13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 1188

DISASTER ASSESSMENT OF GIANT TSUNAMIS ALONG THE NANKAI TROUGH

Yoshiaki KAWATA[1], Tomoyuki TAKAHASHI[2], Shunichi KOSHIMURA[3], Nobuaki KOIKE[4], Yuka KARATANI[5], Shingo SUZUKI[6] and Yoshihiro OKUMURA[7]

SUMMARY

Tsunami sources along the Nankai Trough include lands, and tsunami heights along the Pacific coastal zone and the Inland Sea coastal zone would be affected by the heterogeneity of tsunami source strongly. If an estimation of tsunami damage is carried out without a heterogeneity tsunami source, it is possible that there are underestimated areas.

In this study, a simple method to introduce an asperity distribution of earthquake into a tsunami source model is proposed, and it is applied to the Nankai Earthquake Tsunami. To estimate an effect of the determined heterogenous dislocation for tsunami heights along coastal zones, a tsunami numerical simulation is carried out. It is cleared that the heterogeneity affects local tsunami heights distribution, and some critical scenario is shown in each regions.

INTRODUCTION

Many earthquakes as large as magnitude 8 class had occurred at an interval of 100 to 150 years along the Nankai Trough. The giant tsunamis generated by these earthquakes gave huge damages to Japan, and they propagated toward some countries along the Pacific Rim. Many studies on the earthquakes and the tsunamis along the Nankai Trough has been conducted and Japanese government released the assumed models for the disasters and their estimated damages based on the research results. Because the earthquake model has taken in asperities of fault, it is improved as compared with past models.

[1] Professor, Kyoto University, Kyoto, Japan. Email: kawata@drs.dpri.kyoto-u.ac.jp
[2] Professor, Akita University, Akita, Japan. Email: tomo@ce.akita-u.ac.jp
[3] Research Scientist, Disaster Reduction and Human Renovation Institution, Hyogo, Japan. Email: koshimuras@dri.ne.jp
[4] Professor, Wakayama National College of Technology, Wakayama, Japan, Email: koikenob@wakayama-nct.ac.jp
[5] Research Associate, Kyoto University, Kyoto, Japan. Email: karatani@utel.kuciv.kyoto-u.ac.jp
[6] Student, Kyoto University, Kyoto, Japan. Email: shingo@drs.dpri.kyoto-u.ac.jp
[7] Student, Kyoto University, Kyoto, Japan. Email: okumura@drs.dpri.kyoto-u.ac.jp

The tsunami model, however, reproduces the 1707 Houei event which was largest tsunami along the Trough, and the heterogeneity of tsunami source has not been discussed. An objective of this study is to estimate an effect of the heterogeneity in a tsunami phenomenon. To consider the heterogeneity with the asperity of earthquake, we need a method to introduce the asperity into tsunami source. A simple method to do that is proposed, and it is applied to the Nankai Earthquake Tsunami.

MODELING THE HETEROGENEITY OF TSUNAMI SOURCE

The Headquarters for Earthquake Research Promotion [3] published assumed models about the Nankai Earthquake and the Tou-Nankai Earthquake. Figure 1 shows their assumed earthquake sources. The both models have three asperities respectively. The Headquarters explicated that large dislocations would be occurred on those asperities. Since a dislocation of fault relates a sea water surface elevation, the local large dislocations generate the heterogeneity in the initial profile of the tsunami source.

In many past tsunami source models, such a large dislocation on an asperity had not been estimated. If a tsunami source, however, locates close to a coastal zone, the heterogeneity will affect a tsunami height distribution along the coast strongly. Especially, the tsunami sources along the Nankai Trough include the Pacific coastal zone in Japan, so it is necessary to introduce the heterogeneity into the tsunami model to estimate damages due to the tsunamis correctly.

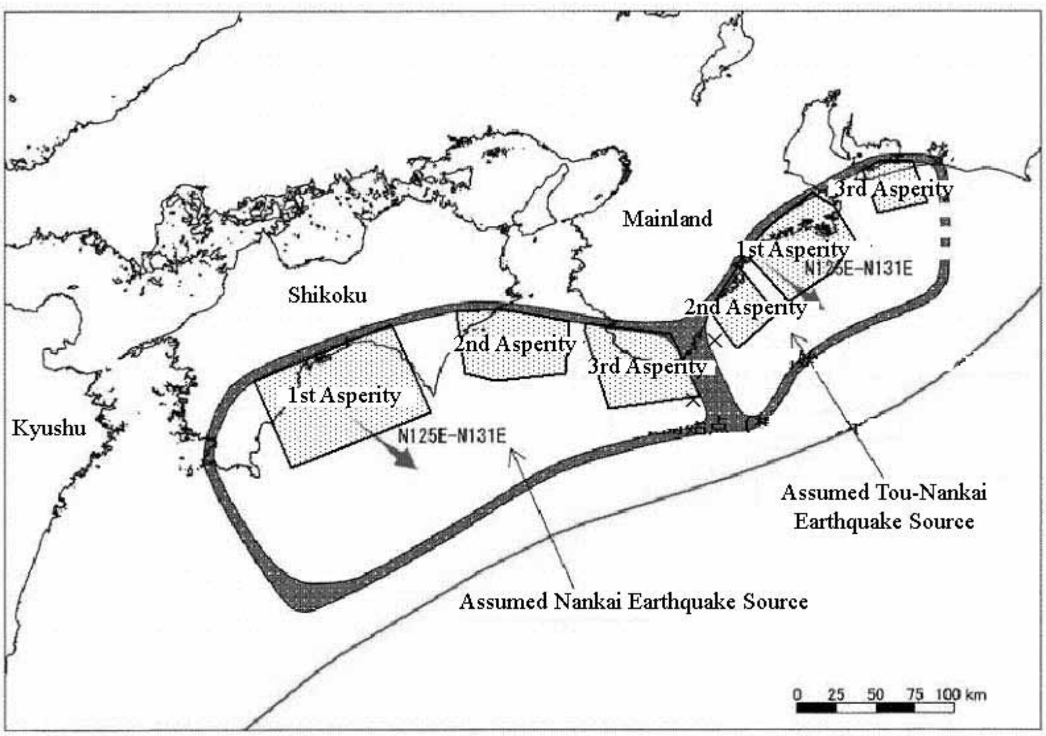


Figure 1. The Nankai Earthquake Source, the Tou-Nankai Earthquake Source and their asperities assumed by The Headquarters for Earthquake Research Promotion (2001)

To introduce the local large dislocations on the asperities of the Nankai Earthquake model into the tsunami model, the model has to consist of several hundreds sub-faults. This high resolution fault model has a very high degree of freedom, but it will be complicated and we don't have enough information to decide some parameters about it. Therefore, as a first step in this study, we propose a simple method. Figure 2 shows a procedure of this method. In 1st step (figure 2(a)), two large faults are assumed, and they are fitted to the earthquake source assumed the Headquarters. In 2nd step (figure 2(b)), a sub-fault is assumed in a west region, and it is fitted to the assumed west asperity. In 3rd and 4th steps (figure 2(c) and (d)), two sub-faults are assumed in a central and an east regions, and they are fitted to the assumed central and east asperities. In final step (figure 2 (e)), the assumed earthquake moments about whole fault and each asperities are allocated to the three sub-faults and back regions in the two large faults. When the assumed earthquake moment is distributed into the three asperities, we need to decide weightings of each asperities. The Headquarters assumed the west asperity would be largest and the central and east asperities would be same. This assumption is a reasonable scenario in an earthquake disaster prevention plan. We, however, need to supplement other scenarios in a tsunami disaster prevention plan, because the heterogeneity is more sensitive in the tsunamis than earthquakes. Therefore, we assume an large central asperity version and an large east asperity version in addition to the large west asperity version.

According as this procedure, three fault models determined shown in table 1 (a) to (c). In those models, fault no. 1 and no. 2 are the large faults include the asperities and back regions, and fault no. 3, no. 4 and no. 5 are corresponding to the west, the central and the east asperities. Figure 3 shows computed initial profiles of tsunami sources with those fault models by Mansinha and Smylie [1] model. In these figures, a solid line means an elevation of the sea water surface, a dotted line means a falling, and the unit is meters. All tsunami sources indicate that the elevation region locates the Pacific Ocean and the falling region locates on land. And each tsunami source has the largest elevation region on the large asperity.

COMPUTED TSUNAMI HEIGHT DISTRIBUTION

A tsunami numerical simulation [2] was carried out with the proposed fault models. Figure 4 shows comparisons of the computed tsunami height distributions along (a) the Pacific coastal zone of the Mainland in Japan, (b) the Pacific coastal zone of Shikoku district and (c) the Pacific coastal zone and the Bungo Strait coastal zone of Kyushu district. A general trend of the distributions by the three models is very close, and the tsunami is very high along the Kii Strait. Those models, however, generate large different tsunami heights in some local area. The difference is caused by the large asperity. The region close to the large asperity has a large tsunami height. Figure 5 shows a distribution of affected areas by the large asperity. The large west asperity affects Kyushu district, a west part of Shikoku district and a west part of the Mainland. The large central asperity affects the Kii Strait and the Inland Sea. The large east asperity affects an east part of the Kii Peninsula.

These characteristics indicate that each region has the most affective type of tsunami source respectively. The heterogeneity of tsunami source can generate very high tsunami locally. To estimate a regional damage due to tsunamis, some scenario of the heterogenous tsunami source should be considered.

Table 1. The proposed fault models

(a) The large west asperity version

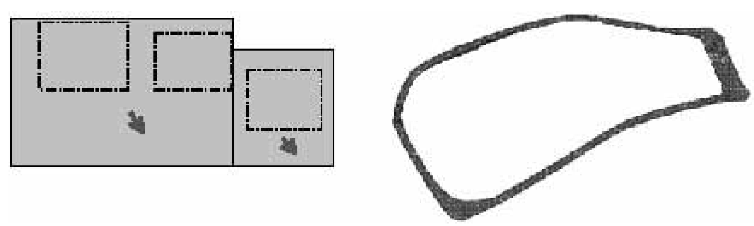
Fault No.	Fault origin (deg)	Depth (km)	Strike (deg)	Dip angle (deg)	Slip angle (deg)	Length (km)	Width (km)	Dislocation (cm)
1	E135.86, N33.07	0.00	250	20	117	70.00	81.70	334
2	E135.15, N32.85	0.00	250	20	117	210.00	140.00	334
3	E134.04, N33.11	29.26	250	20	117	93.46	56.08	1028
4	E135.05, N33.48	32.04	270	20	97	65.53	40.00	629
5	E135.80, N33.30	12.27	270	20	97	52.42	50.00	629

(b) The large central asperity version

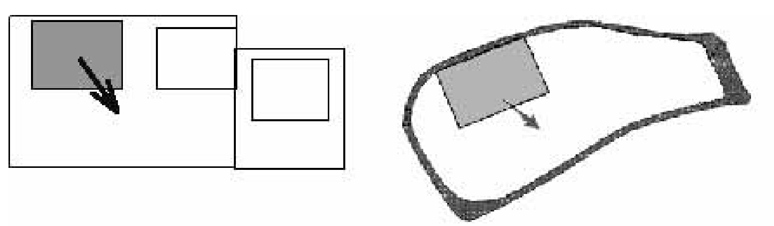
Fault No.	Fault origin (deg)	Depth (km)	Strike (deg)	Dip angle (deg)	Slip angle (deg)	Length (km)	Width (km)	Dislocation (cm)
1	E135.86, N33.07	0.00	250	20	117	70.00	81.70	334
2	E135.15, N32.85	0.00	250	20	117	210.00	140.00	334
3	E133.90, N33.15	33.24	250	20	117	66.10	39.66	629
4	E135.20, N33.48	29.80	270	20	97	92.66	56.56	1028
5	E135.80, N33.30	12.27	270	20	97	52.42	50.00	629

(c) The large east asperity version

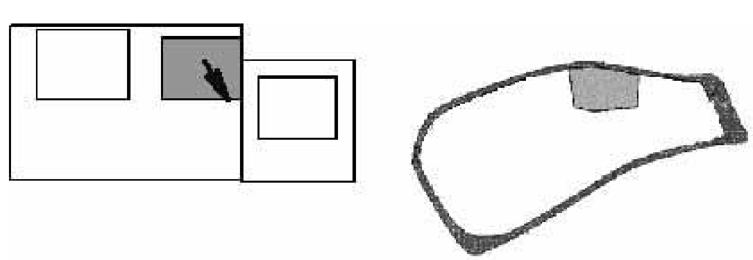
Fault No.	Fault origin (deg)	Depth (km)	Strike (deg)	Dip angle (deg)	Slip angle (deg)	Length (km)	Width (km)	Dislocation (cm)
1	E135.86, N33.07	0.00	250	25	117	70.00	81.70	334
2	E135.15, N32.85	0.00	250	25	117	210.00	140.00	334
3	E133.90, N33.15	33.24	250	25	117	66.10	39.66	629
4	E135.20, N33.48	32.04	270	25	97	65.53	40.00	629
5	E135.80, N33.30	14.17	270	25	97	74.13	70.70	1028



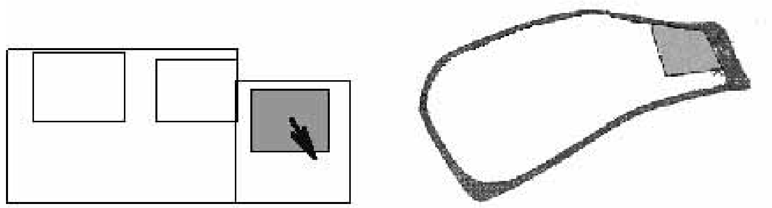
(a) Step 1: Fit two faults (gray square in left figure) to the assumed earthquake source (right figure).



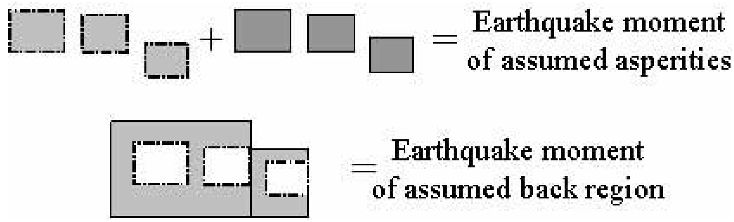
(b) Step 2: Fit a west sub-fault (gray square in left figure) to the assumed west asperity (gray square in right figure).



(c) Step 3: Fit a central sub-fault (gray square in left figure) to the assumed central asperity (gray square in right figure).

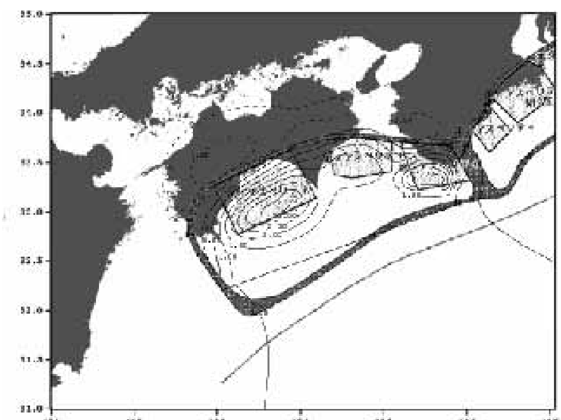


(d) Step 4: Fit an east sub-fault (gray square in left figure) to the assumed east asperity (gray square in right figure).

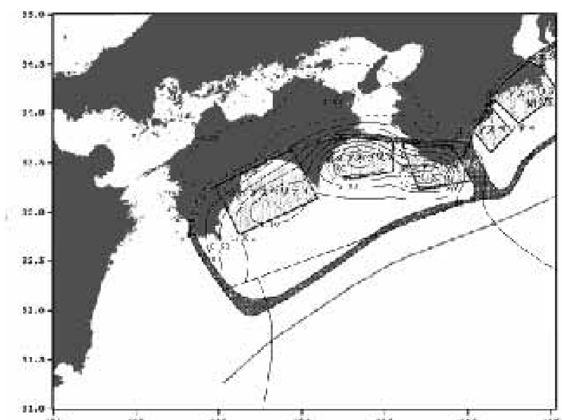


(e) Step 5: Allocate the assumed earthquake moment to sub-faults and back region.

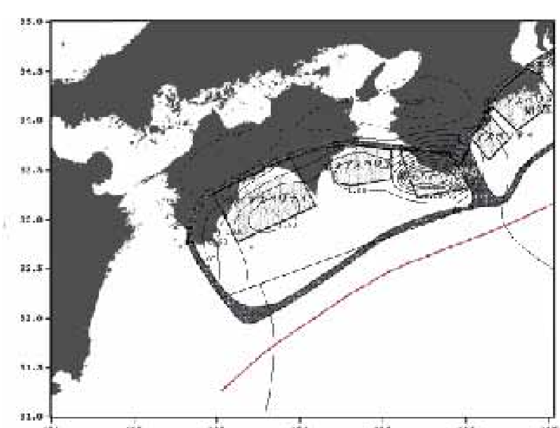
Figure 2. Modeling the heterogeneity of tsunami source with asperities of earthquake.



(a) The large west asperity version



(b) The large central asperity version

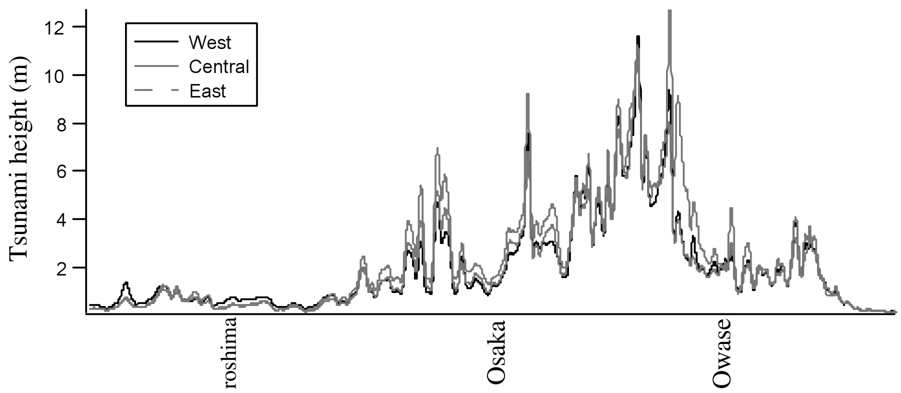


(c) The large east asperity version

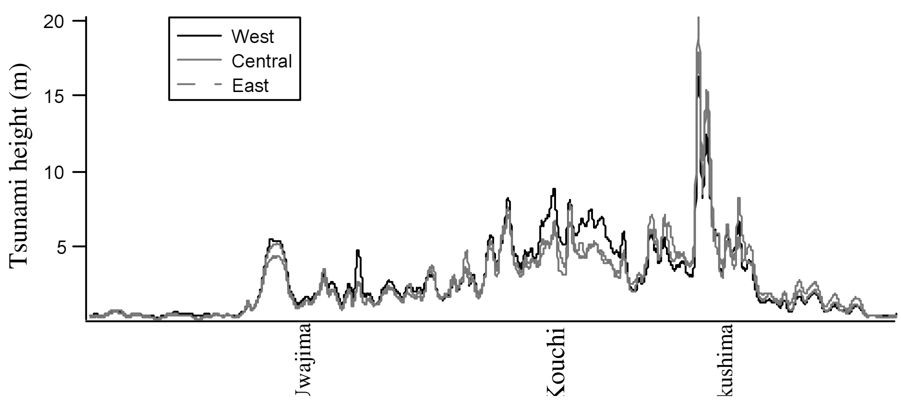
Figure 3. Computed tsunami source by proposed fault model superposed on the Assumed Nankai Earthquake Source.

CONCLUSIONS

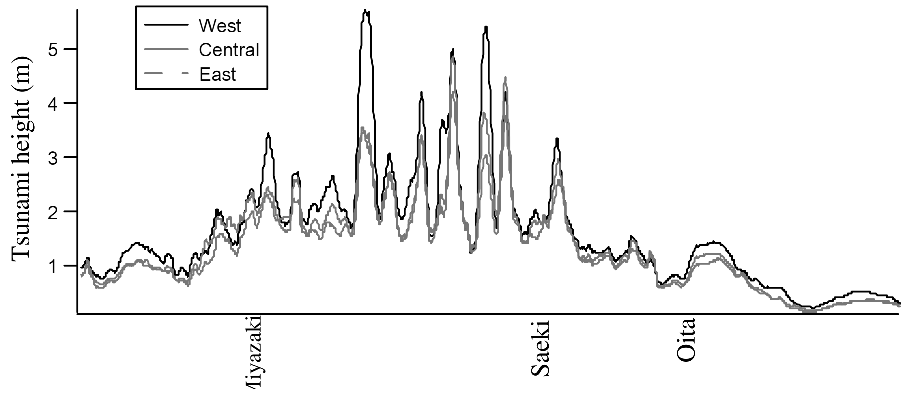
The simple method to introduce the asperity distribution of earthquake into the tsunami source model was proposed. This method was applied to the Nankai Earthquake Tsunami and the three fault models were determined. To estimate tsunami heights along coastal zones by these models, a tsunami numerical simulation was carried out. Therefore, the heterogeneity of the initial profile of the tsunami source affected local tsunami heights distribution, and each region had the most affective scenario respectively.



(a) The Pacific coastal zone of the Mainland



(b) The Pacific coastal zone of Shikoku district



(c) The Pacific coastal zone and the Bungo Strait coastal zone of Kyushu district
Figure 4. Computed tsunami height distribution with proposed fault models.

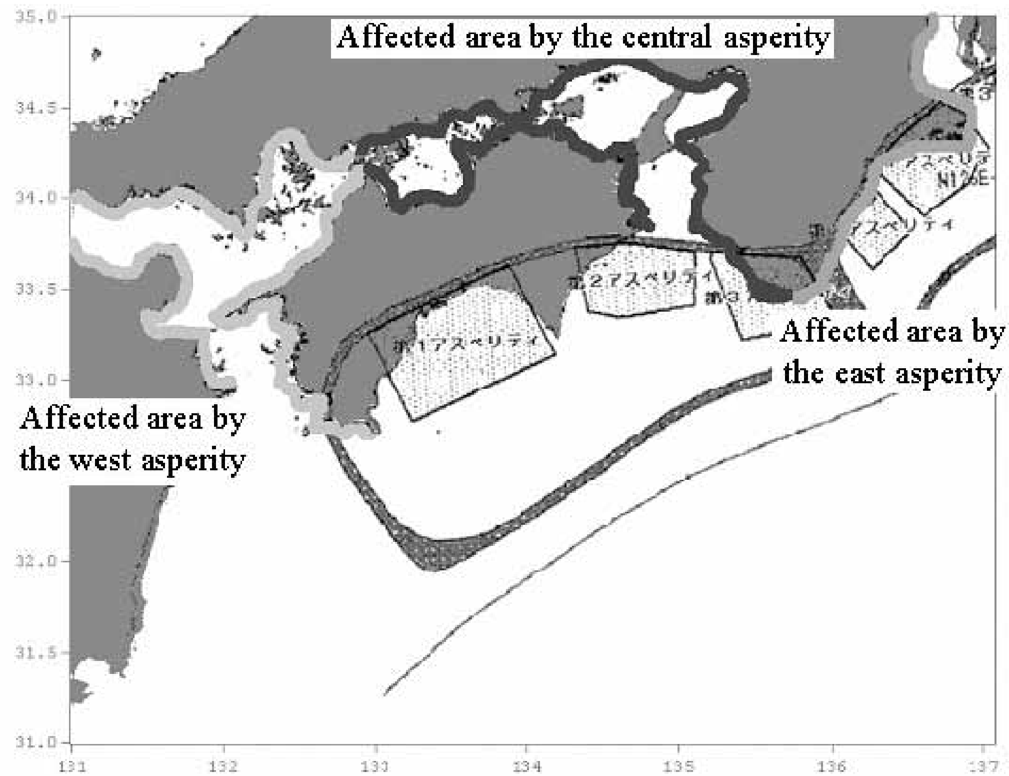


Figure 5. The distribution of affected areas by the three asperities.

REFERENCES

1. Mansinha L, Smylie DE. "The displacement fields of inclined faults." Bulletin of Seismological Society of America, 1971: Vol. 61, No. 5, 1433-1440.
2. Takahashi T. "Analysis Technique on Tsunamis - Case of the Nankai Earthquake Tsunami -" Lecture Notes of the 38th Summer Seminar on Hydraulic Engineering, 2002: B-5-6.
3. The Headquarters for Earthquake Research Promotion "On strong ground motion evaluation methods for projected earthquakes in the Nankai trough (interim report)", 2001.