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FIRE SPREADING ANALYSIS OF A GROUP OF WOODEN HOUSES IN TOWNSCAPE FORMATION DISTRICT

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There was a fire spreading disaster for 18 wooden houses in the historical townscape formation district in a famous spa resort area. In this paper, a fire spreading analysis of a group of wooden houses was carried out under some conditions of wind velocity and direction in order to numerically simulate a fire spreading phenomenon in the spa resort area and also investigate some fire spreading countermeasures for a group of wooden houses and also investigate an appropriate countermeasure for the fire spreading disaster of wooden houses using both fireproof wall and quasi-fireproof wall on wooden houses. As a result, it should be noted that the installation of fireproof wooden wall in every third wooden house can economically reduce a fire spreading area in comparison with the installation of quasi-fireproof wooden wall in every other wooden house.

Keywords: Fireproof wall, Quasi-fireproof wall, Fire disaster simulation.

1 INTRODUCTION

It is well-known that there exist a lot of Japanese-style three-story wooden inns in some famous spa resort areas in Japan, and they may be almost cultural properties and also may produce comfortable cultural scenery for many visiting tourists. Many tourists enjoy spa scenery and street scene with wooden three-story Japanese inn structures and many street trees on both road sides along a river in this historical townscape formation district. Therefore, local city office with these cultural properties must be forced to take prompt countermeasure for their operation and maintenance.

There was a fire spreading disaster for 18 wooden houses in the historical townscape formation district in a famous spa resort area whose burnt area is 2,730m^2. Figure 1 shows a fire fighting state and a fire extinguishing one at Kinosaki Spa resort area. This spreading disaster in the spa resort area is a serious problem for the local city, and an appropriate countermeasure for the fire spreading disaster of a group of wooden houses must be conducted by the local city office.

In this paper, a fire spreading analysis of a group of wooden houses was carried out under some conditions of wind velocity and direction in order to numerically simulate a fire spreading phenomenon in the spa resort area and also investigate some fire spreading countermeasures for a group of wooden houses and also investigate an appropriate and economical countermeasure for the fire spreading disaster of wooden houses previously mentioned using both fireproof wall and quasi-fireproof wall on wooden houses.

Figure 1. Fire spreading site at Kinosaki Spa resort area (Kobe Newspaper 2015).

2 OUTLINE OF FIRE SPREADING ANALYSIS

Many researchers have reported fire spreading theories and papers before. In this paper, a fire spreading velocity equation proposed by Hamada (1969) is briefly described in this section. Figure 2 indicates an outline sketch of fire spreading area under wind condition. Fire spreading area is assumed to be an oval equation with $l_1 + l_2$ in the major axis and $2l_3$ in the minor one.

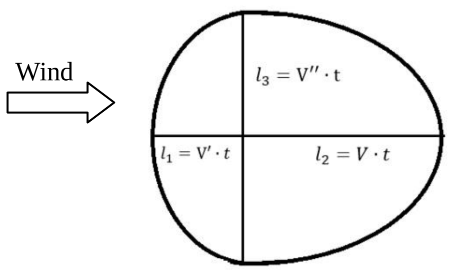

Figure 2. Shape of fire spreading area.

Based on the fire spreading area shown in Figure 2, a fire spreading velocity equation proposed by Hamada can be written in the following equations.

(1) Time from an ignition to the neighboring house's ignition, t(min)

(Leeward)

$$t_0 = \frac{3 + \frac{3}{8}a + \frac{8d}{D_i}}{1 + 0.1v} \quad \text{(First house)} \tag{1}$$

(Upwind)

$$t_i = \frac{3 + \frac{3}{8}a + \frac{8d}{D_i}}{\alpha\left(1 + 0.1v + 0.007v^2\right)}, \quad \alpha = 1.6\frac{t_0 + 14}{t_0 + 25} \tag{2}$$

(Wind side)

$$t' = \frac{3 + \frac{3}{8}a + \frac{8d}{D'}}{1 + 0.002v^2} \tag{3}$$

$$t'' = \frac{3 + \frac{3}{8}a + \frac{8d}{D''}}{1 + 0.005v^2} \tag{4}$$

(2) Spreading velocity, *V*(m/min)

(Leeward)

$$V = n\frac{\alpha\left(a + d\right)\left(1 + 0.1v + 0.007v^2\right)}{3 + \frac{3}{8}a + \frac{8d}{D_i}} \tag{5}$$

(Upwind)

$$n = \frac{a' + b'}{a' + \frac{b'}{0.6}}\left(1 - c'\right) \tag{6}$$

(Wind side)

$$V' = n\frac{\left(a + d\right)\left(1 + 0.002v^2\right)}{3 + \frac{3}{8}a + \frac{8d}{D'}} \tag{7}$$

$$V'' = n\frac{\left(a + d\right)\left(1 + 0.005v^2\right)}{3 + \frac{3}{8}a + \frac{8d}{D''}} \tag{8}$$

(3) Spreading limit distance, D (m)

(Leeward)

$$D_0 = 1.15\left(5 + 0.5v\right), \quad D_i = \beta_i D_0 \tag{9}$$

$\beta_i = 1.0$ (Until 10 minutes from an ignition), $\beta_i = 1.5$ (From 10 minutes to 30 minutes)
$\beta_i = 3.0$ (From 30 minutes to 60 minutes), $\beta_i = 5.0$ (Over 60 minutes from an ignition)

(Upwind)

$$D' = 1.15\left(5 + 0.2v\right) \tag{10}$$

(Wind side)

$$D'' = 1.15\left(5 + 0.25v\right) \tag{11}$$

where, a is an average length of house structure (m), d is a distance to the neighboring house (m), v is wind velocity (m/sec), a' is a wooden structure mixing rate, b' is a fire prevention structure mixing rate, c' is a fireproof structure mixing rate.

3 FIRE SPREADING SIMULATION RESULTS

Figure 3 shows a housing map of Kinosaki Spa resort area. In this paper, several fire spreading analyses are conducted to simulate a real fire spreading disaster occurred in 2015 in Kita district shown in Figure 4. Fire spreading simulation can be conducted using a group of house structures, that is, housing information data. Fundamental housing information data with a scale level 1/2,500 can be easily downloaded from the Geographical Survey Institute in Japan, and also can be modified in accordance with the present house structure shape. Wind data with velocity and direction on that day in 2015 were measured by the Meteorological Agency in Japan, and are employed in this simulation. Wall material of wooden house structure is assumed to be "naked wooden house" without any fire proof walls, wooden house with "quasi-fireproof" walls and fireproof walls. Quasi-fireproof wall and fireproof wall materials mean that the deformation, dissolution and other damage to occur a structural strength reduction does not cause for 45 minutes and 60 minutes respectively even if walls and eaves are heated by a fire. A comparison between the installation of fireproof wooden wall in every third wooden house and the installation of quasi-fireproof wooden wall in every other wooden house is numerically investigated in this paper.

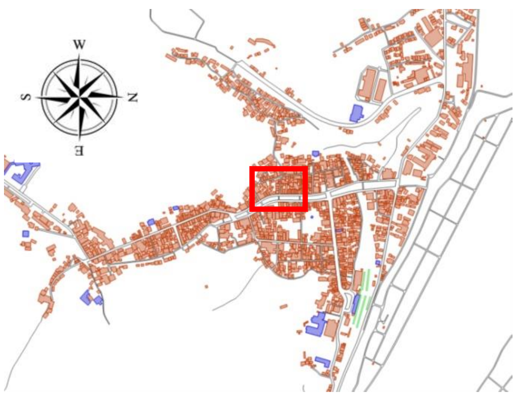

Figure 3. Housing map of Kinosaki Spa resort area.

Figure 4. Kita district.

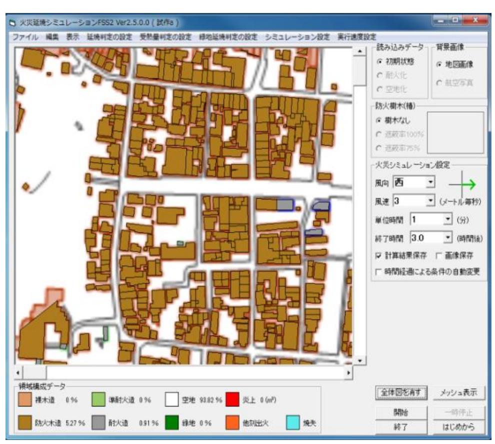

Figure 5. Fire spreading simulation screen.

Fire spreading simulation software developed at Ehime University is briefly described in this paper.

Figure 5 illustrates a simulation screen on the fire spreading simulator, and a fire outbreak point, wind direction, wind velocity, simulation time, and unit time can be easily set on this screen.

Figure 6 shows a fire spreading simulation result for a group of "naked wooden houses" without any fireproof wall materials after 5 hours from fire outbreak. 17 wooden houses were burned down in this fire spreading simulation. 18 wooden houses were burned down in the real fire spreading disaster in Kita district of Kinosaki Spa resort area occurred in 2015. It is found from this figure that fire spreading area spreads to neighboring houses along the front road and also spreads behind the house with a fire outbreak. It should be noted that the effectiveness of fire spreading analysis with time progress can be confirmed through this simulation.

A fire spreading simulation result for a group of wooden houses with quasi-fireproof walls after 5 hours from fire outbreak is indicated in Figure 7. In comparison with "naked wooden houses" without any fireproof wall materials, the installation of quasi-fireproof material on every wooden house can decrease the number of wooden house burned down and also can restrain a fire spreading behind wooden house.

Figure 8 illustrates a fire spreading simulation result in the case of the installation of quasi-fireproof wooden wall in every third wooden house after 5 hours from fire outbreak. As a matter of course, a fire spreading phenomenon to the neighboring house for the installation of quasi-fireproof wooden wall in every third wooden house is faster than that for the installation of quasi-fireproof material on every wooden house.

A fire spreading simulation result in the case of the installation of fireproof wooden wall in every other wooden house after 5 hours from fire outbreak is shown in Figure 9. It can be obvious from Figures 7 and 8 that the installation of fireproof wooden wall in every other wooden house can be significantly reduced a fire spreading area in comparison with the installation of quasi-fireproof material on every other wooden house and fire spreading to the neighboring houses not only in the lateral direction but also the backward can be restrained.

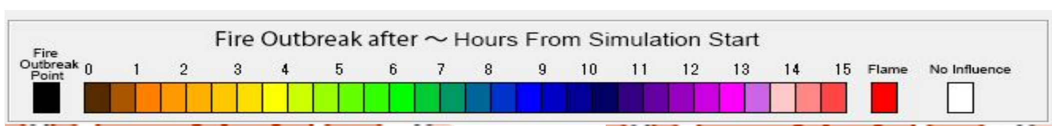

Figure 6. Fire spreading simulation result after 5 hours (Naked wooden house).

Figure 7. Fire spreading simulation result after 5 hours (Installation of quasi-fireproof wall in every wooden house)

Figure 8. Fire spreading simulation result after 5 hours (Installation of quasi-fireproof wall in every other wooden house).

Figure 9. Fire spreading simulation result after 5 hours (Installation of fireproof wall in every third wooden house).

4 CONCLUSIONS

In this paper, a fire spreading analysis of a group of wooden houses was carried out under some conditions of wind velocity and direction in order to numerically simulate a fire spreading phenomenon in the spa resort area and also investigate some fire spreading countermeasures for a group of wooden houses and also investigate an appropriate countermeasure for the fire spreading disaster of wooden houses previously mentioned using both fireproof wall and quasi-fireproof wall on wooden houses.

The summary obtained in this paper is as follows:

(1) An actual fire disaster for a group of wooden houses can be accurately simulated under some conditions of wind velocity and direction by fire spreading analysis.

(2) Fireproof wooden walls on wooden houses can restrain a fire spreading phenomenon in wooden houses in comparison with a fire spreading simulation for wooden houses without fireproof wall.

(3) Installation of fireproof wooden wall in every third wooden house can significantly reduce a fire spreading area in comparison with the installation of quasi-fireproof wooden wall in every other wooden house.

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