Shear wave velocity model beneath CBJI station West Java, Indonesia from joint inversion of teleseismic receiver functions and surface wave dispersion

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Abstract. Earthquake signal observations around the world allow seismologists to obtain the information of internal structure of the Earth especially the Earth's crust. In this study, we used joint inversion of receiver functions and surface wave group velocities to investigate crustal structure beneath CBJI station in West Java, Indonesia. Receiver function were calculated from earthquakes with magnitude more than 5 and at distance 30°-90°. Surface wave group velocities were calculated using frequency time analysis from earthquakes at distance of 30°-40°. We inverted shear wave velocity model beneath the station by conducting joint inversion from receiver functions and surface wave dispersions. We suggest that the crustal thickness beneath CBJI station, West Java, Indonesia is about 35 km.

1. Introduction

Earthquake signal observations around the world allow seismologists to know the internal structure of the earth especially the earth's crust. There are various methods of research that used to investigate the subsurface structure of the earth, such as seismic tomography, surface wave dispersion, and receiver function. In this research, the surface wave dispersion method was combined with receiver function method to investigate the shear wave velocity model beneath CBJI Station West Java, Indonesia. Receiver function method has been widely used to investigate the crustal structure [1-3]. Receiver functions are time series, computed from three-component seismograms that shows the response of earth structure beneath a station. Receiver functions primarily are sensitive to shear wave velocity contrasts and vertical travel time. Teleseismic wave contains information about the seismic source structure, the propagation through the mantle, and the local structure beneath the seismic station [4].

Several studies have used surface wave dispersion to model Earth's velocity layer structure [5-7] because shear wave propagation analysis can explain the difference of medium in the structure of the earth's crust. By conducting joint inversion of receiver function and surface wave dispersion, produces a more tightly constrained crustal structure model than using receiver function or surface wave dispersion separately [8]. Research on the crust and upper mantle with joint inversion of the receiver functions and surface wave dispersion methods has been widely practiced in many countries such as Du et.al in Iceland [9], Chang et.al in Korea [10], and Tkalcic et.al in the Arabian Peninsula [11].

Java Island is located on the southeast edge of Sundaland (figure 1). Java Island has high tectonic
activity because lies above subduction zone between Indo-Australian and Eurasian Plate. Although Java Island has high tectonic activity, it is still very few research in crustal and upper mantle in this region. Hidayat [12] investigated velocity structure beneath Tangkuban Parahu West Java from receiver function analysis. Syuhada and Anggono [13] used teleseismic receiver function to investigate crustal structure in the Southern part of West Java. In this preliminary study, we carried out joint inversion of teleseismic receiver function and surface wave dispersion to obtain information about the shear wave velocity model beneath one IA-network station in West Java, Indonesia.

2. Methodology
We analyzed surface wave and receiver functions from teleseismic recordings in earthquake recorded at three-component broadband seismometer of CBJI station (figure 1). We choose earthquakes with magnitude more than 5 with distance between 30°-40° and has clear arrival of surface waves. Based on categories above, there are 5 teleseismic earthquakes that used in surface waves analysis. For receiver function analysis, there are 27 events that used in this study. The distance of teleseismic events 30°-90° and magnitude more than 5. Figure 1 shows the location of CBJI station and the location of the teleseismic earthquakes.

![Figure 1](image_url)

**Figure 1.** Distribution of earthquakes used in the receiver functions (solid blue) and surface wave (green). Location of CBJI station is also shown in the map (solid yellow triangle).

Rayleigh wave dispersion were analyzed from vertical seismogram’s component. Figure 2 shows an example of one earthquake seismograms recorded in CBJI station. In this study, we analyzed group velocity of fundamental mode Rayleigh wave with period from 10-100 s with Gaussian filter parameter (α) 50. We used multiple filter technique to analyze group velocities from recorded seismograms. Multiple filter technique can separates modes of surface waves when arriving at the station. Frequency time analysis (FTAN) diagram is produced from repeating through different periods. A signal is processed by FTAN method to extract the group velocity dispersion curve of the rayleigh fundamental mode. The frequency time analysis (FTAN) method is used to improve in a significant way the multiple filter analysis which Dziewonski et.al developed [14]. This method employs a system of narrow-band Gaussian filters, with varying central frequency, that does not introduce phase distortion and give a good resolution in the time-frequency domain. A FTAN map is the image of a matrix whose columns are the energy values at a certain period and the rows are the energy values at constant group velocity. A sequence of frequency filters and time window is applied to the dispersion curve for an easy extraction of the fundamental mode. The floating filtering
technique, combined to a phase equalization, permits to isolate the fundamental mode from the higher modes [15]. Figure 2b shows the frequency time analysis diagram of Rayleigh wave for one of earthquake event recorded at CBJI station.

We calculated the receiver function with iterative deconvolution technique. We used Gaussian Filter parameter alpha 1.5. We used Computer Programs in Seismology 330 software package (joint96) in the process of joint inversion. For inversion processing, we used one dimensional (1-D) ak-135 as a starting model.

![Figure 2](image1.png)

![Figure 2](image2.png)

**Figure 2.** (a) Seismogram records at CBJI station. Seismogram sample that recorded in CBJI Station, 2013/04/16 Earthquake. (b) The frequency time analysis diagram showing the dispersion of rayleigh wave for 2013/04/16 earthquake recorded at CBJI Station.

3. Results and discussions
Measured group velocities of fundamental mode Rayleigh waves and calculated receiver functions are shown in figure 3. Joint inversion of surface wave dispersion and receiver functions was carried out to
obtain shear wave velocity model beneath CBJI station. We combined the Rayleigh wave group velocity with receiver functions to determine the subsurface structure. The group velocities of fundamental mode of Rayleigh wave are shown in figure 3a. A total of about twenty seven receiver functions were used for the joint inversion. Figure 3b shows the observed radial components of receiver functions in CBJI station used in this study. Number of iterations is set to be 100.

Figure 3. (a) Measured group velocity of Rayleigh waves at CBJI Station. (b) Calculated radial receiver function at CBJI station. Solid red lines represent theoretical dispersion curve and radial receiver functions from the inverted shear wave velocity model.

Figure 4 shows shear velocity model from joint inversion of teleseismic receiver function and surface wave dispersion. The shear velocity in near surface of CBJI station ~2.5 km/s, which may corresponds to the sediment layer close to the surface. The shear velocity increase up to ~4.1 km/s at the depth ~19 km. We observed shear velocity decrease to about ~3.5 km/s at depth of ~26 km and increase to ~4.0 km/s at the depth of ~30 km. The shear velocity increases sharply at depth ~35 km from ~3.8 km/s to 4.25 km/s. From this condition, we suggested that Moho depth beneath CBJI station is about ~35 km. Our result is consistent with previous studies in the region. For example, Hidayat et.al [15] suggested crustal thickness beneath Tangkuban Parahu is about 30-35 km. Amukti and Suryono [16] using receiver functions suggested that the crustal thickness in Central Java is about 32 km.

The velocity structure decreases at lower crustal depth has been investigated in collision zone or subduction zone by Caldwell [17] and Bostock [18]. These studies suggest the low velocity occur in lower crustal depth. Langston in [19, 20] based on receiver function studies showed that low velocity zone present in the forearc structure in Cascadia subduction zone. In the recent studies at Cascadia subduction zone, low velocity zone occur is observed at depth to about 45 km [21]. Other studies also shown the presence of low velocity zone at the subduction zone revealed from the studies of receiver function or seismic tomography, such as Honsu [22] and Chile [23]. The presence of low velocity zone might be attributed to the partial melting [24], presence of over pressured fluid [25], eclogitization [26, 27], serpentinite or graphitic zone [28].
4. Conclusions
We have carried out the joint inversion of teleseismic receiver function and surface wave dispersion to obtain shear wave velocity model beneath CBJI Station, West Java, Indonesia. The joint inversion of receiver functions and surface wave dispersion data provides constraints on the shear velocity of the propagating medium, which may give better result than inversion of the data separately. The crustal thickness beneath CBJI station, West Java, Indonesia is estimated to be about 35 km.

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