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PROTECTION OF CULTURAL HERITAGES FROM POST-EARTHQUAKE FIRE

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SUMMARY

National treasures and important cultural assets of Japan are mostly concentrated in Kyoto, Nara and Tokyo. Particularly, in Kyoto, cultural assets are scattered in the relatively small basin with high density ,which is incomparable with any other city and/or town. Case studies have been conducted to develop a protection system of the oldest wooden temple structure in Kyoto basin from post-earthquake fire, making use of water curtain and the fire extinguish system for the historical preservation area that is spread on hill side of the Kyoto basin is also proposed.

INTRODUCTION

During the 1995 Kobe earthquake, the fire extinguish systems of two famous temples in Kyoto were disrupted and the function of respective systems were lost in spite of the fact that Kyoto is 50-60km away from the damaged area of Kobe. After the main shock of the earthquake, the post earthquake fires took place in many places in Kobe and more than 7,000 houses were burned out. On the other hand, the ratio of old wooden houses in residential buildings in Kyoto is more than 2-3 times larger than that of Kobe. These facts imply that many fires will take place and fire-extinguish system of temples and shrines will be disrupted once Kyoto is fit by major earthquake.

Kyoto was the capital of Japan for one thousand and hundred years before it moved to Tokyo130 years ago. Then there exist many cultural heritages not only building structures but also movable artistic assets. More than twenty percent of the national treasures of Japan are concentrated in Kyoto basin, relatively small area of 12km by 15km. Considering the fact that the occurrence of strong earthquake due to inland active faults surrounding Kyoto basin is anticipated within next few decades, the risk analysis of burning out of cultural heritages in Kyoto basin should be checked for all the wooden building structures that are designated as national treasure.

One of the authors recognized the importance of protection of cultural heritage from fires post-earthquake after the 1995 Kobe earthquake and the Council for Protection of Cultural Heritage from Post Earthquake

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Fire has been organized in 1997, collecting influential people of relevant field. Two years later, a non-governmental organization "Organization for Protection of Cultural Heritage from Natural Disasters" was established and this organization has been approved by Metropolitan Tokyo in August 2001 as a Non Profit Organization.

The government of Japan organized a committee to explore the feasibility of establishing actual fire protection system of cultural heritage from post-earthquake in June 2003 and this committee will make public the basic concept of protection of cultural assets from natural hazards. On the other hand, the local government of Kyoto examined the safety of infrastructures in Kyoto basin against strong ground motion to be excited by an inland active fault which passes through the city.

Thus, the activities in relevant fields for protection of cultural heritage has been gradually activated and some realistic proposals of protection system are expected. Under the situation described above, the authors conducted case studies for developing a protection system of the oldest wooden temple structure in Kyoto basin from post-earthquake fire, making use of water curtain and the fire extinguish system for the historical preservation areas. The results are to be adopted in a project of the Japanese government for establishing the post-earthquake fire protection system in the near future.

VULNERABILITY OF CULTURAL HERITAGES IN KYOTO

Earthquake disaster management of Japanese Government

Japanese Government has reformed the administrative system in January of 2001 and new ministries and agencies have been established. The Cabinet Office is one of them and given relatively higher status than the other ministries. The Office has four major councils to advice the Prime Minister on important issues. The Councils are (name is not official one)

1) Council on Economy and Fiscal Policy,
2) Council for Science and Technology Policy,
3) Central Disaster Management Council and
4) Council for Gender Equality.

As indicated above, earthquake disaster is one of the most important issues for Japanese Government. Therefore, after the revision of administrative system of central government, the Cabinet Office began to organize technical committees to discuss important issues concerned with earthquake disasters. One of them is the committee for Tonankai and Nankai earthquakes which are inter-plate earthquake in subduction zone along the Pacific Ocean. This committee, however, deals with not only inter-plate earthquake but also intra-plate earthquakes to occur on inland zone of Japanese islands.

Fig. 1 shows the distribution of active faults around the Japanese archipelago. As shown in the figure, inland active faults are concentrated with high density in the center part of the main island of Japanese archipelago, namely central mountain area and Kinki district which include such as old capital cities as Kyoto and Nara.

Kyoto, Nara, Osaka and Kobe are major cities designated as Government Ordinance and these cities are relatively apart from the major subduction earthquake zone. On the other hand, these major cities are surrounded by inland active faults. The Japanese Government started exploration project of 98 active faults in 1995 and will finish in 2004. The exploration project revealed many scientific facts about those active faults, namely the era of past activities of every fault, amount of dislocation and so on, by making use of excavation of trenches across faults.

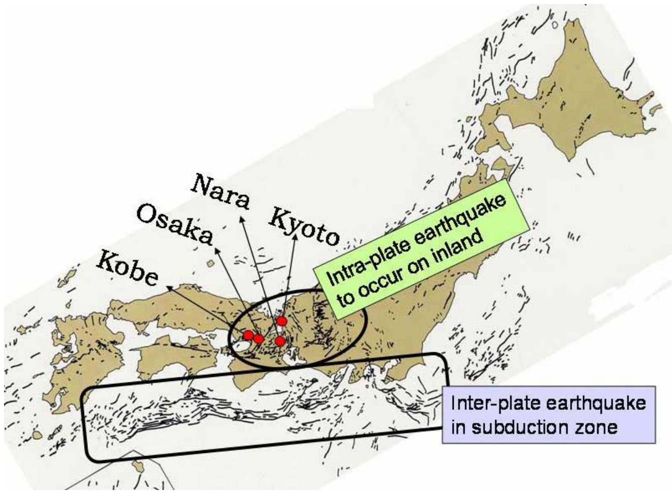


Fig. 1 Active faults around Japanese archipelago

Cultural heritage in Kyoto basin

Nara was the capital of the first centralized government of Japan in 8th century. After that, Kyoto had been the capital of Japan since 794 until the capital was transferred to Tokyo in 1869. During the periods, many temples and shrines were built and lost mostly by war fire in Nara and Kyoto. Still now, however, the density of cultural heritages in Nara and Kyoto is very high compared to the other area as shown in Fig.2.

As shown in the figure, more than 70% of national treasures are concentrated in Kinki district which is unfortunately coincides the district, surrounded by inland active faults are located as shown in Fig.1. This is the reason why we are anticipating that the cultural heritages in Kinki district will be suffered from next major earthquake, probably caused by inland active fault.

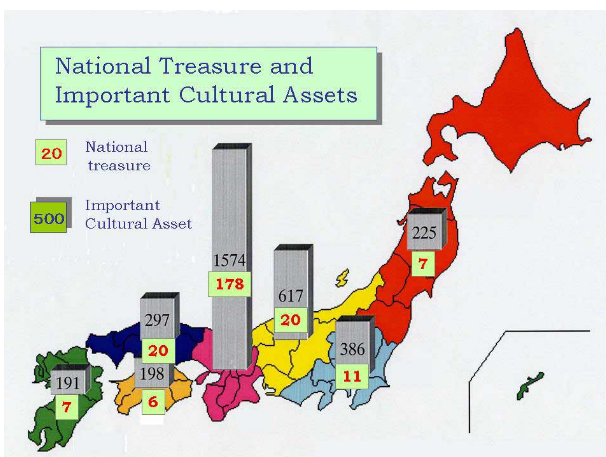


Fig.2 Distribution of National Treasures and Important Cultural Assets

Total number of National Treasures in Nara is almost same with that of Kyoto but the density of that in Kyoto is quite large compared with that of Nara because important cultural assets and national treasures in Nara are dispersed in villages and towns and density in unit area is not high as Kyoto. On the other hand number of National Treasures per 100,000 people in Kyoto is 135 and this is much larger than that of 30 of Tokyo. This implies that Kyoto is most dangerous city in terms of vulnerability of cultural assets against earthquake hazard.

Vulnerability of existing fire extinguish system of temples and shrines

During the 1995 Kobe earthquake, fire-extinguish system of two temples with high prestige in Kyoto lost the function due to break of pipe connecting the water gun and reservoir. Kyoto is about 5-60km away from epicentral area of Kobe earthquake and this fact made us aware of vulnerability of buried water pipe systems of temples and shrines. Once Kyoto is fit by strong earthquake, Kyoto basin will be extensively shaken and most of fire extinguish systems will be disrupted.

On the other hand, fires took place simultaneously in different places during the 1995 Kobe earthquake and more than 10% of casualties lost their lives by fire. The percentage of wooden houses older than 50 years in Kobe was about 6.9% but that of Kyoto is 15.9%. This implies that Kyoto is much vulnerable to fire than Kobe.

ENVIRONMENTAL WATER SUPPLY SYSTEM (EWSS) FOR PROTECTION OF CULTURAL HERITAGE IN KYOTO

Background and Objectives

In Monsoon Temperate Zones, including most of East Asia and Japan, the climate has nourished the wooden cultural city with rich natural water throughout history. Natural water has been used by people for drinking, washing, transportation (Fig.3) and agricultural use with simple management systems such as open channels, wells and rainwater tubs. However, during the modern industrial period, those environmental water devices have been replaced by modern waterworks and sewerage systems, and lost their function in urban areas.

Fig.3 Takasegawa-river, Kyoto

On the other hand, cultural heritage is the result of the crystallization of traditional culture raised by regional environment throughout history. Once it is lost, "culture" can never be reconstructed; unlike "civilization". It is lost forever. Then it is our obligation to maintain a cultural asset as it is and pass them to the next generation of a diverse and sustainable future.

In case of wooden cultural cities, it is essential to prevent wooden heritage buildings from burning out, because they are highly combustible and can not easily be saved from fire. The highest risk of destruction of wooden cultural cities and heritage buildings is due to fire caused by earthquakes. An earthquake will cause innumerable fires over a scattered area to breakout in a very short time. It also results in road blockage at the same time, interfering the capability of fire engines to arrive in time.

In case of Japan, the archipelago was created by transform of the earth's crust. Earthquakes have periodically shaken the archipelago in every century. Whenever major earthquakes took place, many houses and heritages were burned out in the past. The most essential safeguard to fight against these earthquake fires is to keep enough water in each area and to make it accessible for citizens in communities. During the Kobe Earthquake (1995), serious damage in modern infrastructure caused the lack of water for fire-fighting (Fig.4), and at that time, natural water within the neighborhoods was used to initially fight the fires.

Fig.4 Lack of fire fighting water in Kobe Earthquake (1995)

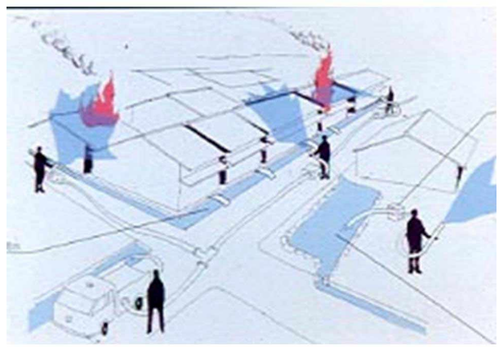


Fig.5 Image of EWSS

The improvement of natural water systems is vital in urban areas. "Environmental Water Supply System (EWSS) for Disaster Mitigation" is an unobstructed water supply that maintains the safety of wooden cultural cities from fire damage, and also preserves the urban water environment. (Fig.5)

Concepts of EWSS

The concepts of EWSS were realized from experiences of the Kobe Earthquake. EWSS must be built using various water resources to make the water supply assure any time, and provide enough water to fight fires in all phases - from initial to final stage. The three fire fighting phases (shown in Fig.6) were originally defined by the Kyoto City Fire Department.

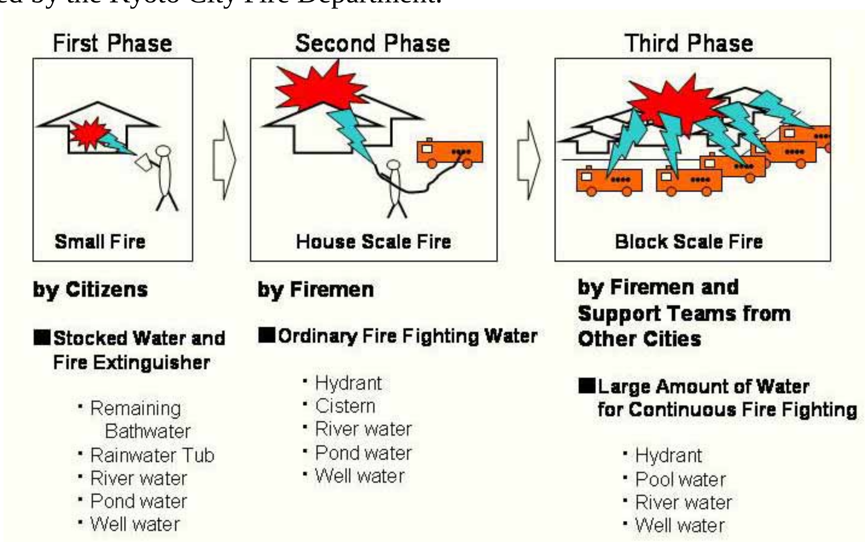


Fig.6 Multiple Phases of Fire Fighting

The first phase is that of a small fire, besieged by citizens with small amounts of water. The accessibility of water is most important in this phase. The second phase is considered as the standard house scale fire, being fought by professional firemen. The amount of water must be sufficient for professional use. Finally, the third phase is block scale fire, grappled with by various support teams for fire fighting, usually from other cities. Continuous and ample amounts of water are needed particularly in this last phase. To uphold the "fail-safe" performance requirements and "redundancy" in safety measures of EWSS, the system must be designed with "diverse" water resources, and be effective in any of the fire fighting phases.

The objectives of EWSS performance are as follows:

- Easy Operation by Citizens,
- Safe and Endless Water Supply,
- Contribution to the Environment,
- Back Up System for Usual Fire Prevention and
- Low Cost Development.

The EWSS will be able to regenerate the water environment, preserve traditional wooden cultural heritage, restitute beautiful country and develop community with safety and ease.

Detection of Earthquake Fire Prone Area in Kyoto

Kyoto was selected as the case study site for EWSS planning due to its diverse wooden cultural heritage that are scattered with high density in Kyoto basin. There are countless number of wooden structures, including fourteen World Heritage sites – the highest number of any other single city in Japan. In addition, there are four Historical Preservation Districts that have been designated by the central government.

On the other hand,, however, Kyoto basin is surrounded by many active inland faults, including the Hanaore fault that extends more than 50km long to the north. And also, Kyoto experienced 13 earthquakes with seismic intensity greater than 6 after Kyoto became the capital of Japan 1200 years ago. Moreover, next big one is anticipated to take place in near future.

In order to choose the case study site, a preliminary research to estimate the earthquake fire risks was carried out. The characteristics of the city area were analyzed from three viewpoints. The statistical data from the Kobe Earthquake were used to determine the risk factors such as the risk of fire, the percentage of people of senior citizen, and the average number of people in each family. Furthermore, the risk of the fire spreading, and the density of flammable structures were also examined. These three risk factors were mapped respectively and the estimated disaster prone areas were revealed and colored in red in Fig.7 .

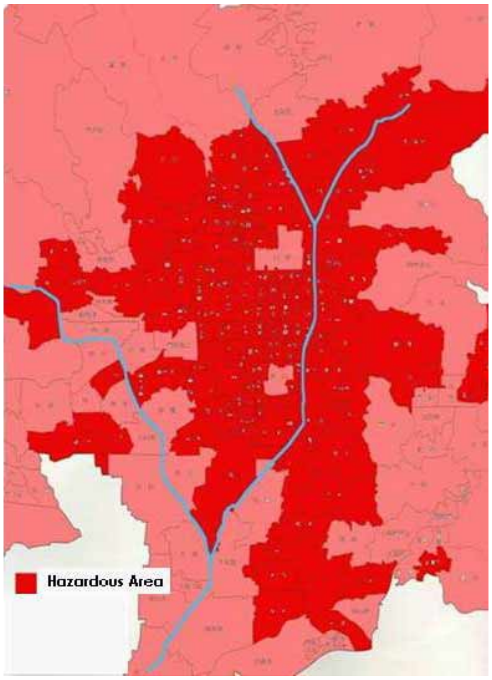
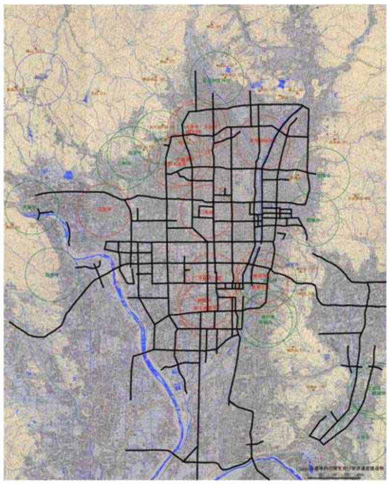


Fig.7 Estimated hazard area of earthquake fire, in KYOTO

In addition, the risk of traffic isolation of an area after an earthquake was analyzed according to the width of the roads in the area analyzed. In the Kobe Earthquake, the blockage of roads occurred where the street width was less than twelve meters. Almost of main streets in Kyoto were examined, and the possibility of passage of fire engines in the roads wider than 12 meters in width was determined (Fig.8) . In usual cases, the prospect of fighting a fire depends on its distance from the fire engine. The standard length of fire hose in Japan is 400 meters, holding the minimum radius of the fire fighting circle of 250 meters. The area colored in purple in figure 9 shows the area where fire fighting is possible along broad streets.



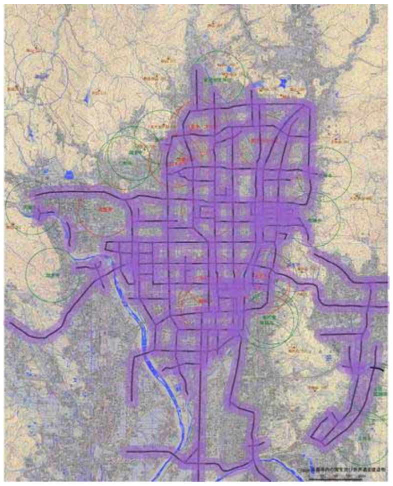


Fig.8 Streets broader than 12 meters **Fig.9 Possible area of fire fighting**

The capacity for a fire to spread from neighborhoods and to cause damage to cultural heritage structures was examined by computer simulations. Through the simulation, it has been detected that Dai-houon-ji Temple and Sannei-zaka Historical Preservation District are the most dangerous areas from the view point of spread of fire from neighborhood residential houses because they locate within the hazardous areas and but outside of the possible area of fire fighting. Then they were selected as specific case study sites for the proposal of EWSS.

EWSS in Dai-houon-ji Temple Area (Case Study-1)

Dai-houon-ji Temple is a wooden national treasure surrounded by a high density of wooden houses in close proximity (Fig.10). The temple was built in 1227, and it is the oldest wooden building in Kyoto. Its wooden roof is made by a large number of small cypress roofing plates (Fig.11).

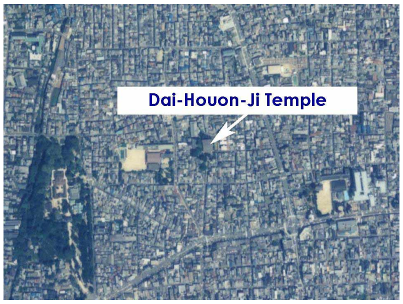


Fig.10 Site of Case Study-1 ; Historical building **Fig.11 Dai-Houon-Ji temple**

The Tenjin-gawa River flows within 250 meters west of Dai-houon-ji Temple. In the planning for this study, this river was considered as a water resource, and the route of water was designed to lead the water to the temple (Fig.12).

It is very important to lead a natural and continuous water flow, without any help of mechanical system, for more assurance. This water circulation route was designed, based on research on geographical view point. The water of Tenjin-gawa River comes from a mountain side within one kilometer, keeping the quality of water quite good for use. However, the level of the water surface is approximately seven meters deeper than ground level at the water feeding point. The open channel is designed along the river, in order to raise the water level to the ground level. Also, scooping pits are located at every 250 meters in the open channel. Citizens will be able to scoop fresh water with any kind of bucket at these points, despite the shallow water depth as shown in Fig.13. It will be useful for the first phase of fire fighting, lead by citizens, since the early stages are crucial in any case of fire fighting.

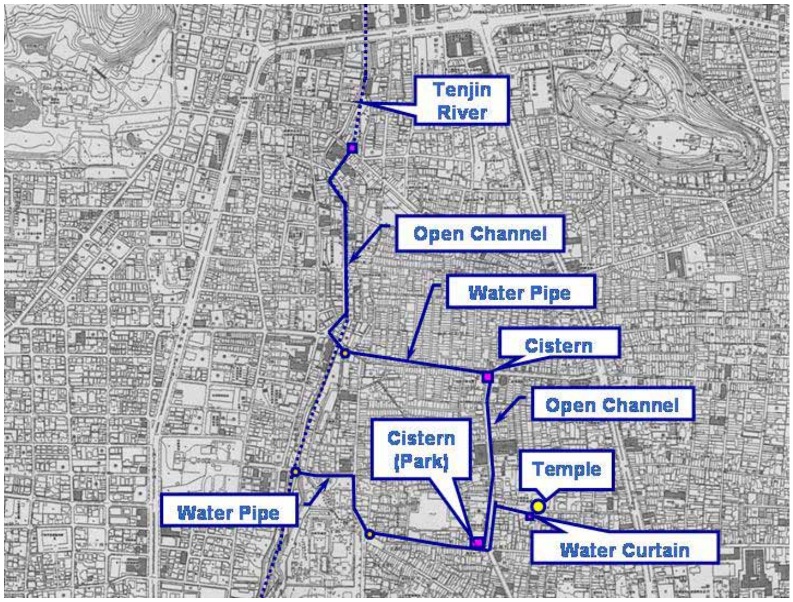


Fig.12 Water route of Case Study-1

The cisterns are designed as a kind of park on water, to keep an adequate supply of water for the first and second fire fighting phases, as well as citizens' daily use. The daily use of the cisterns by citizens is a very important point as it will enable people to access easily to the water. The water surface should remain open so that people are able to access the water more easily, not only for daily use, but also in case of an emergency (Fig.14).

Fig.13 Image of scooping pit in open channel

Fig.14 Image of cistern (Park on water)

The amount of water held in the cistern should be large enough for the third and final phase of fire fighting because it demands the greatest supply. Field research concerning building structure was carried out and five major areas where fire could spread around the temple were revealed (Fig.15). The specification of the water curtain system is expected to keep the temperature of radiant heat less than 200 degrees at the edge of the wooden heritage structure to protect the temple from a block scale fire in case the fire reaches the third phase. At least, 3000 tons of water is needed in the cistern for two hours of use to fight a fire. Dual pumping stations for the water curtain were designed to retain its fail-safe quality (Fig.16).

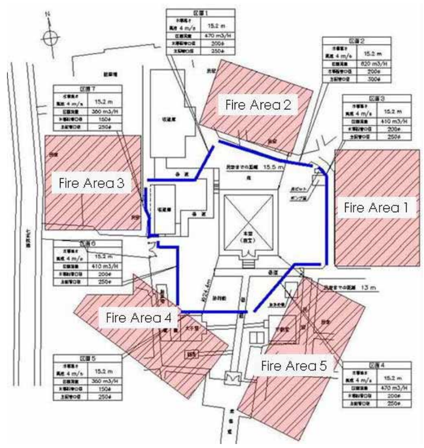


Fig.15 Fire zone and water curtain

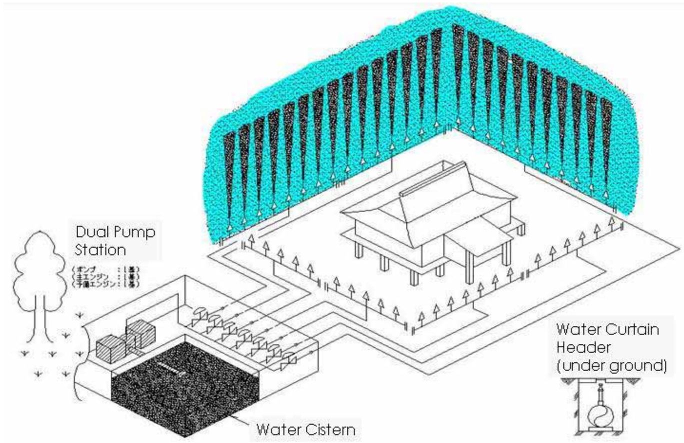


Fig16 Dual pumping station and water curtain

For the second fire fighting phase, four water nozzle systems, which will be able to cover the 50 meter radius circle, were designed to protect not only the temple but also the neighborhood residential area from the spread of fire (Fig.17).

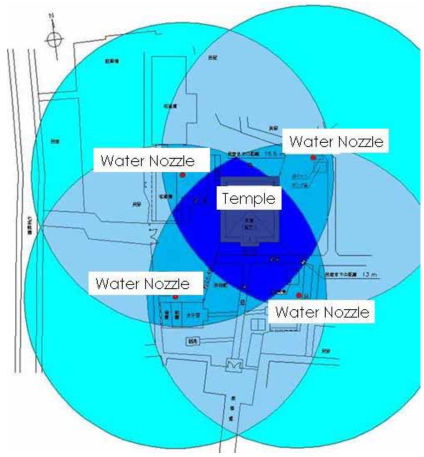


Fig.17 Image of water-nozzle system against fire in neighborhood

EWSS in Sannei-zaka Historical District (Case Study-2)

Case 2 deals with the "Sannei-zaka Historical Preservation District", as a region of high density wooden historical buildings. The district is a region of "National Heritage", and is also included in the "Kiyomizu Temple World Heritage Area". In designing EWSS, research on geographical characteristics of this site was carried out, deriving the proposal with a practical view point.

This district locates at the foot of the Higashi-yama Mountains and it includes two high density areas of wooden structures, the Sannnei-zaka area and Ishibe-kouji area (Fig.18). The area has very narrow streets and stairs, and is pinched between high density wooden structures as shown in the picture of Fig.19. Due to route blockage, this situation will cause difficulty for firemen coming from outside to extinguish a fire in the case of an earthquake. The EWSS must be designed with the "citizens' easy operation" in mind; it is critical in the concept of this system.

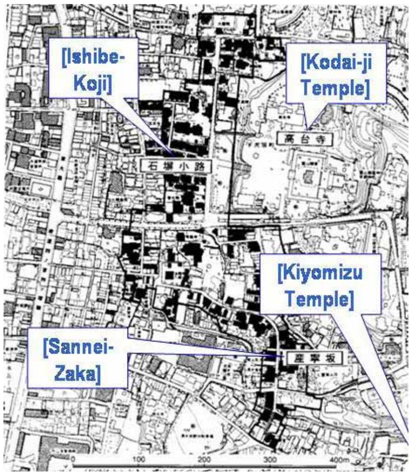


Fig.18 Site of Case Study-2; Sannei-Zaka historical preservation district

Existing water dam is constructed on the mountain side, containing about 600 tons of water. For maintaining "redundancy", two routes of water supply pipeline are designed. One is on the ground surface, and the other is buried in the subsurface ground. An isolation valve is located in the middle of the two districts. The valve will sustain the water pressure if the water network is accidentally broken in the primary route (Fig.20).

Fig.19 Sannei-zaka

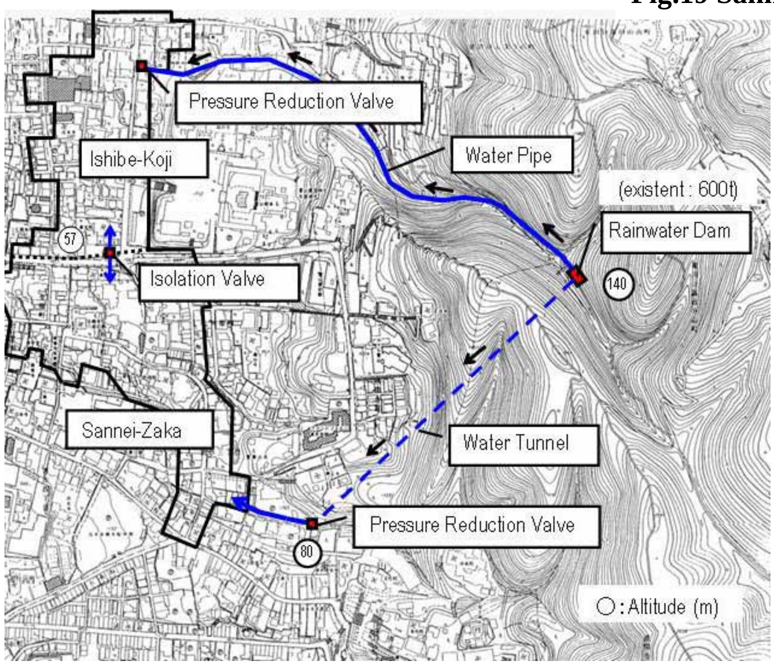


Fig.20 Water route for Case Study-2 area

The difference of water head between dam cite and preservation area is utilized to obtain the water pressure needed at outlet of fire fighting devices because it is important to use simple and natural forces, without complex systems such as pumps, to keep it fail-safe. This system will provide water to every fire fighting instruments such as hydrant and sprinkler systems. Sprinklers are installed along narrow streets and hydrants are arranged each wooden structure every 25 meter along streets (Fig.21) .

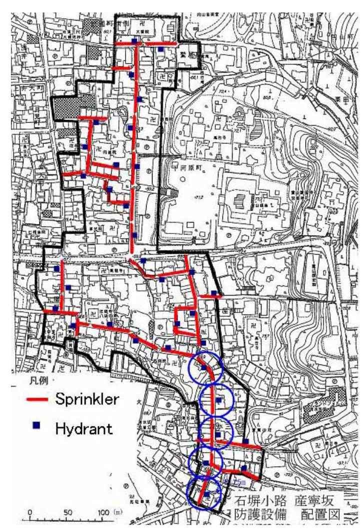


Fig.21 Installation planning of hydrants & sprinklers

These hydrants are designed for citizens to use easily, without special professional knowledge and any particular skill, during the first phase of fire fighting (Fig.22). People will also be able to use this equipment for daily use, such as "Uchi-mizu watering" - a traditional custom of wetting the surface of street to settle the dust every morning. The sprinkler system along narrow side streets is designed for citizens to operate easily in order to keep the surface of wooden structures wet in the second phase of fire fighting (Fig.23). It is effective to keep the street surface wet not to allow the fire beyond the second stage. Should the first phase of fire fighting fail, the second phase would require the citizens to simply turn on the tap for the sprinklers and then maintain a safe distance.

Fig.22 Hydrant system for citizens

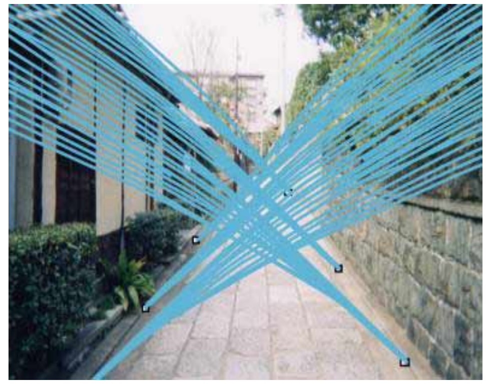


Fig.23 Image of sprinkler system for narrow street

To keep the performance of fail-safe, cisterns and channel networks are designed to back up these water systems. In the present condition, there are a few areas where are outside the supported fire fighting circles which have existing cisterns at the center of them. The traces of existing small rivers around this district will be re-used as open channels, and the new water flow will be led into two more cisterns to cover the rest of the area.(Fig.29).

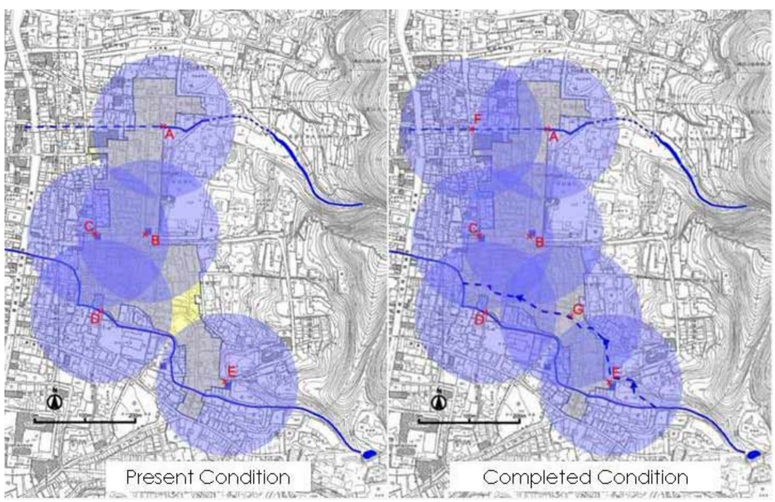


Fig.24 Cisterns and channel network system for back up

The scooping pits built in the open channel will be used to pump out water without air inclusion by fire engines, in spite of the shallow water level. In any case, it is important to adopt the design to provide easy and safe access for citizens. When the design is modified to act as a park incorporating a water basin (Fig.25), citizens can maintain the channel clean, and access the water, not only for daily use, but also for emergency use.

Fig.25 Image of easy access to water

CONDLUDING REMARKS

In March of 2001, the Council for Science and Technology Policy which is mentioned in the beginning of this paper made public the Science and Technology Basic Plan 2001-2005. This plan suggested to put emphasis on the major four fields such as life science, information technology, nano-technology and environmental issues. The Council picked up next four fields to be promoted and the natural disaster issues were included in the suggested fields. In the Plan, the importance of protection of cultural heritage from natural disasters has been recognized for the first time in the official documents of the central government.

In conjunction with the report of the above mentioned council, the Ministry of Land, Infrastructure and Transport began the Research and Development program in the field of construction technology and three proposals were adopted. The authors proposed a project that is concerned with the protection of historical cities from post-earthquake fires. This project is supposed to be the first research project that was supported by the Japanese government in the field of protection of cultural heritage and old town itself.

Most of the results given in this paper was conducted in the research project mentioned above. Namely, "Environmental Water Supply System" was mainly developed in the project as case studies. In the project, authors revealed the potential risk of post-earthquake fire in Kyoto basin , considering the transportation ability of streets after strong ground motion of earthquake. In the research, authors proposed actual and realistic countermeasures to protect cultural heritage from post-earthquake fire for the oldest temple in Kyoto basin and that for a Historical Preservation District.

It is important for us to get back the natural water environment in urban areas. We should create a safe and pleasant environment that preserves wooden cultural heritage structures in communities as well as modern structures. The concept of EWSS put emphasis on the necessity of a sustainable water environment and on the restoration of historical atmosphere with beauty and safe from natural hazards. This outcome of this research can be easily applied to similar problems in developing countries by making use of their ability and low cost technology. It is our obligation to preserve and pass the irreplaceable cultural treasures to the future generations, without damage caused by natural disasters.

ACKNOWLEDGEMENTS

Conducting the two case studies, the authors have collaborated with Kyoto City Fire Department and the members of technical committee of the NPO for Protection of Cultural Heritage from Disaster. We would like to express our deepest gratitude for their cooperation.

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