number of household *1	Number of municipality staff *2	Dead & Re- lated Death	Number of to- tally destroyed houses	Rate of totally destroyed houses *3	Maximum number of evacuees *4
Minamiaso-village	137.32	11,503	4,676	138	16 & 14	699	0.245	3,000
Nishihara-village	77.22	6,802	2,341	64	5 & 3	512	0.207	3,000
Mashiki-town	65.67	33,611	11,477	172	20 & 23	3,026	0.286	16,100
Kashima-town	16.65	9,054	3,170	60	3 & 2	234	0.104	2,800
Kumamoto-city	390.32	740,822	315,456	3,528	4 & 79	2,457	0.020	108,300
*1 October 1st, 2015 tabulated value *2 April 1st, 2016 tabulated value *3 No. of totally destroyed/(No. of totally destroyed + Half destroyed + Partially destroyed) *4 Extracted from “Kumamoto disaster management headquarters meeting materials”, The maximum value between April 17th and 19th and not the same date and time. It seems that private evacuees were not included.								

Table 3 List of offices where the hearings were done

Administrations	Construction contractors
Kumamoto-prefecture. Civil Engineering Dept.	KACC Main Office
Kamimashiki RDB of Kumamoto-prefecture.	KACC Kumamoto-city Branch
Aso RDB of Kumamoto-prefecture.	KACC Kamimashiki Branch
Kumamoto-city Civil Engineering Dept.	KACC Kashima & Mashiki Support Group
Kumamoto-city Water & Sewerage Bureau	KACC Aso Branch
Mashiki-town Disaster Management Depts.	Minamiaso-village Association of Construction Contractors
Mashiki-town Road & Sewerage Depts.	Kumamoto-city Pipe Work Contractor's Association
Minamiaso-village Construction Dept.	Mashiki-town Pipe Work Contractor's Association
Kashima-town Construction Dept.	Japan Federation of Construction Contractors Kyusyu Branch
Nishihara-village Construction Dept.	

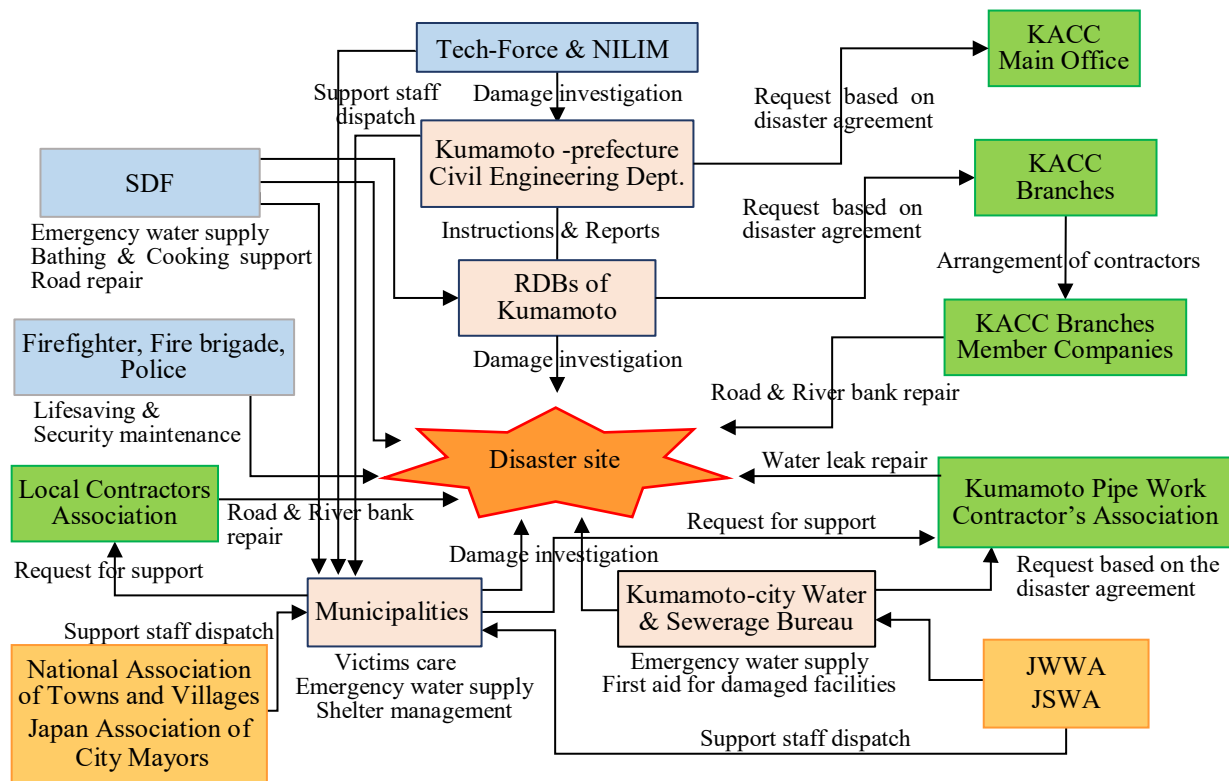


Fig. 2 Flow of the Cooperation of Emergency Response Organizations

5. INTERVIEW RESULT

Although a comprehensive compilation including Kumamoto-city has not been completed yet, characteristic cases found in each area are introduced below.

5.1 Case where response in initial stage was isolated and difficulties encountered

(1) Disaster situation

Aso-city and Minamiaso-village are located inside the great caldera of Mt Aso. The shaking of this area during the foreshock on the evening of April 14th was JMA seismic intensity 5-lower. Some roads were damaged, but they were repaired by the 15th. However, the main shock in the early morning of the 16th in Minamiaso-village was JMA seismic intensity 6-upper and caused major damage to roads and railways in the area. The arterial roads from Kumamoto area (National highway 57, 325 and Prefectural road Kumamoto Takamori Line) were cut off due to damage to bridges and tunnels, landslides, etc. Just one mountain road where only small vehicles could pass through survived. It took six days to restore another mountain road where large vehicles could pass through from the Kumamoto-city area. Although access from Oita-prefecture and Miyazaki-prefecture were possible, roads in the area were damaged here and there and an approach route had to be found by trial and error. A high-voltage transmission line was damaged by landslides and power outage occurred. However, a large number of power generating vehicles were mobilized and power was gradually restored by the 20th. Part of the telephone line was broken, and the mobile system was suspended for several days due to damage to some transmission stations and exhaustion of backup power at relay stations.

(2) Disaster management and lessons

Aso RDB of Kumamoto-prefecture was in charge of the Aso area and had 148 staff. 119 (80%) of them lived outside Aso, and many of them were commuting from Kumamoto-city area by car at the time of the earthquake. The Aso area suffered no major damage on April 14th, so most staff returned home in the evening of the 15th (Friday). The main shock occurred on the early morning of the 16th, and roads and railways were damaged, making it very difficult to enter Aso from the Kumamoto-city area. There were 10 staff in charge of road maintenance and management, but only three young persons were in the Aso area and were able to go to

the RDB office right after the main shock. Other staff could not reach the office until the evening of the next day. Making the situation worse, there was not enough time from the change in personnel status at the beginning of April, and there were insufficient handover conditions in the cooperation system with local construction contractors. Small local contractors who had a one-year maintenance contract with Aso RDB were called for restoration right after the earthquake. However, the damage far exceeded their response capability and confusion occurred. In the meantime, push-type support teams such as SDF and Tech Force accompanied by other prefectures' contractors entered the Aso area and carried out repairs to the damaged roads and infrastructure. KACC Aso Branch, which had signed a disaster agreement with Aso RDB, had assigned one contractor to each road in the area before the earthquake, and was ready to dispatch them if requested by Aso RDB. However, due to the confusion, it took 5 to 6 days for Aso Branch to receive a dispatch request from Aso RDB. Meanwhile, many of the employees of the local contractors participated in the rescue activities, and some contractors had previously signed a disaster agreement with Kumamoto River-and-Highway Office of MLIT and responded to its request. Hence KACC Aso Branch was not involved in the emergency restoration work of Aso RDB in the early stage.

At the Minamiaso-village office, five road section staff and three water supply section staff were forced to pass the cut-off section of road on foot or to detour there by taking a long drive, but they still arrived at the office within 24 hours. Although care for refugees was not their responsibility, they were forced to support people who came to the office in the first 24 hours. Their principal tasks started from the 17th. They surveyed the location of damaged road and went on setting traffic restrictions for safety. Meanwhile, Tech Force, SDF and the water service units from other municipalities came and carried out restoration works as a push-type support. The village office asked SDF to repair local and the prefectural roads that were vitally important in the lives of villagers.

Blackout occurred and telephone lines were broken, and the work of SDF, Tech-Force, police and fire department was initially disorderly. As a result, the requested route for construction contractors was messed up. Local contractors voluntarily conducted emergency rescue activities in cooperation with local fire brigade and repaired affected structures around their office. Some contractors restored prefectural roads necessary for maintaining grazing in response to requests from dairy farmers, and also voluntarily repaired a prefectural road connected to the crematorium. It was about 10 days after the earthquake before the Minamiaso Association of Construction Contractors started to respond systematically to requests from the village office. Then contractors from less damaged areas entered the heavily damaged area, and, because of their extensive local knowledge, were entrusted with emergency construction of a new road connecting the existing village roads.

Isolated areas like Aso can occur anywhere in our hilly and mountainous country. The public sector in Aso as well as the private one should have planned for a large-scale earthquake disaster, set an effective disaster prevention agenda, implement it and carry out practical disaster mitigation drills. In this disaster, support by Tech Force and SDF contributed greatly to the early recovery. However, there was a lack of information on push-type support, and local construction contractors were confused. To make things worse, a so-called “face-to-face relationship” between Aso RDB and KACC Aso Branch had not been established because the earthquake occurred shortly after personnel changes had occurred at Aso RDB. That was why the emergency disaster cooperation arrangement that KACC Aso Branch had prepared previously did not function.

5.2 Case where strong communities with high awareness of earthquake disaster contributed

(1) Disaster situation

Nishihara-village is located on the Kumamoto-city side of Aso somma. The shaking on the evening of April 14th was JMA seismic intensity 6-upper and that of the main shock in the early morning of the 16th was 7. Although the village office building could be used, roads were distorted into a waved pattern, and especially the main roads leading to the Aso area were cut off by damage to bridges and tunnels. The village is located on the fault zone of the main shock, which resulted in numerous land-slides and ground fissures. The bank of Ohkiri-hata dam was damaged, and the water level was lowered as an emergency measure. Housing damage was huge, and there were settlements where 80% of the houses were completely destroyed. The village was out of power but recovered by the 17th. The water supply was a simple system and was managed in each settlement. It took one and a half months to fully recover because of the turbidity that occurred in the water sources. The phone lines were reconnected soon after.

Nishihara-village is under the jurisdiction of the Aso RDB of Kumamoto-prefecture, and is under the umbrella of KACC Aso branch. However, there was little coordination and cooperation between them because of the traffic difficulties. However, this village had been performing a practical disaster mitigation drill assuming a near-field earthquake, and the settlements scattered in 30 places in the village had a spirit of self-sufficiency. Their community-based mutual aid for emergency was demonstrated to be practical and effective.

(2) Disaster management and lessons

Five staff of the village office were in charge of roads, rivers, bridges, slopes, and water supply. After the main shock, they continued to stay in the village office for 24 hours. Even though they were not dispatched to evacuee shelters, five were not enough to handle everything. They asked each head of the voluntary fire brigade of each settlement to gather at the village office every day and to exchange information about the disaster restoration. As there were people with large machinery for their dairy farming or people doing construction work in each settlement, they gathered in their own settlements and carried out tidying, road repair, restoration of water pipes etc. by themselves.

In 2003, the government's Earthquake Research Committee announced that the probability of occurrence of a M6 class earthquake with the Futagawa fault as the source was 6% in 30 years. The announcement became a topic at the meeting of the village office and the fire brigade leaders, and they decided to carry out a practical disaster prevention drill for a big earthquake disaster once in two years. One of the drills had been taken place around 7 months before KE. Although there was no guidance from the experts, each settlement assumed its specific damage, and conducted training to evacuate to an area away from the assumed danger place. Training was also conducted to rescue trapped residents by breaking the roof of a collapsed house model, and nine people were actually rescued using the same procedure right after the earthquake.

Twice a year, each settlement participated in a competition on cleaning of roads in each settlement, and the village office sponsored a prize for the winner. Although the amount of the prize was so small that it could be entirely spent at a drinking party, it not only helped to maintain the roads but also helped strengthen the community. It is said that there were events for a field burning and road maintenance from olden days, and there was also a road cleaning contest in the village that dated from before the Second World War, and that had continued to the present. Light construction work such as filling in pavement pot-holes were carried out by the leader of the settlement after obtaining the material from the village office. Spraying of snowmelt agent on the roads in winter was done in the same manner. Even if the fuel cost and some overhead expenses were added, the cost was low, and it also helped to foster self-help. Residents repaired the roads of their settlements but not the roads outside. Local construction contractors in the village voluntarily decided their range of responsibility for roads outside the settlements, including prefecture roads, to be maintained by each contractor.

About 60% of the villagers lived in hilly settlements and 40% lived in flat and emerging residential areas near the airport. The self-help ability of the residents in emerging areas seemed to be low. The village office had tried to raise their ability, inviting the people there to participate in the road cleaning competition, calling for participation in the children's association and joining the voluntary fire brigade.

The village office gratefully accepted push-type support from Liaison, Tech Force and others. Higashimatsushima-city, which Nishihara-village supported in the case of GEJE, dispatched some staff and advised placement of staff, waste disposal, dealing with the news media and so on. The village office faced the need to issue victims' certificates and created a convenient GIS based system in two week by requesting an IT company that had offered support. While setting up the system, one of the staff was exclusively in charge of it. He has since progressively added other functions to the system, and is utilizing it for various other services too.

Several months after the earthquake, a heavy machinery operator who worked in the debris collection site was hit by a piece of wood and died. Because the contractor was on a normal construction contract, the compensation was paid as a general workers' accident.

5.3 Case where cooperation between municipality staff and local construction contractors was effective

(1) Damage situation

Kashima-town is located between Higashi-ku and Minami-ku of Kumamoto-city. Except for some hills in the east, it is surrounded by three rivers: the Midori River, the Kase River and the Kagata River. It is a small town, but is blessed with ground-water. Each house has its own well; there is no public water supply.

The foreshock was JMA seismic intensity 6-lower and the main shock was 6-upper. The town office building did not suffer major damage. The riverbanks surrounding the town partially sank and cracked, but MLIT and Kumamoto-prefecture repaired them promptly. However, there was a lot of damage to the road facilities managed by the town, such as cracks in pavements and steps at connections to large structures. On the other hand, there was no damage to highway overpasses maintained by the town and no major damage to sewerage facilities. Mobile phones were still usable.

(2) Disaster management and lessons

The construction section of the town at the time of the earthquake had five management units: administration,

construction, city planning, sewerage and environment. They employed 20 staff, and most of them were able to come to the office. However, many evacuees gathered in the town office as well as in the public hall in each district. The staff of the construction section also had to take charge of refugee care, which decreased the time allocated to their original duty. Hence, only two or three of the staff could go out on road patrol.

Thus, JSWA was contacted and came to their support because BCP was prepared by the sewerage team. In addition, it was really helpful that Kashima Town Hall (next to the town office) had been completed just before the earthquake and could be used as a place for outside supporters to stay. Tech Force inspected the bridges on the expressway, and Liaison of MLIT assisted by arranging safety equipment such as lighting vehicles and barricades. On the other hand, the staff of the construction section had a very hard time compiling a disaster assessment document to obtain financial assistance from Central Government, because they had never experienced such a task and also that they were required to present the document as soon as possible. It was difficult for them to produce the document while staying in the allocated refugee shelter.

Kashima-town had signed a disaster mitigation agreement with the Kashima-town Association of Construction Contractors, and most of the requests for emergency restoration were issued to the secretariat of the association. The secretariat searched for a contractor that could handle the content of each request and entrusted him to respond to it. The town's staff patrolled the main roads in the town, and asked the secretariat to take action on portions that needed repair. They asked contractors to patrol other roads and repair them if necessary, and if there was a report of necessary repair work, the staff went to confirm it. The A2 class construction contractors of Kashima-town responded to requests of MLIT and Kumamoto-prefecture, and the B class construction contractors were asked to respond to the request from the town. The head of the construction section of the town said that such a response was possible and effective, based on the trust relationship between the town office and local contractors.

One of the A2 class contractors in Kashima Town, whose home and office had been destroyed by the earthquake, engaged in emergency restoration work using a prefabricated hut as a temporary office. Two staff members suffered injury and could not come to work. Seven or eight staff slept in their cars at night, and continued to be involved the restoration work for about a month. At the time of the earthquake, this contractor had a contract for maintenance work with Kamimashiki RDB office, and also had a disaster agreement with the river management office of MLIT, and hence the site operation became extremely hard. Also, meals had to be prepared for the site staff. SDF's cooked meals were collected and delivered to the site.

5.4 Case that suffered serious damage and met difficulty to launch emergency recovery

(1) Disaster situation

Mashiki-town is located between Higashi-ku of Kumamoto-city and Nishihara-village. The northwestern part of the town is on a gentle plateau, the southeastern part is a mountainous area, and the low-land in the middle is a paddy field along the Kiyama River. The northeastern part is in contact with Kumamoto Airport. Blessed with groundwater, the water source of the public water supply is wells.

Both the foreshock and the main shock were of JMA seismic intensity 7. Approximately 30% of the houses in the town were completely destroyed. The number of evacuees increased dramatically due to the serious damage, reaching 48% of the population at its peak. 18.4% of the houses of town staff were completely destroyed, the main town office building was also damaged and unusable, power outage occurred, the administrative radio system failed, and the disaster response headquarters of the town was forced to relocate again and again. The town office faced serious difficulties in carrying out effective disaster response management.

It was known that there was an active fault just below the town, but Mashiki-town office had not prepared well and, unlike Nishihara-village, had not implemented any effective drill for a large earthquake disaster..

(2) Disaster management and lessons

The attendance rate of town staff had reached 95% by 17th, but many of them had to respond to the refugee shelter. Most of the time, 30 staff were in charge of roads, rivers, water supply, and sewerage. However, only twelve staff (5 for roads and rivers, 3 for water supply, 4 for sewage) were allotted to their original works. Moreover, these twelve persons were forced to deal with frequent telephone calls coming all day as well as to write disaster assessment documents, and became very exhausted. In late April, overtime hours for the staff in charge of roads and rivers reached an average of 153 hours for half the month.

14 local construction contractors in the town were affiliated to the Mashiki-town Association of Construction Contractors. Many of them were supposed to participate in emergency recovery activities even though they themselves had suffered damage. But the upper organization, KACC Kamimashiki Branch, could be in touch with only one contractor in the early stage after the earthquake

Some roads and river facilities are managed by MLIT and Kumamoto-prefecture in Mashiki-town. Requests for dispatch to the MLIT facilities were made directly from MLIT regional office to contractors, and

the requests to the prefecture facilities were announced from Kamimashiki RDB to contractors through KACC Kamimashiki Branch. The constructors outside Mashiki-town responded to these requests, but they did not participate in the repair work of the town roads.

There are around 400 town roads comprising hundreds of kilometers in total length. The town office had insufficient hands and time to grasp the entire damage situation of the town roads and to make a strategic recovery plan. As a result, the road staff of the town office fell into an ad hoc response situation forced by requests from the disaster management headquarters or from large-voiced citizens. Thus, on a first-come-first-served basis, they searched for contractors who could respond. Meanwhile, there was also a situation in which road staff, sewerage staff and agricultural administration staff of the town had to compete for getting manpower of local contractors.

The order system was changed halfway through to a method in which the road network was divided into areas and contractors allocated to each area, as there were many places that were repaired once and then had to be repaired twice or more due to the progress of the damage. Thus, the town office was often told by contractors "We already fixed this", and the town office paid based on submission of photos proving the repair work had been done. There was also an idea of introducing an annual maintenance contract with a local contractor some time before the earthquake, but this had not been realized. One of the difficulties in re-opening a road was to find the right owner of the debris that was blocking the road. They had often been evacuated and could not be located quickly.

The Mashiki-town Pipe Work Contractor's Association had 15 member companies, but many of them had only 2 or 3 staff, and they had to perform emergency restoration work while entrusting their families to refugee shelters. The chief of the association contacted the town's disaster response headquarters every morning and played a role in communicating the needs of the town to each member to enable them to contribute effectively. The town staff in charge of water supply mainly checked the water source, and the support teams of JWWA who came in as push-type support and the above mentioned Mashiki-town Pipe Work Contractor's Association were in charge of pipeline restoration. The JWWA teams were mainly allocated to the urban area, and the local pipe work contractors who were familiar with the geography were dispatched to the mountainous area. Mashiki-town was a member of JWWA, but had not signed a disaster agreement in advance. The town office seemed to have taken about a week to issue a formal support request to JWWA. As there were many types of pipe materials, the support teams had to struggle to get the appropriate repair materials. Kumamoto-city recovered most of its water supply by April 21, six days after the main shock, but it was not until the end of May when Mashiki-town recovered its water supply over the whole area.

The Mashiki-town sewage treatment plant was damaged and the treatment capacity dropped to 1/3, but it was recovered to 2/3 by the end of April due to the contributions of JSWA and cooperating companies. The emergency situation in which untreated sewage would be released to the rice field in the town was thus avoided. The town had not made an agreement with JSWA in advance, but by the 19th, the report system had been prepared by the sewerage BCP and a support request was delivered to JSWA from Kumamoto-prefecture. From the 20th, the support teams of the municipalities in Kyusyu province carried out a primary survey, although there were problems obtaining many kinds of metal fittings to open many kinds of manhole lids. With the partial restoration of the water supply, it was found that some pipelines had suffered damage. Therefore, sewage was removed by vacuum car first, and then a temporary pipe was buried to a shallow depth between the manholes.

In the local disaster prevention plan of Mashiki-town, it was stipulated that measures against wind and flood damage should be applied to the earthquake disaster countermeasures. Therefore, the backup of data was completed and alternative facilities and an alternative command system to be activated when the town office main building could not be used was prepared. However, there remained problems such as seismic reinforcement of the town office building, water and food storage for town staff during a disaster, emergency power supply, multiplexing of communication means, and so on. Administrative radio, homepage of town, and e-mail service were prepared as information provision facilities to town people. However, there were only 2,000 e-mail service registrants (6% of population) at the time of the earthquake. The administrative radio system stopped functioning from the morning of April 17th to 28th due to the power failure and the exhaustion of the emergency power supply at the relay station. Therefore, the town office opened a temporary disaster FM radio station, but it was not easy to make the people aware of it.

Disaster agreements had not been concluded in advance with Mashiki-town Association of Construction Contractors, KACC, JWWA, JSWA, etc. In the initial stage of the disaster response, the town office seemed to have insufficient recognition of the push-type support of Tech Force. However, it later received assistance from Tech Force in preparing a disaster assessment document for the bridges. The town office also received

support from Liaison of MLIT in ordering materials for disaster mitigation operations.

The emergency restoration where prefectural roads intersect with national roads and where prefectural roads run on the river dike managed by MLIT faced some confusion because of poor communication between MLIT regional office and RDB, Kumamoto-prefecture. An incident occurred in which the mobilized construction contractor's staff and workers had to wait on the site all night, which severely affected their morale.

They could have spent the night with the refugees in the shelter, but their sense of responsibility did not allow them to do so. Many of them did their best to participate in the restoration without being able to take a bath or receive enough food. Nevertheless, they still received complaints from refugees from time to time.

Concerning accidents during the recovery work, there was an injury caused by a working vehicle that ran backwards. In another incident, the water supply restoration team had dug a hole about 2 meters deep when an aftershock of JMA seismic intensity 5 happened while workers were in the hole. Fortunately, they were able to jump out.

6. CONCLUSION

The investigation is ongoing, but the following can be pointed out as an interim report.

- (1) Considering that an earthquake disaster may occur in any area, municipalities and local construction contractors should have an emergency restoration plan to handle serious damage to communications, electric power, water supplies, sewage, roads, etc. in their area. In addition, they should carry out joint practical drills and establish a face to face relationship.
- (2) Municipalities should carry out seismic strengthening of their office buildings, maintenance and frequent trials of in-house power generation facilities, multiplexing of broadcast and communication facilities, storage of a certain amount of water and food, and provision of toilet facilities for office staff.
- (3) Construction contractors should carry out seismic strengthening of their offices, prepare storage of a certain amount of food assuming that meals will not be available at restoration sites, develop a method for obtaining heavy machinery fuel, prepare a place for waste storage, provide toilet facilities, and prepare bicycles or motor bikes.
- (4) Municipalities should prepare for support from Liaison of MLIT, Tech Force, SDF, Association of Local Governments, JWWA, JSWA, etc. and complete disaster mitigation agreements with them in advance. In addition, they should inform the local construction contractors of these support systems to enable them to take their important role in recovery.
- (5) The staff in charge of infrastructure restoration at municipalities should be relieved of the refugee support task. In addition, works such as preparation of disaster assessment documents and telephone answering should be outsourced.
- (6) The distinction between a dispatch according to a maintenance contract and a dispatch according to a disaster agreement between municipality and local construction contractor should be made clear.
- (7) When communication between municipality and construction contractor becomes extremely difficult, emergency countermeasures by the contractor at his own discretion could speed up restoration in many cases. Thus, rules for the trigger and range of the automatic dispatch, clearing method of expenses and compensation for accidents should be written into the disaster agreement.
- (8) A representative of the local construction contractors should be present at the headquarters of the municipality during emergency restoration stage, and a system should be adopted in which the representative can promptly mobilize the appropriate construction contractor following a request issued from head-quarters.
- (9) It is inevitable that disaster recovery survey and emergency restoration work are more dangerous than normal works. Local construction contractors and piping contractors have experience with a danger that is directly linked to a fatal accident while doing emergency work. For injury or death during the emergency survey and/or the restoration work, compensation equivalent to the public affairs disaster compensation should be provided.
- (10) There was a village where settlement-level voluntary activity greatly contributed to mitigation of the earthquake disaster of its hilly area. This experience is a good lesson for community-based disaster prevention and mitigation management.
- (11) The utility of a disaster prevention information system is growing with the enhancement of the communication infrastructure and Web resources as well as the advancement of tablet terminals. It would be more utilized if it were also used in daily work and continuously improved in accordance with the user's requirements. Information security measures are also essential.

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APPENDIX

Member List of Sub-committee “Emergency Response of Construction Engineers in the 2016 Kumamoto Earthquake ”

Role	Name	Affiliation	Role	Name	Affiliation
Chairman	Y. Goto		Member	A. Kanbayashi	Takenaka Corp.
Vice-chair	H. Iwahara	Kagawa Univ.	Member	N. Ohbo	ADEP
Vice-chair	R. Kakimoto	Kumamoto Univ.	Member	Y. Ogawa	Bosai International
Secretary	S. Sato	Nippon Koei Co., Ltd	Member	K. Kamita	Keio Univ.
WG Leader	S. Yanagihara	Okumura Corp.	Member	M. Nakamura	Nihon Univ.
WG Leader	K. Yamamoto	TechnicalLink Corp.	Member	H. Murakami	Yamaguchi Univ.
Member	C. Isouchi	Kagawa Univ.	Member	M. Yamamoto	Token C. E. E. Consultants
Member	S. Inoue	Inoueugumi Corp.	Member	Y. Yamamoto	Yamamoto Kensetsu Co., Ltd.

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