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The geometrical investigation of Tafresh fractures with emphasis on joint studies

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Key words: Joint, Joint study, Fracture, Tafresh, Stress analysis.

Abstract

Studied area, is an ancient structure of Central Iran which is located between the central Zagros and Alborz. Numerous fractures can be seen in the Tafresh area. Base on studying on this area, fractures of Tafresh was affected by a major fracture process zone in central Iran and the southern part of Alborz. Although many researchers have been done over the Tafresh area, but due to the complexity of the geological and specific conditions of topography, Geometric studying of joints and fractures of tafresh has not completely done. This paper examines the fracture based on geometry and kinematics and spatial distribution of folds and joints using joint study techniques. Fieldwork was done, at 36 Stations - 498 joints - and during 35 days, using Clark compass. At each station bedding, Attitude, spacing, opening, filling, shape and dimensions of the joint sets plus their relationship to one another and other structures such as faults and folds were done using the selection method (Nickelsen and Hough, 1967) and directory (Davis 1984), Which are fast with measuring and statistical calculations. Joint sets were classified based on the concentrations of the poles to the joint surfaces. The analysis shows that joint sets J1 are main stress on the Tafresh zone and J2 and J3 joint sets show the sheer stresses. The main stress tends the northeast of the area that is perpendicular to the main fault of Tafresh. The statistical analyses show three categories of joint set (J1,J2 & J3) in the region in which J1 is main stress on the Tafresh Zone and J2, J3 joint sets are the sheer stresses.

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Introduction

The studied zone is located in Tafresh Town of Markazi Province which is 221 km away from southwest of Tehran. This zone is in the eastern side of central Iran and located between Zagros and Central Alborz high lands in longitude of 49˚30'-50˚10' east and latitude of 34˚30'-35˚ north, between the zones of Sanandaj, Sirjan and Alborz. The faults of the zone have northeast-southeast and east-south orientations and play a determining role in control of sedimentary basin of the zone. In addition, the facies of the rocks around the mass belong to Mesozoic and Cenozoic eras (Hajian, 1999; Imami, 1992).

There are numerous fractures in Tafresh Zone the studies of which show that Tafresh Zone is affected by general trend of fractures in Central Iran zone (Ghasemi, 2001). In addition, these studies show that the fractures of Tafresh Zone are also affected by the trend of fractures of southern side of Alborz (Hajian, 2002; Nazari, 2006; Alien, 2008).

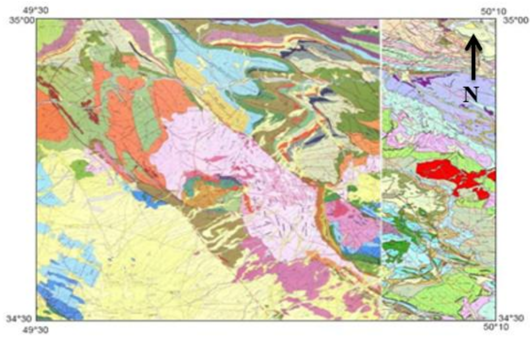

Fig. 1. Geological map of studied zone (1:100,000 scale).

The lithological studies of the zone show that it includes green tuffs of Karaj Formation (Eocene) in northern areas of Tafresh as well as a thick sequence of lytic tuff, crystal tuff and vitric tuff (Kheikhah, 1994). The most significant minerals of these tuffs include plagioclases of andesite and labradorite, pyroxene of augite and quartz. Chlorite, albite, analysm, epidote, prehnite, pumpellyite and clay minerals as well as secondary minerals (Jamali-Ashtiani, 2010).

Two major faults divide Tafresh area into three structural sub-areas. The Ezedin fault in north with northwest-southeast direct and moderate slop towards northeast takes the Eocene volcanic deposits (sub-area 1) over younger Eocene deposits (sub-area 2). The Tafresh fault in the south has similar direction with Ezedin fault but more slop has taken the deposits of southern side of the zone (sub-area 2) over the deposits of Ghom Formation (Oligocene-Miocene, sub-area 2). The structural study of mechanism of the faults, the folds affected by them as well as structural trends of penetrated dikes in the sub-areas shows a right tectonic Trans pressionmodel in this area of volcanic zone of Urmia-Dokhtar (Rajabion, 2006; Jamei, 2006).

There are numerous studies on joints in different zones. The statistical analyses of characteristics of joints in Shi Kalak Dam of Chabahar in south of Sistan and Baluchistan Province are among such studies. The comparison of join study methods (i.e. random and line sampling) of dam structure shows that although both methods represent similar characteristics and major sets of joints but the line sampling method has higher accuracy compared with the random one due to less distribution of studied points. The exact review of this method shows that the direction of sampling line has significant influence upon the registered characteristics of the joints. Therefore, this method also has some disadvantages in regard to determination of alignment and arrangement of the sampling line (Arab, 2002).

Although many researchers have been done over the Tafresh area, but due to the complexity of the geological and specific conditions of topography, Geometric studying of joints and fractures of tafresh has not completely done. This paper examines the fracture based on geometry and kinematics and spatial distribution of folds and joints using joint study techniques.

These studies show that Tafresh joints have not been studied. Therefore, the present study aims to geometrically analyze Tafresh fractures with emphasis on joint study, determine the geometric, cinematic and dynamic relations of fractures and characteristics of the regional joints (e.g. length of the joint, level of opening, type of join, distance between the joints and filling). After data analysis, the main fracturing structures of the zone and their geometrical relations will be clarified. The significance of this issue is more evident for characterization of fractures at the northern boundary of central Iran such as Tafresh, determination of the influence of southern area of Alborz on the zone, and study of geological, economic and engineering potentials.

Materials and methods

Sampling method

In superficial sampling, up to 10 characters of faults and joints were defined based on the objective of studies but in most of the cases, the two characteristics of slop and its direction are used to categorize them. Different methods have been suggested for identification of fractured areas each of which face some practical limitations. Among these methods, we can point to K Nearest Neighbor, Parzen, Neural Network, Linear Classifier, and Minimum Risk. Among the clustering methods, we can point to K Means Clustering, Fuzzy K Means Clustering, and Gustafson-Kessel. In the present paper, a mixed method is suggested for studying a set of joints (Tokhm-chi, 2002).

To do the study, multiple stages of field studies (i.e. 35 days) were done to sample the set of joints. In sum, 498 joints in 36 stations were considered as samples. The pathways mostly included the fractures of roads, plains and protruded surface of the layers.

Software

In each station, the registration of geographical coordinates of the station by GPS is followed by determination of type of rock unit, layering condition (i.e. using campus clark and as slope and its direction), and measurement and characterization of each set of joints. The locations of sampled stations are shown in Fig. 2.

Joint study

To sample the joints the method developed by Nickelsen and Hough (1967) was used in which a facie is analyzed observationally and representatives of each set of major joints were selected. Then, three to five joints were measured from each set. This method is relatively fast and enables us to do measurement in more points (Shfeii, 2012).

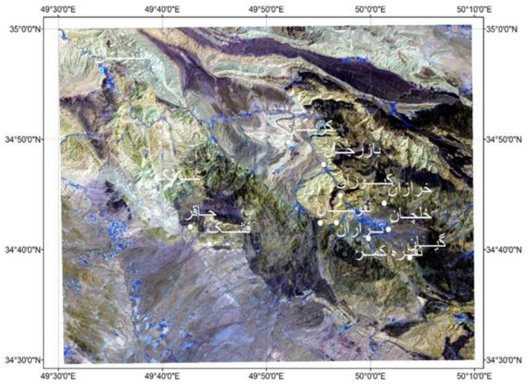

Fig. 2. Sample dstations in GIS.

Results and discussion

On Analysis Of Joints

After sampling, the set of primary joints were defined and their classification was done. In this regard, Dips Software was used to represent all sets of joints on an identical-area and aligned plan (contoured diagram). Then, the areas of the highest concentration were defined. In Figs. 3 and 4, the contoured diagram and rose diagram are drawn for all sampled joints.

Joints Classification

After data analysis, three sets of joints were observed in the zone called J1, J2 and J3. Their characteristics are described in summarized manner as follows:

J1 Joint Set

This set includes 173 measurements the direction slope of which ranges from 2 to 360 degrees with a slope of 71 to 90 degrees. The mean opening gap of this joint set is 10.1 mm and the highest frequency of opening gap is 5 mm (5.7 % of the joints). The shapes of this joint set are relatively straight. In Figs. 4 (a) and 4 (b), the trend and pole of J1 joint set are shown.

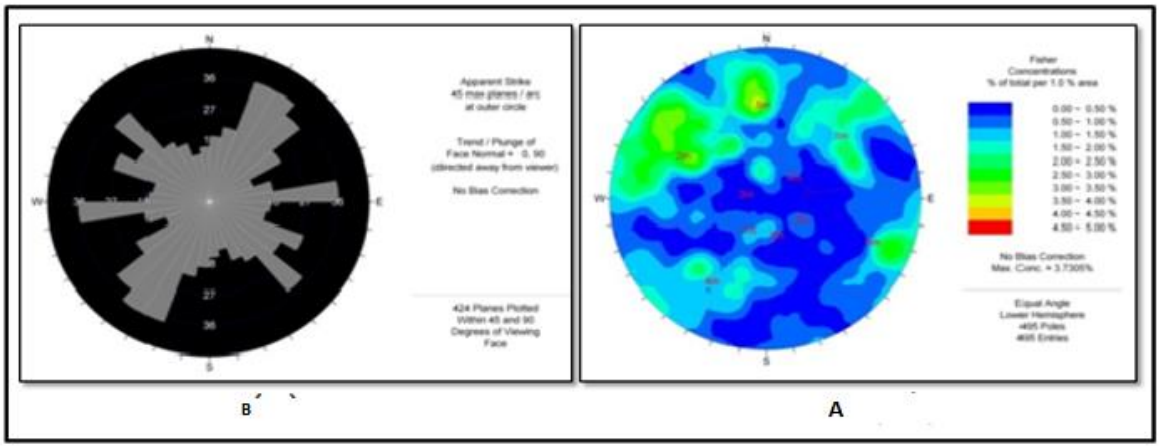

Fig. 3. Similar-Area and aligned diagram of pole of joint sets (A) and rose diagram of direction of sampled joints (B).

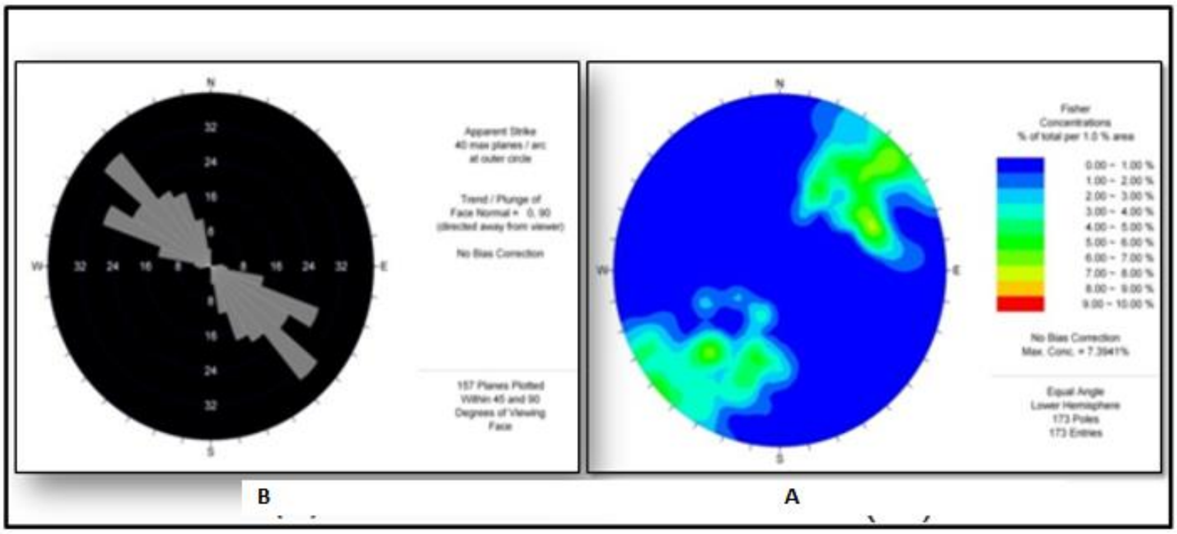

Fig. 4. Contour diagram of J1 joint set (A) and rose diagram of direction of J1joint set (B).

In Figs. (5.a) to (5.d), the statistical analysis of spacing discontinuity, statistical analysis of persistence discontinuity, statistical analysis of filling discontinuities and statistical analysis of roughness are represented. A sample of J1 joint set is shown in Fig. 6. In Fig. (5.a) the minimal distance of the joints in J1 joint set is 5 cm and the maximum distance is 100 cm. The mean distance of the joints was 26.83 cm and the most frequent joint gaps ranged from 6 to 20 cm (47.4 % of the joints). The least length of J1 joint set was 200 cm and the maximal length of the joints amounted to 2000 cm with an average of 1000 cm. The most frequent joints (59 %) ranged 300 to 1000 cm. The statistical mean length of these joints is 585 cm. In Fig. (5.b), the statistical analysis of persistence discontinuities of J1 joint set is shown. In Fig. (5.C), the statistical analysis of filling in J1 joint set is shown and there is no filling in most of the cases. The joints with filling are made of iron and calcite. In Fig. (5.d), the statistical analysis of roughness of J1 joint set is shown. This analysis shows that 44 % of joints are soft

(SM), 33.5 % of joints are rough (RO) and 22.5 % of samples are soft-rough (RO-SM).

J2 Joint Set

This set includes 201 measurements the direction slope of which ranges from 74 to 315 degrees with a slope of 33 to 90. The least opening gap of this joint set is 5 mm and the highest frequency of opening gap is 5 mm (2.48% of the joints) while the mean opening gap in this joint set is 12.54mm. The shapes of this joint set are relatively straight. In Figs. 7 (a) and 7 (b), the trend and pole of J2 joint set are shown.

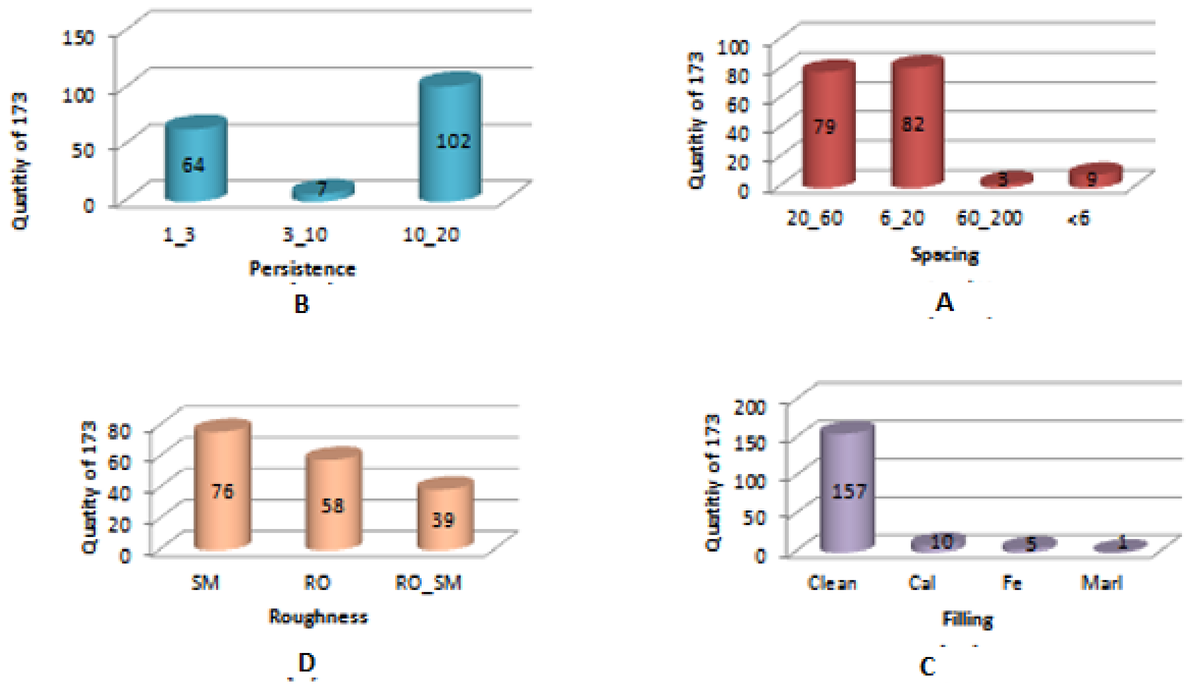

Fig. 5. Statistical diagrams of J1 joint set (A: Statistical analysis of spacing discontinuity; B:Statistical analysis of persistence discontinuity; C: Statistical analysis of filling discontinuity, D: Statistical analysis of roughness discontinuity).

Fig. 6. A sample of filling of J1 joint set in station (2) of Noghre-Kamardefile with northwest view.

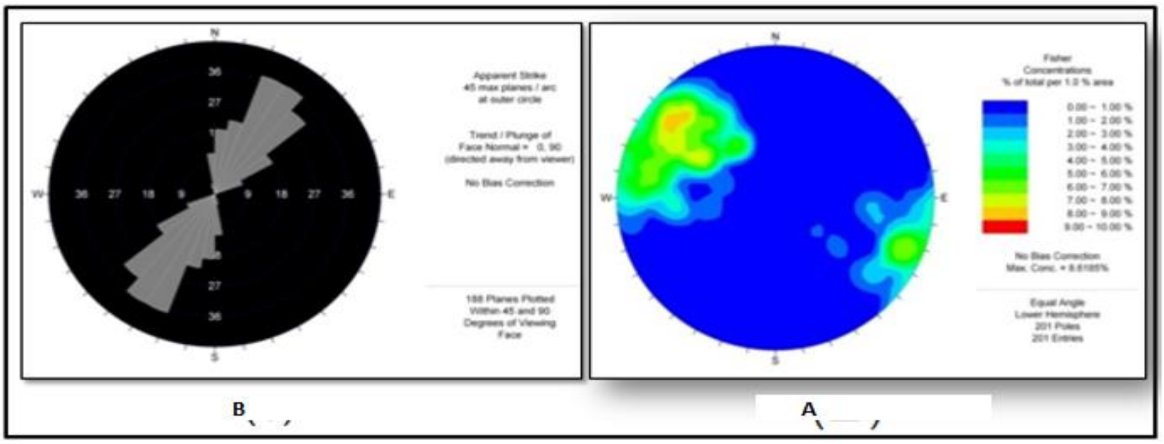

Fig.7. Contour diagram of J2joint set (A) and rose diagram of direction of J2 joint set (B).

In Figs (8.a) to (8.d), the statistical analysis of spacing discontinuity, persistence discontinuity, filling discontinuities and roughness are represented. A sample of J2 joint set is shown in Fig. 9. The statistical analysis of spacing discontinuity of J2 joint set of shown in Fig. (8.a).The minimal distance of the joints in J2 joint set is 10 cm and the maximum distance is 100 cm. The mean distance of the joints was 31.08 cm and the most frequent joint gaps ranged from 20 to 60 cm (50% of the joints). The least length of J2 joint set was 100 cm and the maximal length of the joints amounted to 600 cm with an average of 272 cm. The most frequent joints (65%) ranged 300 to 1000 cm. The statistical analysis of persistence for this joint set is shown in Fig. (8.b). The Fig. (8.c) represents the statistical analysis of filling for J2 joint set. The joints with filling are made of iron and calcite. In Fig. (5.d), the statistical analysis of roughness of J2 joint set is shown. This analysis shows that 44 % of joints are soft (SM), 34.3% of joints are rough (RO) and 21.4% of samples are soft-rough (RO-SM).

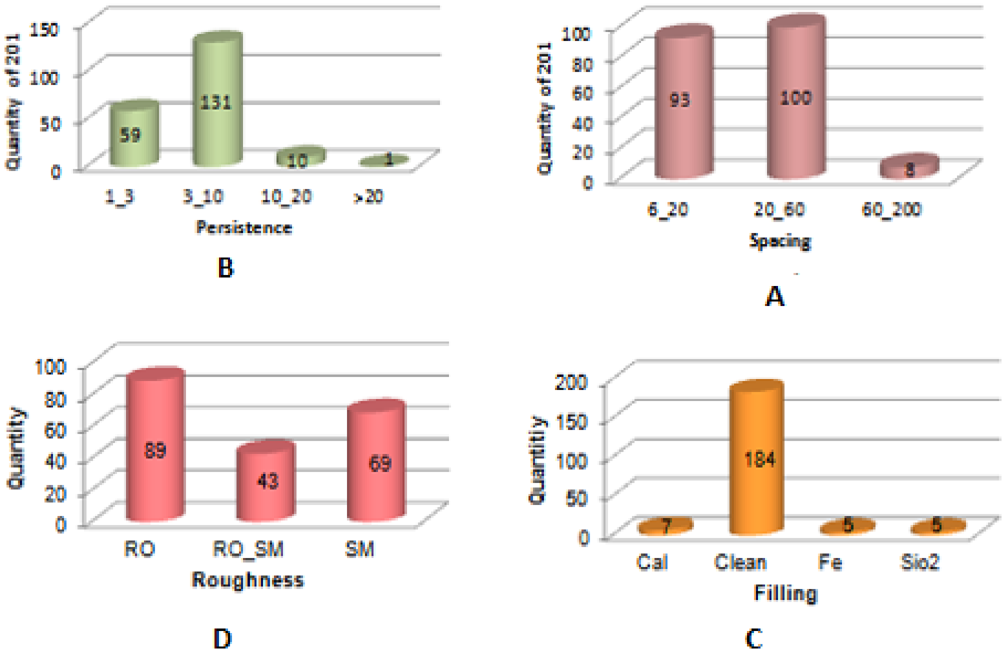

Fig. 8. Statistical diagrams of J2joint set (A: Statistical analysis of spacing discontinuity; B:Statisticalanalysis of persistence discontinuity; C: Statistical analysis of filling discontinuity, D: Statistical analysis of roughness discontinuity).

Fig. 9. A sample of filling of J2 Joint set in station (18) of Traran village with northwest view.

J3 Joint Set

This set includes 69 measurements the direction slope of which ranges from 56 to 312 degrees with a slope of 30 to 88. The least opening gap of this joint set is 4 mm and the highest frequency of opening gap is 10 mm (17.4 % of the joints) while the mean opening gap in this joint set is 11.6 mm. The shapes of this joint set range relatively straight to uneven. In Fig.s 10(a) and 10(b), the trend and pole of J2 joint set are shown.

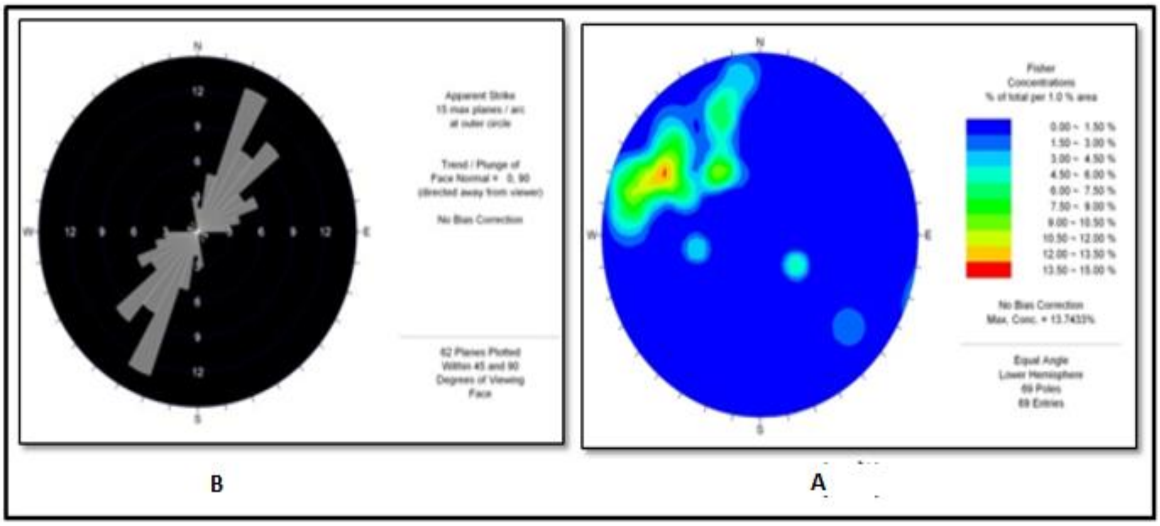

Fig. 10. Contour diagram of J3 joint set (A) and Rose diagram of direction of J3 joint set(B).

In Figs (11.a) to (11.d), the statistical analysis of spacing discontinuity, persistence discontinuity, filling discontinuities and roughness are represented. A sample of J3 joint set is shown in Fig. 12. The statistical analysis of spacing discontinuity of J3 joint set of shown in Fig. (11.a). The minimal distance of the joints in J3 joint set is 10 cm and the maximum distance is 40 cm. The mean distance of the joints was 25.52 cm and the most frequent joint gaps ranged from 6 to 20 cm (53.6% of the joints). The least length of J3 joint set was 100 cm and the maximal length of the joints amounted to 2200 cm with an average of 347.82 cm. The most frequent joints (58%) ranged from 100 to 300 cm. The statistical analysis of persistence for this joint set is shown in Fig. (11.b). The Fig. (11.c) represents the statistical analysis of filling for J3 joint set. There is no filling in most of the cases and the joints with filling are made of silicate. In Fig. (11.d), the statistical analysis of roughness of J3 joint set is shown. This analysis shows that 71% of joints are soft (SM), 14.5% of joints are rough (RO) and 14.5% of samples are soft-rough (RO-SM).

Strain Analysis of Jointing

Strain (the deformation of non-rigid object) refers to deformation in which the relative locations of particles inside an object change. The deformation of a non-rigid object is categorized into two kinds of distortion and dilation. In distortion, the shape of an object changes but during dilation, the object changes without any evident modification of its form (Shafei, 2012).

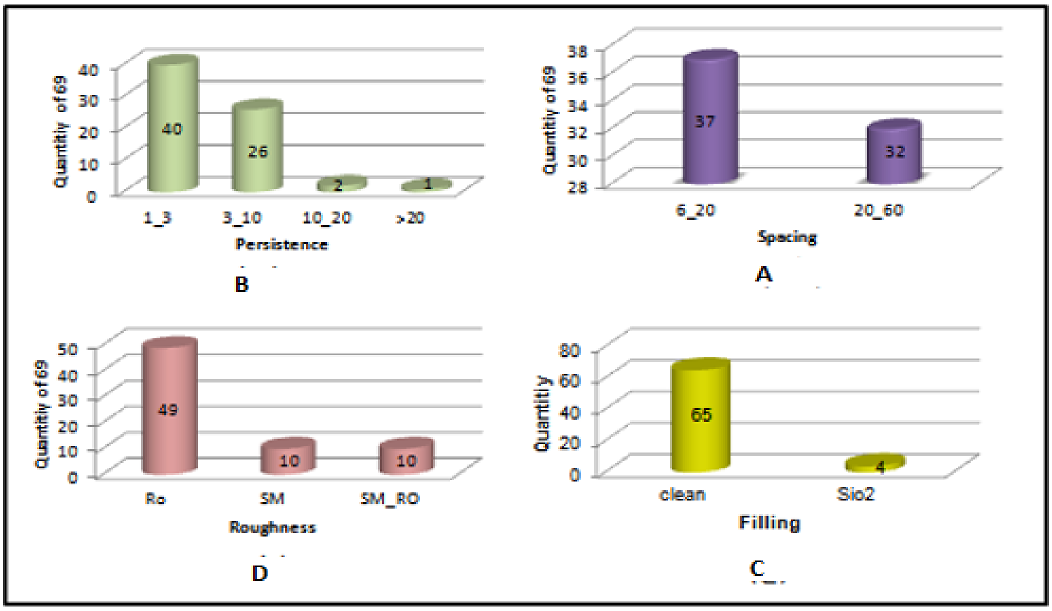

Fig. 11. Statistical diagrams of J3joint set (A: Statistical analysis of spacing discontinuity; B:Statisticalanalysis of persistence discontinuity; C: Statistical analysis of filling discontinuity, D: Statistical analysis of roughness discontinuity).

Fig. 12. A sample of filling of J3 Joint set in station (22) of gian defile with northeast view.

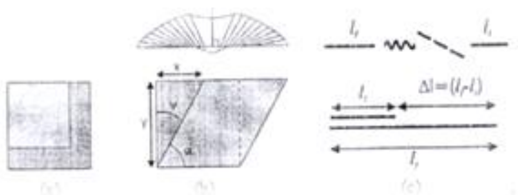

Fig. 13. Shortening and extension of deformed object.

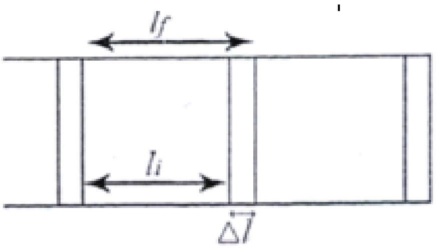

Fig. 14. Proportion of initial length (Li) to final length (Lf) and difference of length (LΔ) as the opening of the joint.

Extension refers to the ration of length change of a one (Δl) to its initial line (l_i).

$$e = \frac{\Delta l}{l_i} = \frac{(l_f - l_i)}{l_i} = \frac{l_f}{l_i} - 1 \qquad (1)$$

The subscripts (i) and (f) respectively refer to initial and final mode. It is noteworthy that although the name of this parameter is extension but it also includes the shortening of line. In fact, the extension is a positive increase of the length of an object while shortening of an object is a type of negative extension.

To estimate the level of strain in the intended joint set, the extension value for each joint set is calculated based on the above equation (Fig 25). In this equation, Δl refers to mean opening of the joint set and lirefers to mean distance of the joint set both of which are measured in mm.

Therefore, the calculation of the strain of J1, J2 and J3 joint set is done through dividing the mean opening of each joint set by mean distance of each joint set. To obtain the mean opening of each joint set, all of the openings are summed and then the summed value is divided by their number. In addition, the mean distances of a join set are summed up and then divided by their number.

$$e_{J1} = \frac{10.15}{268.3} = 0.037 \quad e_{J2} = \frac{12.54}{310.8} = 0.04 \quad e_{J3} = \frac{11.66}{255.2} = 0.045$$

Fig. 15. An instance of opening in different sampled joint sets.

Stretch refers to the ratio of final length (lf) line to its original length (li).

$$s = \frac{l_f}{l_i} = 1 + e \qquad (2)$$

To calculate the stress of each joint set, as shown in the following equation, one (1) is added to the values of strain.

$s_{J1} = 1 + 0.037 = 1.037$

$s_{J2} = 1 + 0.04 = 1.04$

$s_{J3} = 1 + 0.045 = 1.045$

The quadratic elongation is equivalent with quadratic stretch.

$$\lambda = S^2 = (1+e)^2 \qquad (3)$$

To determine the extension of each joint stress, the value of stress for each joint stress is quadrated.

$\lambda_{J1} = 1.037^2 = 1.075$

$\lambda_{J2} = 1.04^2 = 1.081$

$\lambda_{J3} = 1.045^2 = 1.092$

If λ is equal with 1, no change in the line length has occurred. If λ is less than 1, the shortening of line length has occurred but if λ is more than 1, the extension of line length has developed. It is noteworthy that x is always more than or equal with zero because it is a function of stretch of S^2. As shown in the above calculations, all joint sets undergo extension.

The Results Of The Joint Analyses

The studied area is a part of central Iran and located between the two areas of Zagros and Central Alborz. The present paper aimed to investigate the geometry and dynamics of the fractures and folds (with emphasis on joint study) as well as their geographical distribution.

In the zone, there are 5 primary faults with northwest-southeast direction the most significant of which is Noghre Kamar Fault with a length of 70 km. The trend of folds and faults is relatively identical. The study of regional joints in 36 stations was done with 498 samples. Their statistical analyses were done by Dips Software which led to categorization of 443 samples of the joint into 3 groups called J1, J2, and J3.

The J1 joint set has a northwest direct. The orientation and pole of which are represented in Fig. 16. This joint set is of tensional type which shows the (σ1)trend of the zone. The studies show the main stress applied on the zone which confirms its verticality relative to axis of the folds and the main faults.

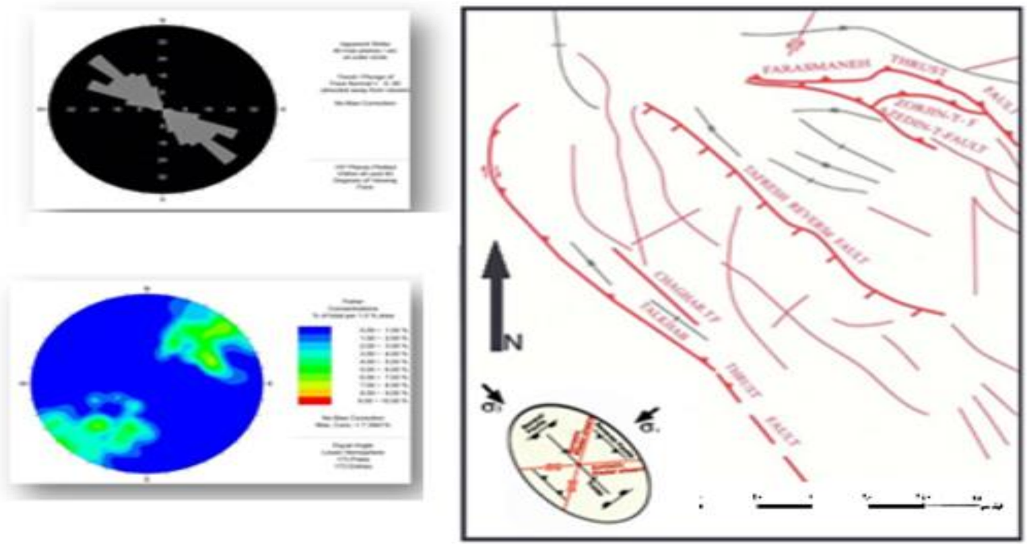

Fig. 16. Analysis of structural map of the zone with contour and rose diagrams of J1 joint set.

As shown in Fig. 17, the J2 and J3 joint sets have northeast orientation which shows their shear stresses. Based on their orientation compared with the main stress and shear effects of the joints verified in field study and surfaces of regional joint, this claim is proved. The highest frequency of joints were found in station (2) in Noghre Kamar Defile (0.8) while the least frequency of such joints were found in Gian Defile of station 19 (0.16).

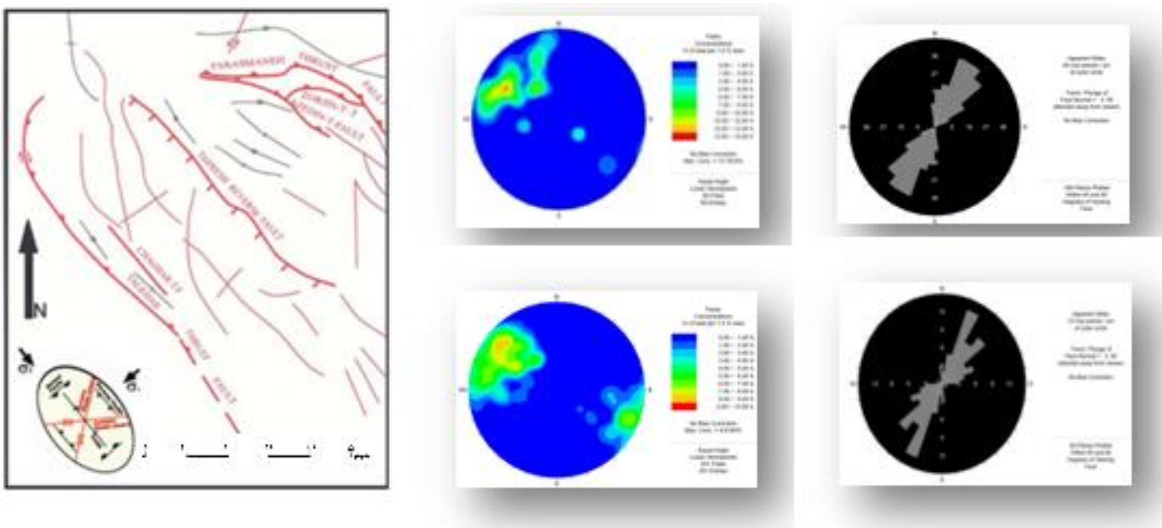

Fig. 17. Analysis of structural map of the zone with contour and rose diagrams of J2 and J3 joint sets.

The parameters of longitudinal strain of the zone were studied and the level of extension in the zone of J1 joint set was 0.37. The values of this quantity for J2 and J3 joints were respectively 0.4 and 0.045. The significant uplift of these joint sets was due to the effects of folds and faults of the zone. In Table1, a summary of calculated longitudinal parameters for three sets of joints is shown.

Table 1. Calculation of Strain for J1, J2 and J3 Joint Sets.

Type of Joint	Mean of Opening L(mm)Δ	Mean of Joint Distance L(mm)	Strain e	Extension S	Shortening λ
J1	10.15	268.3	.037	1.037	1.075
J2	12.54	310.8	.04	1.04	1.081
J3	11.66	255.2	.045	1.045	1.092

As shown in Table 1, the values of extension in J1, J2 and J3 joint sets were 1.037, 0.04, and 1.045. Another calculated longitudinal parameter is shortening the values of which for J1, J2 and J3 joint sets were 1.075, 1.081 and 1.092.The amount of longitudinal strain in the studied zone increases from south to north and from east to west. This issue can be attributed to the stresses applied on the studied zone due to placement of the zone between Zagros and Alborz zones. To determine the level of this effect, more comprehensive studies, even cross-regional, are needed.

Based on the results of analyzing the joints and faults, it can be concluded that the studied zone has a significant level of fracturing, especially in Noghre Kamar Defile, and the existing joints are of J1 type with vertical position relative to Noghre Kamar fault. In addition, the Noghre Kamar Tunnel has been drilled for numerous types due to the type of bed rock, orientation of joints, and similar direction of layers' slope and that of the tunnel' axis. Therefore, the progress of the tunnel is associated with increase of downfall of surrounding layers. The incomplete roads, especially the road of Gian Defile, face with numerous fractures in this zone. Besides, the similar direction of underlying layers' slope towards the road and removal of soil for constructing the road and the construction of new road have caused the landslide of large amount of soil and rock from surrounding areas of the road into the road. The construction of a new road has also changed into a difficult challenge due to the fall of a large amount of soil and rock from surrounding areas of the road into it. As a result, the construction of water barrier, the direction of water output channel, the downfall of the tunnel and other events and plans associated with civil engineering should be preceded by sufficient attention to level and direction of fractures and faults of the zone so as to fully accomplish the essential corrections and revisions of engineering activities.

Conclusion

In this paper we emphasis on joint studies well as geometric, kinematic and dynamic relationships of fractures and characteristics of joints in the region, the fractures of Tafresh were geometrically analyzed. The J1 joint set has a northwest direct. This joint set is of tensional type which shows the (σ1) trend of the zone. The studies illustrate the main stress applied on the zone which confirms its verticality relative to axis of the folds and the main faults. The J2 and J3 joint sets have northeast orientation which shows their shear stresses. According to the results of analyzing the joints and faults, it can be concluded that the studied zone has a significant level of fracturing, especially in Noghre Kamar Defile, and the existing joints are of J1 type with vertical position relative to Noghre Kamar fault.

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