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Prediction of building damage at the district level due to the Nankai earthquake - Taking Minamiawaji City and Kakogawa City as examples -

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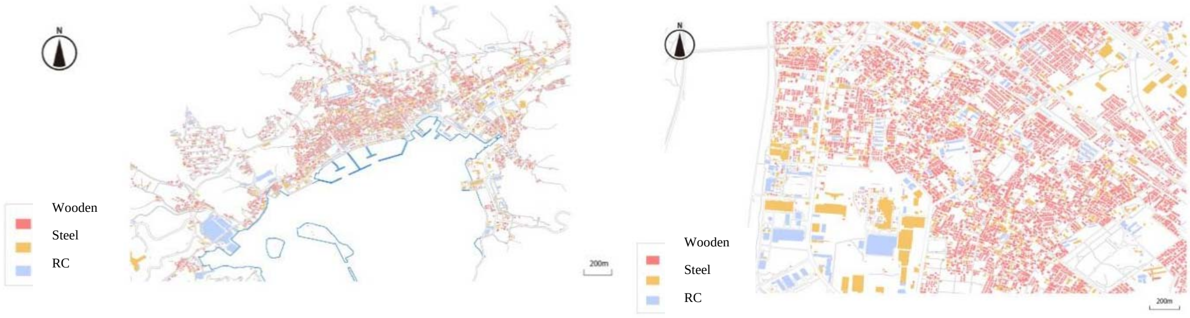
Abstract

In Japan, it is said that the Nankai earthquake will occur sometime in the 21st century. At that time, building damage is assumed in a wide area. Traditionally, building damage has been predicted by empirical methods. The purpose of this study is to model the buildings at the district level one by one, conduct the seismic response analysis, and predict the building damage from the maximum interlayer deformation angle. We focus on Kakogawa City and Minamiawaji City in Hyogo Prefecture as examples.

Awaji Island is particularly close to the hypocenter that is expected in Hyogo Prefecture, and Minamiawaji City located on the seaside which is expected to be damaged by the tsunami. In addition, Minamiawaji City has a high awareness of disaster prevention. It is hoped that simulating an anticipated Nankai earthquake (landside case) in this area will lead to grasping the current situation and future specific measures. Fig.1 (a) shows the building distribution in Minamiawaji City.

Kakogawa City faces the Seto Inland Sea and is expected to be damaged by the tsunami. Kakogawa City is also working on a Community Disaster Management Plan (CDMP). However, the characteristics of each district are not taken into account, thus it is necessary to prepare the CDMP and reflect it into the Local Disaster Management Plan. The CDMP is a new framework which allows residents to work on disaster management plans suitable for the district so that residents can act smoothly in the event of a disaster. In this study, it is expected that more detailed evacuation plans will be created by presenting simulation results in planning evacuation plans, focusing on the case of the Yota Minami area of Kakogawa City. Fig.1 (b) shows the building distribution in Kakogawa City.



(a) Minamiawaji City (b) Kakogawa city

Fig.1 Building distribution

Keywords: Building damage prediction; Assumed Nankai earthquake; Evacuation plan; Disaster prevention plan

1. Introduction

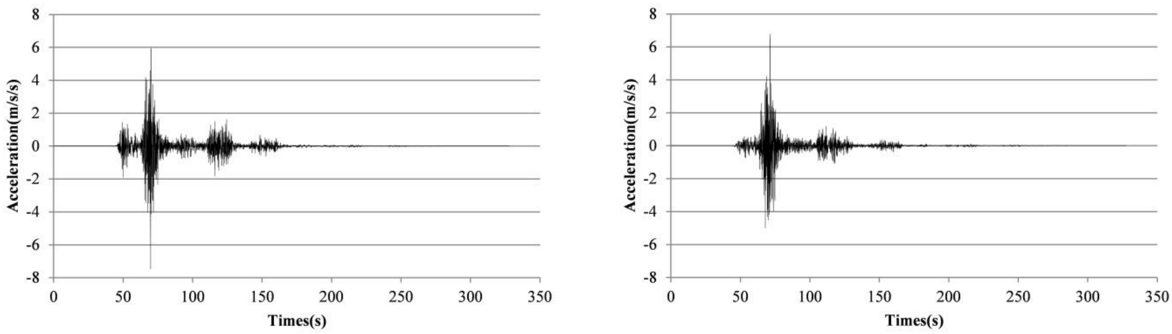
Countermeasures against the anticipated Nankai earthquake are highly necessary. If only the empirical method is used to predict the damage of the assumed Nankai earthquake, it is difficult not only to focus on each building but also to formulate a specific policy. Therefore, it is thought that a simulation that performs damage prediction can be used in evacuation planning to help with more concrete measures.

The purpose of this study is to introduce a concrete evacuation plan for the assumed Nankai earthquake and some examples of grasping the current situation using the results of the regional time history response analysis by IES[1], and to introduce the regional scale analysis.

2. Earthquake response analysis in Minamiawaji city

Awaji Island is particularly close to the hypocenter of the hypothetical Nankai earthquake in Hyogo Prefecture, and Minami-Awaji City, located on the seaside, is expected to be heavily damaged by the tsunami. Minami-Awaji City is also highly aware of disaster prevention due to concerns about tsunami damage. In particular, we focused on the Fukura district, which has a high population in Minamiawaji City.

Next, the waveforms created from the ground surface acceleration in the NS and EW direction for an assumed Nankai earthquake (landside case) in an arbitrary building in the Fukura area are shown in Fig. 2.1 ((a) is the NS direction, (b) is the EW direction). Table 2.1 shows the maximum acceleration of the ground surface at that point.



(a) NS direction (b) EW direction

Fig. 2.1 – Acceleration of time history waveform (Fukura area)

Table 2.1 – Maximum ground acceleration (unit : m/s^2)

NS direction	7.48
EW direction	6.78

The assumed distribution of 3,627 Wooden, Steel, and RC buildings in the Fukura area is based on the Zenrin Electronic Residential Map Digitown Minami-Awaji City, Hyogo Prefecture. We superimposed roads and coastlines based on this building data and the Geographical Survey Institute's basic map information (mesh numbers 513416, 513425, 513426, 513435, 513436) using ESRI's ArcGIS[2]. Fig. 2.2 shows the superimposed structure. Table 2.2 shows the classification of a total of 3,627 buildings of wooden, S, and RC in the range shown in Fig. 2.2.

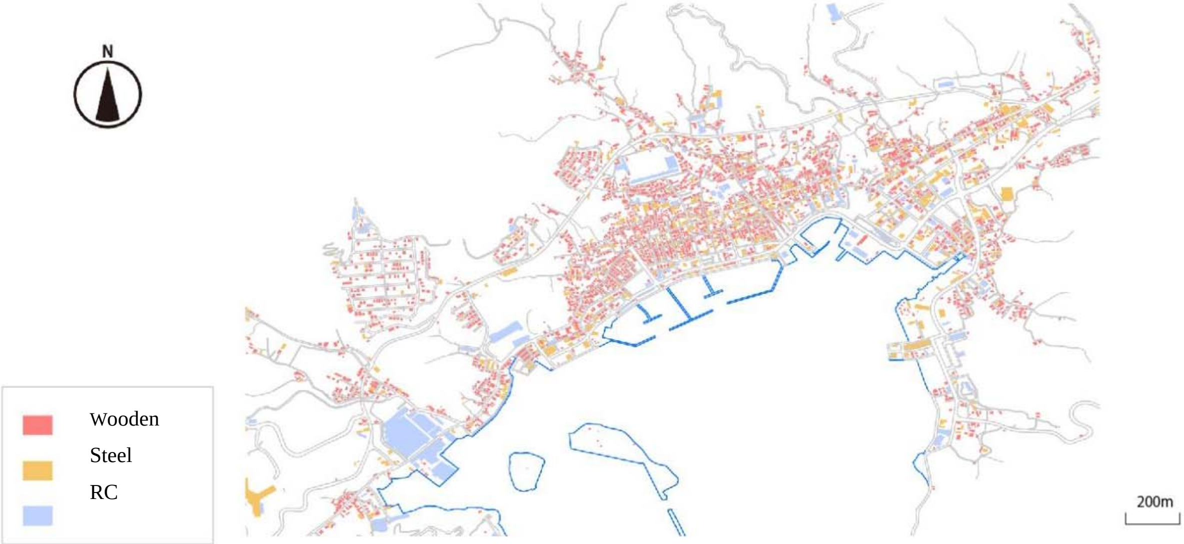


Fig. 2.2 – Building distribution (Fukura district)

Table 2.2 – Number of buildings by structure type (Fukura district)

Structure type	Number of buildings
Wooden	3,062
Steel	447
RC	118

In performing the damage estimation, time history response analysis was performed for the area shown in Fig. 2.2 using IES. The maximum story drift angle in the analysis results was set to a threshold of 1/10 (rad), 1/50 (rad), and three cases were classified. Fig. 2.3 shows the results of classification based on the values of SDA (Story Drift Angle). Table 2.3 shows examples of the possibility of damage to buildings for each of the three categories.

Table 2.3 – Classification of damage assumption

1/10 ＜ Maximum story drift angle	In some cases collapse
1/50 ＜ Maximum story drift angle ≦ 1/10	May collapse
Maximum story drift angle ≦ 1/50	Unlikely to collapse

Fig. 2.3 – Building damage assumption

From Fig. 2.3, it can be seen that red dots are relatively concentrated on the north side of Fukura Port, and yellow ones are often seen. An aerial photograph of this area on Google Maps is shown in Fig. 2.4.

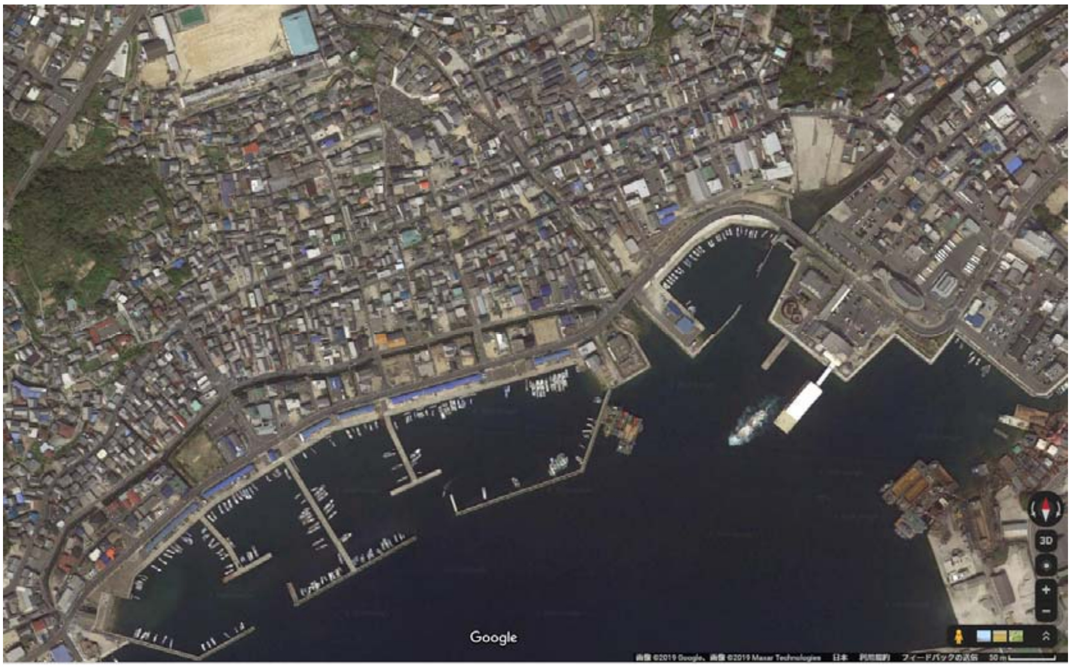


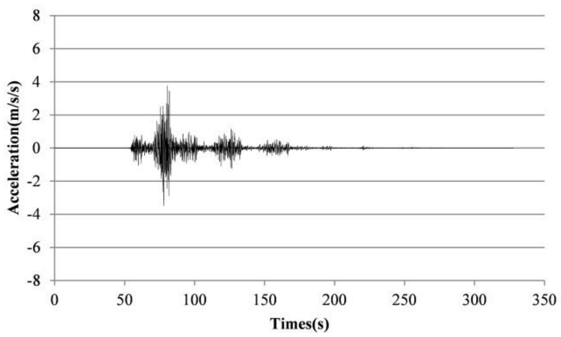
Fig. 2.4 – Aerial photograph of Fukura area (quoted from Google Maps)

Once you watch Fig.2.4, you can see that the residential area spreads north of Fukura Port. Therefore, it is probable that the distribution was as shown in Figure 2.2 due to the large number of wooden houses as the building structure type. Furthermore, looking at the distribution in Fig. 2.3 and Fig. 2.4 the places where red color is concentrated have many narrow roads and residential areas are spreading. After a big earthquake occurs, there is a possibility that the evacuation route may be blocked due to the collapse of the building.

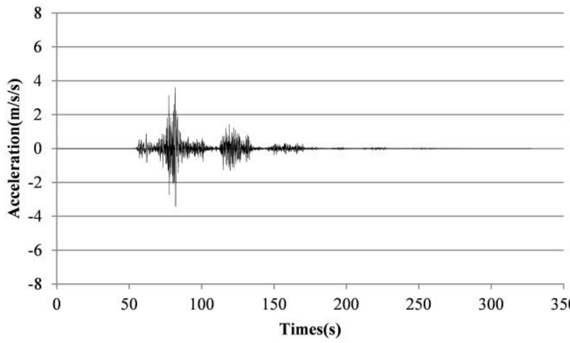
3. Earthquake response analysis in Kakogawa city

Kakogawa City faces the Seto Inland Sea, and tsunami damage is expected in some areas even in the supposed Nankai earthquake. In addition, Kakogawa City has formulated a regional disaster prevention plan based on the damage assumptions announced by the Cabinet Office, with a correction of tsunami damage. However, the characteristics of each district are not taken into account in the Local Disaster Management plan, and it is necessary to prepare a Community Disaster Management plan to reflect it in the Local Disaster Management plan. The Community Disaster Management Plan is a framework that allows residents to work on an evacuation plan suitable for the district at the level of the elementary school district and to be able to act smoothly in the event of a disaster. The target area is the Yota Minami district, where tsunami damage is expected in Kakogawa City. It is thought that presenting the simulation results when making an evacuation plan in the Community Disaster Management plan in the Yota Minami area will lead to the creation of a more specific evacuation plan.

The waveforms created from the ground surface acceleration in the NS and EW direction for an assumed Nankai earthquake (landside case) in an arbitrary building in Yota Minami area are shown in Fig. 3.1 ((a) is the NS direction, (b) is the EW direction).



(a) NS direction



(b) EW direction

Fig. 3.1 – Time waveform of acceleration time history (Yota Minami area)

Table 3.1 – Maximum ground acceleration (unit : m/s^2)

NS direction	3.78
EW direction	3.61

The assumed distribution of 8,471 Wooden, Steel, and RC buildings in the Yota Minami area is based on the Zenrin Electronic Residential Map Digitown Kakogawa City, Hyogo Prefecture. We superimposed roads and coastlines based on this building data and the Geographical Survey Institute's basic map information (mesh numbers 52344406, 52344416) using ESRI's ArcGIS[2]. Fig. 3.2 shows the superimposed structure. Table 3.2 shows the classification of a total of 8,471 buildings of Wooden, Steel, and RC in the range shown in Fig. 2.2.

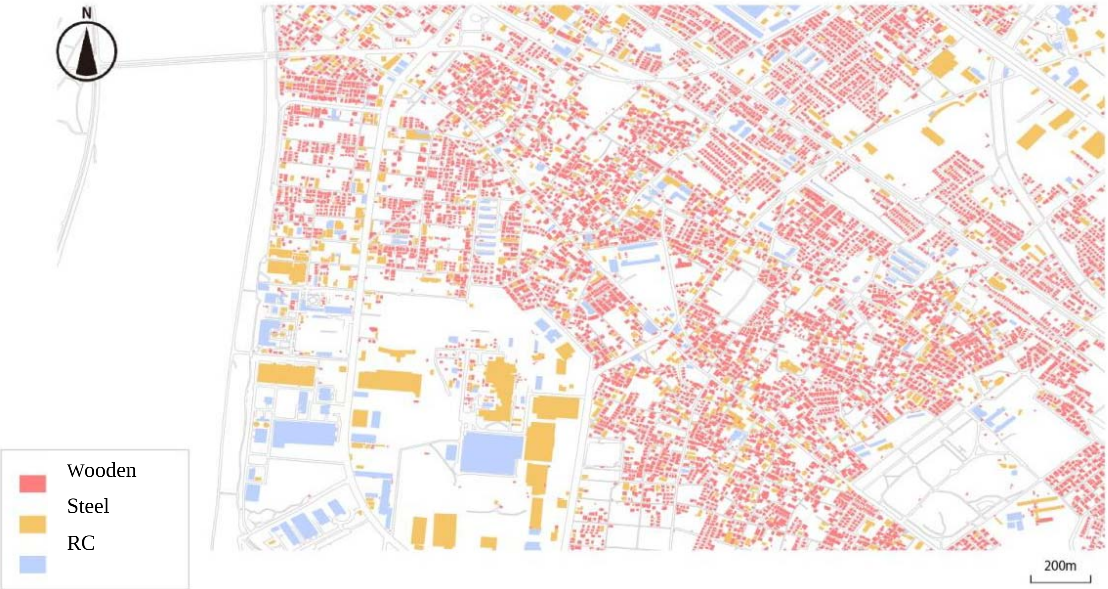


Fig. 3.2 – Building distribution (Yota Minami district)

Table 3.2 – Number of buildings by structure type (Yota Minami district)

Structure type	Number of buildings
Wooden	7,516
Steel	771
RC	184

In conducting the damage estimation, time history response analysis was performed on the area shown in Fig. 3.2 in the same way as Minamiawaji City. The maximum story drift angle in the analysis results was set to a threshold of 1/10 (rad), 1/50 (rad), and three cases were classified.

Fig. 3.3 – Building damage assumption

It is assumed that the three categories are equivalent to Minami-Awaji City as shown in the table 2.3. From Fig.3.3, it can be seen that red dots are relatively concentrated on the north side of the Yota Minami district, and yellow ones are often seen. Figure 3.4 shows an aerial photograph of the area on Google Maps.

From Fig. 3.3, it can be seen that yellow and red buildings tend to be large in the Yota Minami district. This is thought to be due to the fact that most of the target buildings are wooden buildings in comparison with Fig. 3.2. In the model assumed this time, it was confirmed that the buildings were densely packed with a story deformation angle exceeding 1/10. In such places, it is expected that evacuation will be difficult after big earthquakes.

Fig. 3.4 – Aerial photograph of Yota Minami district (quoted from Google Maps)

4. Workshop using the map of the building damage assumption in Kakogawa

Third and fifth authors participated in a Community Disaster Management Plan workshop held in the Yota Minami district of Onoe-cho, Kakogawa on November 23, 2019 (Saturday). In the workshop, about 30 local residents gathered and discussed to prepare a plan described in Chapter 3. In this workshop, we showed a Figure(see Fig. 3.3) of the time history response analysis results of the Yota Minami district. Some residents experienced the 1995 Southern Hyogo Prefecture Earthquake. At the time of the 1995 Southern Hyogo Prefecture Earthquake, Kobe City and others determined that the seismic intensity was 7. However, the area, about 40 km away from Kobe, was seismic intensity 4 or 5. Therefore, there is a feeling that "it does not shake" based on actual experience. This feeling leads to the consciousness of "no shaking" even in the supposed Nankai earthquake. We believe that providing visualized simulation results will lead to raising awareness. On the other hand, the figures shown in Chapter 3 were actually presented during the workshop, but they are a current model created based on the standard models considered by the IES, and the accuracy of the models will be improved in the future. It should be noted that it is necessary to sufficiently show that the results may be different by performing the simulation under different conditions. Participants of the workshop were impressed by the presentation, and it was effective to raise awareness. In addition, in areas where buildings are greatly deformed, measures such as removing them from the evacuation route, and methods such as removing block walls and fixing furniture can be considered. In this way, it is possible to contribute to actual Community Disaster Management Plan considering building damages.

5. Conclusions

In this study, we simulated the damage prediction of the assumed Nankai earthquake for two cities. The model shows that the two cities have many wooden buildings. We visualize areas with large shaking. By working on disaster prevention based on them, measures can be taken that are conscious of actual damage. In addition, we participated in a workshop held in Kakogawa City with the contents visualized in this study. We believe that this research will lead to more specific proposals when considering disaster prevention enlightenment and countermeasures. If a city model can be created, it is possible to estimate the damage in other areas using simulations.

Acknowledgements

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References

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[2] ESRI's ArcGIS : https://www.esri.com/en-us/home

