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Stability Analysis of Tunnel Support Systems Using Numerical and Intelligent Simulations (Case Study: Kouhin Tunnel of Qazvin-Rasht Railway)

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Abstract

According to underground construction development and its high cost process, an accurate assessment and prevention of probable risks are of significant importance. Different methods have been developed to assess underground constructions. In this paper, the aim is to develop a new soft computing model to evaluate tunnel support systems. Firstly, a numerical analysis was performed using the explicit finite difference model by FLAC^{2D} software to excavate a sequence model and support system installation. The design loads including the axial force, moment, and shear force were calculated for some important points of the support system including the crown, the middle of the bottom and the side walls. In order to analyse the stability of the support system, the section points were evaluated into 3 clusters by the artificial bee colony as a meta-heuristic algorithm and a k-means algorithm using Matlab software. The results of clustering were compared by the safety factor of the support system. The results indicated that the section points that are in cluster 1 have a lower safety factor than clusters 3 and 2, respectively. It concluded that the artificial bee colony can be reliably used in the initial assessment of tunnel support systems based on the axial force, moment, and shear force.

Keywords:
soft computing, artificial bee colony, clustering, support system, safety factor

1. Introduction

A wide range of unpredicted and uncertain conditions may be faced in projects with deep excavations which lead to many different design problems. These projects may include tunneling, underground subway construction, dam construction, mining and deep foundations. In the meantime, tunneling projects have a special position in this area. In fact, in this case, the stability analysis of a tunnel support system and methodology are a matter of concern which demand a high level of precision and skill in analysis **(Dekovic et al., 2003; Frgić et al., 2003; Jalilvand and Haghshenas, 2013; Jalilvand et al., 2014; Klanfar et al., 2015)**. Therefore, the need for methods capable of solving complex and vague problems is more substantial than ever. Fuzzy neural networks and fuzzy logic are techniques of soft computing that are applied for optimizing and solving problems in different sciences **(Rad et al., 2014; Bouzon et al., 2016; Zhou et al., 2016; Yari et al., 2016; Dormishi et al., 2018; Mikaeil et al., 2018a; Faradonbeh and Taheri, 2018; Ooriad et al., 2018)**. Lee et al. **(Lee et al., 2006)** carried out numerical simulations of centrifuge model tests to investigate tunnel stability and arching effects developed during tunneling in soft clayey soil. Using the fuzzy analytical hierarchy process in the protection of the body slope of the reservoir dam in Iran was assessed by Rad et al. **(Rad et al., 2012)**. The prediction of convergence in the Amir Kabir tunnel was carried out based on a dynamic model of the support vector machines (SVMs) algorithm and an unknown non-linear relationship between the soil parameters and tunnel convergence was estimated by Mahdevari et al. **(Mahdevari et al., 2013)**. Feng and Jimenez (Feng and Jimenez, 2015) presented a novel application of Bayesian networks (BNs) to predict tunnel squeezing by employing a Naïve Bayes classifier based on five parameters – the support stiffness (K), rock tunneling quality index (Q), tunnel depth (H), tunnel diameter (D), and strength–stress ratio (SSR). Yagiz and Karahan **(Yagiz and Karahan, 2015)** utilized several optimization methods to estimate tunnel boring machine (TBM) performance. Lou et al. **(Luo et al., 2015)** established a model for the calculation of the stability of the original slope-tunnel-bank slope based on the Janbu slices method, and they used a genetic algorithm to implement the calculation variables, safety coefficient expression and fitness function design. Using the direct boundary element method

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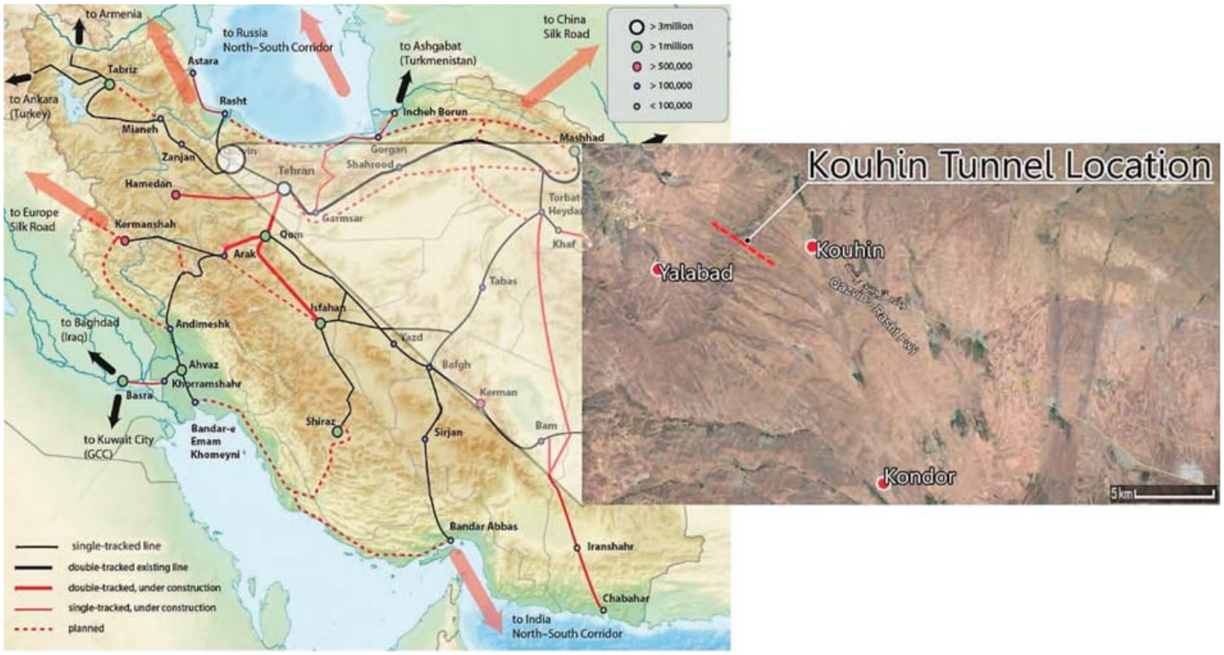

Figure 1. Location of the Kouhin tunnel

(BEM), the stress behavior of shallow tunnels under simultaneous non-uniform surface traction and symmetric gravity loading was studied by Panji et al. **(Panji et al., 2016)**. The fuzzy c-means (FCM) technique was used for the evaluation and analyzation of the risk in the tunneling project by Haghshenas et al. **(Haghshenas et al., 2016).** Utilizing sequential quadratic programming (SQP) based on the upper-bound limit analysis, Zhao et al. **(Zhao et al., 2017)** considered the effects of the tunnel inclination angle and the tunneling length (L) to obtain the optimal upper-bound solutions of the active and passive failure pressures. Using the integration of numerical and meta-heuristic techniques, the behavior of the concrete lining of circular shallow tunnels in a sedimentary urban area under seismic loads was investigated by Salemi et al. **(Salemi et al., 2018)**. Also, a reputable database including information about the pile geometry, material, installation, full-scale static pile load test and cone penetration test (CPT) was collected to probe the possible adaptive neuro-fuzzy inference systems (ANFIS) for forecasting the final axial load bearing capacity of piles **(Ghorbani et al., 2018)**.

Nowadays, the development of underground construction and its utilization for the railway (network) is increasing. Due to the high cost of such constructions and considering probable risks, it is necessary to assess the resistance of these constructions to static loads. In this regard, the Kouhin railway tunnel at the first part of Qazvin-Rasht-Bandar Anzali railway is not an exception. The main issue in this kind of excavation is an accurate assessment and the prevention of probable risks concerning different geological conditions in each section. Based on the designed loads on the different sections of the tunnel, this paper aims to carry out the initial stability of the Kouhin railway tunnel of the Qazvin-Rasht-Bandar Anzali axis by combining the k-means algorithm and the artificial bee colony (ABC) algorithm.

2. Materials and Methods

The Kouhin tunnel is located at the sediments of Hezardarreh which contains alternating layers of sandstone clay, silt clay, highly weathered loose sandstone with clay, etc. Due to a lack of several important factors, rock mass classifications such as RMR, RSR and Q were not used in this study. One of the most important factors in this regard is that the Neogene sediments in this area are young and have not been completely lithified. Due to their location at the surface and incomplete diagenesis process, Neogene deposits of sandstone and silt stone are not included in the rock classification. On the other hand, geotechnically speaking, their lower adhesiveness among components means they have better characteristics than soils. A covered area with the weathered surface soil and outcrop absence of probable discontinuities is another parameter causing this area to be out of the rock mass classification. The Kouhin tunnel location is shown in **Figure 1**.

Modelling was carried out by FLAC^{2D} software. There are several behaviour models in FLAC^{2D} and we can use one or more depending on the conditions. One of these behaviour models is the Mohr-Coulomb plastic model. This model represents materials that are only yielded by shearing. This is a common model among plastic models in rock and soil mechanics **(Itasca-Consulting-Group, 1992)**.

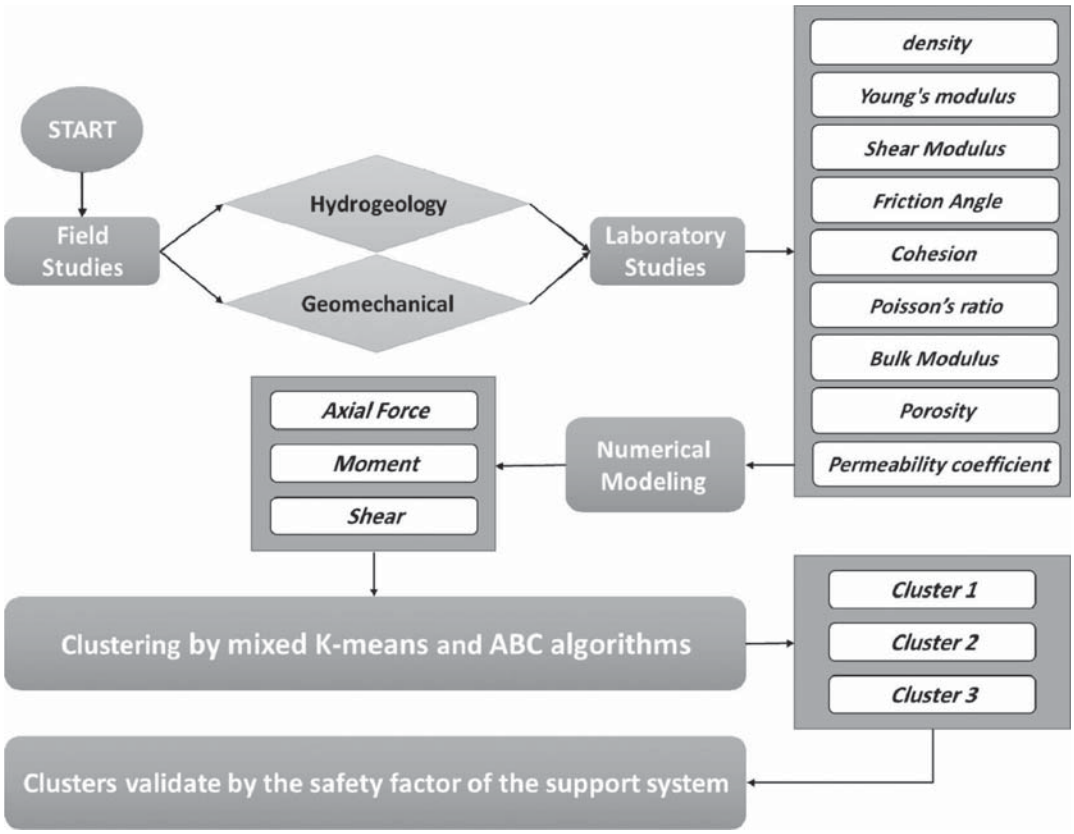

Figure 2. Flowchart of the methodology of research

The parameters required in the Mohr-Coulomb model are: density, bulk modulus, shear modulus, cohesion, friction angle, dilation angle and tensile strength. If one of the above parameters were not defined, the software considers it to be zero. In the Mohr-Coulomb model, a dilation angle is one of the required parameters for the behavior simulation after failure. It is generally determined via a triaxial compression test or shear test. Generally, the dilation angle in soils, rocks and concretes is less than the friction angle. The dilation angle of the materials used in the initial support system were estimated to be approximately 0° to 20° in 1984 according to Vermeer and de Borest's research **(Itasca-Consulting-Group, 1992)**.

Excavating and installing the initial support system was carried out by FLAC^{2D} software after the tunnel outlines had been designed. The forces and the moment of the initial section coverage and the initial support system characteristics were determined for different sequences of excavation. Clustering of designed loads on different sections of the tunnel were carried out and were identified in three clusters at the fourth portion by ABC and k-means algorithms. According to identified clusters based on designed loads, algorithm validation was carried out by comparing the initial support system's safety factors achieved in the fifth portion. A methodology flowchart of the research is shown in **Figure 2**.

3. The tunnel route geotechnical studies

The first part of the Kouhin Railway is located in 15 km away from Qazvin-Zanjan railway at 1250 m above sea level, it goes through countries such as Dolat Abad, Dastjerd, Kandar, Meshkin and Yal Abad with an approximately north-south direction and has a length of 216 km. The end of the above-mentioned part is located at49° 32′ 22″ E and 36° 12′ 22″ N, 1300 m above sea level, which is 50 m higher than the starting point. It is necessary to construct a tunnel to pass the Kouhin mountainous and impassable area. Due to the observed maximum longitudinal slope and minimum arc radius, it is difficult to pass without the construction of a tunnel.

A geotechnical study was carried out on the Kouhin Railway tunnel route. It was collected wherever possible in the preliminary phase using some boreholes along the route based on the presented guidelines and technical specifications. Geomechanical and hydrogeological characteristics of the Kouhin Railway tunnel route are given in **Tables 1 and 2**. According to hydrogeological studies, the water table of the two studied areas (40 m and 100 m) were 25 m and 55 m, respectively.

3.1. Excavation

The excavation was carried out by Roadheader. Three excavating plans were proposed for the Kouhin railway

Table 1: Geomechanical characteristics of the Kouhin railway tunnel route

density ρ (Kg/m3)	Young's modulus Em (Pa)	Shear Modulus Gm (Pa)	Friction Angle f (°)	Cohesion C (Pa)	Poisson's ratio -
2050	3×10^8	1.071×10^8	34	2×10^5	0.4

Table 2: Hydrogeological characteristics of the area for analyzing fluid flow

Density ρ(kg/m3)	Bulk Modulus (Pa)	Porosity –	Permeability coefficient K (m/s)
1×10^3	1×10^4	0.3	3.06×10^{-6}

tunnel, in order to choose the appropriate pattern of excavation. Finally, according to the executive operation and economic aspects, the most appropriate plan was chosen. The final plan of the Kouhin railway tunnel was proposed in two sections, dry and watery. The simplicity of the executive operation and installing the initial support system, saving time and operational costs, balancing hydrostatic forces caused by water pressure and lack of inductive stress concentration in the final support system are the advantages of this plan.

The excavating plan is carried out in 3 stages by eliminating the crown, middle of bottom, side walls, respectively. For example, in the dry section, firstly, the crown is removed in 13.5 m of width and 5.63 m of length. In the second stage, the middle of the bottom is removed in 7.2 m of width and 6.12 m of height. At the end, the walls are removed by 6.12 m of height. The geometric characteristics and the excavating plan for the dry and watery sections are shown in **Figures 3 and 4**, respectively.

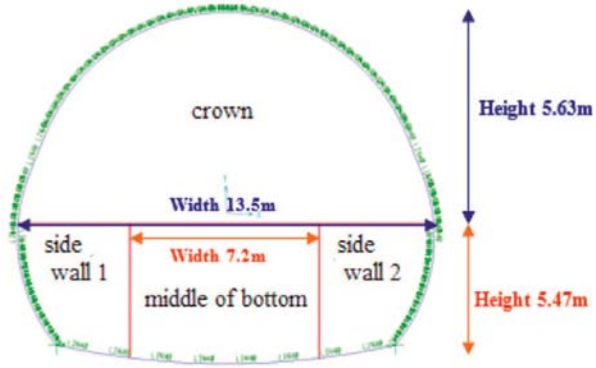

Figure 3. Dry section geometric characteristics and excavating stages

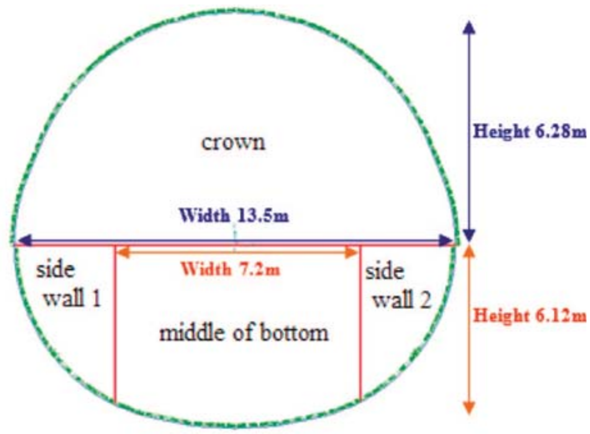

Figure 4. Watery section geometric characteristics and excavating stages

3.2. Support system installing

One of the most important issues in tunnel stability design is estimating the initial support system. Third di-

Table 3: The forces and moments which were designed on the initial coverage of a dry section of 40m

Excavation steps	Characteristics of the initial support system	T max (N)	M max (N.m)	V max (N)
crown	25 cm of wet shotcrete + IPE180 at a distance of 1 m (arch)	1032640.25	28831.55	32950.34
middle of bottom	25 cm of dry shotcrete + IPE180 at a distance of 1 m (arch)	1073828.18	19662.33	35303.94
side wall 1	25 cm of dry shotcrete + IPE180 at a distance of 1 m (arch)	1163068.69	56780.50	101989.16
side wall 2	25 cm of wet shotcrete + IPE180 at a distance of 1 m (floor)	791396.66	56780.50	44326.06

Table 4: The forces and moments designed on the initial coverage of a watery section of 40m

Excavation steps	Characteristics of the initial support system	T max (N)	M max (N.m)	V max (N)
crown	25 cm of wet shotcrete + IPE180 at a distance of 1 m (arch)	1057156.87	23369.25	27360.55
middle of bottom	25 cm of dry shotcrete + IPE180 at a distance of 1 m (arch)	1129726.08	29812.22	49405.90
side wall 1	25 cm of dry shotcrete + IPE180 at a distance of 1 m (arch)	1161107.36	45130.20	78953.34
side wall 2	25 cm of wet shotcrete + IPE180 at a distance of 1 m (floor)	836114.98	45130.20	47640.71

Table 5: The forces and moments designed on the initial coverage of a section of 100m

Excavation steps	Characteristics of initial support system	T max (N)	M max (N.m)	V max (N)
crown	35 cm of wet shotcrete + IPE200 at a distance of 0.5 m (arch)	2382035.29	68401.38	118268.20
middle of bottom	35 cm of dry shotcrete + IPE200 at a distance of 1 m (arch)	2362421.99	114149.41	78874.89
side wall 1	35 cm of dry shotcrete + IPE200 at a distance of 1 m (arch)	2459507.82	130330.38	96781.83
side wall 2	35 cm of wet shotcrete + IPE200 at a distance of 1 m (floor)	908488.06	89779.88	96517.05

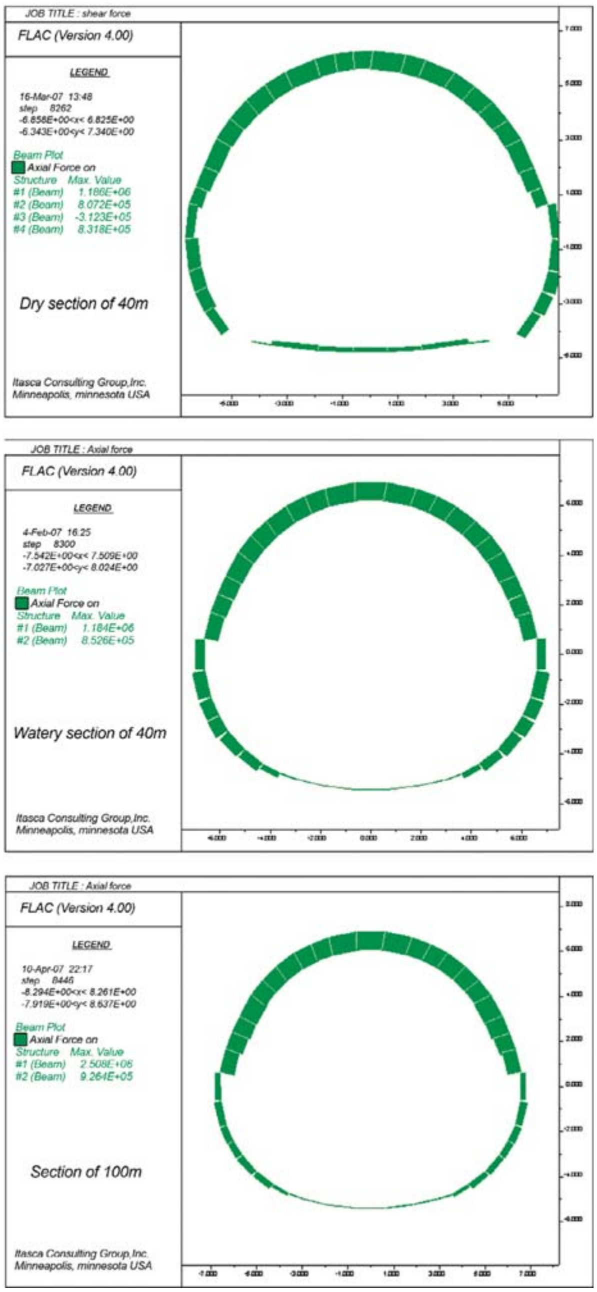

Figure 5. Designed axial force on sections

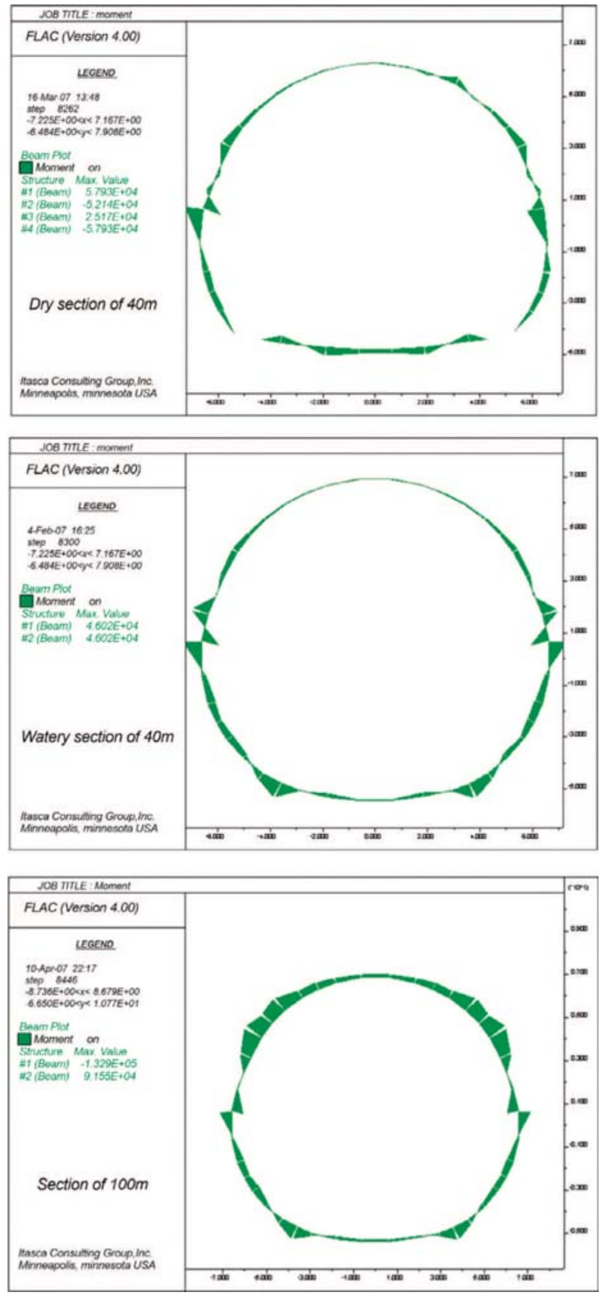

Figure 6. Designed moment on sections

mension issues, which are the impact of step progress and the face distance from the initial coverage, can be solved in two dimension issues through drawing a ground reaction curve using the numerical finite difference method, determining the value of the non-convergence rate from the Panet chart and stress discharge,

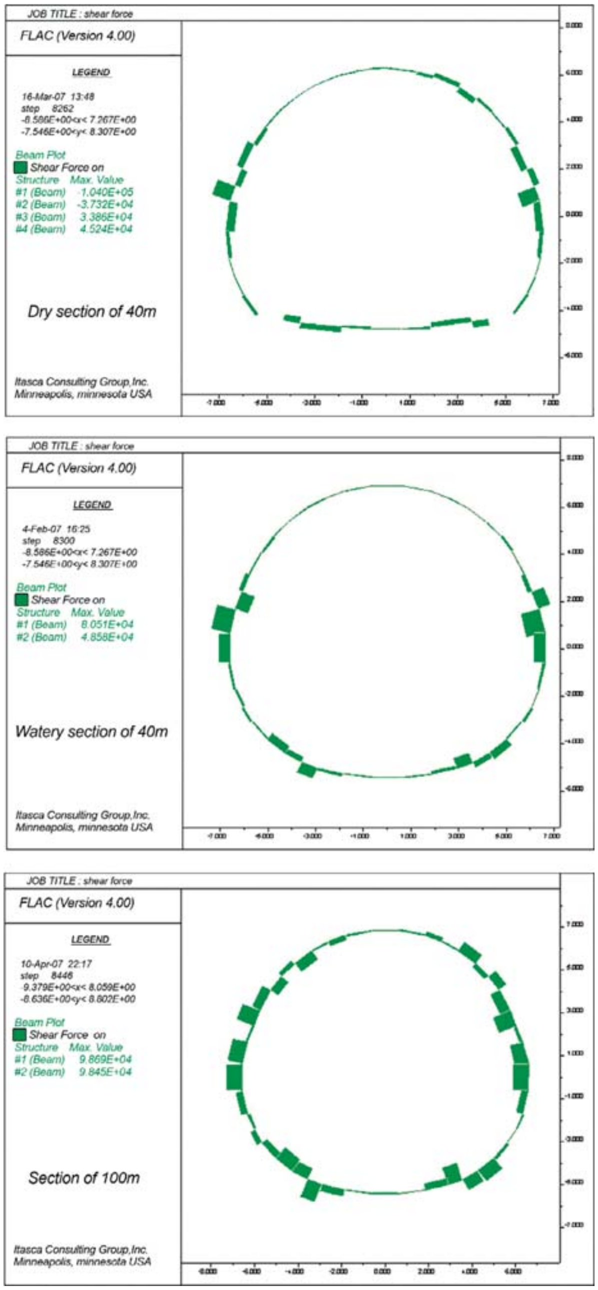

Figure 7. Designed shear force on sections

which is equivalent to the convergence made before the initial coverage in the numerical model. The convergence-confinement method and drawing a ground reaction curve with the help of FLAC^{2D} software were used for determining the appropriate initial coverage in order to maintain the stability of excavated space and to help create new ground balance. For the first part of excavation, the initial coverage design includes the following steps:

- Choosing step progress and face distance from the support system
- Drawing a ground plot curve
- Stress discharge, which is equivalent to the convergence made until the moment of initial coverage.

According to the analyses, the initial appropriate coverage was proposed as two 100 m and 40 m sections, 35 cm shotcrete with IPE200 steel at the distance of 0.5 m and 25 cm shotcrete with IPE180 steel at a distance of 1 m, respectively.

In this section, the value of the forces and the moment were calculated, which were designed on the different points by pressures of over loads. The results are indicated in **Tables 3 to 5**, respectively. Also the plots of forces are shown in **Figures 5 to 7**.

4. Support system stability assessment based on meta-heuristic algorithms

Exact and approximate algorithms are two categories of optimization algorithms. Even though the optimal exact response is achieved by the exact algorithms, they are not efficient in difficult optimization problems, or their performance time increments during the algorithm differ, depending on the dimension of the problems. On the other hand, an approximately optimal response is achieved by approximate algorithms for difficult optimization problems at a low performance time. Heuristic, meta-heuristic, and hyper-heuristic algorithms are three categories of approximate algorithms. Heuristic algorithms have two problems; early convergence to local optimum points and becoming stuck at these points. Actually, meta-heuristic algorithms are introduced to solve these problems. In fact, local optimum points are eliminated by meta-heuristic algorithms, and a variety of problems are solvable by these algorithms. Various types of meta-heuristic algorithms have been extended in the last decades **(Eshghi and Kariminasab, 2012; Merikhbayat, 2014; Sabzi et al., 2016; Yaghini M and Kazemzadeh, 2016; Mikaeil et al., 2016; Mikaeil et al., 2017; Mikaeil et al., 2018b; Aryafar et al., 2018)**.

4.1. Artificial Bee Colony Algorithm

Dervis Karaboga **(Karaboga, 2005)** introduced the artificial bee colony algorithm. An artificial bee colony (ABC) algorithm simulates real honey bees' behavior in order to solve multidimensional and multimodal optimization problems.

The presented artificial bee colony includes three kinds of bees: the onlookers, scouts and employed bees. The artificial bee colony is comprised of two parts. The employed bees are in the first part and the onlookers are in the second part. The number of employed bees is the same as the numbers of food sources around the beehive. In other words, there is exactly one employed bee for every food source. The scout is an employed bee whose food source has been consumed by bees **(Karaboga, 2005; Mikaeil et al., 2018c)**. The main steps of the ABC algorithm are given below:

The scouts are sent to the primary sources of food

REPETITION

The employed bees are sent to the sources of food and specific amount of nectars

The onlooker bees prefer the sources based on the calculated probability value

The onlooker bees are sent to the sources of food and specific amount of nectars

The exploitation process of sources is stopped when they are finished by the bees

To find new sources, scouts are sent to search the region at random

Maintain the best source thus far

Repeat until the requirements are met **(Karaboga, 2005)**.

The searching cycle includes three steps: moving to the food sources and counting the amount of nectar by the employed and the onlooker bees. The scout bees are determined, and are directed onto probable food sources. Each position of the food source is possibly an optimized solution for the issues **(Karaboga, 2005)**.

4.2. K-means algorithm

A k-means clustering algorithm is a simple but useful method and foundation for some other methods such as fuzzy clustering. In this method, firstly, an optional number of points are considered as the center of the cluster, and then, every data point is related to the nearest cluster center by checking the data. After the first part, the cluster center is created by getting an average of each cluster so that, in consequence, it is possible to create new clusters (by repeating the previous steps).

One problem in this method is that its optimality depends on the initial selection of the centers that are not optimal. Other problems include determining the number of clusters and zero clusters **(Armano and Farmani, 2014)**.

4.3. A Combination of the Artificial Bee Colony Algorithm and the K-Means Technique

Getting stuck in local optimums and assigning an initial value to centers are the disadvantages of the k-means algorithm. As previously mentioned, a global search throughout the whole solution space is performed by the ABC algorithm. If the required time is provided, global and good results are produced by the ABC algorithm. Hence, a combination of these algorithms solves clustering issues which do not get stuck in a local optimum solution and this solution is also independent of the initialization of centroids **(Armano and Farmani, 2014)**.

The clustering of designed loads was carried out in 38.21 seconds by a combined algorithm while using Matlab software in 3 clusters, with a cycle number of 300 and 50 bees. An algorithm convergence plot is shown in **Figure 8**. The distance between each designed load from the center of each cluster and the center distance of each section from each cluster based upon Euclidean distance are shown in **Tables 6 and 7,** respectively**.**

Table 6: Distance of each designed load from the center of each cluster

Clusters	designed loads		
	V (N)	M (N.m)	T (N)
1	9.9558	10.183	243.57
2	5.1917	5.2921	85.596
3	4.9357	3.2595	111.67

V: shear force, M: moment, T: axial force

Table 7: Clustering of sections by ABC algorithm with 3 clusters

Sections		Clusters	Distance from center
Watery section of 40m	crown	3	4.5083
	middle of bottom	3	3.8608
	side wall 1	3	7.5395
	side wall 2	2	0.83686
Section of 100m	crown	1	3.8952
	middle of bottom	1	3.5968
	side wall 1	1	7.8654
	side wall 2	2	9.2827
Dry section of 40m	crown	3	6.5667
	middle of bottom	3	2.8377
	side wall 1	3	9.1832
	side wall 2	2	4.9666

According to the obtained results from **Table 6**, it is determined that in the first and second classes, shear force played a key role, moment and axial force had the next maximum effects in descending order, respectively. However, in the third class, moment had the most im-

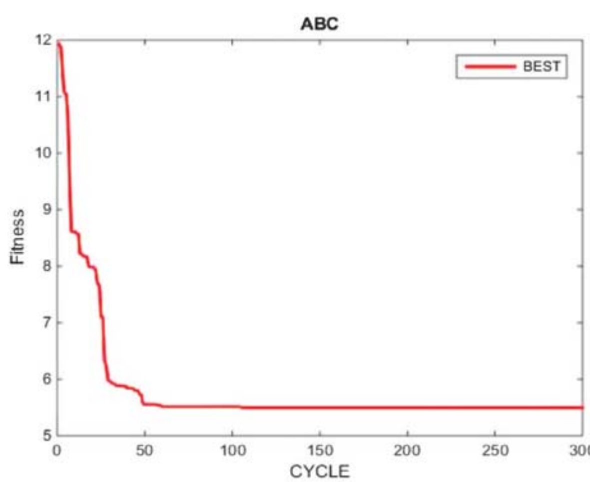

Figure 8. Algorithm convergence to achieve an optimal response

pact, and then the shear force was the second effective factor and, axial force had the least effective factor. In addition, based on the distance from the center of each cluster from each section, the cluster of each section is determined. As a result, it can be understood that shear force has a critical role in the crown, middle of bottom, side wall 1 and side wall 2 in the section of 100m, side wall 2 in the watery section of 40m and the dry section of 40m. Also, moment plays a key role in the crown, the middle of the bottom and side wall 1 in the watery section of 40m and the dry section of 40m. However, axial force has the least influence on all sections.

According to **Figure 8**, the process of optimization is reached to the desired precision level from the 110th cycle and it was fixed from the 110th to 300th cycle. Consequently, it can be concluded that based upon the appropriate convergence speed of the algorithm in this analysis, it can be applied as a powerful tool for clustering modelling and evaluating the initial stability of a tunnel.

5. Validation of the ABC algorithm

In order to validate the combined algorithm, all the sections' safety factors were calculated according to characteristics of the initial support system, then, the safety factors of clusters were calculated according to the sections which are located in it. The accuracy of the mentioned clustering was confirmed by safety factors. The achieved results in clusters in comparison to the center of clusters is determined based on the designed loads.

Allowable stress design (ASD) was used for the forces and the moment control in the section of initial coverage. A value for safety factors can be calculated in **Equation 1** for different excavation sequences by applying the axial force and moment calculated in FLAC^{2D} software. **Equation 2** was used for shear force control in the initial coverage. Results of this investigation for two sections of 40m and 100m are shown in **Tables 6 to 8.**

$$\delta_{max} = \frac{MC}{I} \quad (1)$$

Where M is the value of designed moment in the section, C is the maximum distance of the upper and lower levels (½ the height of coverage thickness). I is the moment of inertia and δ_{max} is the maximum tolerated force for the section.

$$V_n = V_s + V_c \quad (2)$$

Where V_n is shear strength of the army section, V_c is shear strength of concrete and V_s is shear strength of IPE steel. **Equations 3 and 4** can be used for the determination of the shear force bearing of concrete and IPE steel, respectively **(Keynia, 2005)**.

$$V_c = 0.45\sqrt{f_c^{'}} b_w d \quad (3)$$

$$V_s = 0.34 f_y A \quad (4)$$

Table 8: Safety factors of the support system

Sections		Clusters	SFV	SFTM
Watery section of 40m	crown	3	12.69	1.87
	middle of bottom	3	7.03	2.23
	side wall 1	3	4.40	3.28
	side wall 2	2	7.29	4.56
Section of 100m	crown	1	3.78	1.26
	middle of bottom	1	5.66	2.12
	side wall 1	1	4.61	2.33
	side wall 2	2	4.63	4.34
Dry section of 40m	crown	3	10.54	2.36
	middle of bottom	3	9.84	1.55
	side wall 1	3	3.41	4.12
	side wall 2	2	7.83	6.06

Note: SF_V is the safety factor of the support system based on shear force,
SF_{TM} is the safety factor of the support system based on axial force and moment.

Where $f_c^{'}$ is the compressive strength of concrete, b_w and d are the width and height, respectively. In addition, f_y and A are yield stress and cross section in **Equation 4**, respectively.

According to clusters, centers of clusters and safety factors were achieved as indicated in **Table 8**. It is observed that sections located in cluster 1 have a max of designed loads, this cluster also has a min of safety factors in comparison to the other two clusters. Thus, a min of cluster centers and a max of safety factors are related to cluster 2. According to safety factors and cluster centers, cluster 3 is in the middle of these clusters.

A number of sections are located in one cluster through the applied clustering. For example, 6 points of different sections are located in cluster 3. According to the average safety factors in sections and clusters, it is observed that sections located in one cluster do not have the same safety factor. This point was identified in clustering by distance of sections from the center of clusters in **Table 7**. Therefore, if the distance of an intended section from the cluster center is lower, the safety factor of the cluster is closer to the average cluster's safety factor. If the safety factor of a section is higher than the safety factor of the cluster, the distance from the section increases which establishes the second close distance with the cluster having a higher safety factor (cluster 2). On the other hand, if the safety factor of a section is less than the cluster's safety factor, the second close distance establishes the cluster which has a lower safety factor. The distance from the main cluster center is increased in both cases. It is interesting to note that in comparison between the SF_V and SF_{TM}, low accuracy for the classification of sections based on the safety factor of the support system based on shear force (SF_V) using a combination of the k-means algorithm and artificial bee colony describes its low capability in the evaluation of SF_V, al-though using a combination of the k-means algorithm and artificial bee colony is a reliable system modeling technique for evaluating SF_{TM} (safety factor of the support system based on axial force and moment) with highly acceptable degrees of accuracy and robustness.

6. Conclusions

Clustering was carried out by using a combination of the k-means algorithm and ABC as a meta-heuristic algorithm based on the forces achieved in different sections by the excavation modeling of the Kouhin railway using $FLAC^{2D}$ software. After installing the initial support system, each section of the tunnel was divided into three clusters by a meta-heuristic algorithm based on the axial force, moment and shear force. According to the clustering, model convergence and safety factors, it was observed that the sections with higher loads were located in the first cluster, while at the same time, they had lower safety factors. Also, the sections located in the third cluster had middle designed loads while at the same time, they had middle safety factors as well. In a similar manner, the second cluster had a lower value of designed loads and the highest value in comparison to safety factors. Accordingly, in regard to the average safety factors, cluster 1 had a mean of 3.29, which is the least, and cluster 3 with a mean of 5.28, which is higher than cluster 1, and cluster 2 with a mean of 5.79 had the maximum amount of means. In addition, the results clearly showed the superiority of moment in comparison with the other designed loads in the crown, the middle of the bottom and side wall 1 in the watery section of 40m and the dry section of 40m. Also, shear force had the highest impact on side wall 2 in all the sections and the crown, middle of bottom and side wall 1 in the section of 100m than the moment and axial forces. However, in comparison between the designed loads, axial force was determined as the least effective load.

It was found that the clustering of sections based on the safety factor of the support system based on axial force and moment can provide a higher performance capacity for evaluating a model compared to the safety factor of the support system based on shear force. Consequently, it can be concluded that the meta-heuristic algorithm achieved a primary accurate investigation of the initial support system safety in different sections of the tunnel according to the designed loads of sections and the validation of the safety factors.

7. References

Armano, G., Farmani M. R. (2014): Clustering analysis with combination of artificial bee colony algorithm and k-means technique. International Journal of Computer Theory and Engineering, 6, 2, 141-145.

Aryafar, A., Mikaeil, R., Haghshenas, S. S. and Haghshenas, S. S. (2018): Application of metaheuristic algorithms to optimal clustering of sawing machine vibration. Measurement, 124, 20-31.

Bouzon, M., Govindan, K., Rodriguez, C. M. T. and Campos, L. M. (2016): Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. Resources, Conservation and Recycling, 108, 182-197.

Dekovic, Z., Ester, Z. and Dobrilovic, M. (2003): Optimal Parameters of Blasting in Tunnels Using Patroned and Pumped Explosives with Electric and Non-electric Initiation. Rudarsko-geolosko-naftni zbornik (The Mining-Geology-Petroleum Engineering Bulletin), 15, 1, 31.

Dormishi, A., Ataei, M., Khaloo Kakaie, R., Mikaeil, R. and Shaffiee Haghshenas, S. (2018): Performance evaluation of gang saw using hybrid ANFIS-DE and hybrid ANFIS-PSO algorithms. Journal of Mining and Environment.

Eshghi, K., Kariminasab, M. (2012): Combined Optimization and Meta Heuristic algorithms. Azarin Mehr Publications. (In Persian).

Faradonbeh, R. S., Taheri, A. (2018): Long-term prediction of rockburst hazard in deep underground openings using three robust data mining techniques. Engineering with Computers, 1-17.

Feng, X., Jimenez, R. (2015): Predicting tunnel squeezing with incomplete data using Bayesian networks. Engineering Geology, 195, 214-224.

Frgić, L., Tor, K. and Hrestak, T. (2003): STRESSES IN MULTIPHASE EXCAVATION OF TUNELL. Rudarsko-geološko-naftni zbornik (The Mining-Geology-Petroleum Engineering Bulletin), 15, 1, 63-70.

Ghorbani, B., Sadrossadat, E., Bazaz, J. B. and Oskooei, P. R. (2018): Numerical ANFIS-based formulation for prediction of the ultimate axial load bearing capacity of piles through CPT data. Geotechnical and Geological Engineering, 36, 4, 2057-2076.

Haghshenas, S. S., Haghshenas, S. S., Barmal M. and Farzan, N. (2016): Utilization of Soft Computing for Risk Assessment of a Tunneling Project Using Geological Units. Civil Engineering Journal 2, 7, 358-364.

Haghshenas, S.S., Ozcelik, Y., Haghshenas, S.S., Mikaeil, R. and Moghadam, P.S. (2017): Ranking and assessment of tunneling projects risks using fuzzy MCDM (Case study: Toyserkan doolayi tunnel). IMCET 2017: New Trends in Mining - Proceedings of 25th International Mining Congress of Turkey, 289-296.

Sabzi, H. Z., Humberson, D., Abudu, S. and King, J. P. (2016): Optimization of adaptive fuzzy logic controller using novel combined evolutionary algorithms, and its application in Diez Lagos flood controlling system, Southern New Mexico. Expert Systems with Applications, 43, 154-164.

Itasca-Consulting-Group (1992): Flac version 3. 0 User's manual, Minneapolis.

Jalilvand, P., Haghshenas, S.S. (2013): The study of the stability of Tuyserkan Dolaei tunnel using reinforce shotcrete and rock bolt under static condition. In The 23rd International Mining Congress and Exhibition of Turkey. 1299-1305.

Jalilvand, P., Haghshenas, S. S., Haghshenas, S. S. and Javan, M. H. (2014): Evaluation of Dynamic Resistance of the

Toyserkan Doolayi Tunnel by Rock Bolt and Reinforced Shotcrete Composite System. Tunneling and Underground Construction, 376-384.

Karaboga, D. (2005): An idea based on honey bee swarm for numerical optimization, Technical report-tr06, Erciyes university, engineering faculty, computer engineering department.

Keynia, A. M. (2005): Analysis and Design of Army Concrete. Isfahan University Publications (In Persian).

Klanfar, M., Vrkljan, D. and Lončarić, M. (2015): Air Quality and Microclimatic Parameters During Excavation of Mala Kapela Tunnel. Rudarsko-geološko-naftni zbornik (The Mining-Geology-Petroleum Engineering Bulletin), 30,1, 55-66.

Lee, C., Wu, B., Chen, H. and Chiang, K. (2006): Tunnel stability and arching effects during tunneling in soft clayey soil. Tunnelling and Underground Space Technology, 21, 2, 119-132.

Luo, T., Wang, S., Liu, X., Zou, Z. and Cao, C. (2015): Stability Analysis of Tunnel-Slope Coupling Based on Genetic Algorithm. Journal of Engineering Science and Technology Review, 8, 3, 65-70.

Mahdevari, S., Haghighat H. S. and Torabi S. R. (2013): A dynamically approach based on SVM algorithm for prediction of tunnel convergence during excavation. Tunnelling and Underground Space Technology, 38, 59-68.

Merikhbayat, F. (2014): Meta Heuristic Optimization Algorithms (usage in Electrical engineering). Zanjan University publications (In Persian).

Mikaeil, R., Haghshenas, S. S., Shirvand, Y., Hasanluy, M. V. and Roshanaei, V. (2016): Risk assessment of geological hazards in a tunneling project using harmony search algorithm (case study: Ardabil-Mianeh railway tunnel). Civil Engineering Journal, 2, 10, 546-554.

Mikaeil, R., Shaffiee Haghshenas, S., Ozcelik, Y. and Shaffiee Haghshenas, S. (2017): Development of Intelligent Systems to Predict Diamond Wire Saw Performance. Soft Computing in Civil Engineering, 1, 2, 52-69.

Mikaeil, R., Haghshenas, S. S., Ozcelik, Y., and Gharehghesh-lagh, H. H. (2018a): Performance evaluation of adaptive neuro-fuzzy inference system and group method of data handling-type neural network for estimating wear rate of diamond wire saw. Geotechnical and Geological Engineering, 1-13.

Mikaeil, R., Haghshenas, S. S., Haghshenas, S. S. and Ataei, M. (2018b): Performance prediction of circular saw machine using imperialist competitive algorithm and fuzzy clustering technique. Neural Computing and Applications, 29, 6, 283-292.

Mikaeil, R., Haghshenas, S. S. and Hoseinie, S. H. (2018c): Rock penetrability classification using artificial bee colony (ABC) algorithm and self-organizing map. Geotechnical and Geological Engineering, 36, 2, 1309-1318.

Ooriad, F. A., Yari, M., Bagherpour, R. and Khoshouei, M. (2018). The development of a novel model for mining method selection in a fuzzy environment; case study: Tazareh Coal Mine, Semnan Province, Iran. Rudarsko-geološko-naftni zbornik (The Mining-Geology-Petroleum Engineering Bulletin), 33, 1, 45-53.

Panji, M., Koohsari, H., Adampira, M., Alielahi, H., and Marnani, J. A. (2016): Stability analysis of shallow tunnels subjected to eccentric loads by a boundary element method. Journal of Rock Mechanics and Geotechnical Engineering, 8, 4, 480-488.

Rad, M. Y., Haghshenas, S. S. and Haghshenas, S. S. (2014): Mechanostratigraphy of cretaceous rocks by fuzzy logic in East Arak, Iran. In The 4th International Workshop on Computer Science and Engineering-Summer, WCSE.

Rad, M. Y., Haghshenas, S. S., Kanafi, P. R. and Haghshenas, S. S. (2012): Analysis of Protection of Body Slope in the Rockfill Reservoir Dams on the Basis of Fuzzy Logic. IJCCI, 367-373.

Salemi, A., Mikaeil, R. and Haghshenas, S. S. (2018): Integration of finite difference method and genetic algorithm to seismic analysis of circular shallow tunnels (Case study: Tabriz urban railway tunnels). KSCE Journal of Civil Engineering, 22, 5, 1978-1990.

Yari, M., Bagherpour, R., and Almasi, N. (2016): An approach to the evaluation and classification of dimensional stone quarries with an emphasis on safety parameters. Rudarsko-geološko-naftni zbornik (The Mining-Geology-Petroleum Engineering Bulletin), 31, 3, 15-26.

Yaghini M., Kazemzadeh, M. (2016): Meta Heuristic Optimization Algorithms. Amir Kabir university Publications (In Persian).

Yagiz, S., Karahan, H. (2015): Application of various optimization techniques and comparison of their performances for predicting TBM penetration rate in rock mass. International Journal of Rock Mechanics and Mining Sciences, 80, 308-315.

Zhao, L., Li, D., Li, L., Yang, F., Cheng, X. and Luo, W. (2017): Three-dimensional stability analysis of a longitudinally inclined shallow tunnel face. Computers and Geotechnics, 87, 32-48.

Zhou, Y., Luo, Q., Xie, J. and Zheng, H. (2016): A hybrid bat algorithm with path relinking for the capacitated vehicle routing problem. Metaheuristics and Optimization in Civil Engineering, Springer, 255-276.