Journal of Geotechnical Geology

Journal homepage: geotech.iauzah.ac.ir

Zahedan Branch,
Islamic Azad University

A case study for utilization of image processing in jointed network detection in open-pit mining

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ARTICLE INFORMATION

Received 07 May 2018
Revised 10 September 2018
Accepted 23 October 2018

KEYWORDS
Image processing techniques; Mining Engineering; Discontinuity network; Digital image processing; Open-pit mining.

ABSTRACT

This study attempted to use the image processing techniques for estimating the discontinuity network detection in dimension stones from open-pit mining work front. The mentioned processing techniques are utilized to determine the discontinuities distribution of the rock mass as geometrical properties charging instability condition in excavation process in quarry. To evaluate the discontinuity network detection from quarry work front used image processing-based algorithm were run in Python programming languages. The algorithm, first of all, identifies the discontinuities and generates the network of discontinuities emplacements to model the rock body in quarry work front. To this end, the triple processing steps included pre-processing, main processing and post-processing are conducted to model. According to the results of computer-based simulation of discontinuity network, the used algorithm is capable to detect the discontinuities emplacements in rock mass and recognize the main rock block spatial distribution in quarry work front.

1. Introduction

Discontinuity network in rock mass is the main disruption cause which plays an important role in structural failure especially in jointed rock slopes and surface cuts. In open-pit, mining structural failure in excavation faces, ramps, walls, galleries and tailing dams is always considered as main concern in mining engineering. This network is applied to assess the stability of rock mass (Nikoobakht et al., 2016), preparing the blasting patterns for mineral excavations (Yarahmadi et al., 2015; Azarafza et al., 2017), mine design (Alejano et al., 2007), geometric investigation and rock block volumetric analysis (Palmstrom and Stille, 2015). Goodman (1989) and Priest (1992) state that the discontinuity network in rock bodies causes high variation in the geo-mechanical behavior and rock masses characteristics. Hudson and Harrison (1997) used the discontinuities geometrical properties for evaluation and quantification of rock mass engineering features which is classified 10 groups of factors included orientation, spacing, roughness, wall strength, filling, discontinuity set, persistence, aperture (opening) and seepage which is presented in Fig. 1.

In geo-mechanical investigation in rock structures identification of rock mass geometrical condition is the first step used to evaluate the emplacement of discontinuities and recognize the discontinuity network in rock bodies (Jaeger et al., 2009). Various methodologies have been utilized for geometrical survey of rock masses generally can be divided into empirical-based and computer-based methods. In empirical-based methods described by Brady and Brown (2010) were classified in spot survey (important discontinuities recorded), linear survey (known as scan-line survey) and areal survey (all discontinuities within a selected area of the face or window are recorded). Discontinuity density is the newest survey method used by geo-engineers to quantify the discontinuity network in jointed rock masses (Azarafza et al., 2017). In computer-based methods categorized in laser scanning (Cacciari and Futai, 2016), image processing (Porsani et al., 2006), digital image mapping, geophysical

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(Bozzini et al., 2014) utilized the different computer equipments to measure the discontinuity network. In other word, the empirical-based procedures entirely require the geo-engineers work experience and extensive field operations, whereas computer-based methods use the artificial intelligence techniques to help for achieving the more accurate results. Although computer-based method shows more accurate results, but equipment is usually expensive. In the meantime, application of image processing techniques requires less cost and equipment.

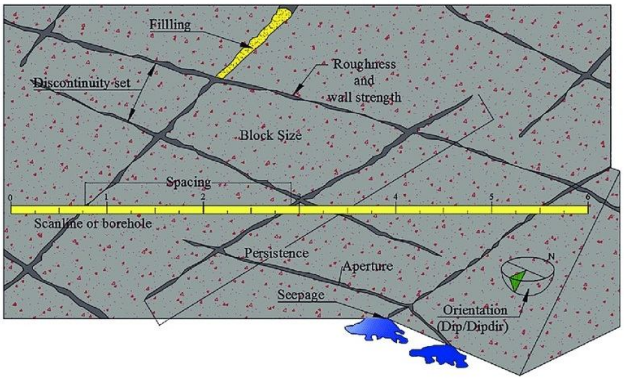

Figure 1. Discontinuity network properties (Hudson and Harrison, 1997)

In computer science, digital image processing is a digital computer application for image processing based on image editing and evaluations used several pattern recognitions, data process on digital image assessment algorithms which image processing uses mathematical operations on input images to extract useful information (Cao, 2003). Application of the image processing in geo-engineering field is very wide and mainly used for identification the rock structures such as discontinuities, faults, shear zones, tectonical structures, rock blocks geometry, etc.

In this study, attempted to use the image processing feature for spatial rock blocks identifications in order to generate the rock mass jointed network detection in quarry work front of open-pit mining. To this purpose, Azarshahr-travertine mine is our case study. Figure 2 illustrates the view-shot of the main quarry work fronts of studied mine. Also, the figure 3 presents the studied quarry place located in northwest of Iran, in East-Azerbaijan province.

Figure 2. A view of studied quarry work fronts

Figure 3. Studied quarry mine location in Iran

2. Material and Methods

In order to use the image processing techniques in rock structural assessment and jointed network detection is utilized the high resolution images for base of assessment named ‘basic image’. The figure 4 presents the basic image used for geometrical feature extractions. To prepare the basic image following conditions must be considered (Azarafza et al., 2018):

- Image must be taken directly from the surface;
- Outcrop should be free from vegetation or external effects;
- Any shadow on the imaging surface should be avoided;
- Outcrops should be marked and scaled;
- Same lighting or angle of the sun’s radiation must be selected for all images.

After preparing the right image for studied work face, taken picture must be modified by applying the pre-processing and image filtering. Python software and simulation process toolbox (Lutz, 2013) have been used to conduct the processing on basic image (Gonzalez and Woods, 2017). In pre-processing stage by removing the basic image background attempted to stabilize the main photograph. Grey-scale, local entropy of grayscale, laplacian and laplacian of gaussian, adaptive noise-removal, gradient and gradient orientation, pad-array and solbel filtrations are used for preparing the appropriate image for main processing and feature extraction. At the end, sharpening and edge enhancement commands re used for modifying the final image. Figures 5 to 7 illustrate the results of the pre-processing application. After preparing the suitable photograph, main images are processed in main processing which utilized for feature detection and extract the district data from images. In main processing stage, the edge detection and edge sharpening functions are used for extract the block geometry emplacement in rock body. Application of these functions helps to segment and prepare the appropriate results to develop main frame of jointed network detection in work face. By using the Python software (Lutz, 2013) the discontinuity network related to the dimension stones in work front is simulated.

Computational intelligence application in image recognition and preparing the district feature data in windows survey is capable to evaluate the rock blocks geometry and emplacement of discontinuity in rock bodes. These methods try to simulate the rock mass media in computers, so preparation in necessary. As mentioned before, the simulation procedure is conducted in pre-processing and main processing stages leading to rock mass jointed data extraction and quarry work front discontinuity network establishment. Figure 8 presents the flowchart of using this method in this study.

Figure 4. The work face where used in this study

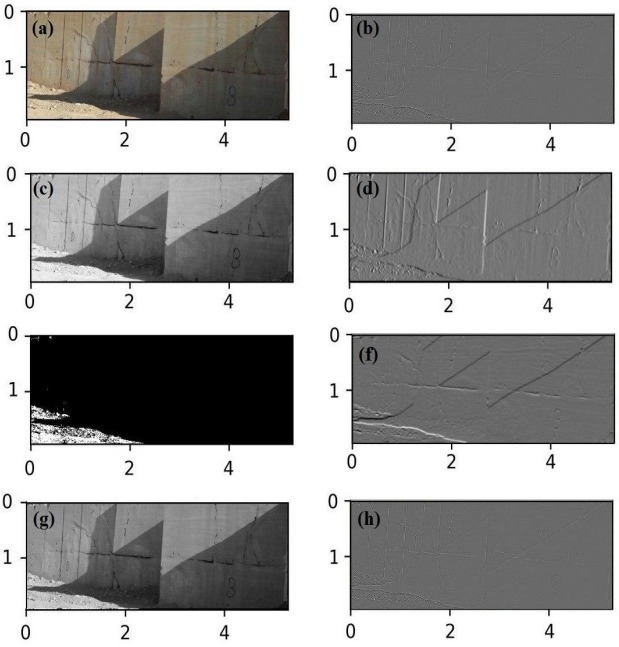

Figure 5. Application of several pre-processing filters (dimension is m): (a) basic image, (b) gray-scale, (c) laplacian, (d) laplacian of gaussian, (e) adaptive noise-removal, (f) gradient and gradient orientation, (g) pad-array, (h) solbel

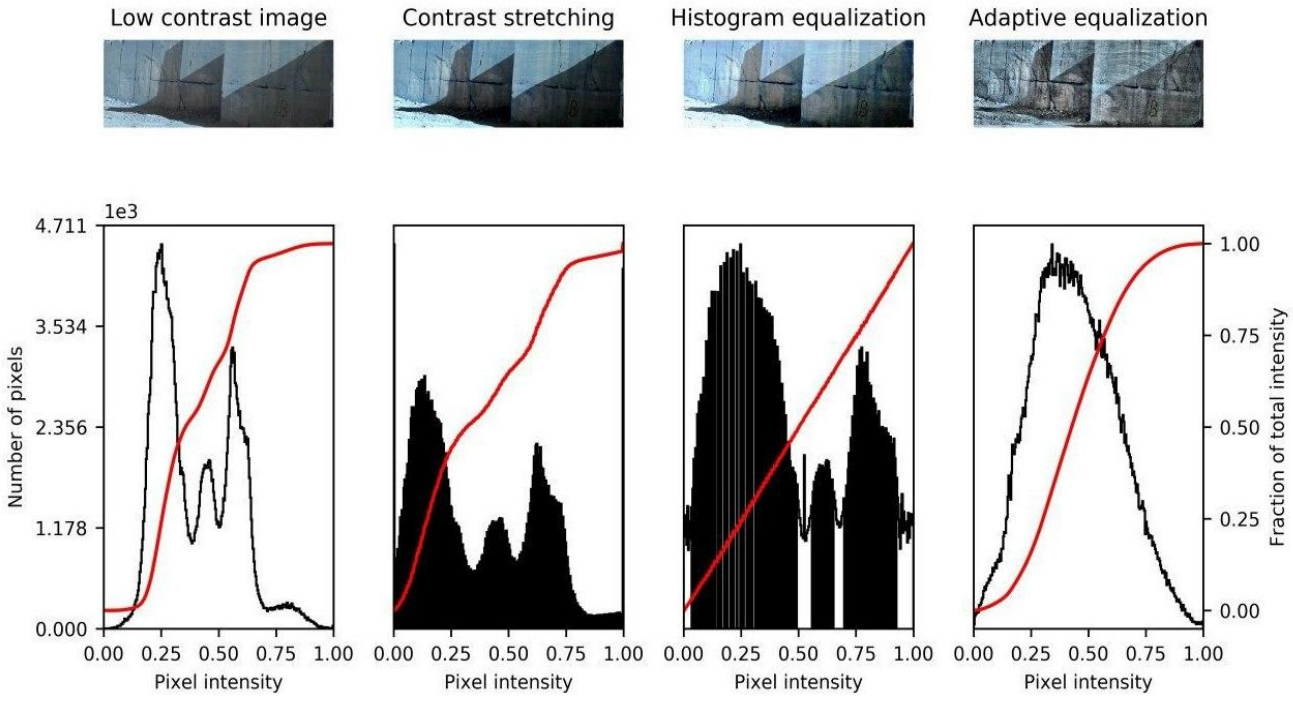

Figure 6. Application of pre-processing adjustments for preparing the main process

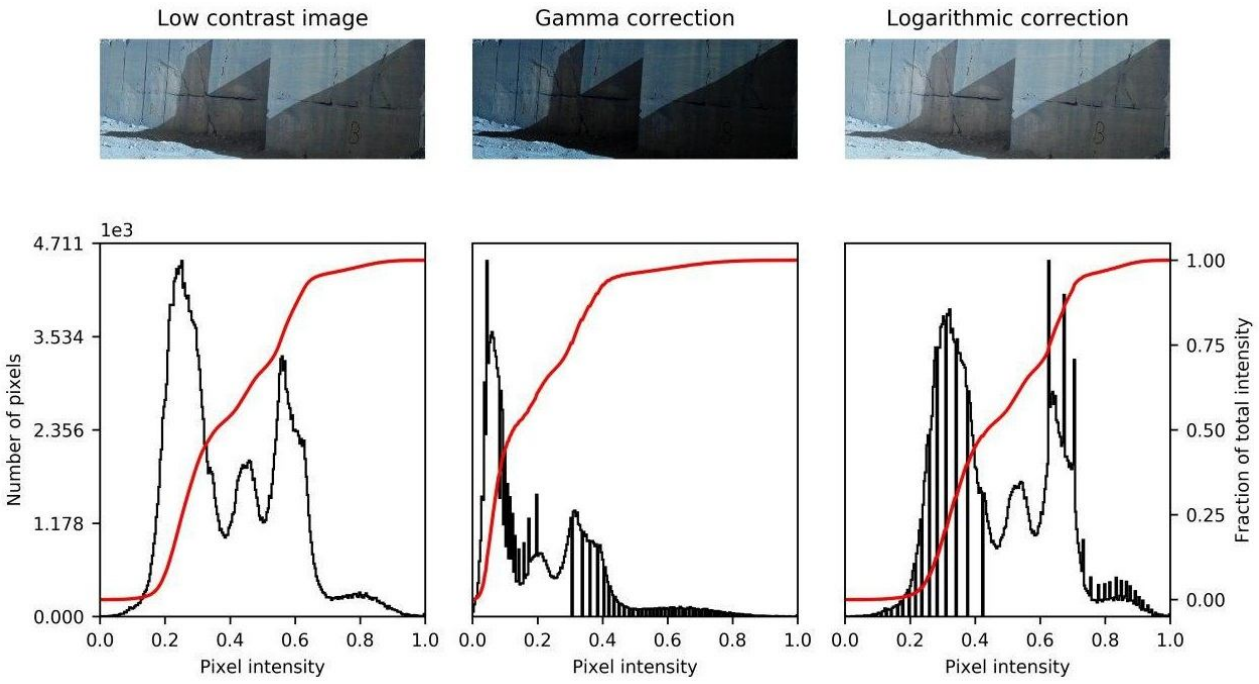

Figure 7. Application of pre-processing adjustments for preparing the main process

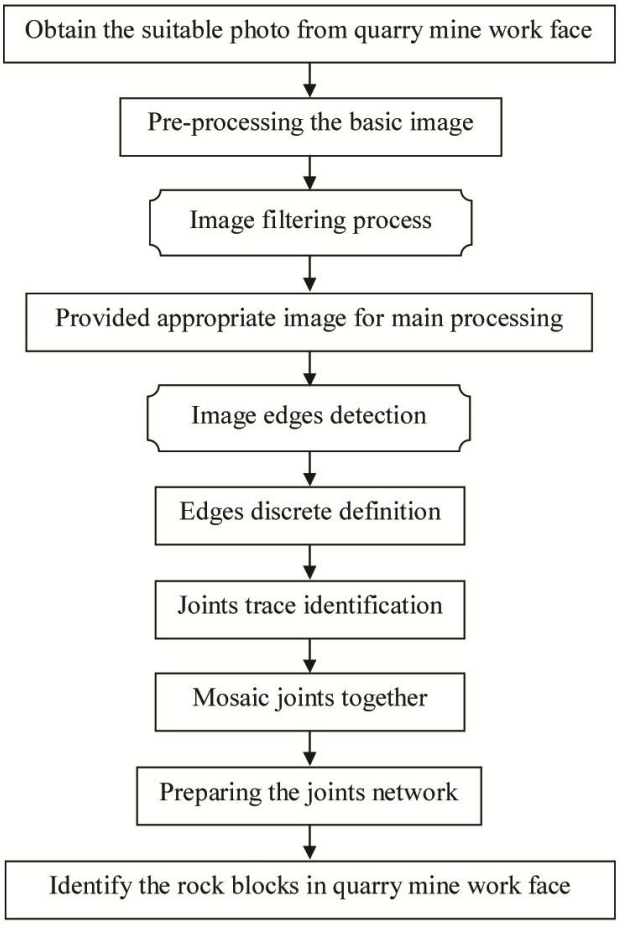

Figure 8. Flowchart of image processing task usage in this study

3. Results and discussions

By considering presented method for feature detection and extract the jointed data from the quarry work front in studied mine, the algorithm is identified the 5+5 discontinuity in dimension stones in which 5 jointed are artificially added by bank chainsaw machine (BCM) and 5 discontinuity related the original rock mass. By application of the detection functions of image processing techniques in the result image (final image) from main processing stage, the model of rock mass jointed network is prepared and simulated by Python software (Lutz, 2013). The results of the simulation are presented in figures 9 to 12. According to the results of simulation the jointed network perform the 21 block which is six of them are completely healthy and extractable, 4 of them suffered minor damages and sustained limited crushing and 2 slaps and other blocks smaller permitted and considered to be a waste in mining.

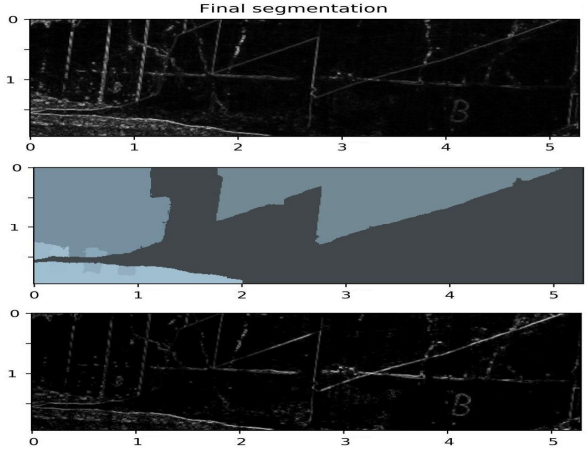

Figure 9. The main processing preparation

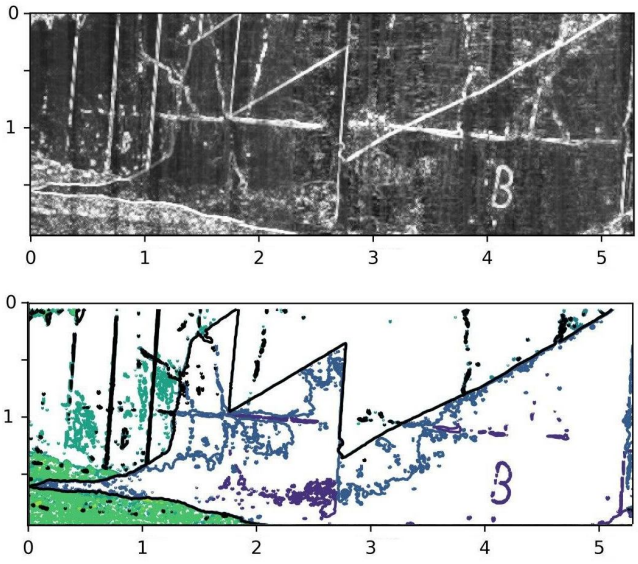

Figure 10. Edge detection stage

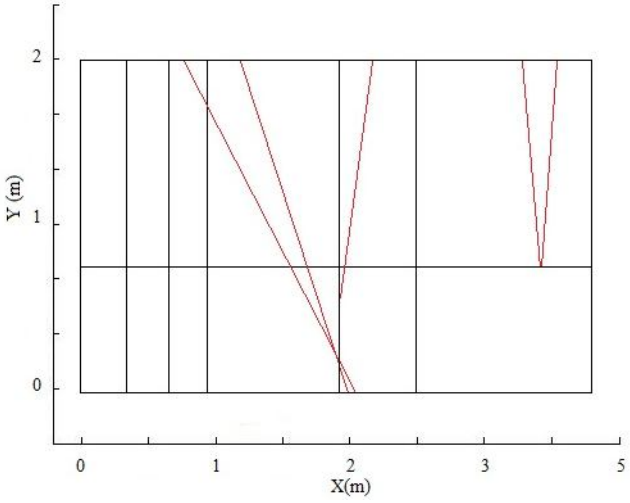

Figure 11. The jointed network identification in work face

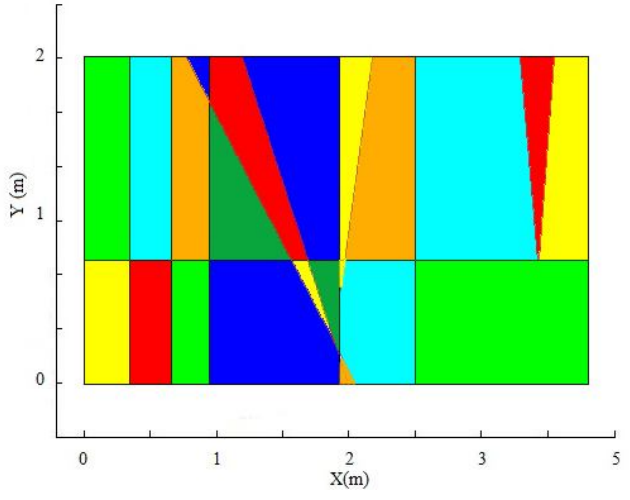

Figure 12. The rock block geometry identification in work face

4. Conclusion

Geometrical investigation of jointed rock mass is the first step in evaluation of stability and preparing the failure moods containing high invaluable information about the discontinuities, block size, shape and dimensions. Various methodologies are utilized for geometrical survey of rock masses generally can be divided in empirical-based (concluded spot, linear and aerial surveys) and computer-based methods (laser scanning, image processing, geophysical procedures) which used for identification of jointed networks in rock mass. The computer-based methods are more accurate then field investigations which less required for geo-engineers experience. This study is focused on application of computer-based image processing technique for identifying the jointed network of quarry work face in Azarshahr-travertine open-pit mine. The used algorithm is identified 5+5 discontinuity in dimension stones which is 5 joint sets are artificially added by BCM and 5 discontinuity related the original rock mass related to joint network perform the 21 block is six of them are completely healthy and extractable, 4 of them suffered minor damage and sustained limited crushing and 2 slap and other blocks smaller than permitted and considered to be a waste in mining.

Acknowledgements

The authors wish to thank the Department Computer Engineering, Faculty of Electrical & Computer Engineering, University of Tabriz for giving the concrete tests laboratory and preparing experiments studies.

References

Alejano L.R., Pons B., Bastante F.G., Alonso E., Stockhausen H.W. (2007). Slope geometry design as a means for controlling rockfalls in quarries. *International Journal of Rock Mechanics and Mining Sciences*, 44(6): 903-921.

Azarafza M., Asghari-Kaljahi E., Akgün H. (2017). Assessment of discontinuous rock slope stability with block theory and numerical modeling: a case study for the South Pars Gas Complex, Assalouyeh, Iran. *Environmental Earth Sciences*, 76(11): 397.

Azarafza M., Feizi-Derakhshi M.R., Jeddi A. (2017). Blasting pattern optimization in open-pit mines by using the genetic algorithm. *Journal of Geotechnical Geology*, 13(2): 75-81.

Azarafza M., Ghazifard A., Akgün H., Asghari-Kaljahi E. (2018). Development of a 2D and 3D computational algorithm for discontinuity structural geometry identification by artificial intelligence based on image processing techniques. *Bulletin of Engineering Geology and the Environment*, doi: https://doi.org/10.1007/s10064-018-1298-2.

BozziniM., Lenarduzzi L., Rossini M. (2014). Non-regular surface approximation. *Mathematical Methods for Curves and Surfaces*, 8177: 68-87.

Brady B.H.G., Brown E.T. (2010). *Rock mechanics: for underground mining (3rd Edition)*. Springer SBM, 648 p.

Cacciari P.P., Futai M.M. (2016). Mapping and characterization of rock discontinuities in a tunnel using 3D terrestrial laser scanning. *Bulletin of Engineering Geology and the Environment*, 75(1): 223-237.

Cao F. (2003). *Geometric curve evolution and image processing*. Springer-Verlag, 194 p.

Gonzalez R.C.,Woods R.E. (2017). *Digital image processing*. Pearson, 1192 p.

Goodman R.E. (1989). *Introduction to rock mechanics.* Wiley & Sons, 576 p.

Hudson J.A., Harrison J.P. (1997). *Engineering rock mechanics—an introduction to the principles*. Elsevier Science, 456 p.

Jaeger J.C., Cook N.G., Zimmerman R. (2009). *Fundamentals of rock mechanics*. Wiley, 488 p.

Lutz M. (2013). *Learning Python (5th Edition)*. O'Reilly Media, 1648 p.

Nikoobakht S., Ghazifard A., Azarafza M. (2016). Stability analysis of sliding wedges in exit portal of Golab 2 tunnel. In: *Proceedings of the 34th National and the 2nd International geosciences congress of Iran*, Tehran, Iran, February 2016. [In Persian]

Palmstrom A., Stille H. (2015). *Rock Engineering*. ICE Publishing, 444 p.

Porsani J.L., Sauck W.A., Junior A.O. (2006). GPR for mapping fractures and as a guide for the extraction of ornamental granite from a quarry: a case study from southern Brazil. *Journal of Applied Geophysics*, 58(3): 177-187.

Priest S. (1992). *Discontinuity analysis for rock engineering*. Chapman & Hall, 496p.

Yarahmadi R., Bagherpour R., Sousa L.M.O., Taherian S. (2015). *How to determine the appropriate methods to identify the geometry of in situ rock blocks in dimension stones*. Environmental Earth Sciences, 74: 6779-6790.