“Strong Ground Motion Assessment Scheme for Specified Source Faults” and the Kumamoto Earthquake

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Abstract

“Strong Ground Motion Assessment Scheme for Specified Source Faults” developed by the Earthquake Research Committee has been used for ground motion scenario predictions in various fields of Japan including design basis ground motions for nuclear power plants. However, based on Shimazaki (2016), TV stations and newspapers recently reported that the regression equation used in the scheme could provide underestimates for design basis ground motions. Here, we verify this criticism using the data of the 2016 Kumamoto earthquake, which occurred along a known active fault and for which a scenario prediction had already been performed in 2009.

Keywords: ground motion scenario prediction, Kumamoto earthquake

INTRODUCTION

“Strong Ground Motion Assessment Scheme for Specified Source Faults” (Earthquake Research Committee, 2009, 2016) has been used for ground motion scenario predictions in various fields of Japan including design basis ground motions for nuclear power plants. However, based on Shimazaki (2016), TV stations and newspapers recently reported that this assessment scheme could underestimate design basis ground motions. Dr. Shimazaki himself proposed the Nuclear Regulation Authority to replace the regression equation used in the scheme with another one for the reason of possible underestimation. Here, we verify these criticisms using the data of the 2016 Kumamoto earthquake, which occurred along a known active fault and for which a scenario prediction had already been performed in 2009.

ASSESSMENT SCHEME

The flow chart in Figure 1 shows the source modelling part of “Strong Ground Motion Assessment Scheme for Specified Source Faults” (hereafter, “Assessment Scheme”). First, the magnitude of a future earthquake along a specified source fault is determined following the upper-left section of Figure 1. For this determination, there are two methods, which are shown in Figure 1 with labels **A** and **B**. In the method **A**, the area S of the specified source fault is determined using its length L from active fault surveys and its width W from seismicity observations. The seismic moment M_0 is then calculated with the regression equation by Irikura and Miyake (2001) (hereafter, “Irikura-Miyake equation”). The M_0 yields a magnitude M in the Japan Meteorological Agency scale via a moment magnitude M_w. On the other hand, in the method **B**, M is determined from an active fault length L and the regression equation by Matsuda (1975) (hereafter, “Matsuda equation”). M is converted to M_0 and then S is calculated from M_0 and the Irikura-Miyake equation. The Nuclear Regulation

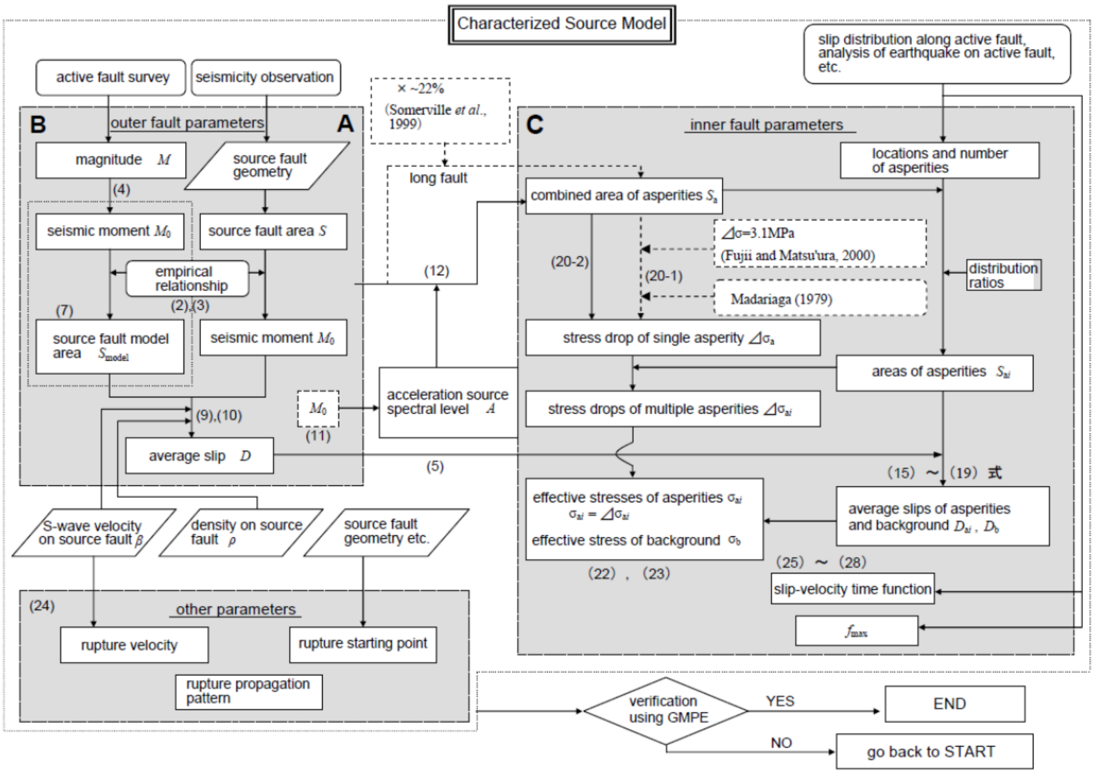

Figure 1. Source modelling part of “Assessment Scheme”.

Authority of Japan is using the method **A** for nuclear safety assessments, while the Earthquake Research Committee is using the method **B** for the National Seismic Hazard Maps. Since the section **C** and later after the upper-left section is common for all assessments, differences in results by the methods **A** and **B** lead to differences in final assessment results.

KUMAMOTO EARTHQUAKE

Among the Kumamoto earthquake sequence in 2016, we take the largest event of M 7.3 on 16 April as a target of the verification. Kobayashi et al. (2016) constructed an initial source fault model 54 km long and 16.5 km wide, and performed a joint inversion of teleseismic, strong motion, and geodetic data for the distribution of slip on this model. We then obtained the substantial source fault model in Table 1 from the inversion result using the method of Somerville et al. (1999).

Table 1. Substantial source fault model from the inversion result.

length	width	area	lower end depth	seismic moment
45km	16.5km	742.5km^2	16.0km	4.6×10^{19}Nm

Comparing the area S and seismic moment M_0 (red dot) with the Irikura-Miyake equation (thick, dashed line) in Figure 2 Left, we found a good fit between them and no problem in the Irikura-Miyake equation, which is used at (3) of Figure 1 in both the methods **A** and **B**.

Yoshimi (2016) estimated the length of the zone of surface rupture by the earthquake to be 34 km. Geospatial Information Authority (2016) constructed a uniform slip fault model for the earthquake. The total length of this model is 35.4 km. Comparing these lengths (hollow and solid red dots) with the Matsuda equation (dashed line) in Figure 2 Right, we found a good fit between them and no problem in the Matsuda equation, which is used in the method **B** to determine M from the results of active fault surveys.

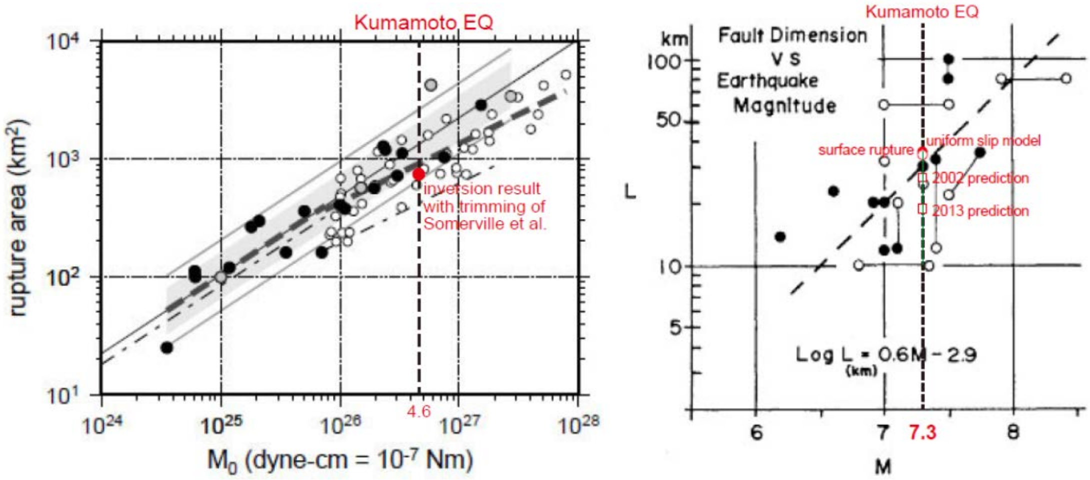

Figure 2. (Left) Irikura-Miyake and (Right) Matsuda equations.

PREDICTIONS

The 2016 Kumamoto earthquake occurred along the northeast segment of the Futagawa-Hinagu fault. In 2002, the Earthquake Research Committee evaluated the length of the segment to be 27 km based on the results of active fault surveys. This value is fairly close to the actual length of the surface rupture zone (34 km), but quite shorter than the length of the substantial source fault model (45 km). The lower end depth of the seismogenic zone around the segment was also evaluated to be about 15 km based on the results of seismicity surveys.

In the National Seismic Hazard Maps (Earthquake Research Committee, 2009; hereafter, "Hazard Maps 2009"), a scenario prediction was already performed and *M* 7.2 was obtained for the segment using the method **B**. This estimate is close to *M* 7.3, which is the actual magnitude of the 2016 Kumamoto earthquake. On the contrary, a scenario prediction with the method **A** has not yet been performed. Here, we carry out the source modelling part of "Assessment Scheme" with the method **A** as follows.

We start with the length of 27 km and seismogenic zone lower end depth of 15 km, which were evaluated in 2002 for the segment. In "Hazard Maps 2009", the source fault was assumed to be vertical and its upper end was assumed to be located at a depth of 3 km. Accordingly, we then take 15 –3 = 12 km for the width W of the source fault, while 27 km is simply used for the length L of the source fault. The area S of the source fault is now $L \times W = 27 \times 12 = 324$ km^2. By substituting this S into the Irikura-Miyake equation, we obtain $M_0 = 5.53 \times 10^{18}$ Nm. This moment further yields M of 6.9 using the conversion equation by Takemura (1990). This underestimates the actual magnitude by 0.4.

CONCLUSIONS AND DISCUSSION

Although detailed active fault surveys were conducted in 1996 and 1998 for the Futagawa-Hinaku fault, the actual source fault area of the 2016 Kumamoto earthquake, which occurred along the Futagawa-Hinaku fault, could not be estimated in advance. The estimate was smaller than a half of the actual area. Therefore, the method **A** based on an estimate of source fault area can underestimate an earthquake magnitude. However, the method **B** is based on an active fault length, which is a fairly good estimate of surface rupture length, so that the method **B** can provide a better estimate of earthquake magnitude leading to a better ground motion prediction.

The first reason why the method **A** does not work is that the source fault of a large earthquake often extends beyond the lower end of the seismogenic zone. The second reason is that a source fault length is usually longer than a surface rupture length because of hidden parts of a fault. On the contrary, the reason why the method **B** works is that the Matsuda equation was constructed using data of surface rupture and a surface rupture length can be estimated from an active fault length fairly well.

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