Study of terrain correction computation using square pattern and sloped triangle methods in Karangsambung

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Abstract. Conventional assessments of terrain correction are carried out by laying transparent paper containing the Hammer chart on topographic maps, then estimating the elevation for each of Hammer chart’s compartment. This procedure has disadvantages, the number of compartments is too small, and there is a subjectivity from the observer in estimating the compartment’s height, especially in an area with varied topography, such as Karangsambung. These research aims are to study the effect of the topography around Karangsambung on terrain correction value and to overcome problems in conventional terrain correction estimation. Estimation of terrain correction carried out using square pattern and sloped triangle method, where the area around measurement points divided into square and triangle compartment. Based on the results, South Seraju Ranges, with an altitude of 1000 m at a distance of 20 – 30 km from Karangsambung gives an effect of 0.05 mGal on terrain correction, while the Quaternary Volcano with height of 3000 m at range of 30 – 40 km gives the effect of 0.1 mGal. The results of applying the program at the gravity data show that the use of the square pattern and sloped triangle method can correct errors from conventional estimation up to 3 mGal.

1. Introduction
Conventional assessment of terrain correction performed by spreading transparent paper containing a Hammer chart on a topographic map, then the average height of each compartment is estimated. This procedure has weaknesses, namely the relatively small number of compartments and the observers is subjective in determining the average height of compartments, especially in an area with varied topography [1]. A practical example of this method is applied at the Geophysical Engineering ITB field study in Karangsambung. The division of zones on the Hammer chart is simplified into four concentric ring compartments with an inner radius of 2 meters and an outer radius of 100 meters. The height difference of the compartment to the height of the station is estimated visually in the field.

Terrain correction estimation method is continuously developing. In 1962, Kane presented a study of terrain correction calculation using computer, by dividing the area around the station into grids [2]. Nagy (1966) developed the application of the prism rock body approach for terrain correction [3]. The study of elevation satellite data for calculation of terrain correction [4]. Whereas the authors’ aims in this research are to see the effect of the topography around Karangsambung on terrain correction value and to overcome problems in conventional terrain correction estimation. In this study, the topography data was taken from DEM (Digital Elevation Model), and the calculation of terrain correction was performed using Matlab software.
2. Data and methodology

2.1. Data
The data used in this study are topographic and gravity data. Topographic data are taken from the 2012 SRTM (Shuttle Radar Topography Mission) elevation model, with a resolution of 3 arcseconds or around 90 m, covers 103 km x 103 km, with the center being the Karangsambung area. Meanwhile the gravity data are from the result of a field study of Geophysical Engineering ITB in 2018. The tool used was La Coste Romberg.

2.2. Methodology
In the calculation of terrain correction using the square pattern and sloped triangle methods, the area is divided into the near zone and intermediate zone, as shown in figure 1. The intermediate zone will be approached using a quadrilateral prism rock body published by Plouff [5], while the near zone approached using a sloped triangle rock body from Kane [2]. The illustration of the rock body approach can be seen in figures 2 and 3.

The formulation of the vertical direction gravity for the quadrilateral prism rock body approach is as follows [5]:

\[
g = G \rho \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \mu_{ijk} \left[ z_k \arctan \frac{x_i y_j}{z_k d_{ijk}} \cdot x_i \ln \left( d_{ijk} + y_j \right) - y_j \ln \left( d_{ijk} + x_i \right) \right]
\]

\[
d_{ijk} = \sqrt{x_i^2 + y_j^2 + z_k^2},
\]

\[
\mu_{ijk} = (-1)^i (-1)^j (-1)^k
\]

while calculation of the sloped triangle rock body based on the results of Kane's research [2] is as follows:

\[
g = G \rho \phi \left( A - \sqrt{A^2 + h^2} + \frac{h^2}{\sqrt{A^2 + h^2}} \right)
\]
3. Result and discussion

3.1. Study of the topographic area around Karangsambung

The topographic map of Karangsambung and surrounding areas can be seen in figure 4. In Hammer chart, the radius of terrain correction calculation is about 21.9 km, in case the topography around the station is not varied too much [6]. In Karangsambung, there are South Serayu Mountains range and the Quaternary Volcano that have the potential to provide significant terrain correction values even though the distance is above 21.9 km. To find this out, six trial points were taken, namely points A, B, C, D, E, and F, which had elevation variations around 40-500 m. The illustration can be seen in figure 5.

![Figure 4. Topographic map of Karangsambung and the surrounding area.](image1)

![Figure 5. Distribution of trial points in the study area.](image2)

Each point’s terrain correction is calculated with the variation of calculation distance (R), start from 0 to 50 km. The parameters used in the calculation are 100 m grid, and rock density 2400 kg m$^{-3}$. These value is taken from the clay rock density, which is the basic matrix of the Karangsambung. The results are shown in figure 6. The plot results show after a distance of 21.9 km, there is still a rise in the value of terrain correction. To see the increase more clearly, a plot composed of distance range and increased value with a spacing of 5 km was made. The results are presented in figure 7.

![Figure 6. Terrain correction of trials points in variated calculation distance (R).](image3)
Based on the results, South Seraju Ranges, with an altitude of 1000 m at a distance of 20 – 30 km from Karangsambung gives an effect of 0.05 mGal on terrain correction, while the Quaternary Volcano with height of 3000 m at range of 30 – 40 km gives the effect of 0.1 mGal. These additions can be taken into consideration when determining the farthest distance in the calculation of terrain correction.

Figure 7. Increased value of terrain correction for every 5 km distance.

3.2. Comparison of the program with the conventional method

The program was applied to the 2018 Karangsambung Geophysical Engineering ITB field study data. Figure 8 shows the distribution of stations.

Figure 8. 175 data are collected within an area of 2.5 x 2.5 km, with an elevation variation of 40 – 270 m above mean sea level. The tool used for acquisition is La Coste Romberg. The topographic data used is derived from the SRTM (Shuttle Radar Topography Mission) elevation model released in 2012.

The terrain correction value is estimated using two methods, the first method is based on visual observations in the field using a simplified Hammer chart method (from now on referred as TC 1). In contrast, the second method estimates terrain correction based on the SRTM elevation model using the square pattern and sloped triangle methods (referred as TC 2). The difference between the two is analyzed (TC 2 - TC 1). The results obtained show that the value of TC 2 is relatively higher than TC 1.
From 175 data taken, there is only 1 data that have less value. The difference values vary from -0.518 to 3.176. The histogram of the data can be seen in figure 9. Based on this, calculations using this method can get the value of terrain correction better than the simplification of the Hammer chart method up to about 3 mGal.

![Figure 9. Histogram of TC 2 – TC 1 difference.](image)

The results of terrain correction from the two methods are then processed to get the CBA map. The CBA maps are shown in figure 10. From the comparison, we can see there is continuity with the same orientation in two maps, with direction northeast-southwest and north-south. Whereas there is also a difference between the two maps, the value of CBA 2 is relatively greater than CBA 1, clearly visible in the northeast area. However, in modeling a structure, the value is likely not to have a significant effect on the result of the subsurface model.

![Figure 10. Comparison of calculated CBA maps between two method](image)

Meanwhile, when viewed in cross-sections A-A' and B-B', it appears that the difference in CBA 1 and CBA 2 is relatively higher in high elevation areas, especially in the slope area. Cross-section A-A' and B-B' can be seen in figure 11. On the A-A' section, the projections of stations 1 and 2 on the slope
area have a CBA difference of around 2-3 mGal. Meanwhile, station 3 and 4 projections, which are in relatively sloping areas, have a CBA difference of only about 1 mGal. The same thing is also found in the cross-section B-B'. In station projection 5 and 6, the difference in CBA is around 1.5 mGal, while in the projection of stations 7 and 8, the difference in CBA is only about 0.5 mGal. It happens because the conventional method relies on visual observations; the estimation of visible topographic height differences around the slope area will be far more complicated than the estimation on relatively flat areas.

4. Conclusion
Based on the results and discussion, the following conclusions can be drawn:
1. South Serayu Mountains with a height of 1000 m at a distance of 20-30 km gives an effect of 0.05 mGal on terrain correction, while the Quaternary Volcano with an altitude of 3000 m at a distance of 30-40 km gives an impact of 0.1 mGal,
2. Calculations using the square pattern and sloped triangle methods can get better terrain correction values than simplified Hammer chart methods up to about 3 mGal,
3. CBA maps using the square pattern method and the Hammer chart method have a similarity in the anomaly pattern with the orientation of northeast-southwest and north-south,
4. The difference in the calculation of the two methods is higher in the slope because there are more significant topographic variations, as well as estimation of topographic height differences that are increasingly difficult to do.

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