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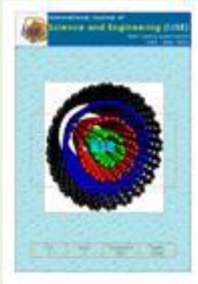

Subsurface Structure in Japan Based on P and S waves Travel Time Analysis Using Genetic Algorithm in Japan Seismological Network

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Abstract *- The experiment to obtain the subsurface structure in Japan is done by seismograms analysis of earthquakes in Japan. All 101 data was used from events in 2012, selected by a maximum depth of 60 km and magnitude between 4.2 to 5.5 Mj. 1-D of subsurface structure is determined by utilizing the inversion method with genetic algorithm approach. P wave and S wave velocity structure are determined based on arrival times at receiver. The crustal thickness is known of 33,66 km. P wave velocity for the upper and lower crust, respectively is 6,03 km/s and 6,92 km/s, and velocity in the upper mantle is 8,18 km/s. S wave velocity for the upper and lower crust is given respectively 3,38 km/s and 3,89 km/s, and the velocity in the upper mantle is 4,59 km/s. If the range integrated to the stable parameter of velocity structure, it shows stable result and the subsurface structure has sufficiently high compatibility.*

Keywords *— Velocity Structure, Genetic Algorithm, Travel Time, Japan Seismological Broadband*

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I. Introduction

Japan is one of area with high seismic activity. Current research on seismology to obtain subsurface structure of Japan still need a reference model, especially for research using seismogram data analysis. 3-Dimensional analysis of velocity structure have been conducted in southwest of Japan using geo-tomography and double-difference of tomography (Hirahara, 1986; Hirose, et al., 2008), P wave and Bouger anomaly correlation was used in Kanto-Tokai district (Ishida & Hasemi, 1988), LSQR algorithm was used in northeast of Japan (Zhao, et al., 1992) and Kyushu area with reference model from Kyushu University (Matsubara, et al, 2008; Saiga, et al., 2010). Almost of them ignored the presenting S wave and used only P wave analysis, although S wave have good influence on real condition in the field (Gomberg, et al., 1990).

This research conducted to find substructure model of Japan. Popular technique currently used still have some disadvantages, such as Lee and Lahr's technique (Lee & Lahr, 1972), the analysis is compatible only for local and regional earthquakes, Billing's technique (Billings, et al., 1994) only suitable for teleseismic, and both of them still need a initial model of earth from field study. To obtain reference model become very difficult, because the model must be presented first. Introduced by Lopez (De Vasconcelos Lopes & Assumpccão, 2011) is a new technique to determine structure model of crust without a reference model from field using genetic algorithm, enable to get the best 1 dimension model. Furthermore, it also can be used as reference model to the most popular program for determining velocity structure, VELEST, have been done by Supardiyono and Santosa using P wave, they use the result of hypoGA program as an initial model and shown the robustness of velocity structure (Santosa & Supardiyono, 2012).

Recent studies on Japan structure, it was conducted by researchers in 3-Dimensional field using tomography methods, but they need an initial model or reference model. This condition will give a disadvantage, if the model doesn't reliable to the real structure. The reference model which is introduced by National Research Institute

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of Earth Sciences and Prevention Disaster (NIED), it used almost the entire research, using Hi-Net data (Matsubara et al, 2008), KiK-Net and K-Net data (Koketsu et al, 2008), and also from Japan Meteorological Agency (JMA) 2001 based on Hi-Net data (Nishida & Nakajima, 2013).

Taking all of those into consideration, research is conducted to determine 1 dimension of velocity structure beneath Japan, by purpose to create a reference model for daily routine hypocenter determination in Japan area. This research arranged using Lopez technique to get velocity structure using P and S wave data analysis, which hopefully can create a primary data for daily routine hypocenter in Japan, as a resource of information contributing to minimize the risk of earthquake hazard.

II. METHODS

Seismic data (seismogram) is taken from Japan's earthquake observatory, provided by NIED from F-Net Broadband on website *http:\\www.f-net.bosai.go.jp* in *seed* file type. Data selection is very important to keep high validity of result. Selected data is earthquakes event with magnitude between Mj 4,2 to 5,5 in 2012. Total 101 data recorded by 97 stations around Japan, shown by Figure 1.

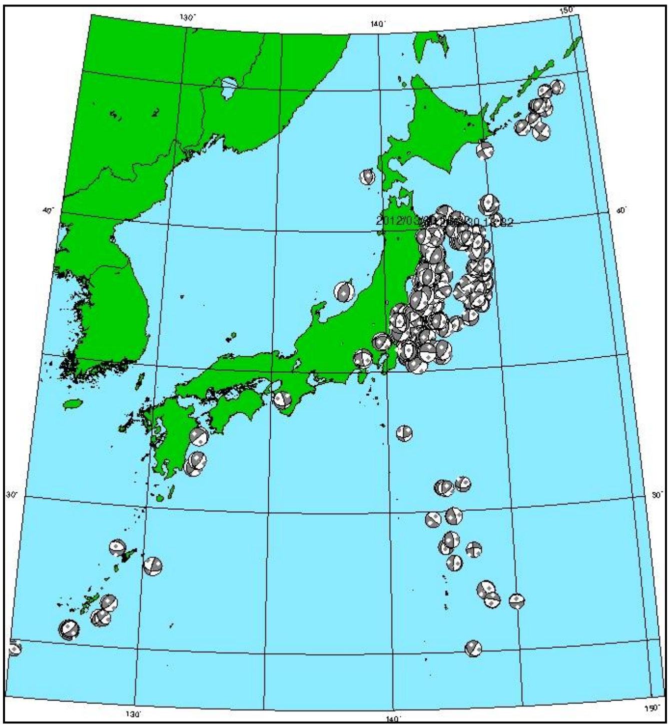

Figure 1. Seismicity map of earthquake events with magnitude Mj 4,2 to Mj 5,5 and depth less than 60 km in 2012.

First, data extracted from *seed* to *sac* file type, then seismogram divided into three component, two horizontal component (-E, -N) and the other one is vertical component (-Z). The component need to be rotated, especially for horizontal components, so it's done by using Seismic Analysis Code (SAC) (Peng, 2013) to obtain pure SH wave (Kennett, 1991). The components will change to radial component (-R) and transversal component (-T). At this point, primary data for analysis is obtained, which are -R, -T, -Z components (Reading, et al,. 2003). The data is analysed to find arrival time of P wave and S wave. P wave is indicated as the first fault found at the seismograms recording, while the S wave is the changes in P wave phase and always present before the surface waves. Arrival time data is important to obtain and then everything is converted into seconds. To determine the speed of P waves and S waves in the crust and upper mantle, genetic algorithm approach is used in hypoGA program. HypoGA program provide output in the form of wave velocity, depth of the layer structure, Vp/Vs ratio (Poisson's ratio), as well as the standard deviation. Then the output is plotted using the Generic Mapping Tools (Wessel & Smith, 1998).

Table 1. Results from twenty repetitions of hypoGA running for P and S wave velocity structure

Parameter	Result
Vp upper crust	6,03±0,23 (km/s)
Vs upper crust	3,38±0,13 (km/s)
Vp lower crust	6,92±0,21 (km/s)
Vs lower crust	3,89±0,12 (km/s)
Vp upper mantle	8,18±0,18 (km/s)
Vs upper mantle	4,59±0,10 (km/s)
Upper crust thickness	14,08 (km)
Crust thickness	33,36 (km)
Vp/Vs	1,78

Table 2. Stable measured data of velocity structure, crustal thickness, and Poisson ratio (De Vasconcelos Lopes & Assumpccão, 2011)

Parameter	Range
Vp upper crust	5,75-6,50 (km/s)
Vp lower crust	6,55-7,48 (km/s)
Vp upper mantle	7,88-8,50 (km/s)
Upper crust thickness	9,5-25 (km)
Crust thickness	28,3-50 (km)
Vp/Vs	1,65-1,80

III. RESULTS AND DISCUSSIONS

Output data obtained after 20 times running of hypoGA program. The purpose is to achieve a high level of compatibility, so error correction can be minimized. The program is ran by regarding to the value of the former models that had already been reported by the seismologists who work in similar topics. Twenty repetitions of hypoGA running give the results as Figure 2 for P and S wave velocity and Figure 3 for S wave velocity. The results from data processing of local earthquakes in Japan in order to obtain the structure of the crust and upper mantle as well as the P and S wave velocity respectively in the layer are shown in Table 1 which can be plotted as Figure 4.

P wave velocity has value of 5,57 km/s based on sn12c model (Kato & Nakanishi, 2000) and ARC-TR (Fukao, 1977) located at 0-15 km depth, similarly issued by the Preliminary model, Jeffrey model, and CIT11CS3 model (Kanamori, 1967).

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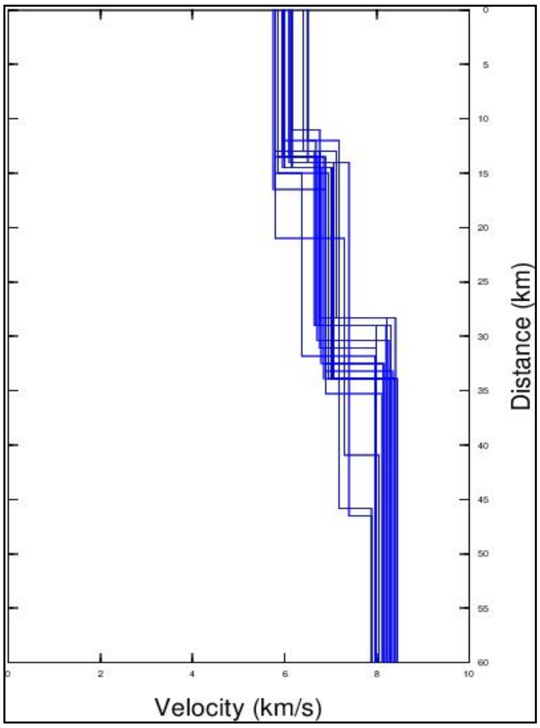

Fig. 2. P wave velocity structure obtained by 20 times running of hypoGA program.

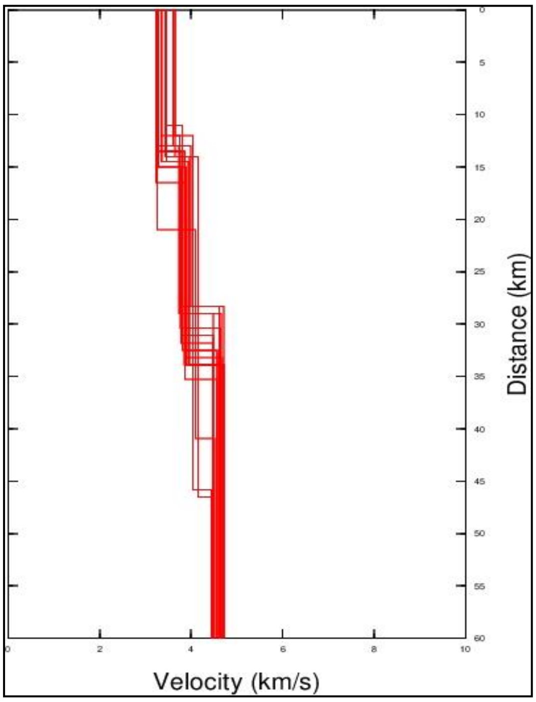

Fig. 3. S wave velocity structure obtained by 20 times running of hypoGA program.

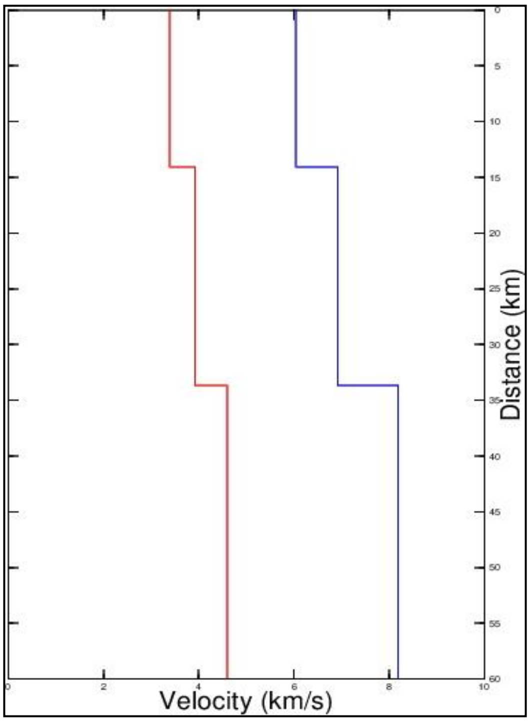

Fig. 4. 1-dimensional cross-sectional structure of the P wave velocity (Vp) in blue and S (Vs) in red.

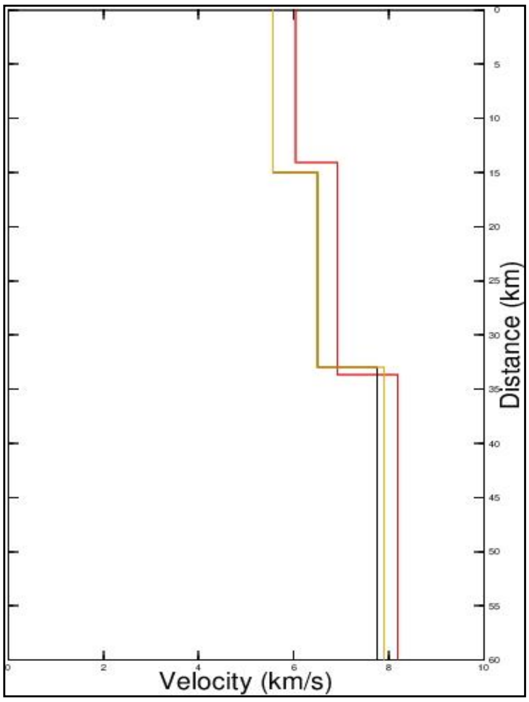

Fig. 5. Comparing velocity structure of P wave velocity (Vp) for Jeffrey's (black), CIT11CS3 (yellow), and hypoGA inversion (red) in km.

P wave velocity obtained has value of 6,03 ± 0,23 km/s and depth of 0-14,08 km, which 0,46 km/s higher and 0,82 km difference of depth located on the upper crust. At lower crust layer on depth of 14,08 to 33,66 km, P wave velocity increase up to 6,92 ± 0,21 km/s , while Jeffrey's have values of 6,5 km/s on depth of 15-33 km, and Preliminary also CIT11CS3 has value of 6,5 km/s at the same depth.

This means the results on the lower crust layer close to the limit of these models. On perspective as a whole for the upper crust and lower crust, it is obvious that the P wave velocity structure generated by hypoGA inversion is on the searched range, as reported in Table 2, the search range of upper and lower crust are respectively 5,75-6,50 km/s and 6,55 to 7,48 km/s (De Vasconcelos Lopes & Assumpccão, 2011). The third layer is interpreted as upper mantle by hypoGA, with boundary values between

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7,88 to 8,50 km/s . Inversion results P wave velocity still available in the range, that is 8,18 km/s with depth ranging from 33,66 km up to range unreachable by hypoGA because hypoGA only provide for velocity structure in the upper crust , lower crust, and upper mantle, and the limit of upper mantle depth can't be reached (De Vasconcelos Lopes & Assumpccão, 2011).

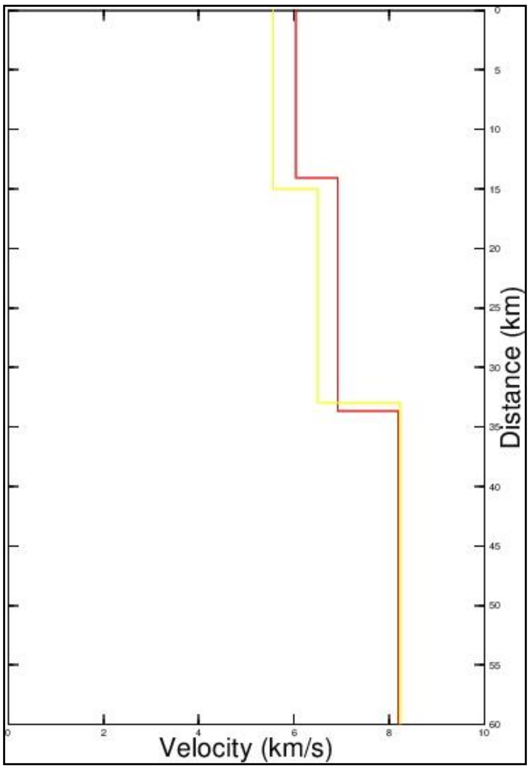

Fig. 6. Comparing velocity structure of P wave velocity (Vp) for ARC-TR (yellow) and hypoGA inversion (red) in km.

When velocity at upper mantle correlated with Jeffrey model, CIT11CS3 model, and Preliminary model, it is relatively compatible with difference value 0,28-0,33 km/s. Jeffrey has value of 7,75 km/s to depth of 33-100 km, CIT11CS3 provide value 7,9 km/s to depth of 33-75 km , and Preliminary also give the same value of 7,9 km, but with different depth 33-95 km (Kanamori, 1967), the result is shown in Fig. 5. When it's correlated to ARC–TR's models that provide value of 8,23 km/s at 33-95 km depth, there only difference of 0,05 km/s, indicating the inversion results highly suitable (Fukao, 1977) as shown in Fig. 6. Vp/Vs ratio obtained, as shown on Table 1, is 1,78, resulting in S wave velocity (Vs) can be obtained by dividing P wave velocity to Poisson ratio. Table 1 provides data of dividing results complete with standard deviation to each S wave velocity for each layer. Standard deviation of S waves obtained in upper crust is ± 0,13 km/s, for lower crust is ± 0,12 km/s, and for upper mantle is ± 0,10 km/s. The contribution to the value of S wave velocity in upper crust become 3,38 ± 0,13 km/s, lower crust become 3,89 ± 0,12 km/s, and upper mantle become 4,59 ± 0,10 km/s. Compared to the model from F-Net broadband to calculate moment tensor, the results of this inversion has an anomaly. F-Net references requires up to 3 layers of the crust.

However, because the hypoGA only detect the upper crust, lower crust and upper mantle, the study came to the conclusion of the two layers in crust beneath Japan, for the value of velocity structure on the allowable range and accurate with previous research, which still uses initial model of velocity structure. P and S wave rate propagations shown that proportional to deeper of earth, especially through to upper mantle, the wave velocity goes to faster. This reason is responsible to an assumption that the velocity structure is depends on material building in elastic medium (earth structure). Crustal structure beneath Japan island is predicted containing geological structure as granitic in upper crust and basaltic in lower crust (Zhao et all, 1992b).

IV. Conclusion

Japan subsurface conditions can be represented by values of P (Vp) and S (Vs) wave velocity recorded by the Japanese seismological network, which records all events that occurred in 2012. Analysis using genetic algorithms provide new breakthrough and greatly assist in determining the structure of P and S wave velocity without providing any reference data first, and have a fairly high accuracy with models of Jeffrey, ARC-TR, CIT11C3S, Preliminary, and sc12c. hypoGA program is useful to solve non-linier problem and capable to determine the new velocity structure from the known and unknown area, because it didn't require initial model.

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