Interpretation of Conventional Reciprocal Method (CRM) refraction data for identification of subsoil structure in the tourism area at Batu Kuda Bandung

S Nurasiah1,*, F H Muhammad1, R D Agustina2 and H Sugilar3

1 Department of Physics, Faculty of Science and Technology, UIN Sunan Gunung Djati Bandung, JL. AH. Nasution No. 105 Cibiru Bandung, Indonesia
2 Department of Physics Education, UIN Sunan Gunung Djati Bandung, JL. AH. Nasution No. 105 Cibiru Bandung, Indonesia
3 Department of Mathematics Education, UIN Sunan Gunung Djati Bandung, JL. AH. Nasution No. 105 Cibiru Bandung, Indonesia

*snurasiah1@gmail.com

Abstract. The purpose of this study is to identify the subsurface geological structure by using the seismic refraction method in the Wana area of Batu Kuda tourism using Seismic Data Interpretation Refractive Conventional Reciprocal Method (CRM) which aims to produce a GUI. Data obtained in the form of wave propagation time as time forward and time reverse, from the travel time of the wave and distance and time geophone analysis. From the results of the data interpretation, the velocity of P wave propagation in the medium and depth is obtained in 2 layers. In the first layer obtained a velocity value of 628.98 m/s with the depth of the first layer ranged from 0 m - 8.73 m and the seismic wave velocity in the second layer was 1228.99 m/s with the depth of the second layer ranged from 8.73 m - 20 m. Based on the 2D model the distribution pattern of velocity values, it can be indicated that the first layer is the latosol soil layer containing sand, gravel, fine sediment and clay. The second layer contains fine deposits, sandstone, gravel, sand, fine sand (silt), clay and clay. These materials as a result of the process of the eruption of an undefined young volcano.

1. Introduction
Wana Wisata Batu Kuda is located at the foothill of Mount Manglayang, Cibiru Village, Ujung Berung District, North Bandung. The location of Wana Wisata is quite far from the access road. The type of soil in the Batu Kuda tourism area as a whole belongs to the type of latosol soil or rocky soil type formed from igneous rock that originates from the eruption of the volcano. The type of soil latosol is soil that contains a lot of iron and aluminum. This type of soil is old soil so that the soil fertility rate is low. The mineralogy composition of sand fraction is varies, some of them rich in weatherable minerals resistant minerals such as quartz and opaque [1].

The spatial connectivity in rock physical property distributions has to be inferred from uncertain and incomplete sources of information, including qualitative geologic interpretations, formation type and outcrop maps, as well as scattered measurements [2]. To identify the subsurface geological structure by using the seismic refraction method, because by propagating seismic waves can identify the subsurface geological structure, the seismic refraction technique to a site that has a more complex structure [3].
However, additional information provided by seismic refraction tomography is capable of eliminating some potential pitfalls in resistivity data interpretation [4]. The interaction method used in this study is the seismic refraction method which is interpreted using the Conventional Reciprocal Method (CRM), using these interpretations to find out the carrying capacity of the soil, find out the velocity and rock density at that location, and know the wave velocity value. By knowing the implicit wave velocity value, it can find out the value of 2D geological cross section at the research location. In terms of determining the type of rock layers suspected to be the subsurface substrate, it can be seen from its high resistivity value ranges above 100 Ωm [5].

2. Method

2.1. Theory

The seismic method is one method that is often used to explore geophysical techniques to estimate the geological conditions below the surface based on wave propagation properties. The symmetric method is divided into 2 parts, namely the seismic refraction method (bias or shallow seismic) and the seismic reflection method (reflective or deep seismic) [6]. Seismic refraction or seismic bias is one of the active seismic methods that works by utilizing the wave arrival time recorded by the first geophone. At a certain distance, seismic refraction can be calculated based on the time required by the wave to propagate on the rock from the position of the seismic source to the receiver, namely the geophone [7].

Conventional Reciprocal Method (CRM) is one of the easiest methods of interpreting seismic refraction for processing and determining the structure of the land surface (Figure 1). Seismic refraction data are characterized by large moveouts between adjacent traces and large amplitude variations across the refraction spread [8]. The reciprocal method has a name difference, in which different countries have different names for this method. However, all of these methods remain mathematically the same [9]. This method is done with an intercept time and is carried out with two shots from the front and vice versa. The shot can be done in the measurement. Measurements from the beginning to the specified track limit can be said as a forward measurement, then the measurement is carried out on the same track with the opposite direction as a reverse measurement.

As for some equations regarding the Conventional Reciprocal Method (CRM), Time modeling for the \( t_G \) function can be defined based on wave propagation geometry from shot point F in the form of forward and shot point R in the form of reverse. The wave propagation can be seen with a yellow arrow. From source, F spreads to the boundary layer and then refracts with a critical angle of 90 ° along with the boundary layer to the geophone. From the wave propagation, it can be determined the travel time of waves from the geophone to the boundary layer with the equation:

\[
t_G = \frac{1}{2} (t_{FG} + t_{RG} - t_{FR})
\]

From equation 1 can produce equations to determine the depth of the reverse time model and time forward using seismic speed:

\[
Z_g = t_G \frac{v_2 v_1}{\sqrt{v_2^2 + v_1^2}}
\]
2.2. **Study area**

The timing of seismic refraction data was carried out on April 27, 2018 at Batu Kuda Tourism Site, located at the foot of Mount Manglayang, Cibiru Village, Ujung Berung District, North Bandung (Figure 2).

2.3. **Research flowchart**

Figure 3 shows the research flowchart.

![Research flowchart](image)

**Figure 2.** Research location map (source: arcgis 10.3 software).

**Figure 3.** Research flowchart.
3. Results and discussion
The working principle of the GUI has been made for processing seismic refraction data using the interpretation of the conventional reciprocal method (CRM) data similar to the winsism software and seismimager software, with the existence of this seismic data processing GUI where seismic refraction data can be processed using winsism software, seismic software and the other, then the refraction seismic data can be processed using the Matlab GUI.

![Figure 4. GUI seismic data processing conventional reciprocal method (CRM) refraction.](image)

Layer of the research location and produce 2D cross sections to determine the subsurface geological structure. From the results of the Matlab GUI there are 2 layers of land (Figure 4), based on the 2D model of the distribution of velocity values, it can be indicated that the first layer with a depth of 0 m - 6.5 with a velocity value of 628.98 m / s including the latosol soil layer and according to the distribution pattern speed contains sand, gravel, fine sediment, and clay. As for the second layer with a range of 6.6 m - 20 m with a velocity of 1228.99 m / s belonging to the lower soil layer containing fine deposits, sandstone, gravel, sand, fine sand (silt), clay and clay [10].

The plotting results v_1 and v_2 use the matlab programming language that is validated with origin8.5.1 software as a comparison material that the matlab script used is appropriate, because the results obtained show similarities. From the results of the gradient / slope obtained from both, we can determine the wave velocity value. As a result of the travel time curve in the interpretation of matlab, the results obtained were very good (Figure 5).

From the results of the 2D cross-section using Matlab software (Figure 6) and seismimager software (Figure 7), depth values are obtained. the depth value obtained is almost similar, because the results obtained using the Matlab programming language only differ by approximately 0.4 m with the results obtained using seismimager software. This is due to the difference in determining the velocity value of each rock layer. From the results of the depth data can be known as the truth by making a distance graph of the depth between the two software as in the Figure 7.
Figure 5. First break chart using software Origin 8.5.1, (A). Geophone distance to Time Forward (Direct Wave) (B). Geophone distance to Time Forward (Reflected Wave) (C). Geophone distance to Time Reverse (Direct Wave) (D). Geophone distance to Time Reverse (Reflected Wave). Likewise the results of 2D cross sections when validated using Seisimager software show the results of compatibility.

Figure 6. Section 2D interpretation of seisimager software.

Figure 7. Depth graph using matlab software and seisimager software, The graph shows that the results of the truth test produce the same trend. Then the results of data processing using the matlab programming language when validated with 2D cross section results from the firmware software show compatibility.
4. Conclusion

Seismic refraction data processing which can only be interpreted using seismic software, Winsism, it turns out processing refraction seismic data can also be processed using the Matlab programming language. By applying the conventional Reciprocal Method (CRM) seismic data interpretation method with the Matlab script form that can produce a GUI for seismic refraction data processing, the data processing GUI can produce wave velocity values and a 2D cross-section.

References

[1] Prasetyo B 2007 Perbedaan sifat-sifat tanah vertisol dari berbagai bahan induk. J Ilmu-Ilmu Pertan Indones. 9 20–31.
[2] Khaninezhad MM, Jafarpour B, Li L 2012 Sparse geologic dictionaries for subsurface flow model calibration: Part II. Robustness to uncertainty Adv Water Resour 39 122–36
[3] Hayashi K, Takahashi T 2001 High resolution seismic refraction method using surface and borehole data for site characterization of rocks Int J Rock Mech Min Sci 38 (6) 807–13
[4] Cardarelli E, Cercato M, Cerreto A, Di Filippo G 2010 Electrical resistivity and seismic refraction tomography to detect buried cavities. Geophys Prospect 58(4) 685–95
[5] Agustina R, Pazha H, Sugilar H 2018 Identification of subsurface basement rock using geoelectrical resistivity method in development area (campus 2 UIN Sunan Gunung Djati Bandung). In IOP Publishing p. 012289
[6] Sri W, Gatot Y, Irham N 2006 Interpretasi Data Seismik Refraksi Menggunakan Metode Reciprocal Hawkins dan Software SRIM (Studi kasus daerah Sioux Park, Rapid City, South Dakota, USA). Berk Fis 9(4) 177–84.
[7] Boko N, Eddy H, Drajet N, Bambang S, Pupung S 2011 Penentuan Tingkat Kekerasan Batuan menggunakan Metode Seismik Refraksi J Meterologi Dan Geofis 12(3)
[8] Palmer D 2001 Imaging refractors with the convolution section Geophysics 66(5) 1582–9
[9] Deracke P 2011 The Mt Bulga Tutorial The Bulletin of the Australian Society of Exploration Geophysicists (Australia)
[10] Murteza N I R, Budi L, Artono D S 2014 Identifikasi Batuan Dasar (Bedrock) Menggunakan Metode Seismik Refraksi di Lokasi Pendirian Rumah Sakit Pendidikan Universitas Sebelas Maret Indones J Appl Phys 4(1) 28