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# RE-EVALUATION OF STRONG SEISMIC MOTION FROM THE MEDIAN TECTONIC LINE FOR AN EXISTING NUCLEAR POWER PLANT IN SHIKOKU, JAPAN

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**Abstract.** Ikata Nuclear Power Plant (NPP), West Shikoku Island, Japan, is located close to the Median Tectonic Line (MTL). Therefore, up-to-date seismic input motion associating fault rupture is required to confirm seismic safety. A design basis spectrum and seismic safety of the plant were re-evaluated. We confirmed that the spectrum was appropriate by using a semi-empirical Green's function method in 2001. However, recent strong motion simulation for inhomogeneous fault rupture is more progressive than the latest estimation: Required fault parameters can be determined by empirical and physical scaling. Accerelograms from small events that can be used as the Green's function for the simulation have been observed at the site. Broadband seismic network by the National research Institute for Earth science and Disaster prevention (NIED) improved precise determination of source mechanisms for the empirical Green's function. The Headquarters for Earthquake Research Promotion (HERP) of Japanese governmental authority published a long-term evaluation of MTL. Although probability of fault rupture is very low in the long-term evaluation, we extendedly confirmed the spectrum by newly observed data and the recent approach for the new scenario of MTL. Simulated strong motion was below the design spectrum.

## 1. Introduction

The seismic design spectra for Ikata NPP were estimated by semi-empirical methods for an existing fault along MTL, because distance from the site to the fault is around 8km. The design basis S1 (similar concept to 'SL1' of IAEA seismic safety standard, here after S1-new) was conservatively re-evaluated and seismic safety capacity was confirmed by S1-new. However, the recent scenario scheme for inhomogeneous fault rupture has been much improved by empirical and physical basis [1] and more progressive than the previous reassessment [2]. On the other hand, long-term evaluation for MTL was published by HERP and it was found out that probability of longer rupture than the previous model could not be ignored [3]. Since conservative evaluation of seismic safety is required for NPP, we estimated strong motions from the evaluated fault model using the scenario scheme.

## 2. MTL and Observation Site

MTL of Quaternary fault is located across the Shikoku island from the north shore of the west-end of Shikoku to Kii peninsular of Honshu main island Japan and the total length is about 360km. As shown in Fig.1, Ikata site is located close to the West Ishizuchi-Iyonada segment of the west end of the MTL. Further, this segment of 130km seems to consist three minor segments of Iyonada, Iyo and Kawakami-Shigenobu of 55, 35 and 40km.

Ikata site is located on green schist of Vs=2600m/s (PS well-log). A vertical array observation is installed with accelerometers at depth GL-5m, -80m and -160m at the site. 10 small events has been observed by the array. Records at GL-5m could be used as a Green's function for the semi-empirical approach. We compared Fourier spectra of the observed acceleration with $\omega^{-2}$ model. By the broadband seismic observation of NIED [4], *Mo* of the Green's function has been determined more precisely than the previous estimation [2]. As the mean radiation pattern, 0.63 was assumed for the random phases of high frequency. We selected records of March 26th, 2001 as the best empirical Green's function, which was well corresponding to the theoretical spectrum model as shown in Fig. 2. While, stress drops for the several cases were inspected and 20MPa was finally adopted.

## 3. Modeling and Scenario

Assumed fault model parameters are shown in Table 1. Global parameters such as location, dip, length, width and dislocation were in accordance with values by HERP. The depth of the model, rigidity, S-wave and rupture velocities were the same as those in the previous simulation [2]. An average stress drop was estimated by the following equation, which was derived for the line source of strike slip in the half space.

$$\Delta\sigma = 2\mu D / \pi W \quad (1)$$

Where, $\mu$, $D$ and $W$ are rigidity, slip dislocation and fault width. Rupture initiations were assumed to be at the bottom of the east edge of the West Ishizuchi - Iyonada segment.

Asperity area $S_a$ was assumed to be 22% and slip dislocation of the asperity was twice as much as global one according to an empirical assumption. Leftover moment was pasted on non-asperity area. Stress drop of the asperity $\sigma_a$ was determined by a dynamic asperity model by the following equation[1]:

$$\sigma_a = \Delta\sigma * S / S_a \quad (2)$$

Where, $S$ is the total fault area. Asperity locations were assumed to be near the center of the sub-segments, and the closest asperity to the site was located just ahead of the site.

## 4. Methodology and Result

First, the dislocation and stress drop of selected record as Green's function were corrected to those of asperity and non-asperity of the model in frequency domain. Second, the small events were placed geometrically on finite elements of the model. Then these corrected records were synthesized with arrival time delay to compensate for the rupture propagation of the model and the geometrical spreading from model elements to the site.

Synthesized seismic strong motion for the fault model is shown in Fig. 3. Three phases around 7, 13 and 20 second are excited by each of three asperities. The third phase is due to the closest asperity to the site and the most dominant. Other two phases are much lower than the third one due to far distance from the site to these asperities, therefore we can expect almost no influence by other farther segments. The response spectra (h=5%) of the synthesized motions are compared with the S1-new and as well as S2 (similar concept to 'SL2' of IAEA seismic safety standard).

## 5. Conclusion

Reassessment with updated knowledge is required for the seismic safety of existing NPPs. The latest earthquake scenario was applied to confirm the design spectrum of Ikata NPP, Shikoku, Japan, where MTL crosses around 8km apart from the site. Since long-term evaluation of MTL could not exclude probability of rupture longer than 130km, we estimated the strong motion for the fault model. The synthesized ground motion was covered by the design spectrum.

## REFERENCES

[1] Dan K., *et. al.*, Characterizing source model for strong motion prediction based on asperity model, *11th Japan Earthq. Eng. Symp.*, (2002) 555-560.(in Japanese)

[2] Fukushima Y., *et. al.*, Semi-empirical estimation of ground motion using observed records at a site in Shikoku, Japan, *J. Seismology*, 5, (2001) 63-72.

[3] HERP, Japan, http://www.jishin.go.jp/main/index.html, (in Japanese)

[4] NIED, Japan, http://www.fnet.bosai.go.jp/freesia/index.html


Table 1. Parameters for strong motion simulation

| Empirical Green's function | | | | |
|---|---|---|---|---|
| Origin date(local) | hypocenter | Mo (N*m) | $\Delta\sigma$ (MPa) | $\mu$ (N/m$^2$) |
| 2001.03.26 | 132.72E, 34.11N, h=49km | 4.76E16 | 20 | 4.0E10 |

| West Ishizuchi -Iyonada segment | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length | width | dip | dislocation | Mo (N*m) | $\Delta\sigma$ (MPa) | Vs (km/s) | Vr (km/s) |
| 130km | 25km | [a]70° N | 250cm | 3.25E20 | 2.55 | 3.5 | 2.5 |

| Asperity | | | | Non-asperity | | | |
|---|---|---|---|---|---|---|---|
| Area | Mo (N*m) | dislocation | $\Delta\sigma$ (MPa) | Area | Mo (N*m) | dislocation | $\Delta\sigma$ (MPa) |
| 715km$^2$ | 1.43E20 | 500cm | 11.6 | 2535km$^2$ | 1.82 E20 | 180cm | [b]2.3 |

| Other segments | length | width | dip | dislocation | Mo(N*m) | [c]distance |
|---|---|---|---|---|---|---|
| Sanuki-East Ishizuchi | 130km | 25km | 35° N | 650cm | 8.45E20 | 100km |
| Kitan-Naruto | 40km | 40km | 30° N | 350cm | 2.24E20 | 230km |
| Izumi | 60km | 40km | 30° N | 450cm | 4.32E20 | 270km |
| Kongoh | 20km | 40km | 30° W | 350cm | 1.12E20 | 330km |

[a] Assumed angle due to high dip angle by the Headquarters for Earthq. Res. Promotion,

[b] $\Delta\sigma$ of non-asperity is 20% by an empirical result.

[c] Closest distance from the site to lineaments

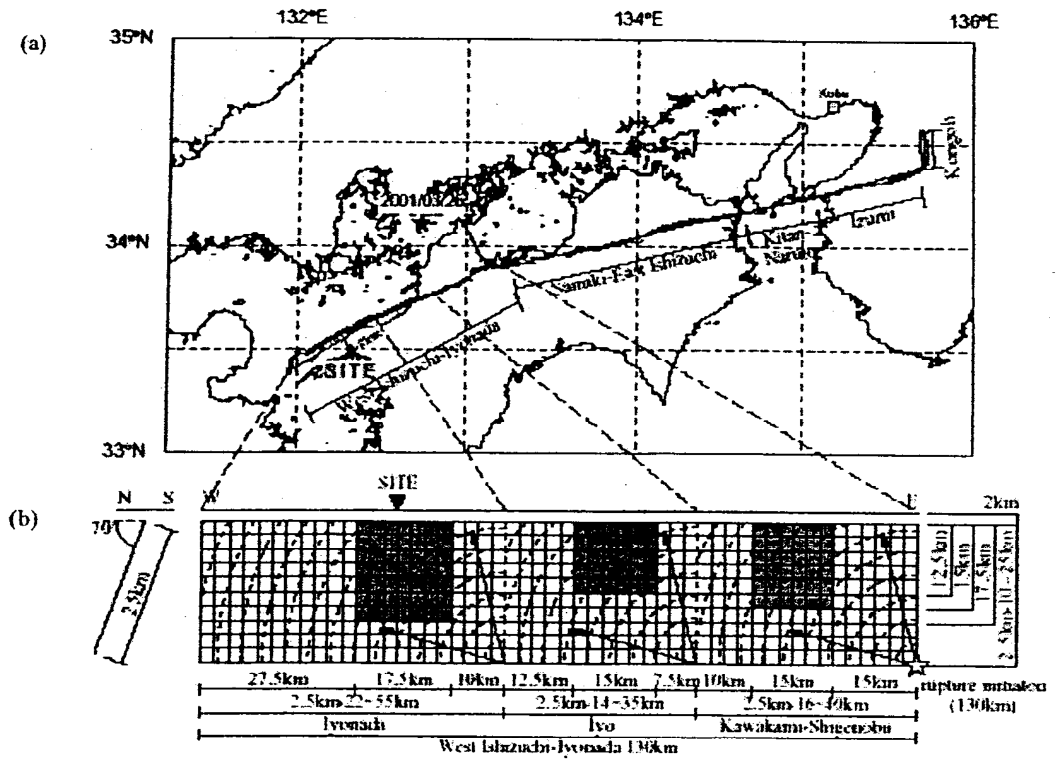

Fig.1. (a) Map showing site, event epicenter, MTL(bold lines) and model locations(thin lines), (b) Assumed model for West Ishizuchi -Iyonada segment. Shaded rectangles are asperities. Arcs indicate rupture fronts. The left figure shows section.

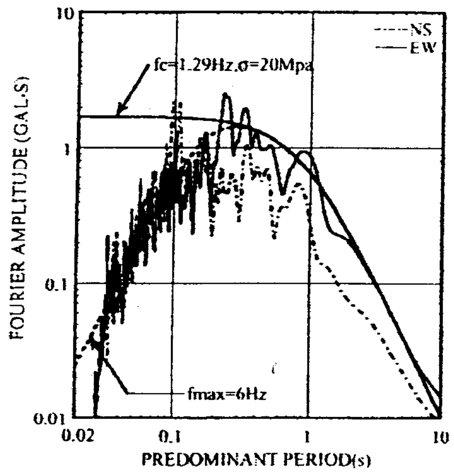

Fig.2 Comparison between observed Fourier spectra and $\omega^{-2}$ model both with and without $f_{max}$

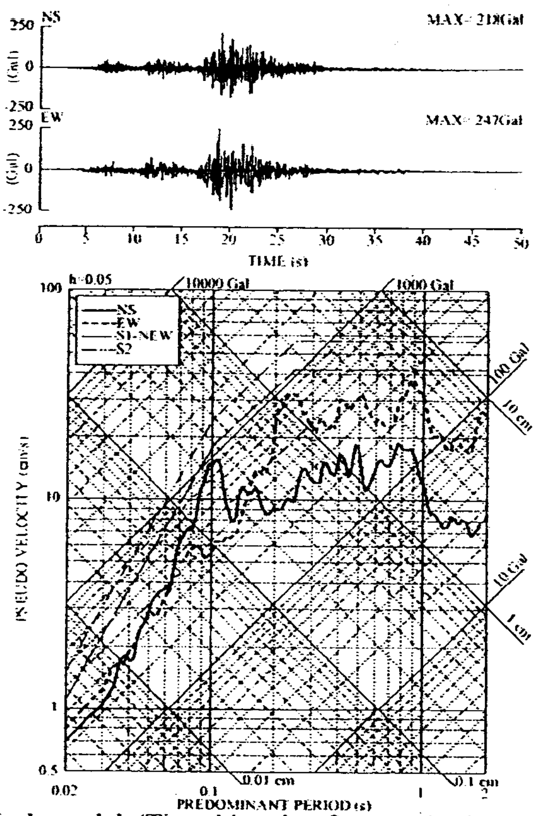

Fig.3. Synthesized strong motion for the fault model (Time histories for two horizontal components at the top and pseudo response spectra for 5% damping from acceleration comparing with S1-new and S2 at the bottom).