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The effect of brittle fault performance on rock mass engineering characteristics (North Tehran fault), Iran

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Abstract

Brittle faults have the most influence on the engineering properties of rock masses and they are of special importance. The complexity of the faults makes it difficult to survey their geotechnics, and even the type of fault, has a different effect on the fragility of rock masses. For this purpose, in this study, the geomechanical properties of rock faults and Bimrocks in the North Tehran fault zone, which is located in the southern part of central Alborz and north of Tehran, are investigated and analysed. Therefore, by using BIMROCKS investigation (Block-in-matrix rocks), we can reduce the high costs of boreholing for the construction of engineering structures within the limits of the fault zone. Bimrocks, which are a group of limited rocky blocks in the matrix, have irregular textures and properties, thus creating problems for civil works in the area and also causing slope instability. The cross-sectional measurement of the North Tehran thrust zone from the forehead to the end of the zone indicates some regular changes in volumetric proportion and uniaxial strength of the fault rock blocks, So that the amount of fragmentation of rocks decreases from the forehead to the end of the zone, and therefore the volumetric proportion and their strength increase. Having the result of this study shows that the resistive properties of the fault rocks depend on the presence of micro-faults, the spacing of shear-plates from each other and the amount of displacement created by the fault.

Keywords: *North Tehran Fault; Block in matrix rock (Bimrock); Strength of fault rock; Volumetric block proportion; Iran*

1. Introduction

Fault zones are geologically complex structures which are formed of different rocks having different properties. In order to evaluate the characteristics of fault zones and, as a result, successful construction around fault rupture, knowledge of structural and engineering geology is essential. The study of these fault zones is of the upmost importance due to the fact that the brittle faults have the most influence on the characteristics of rock masses; and the rocks of fault zones, especially sheer faults, have very weak engineering characteristics and are included in the group of weak rocks; and also because the most considerable geological problems related to rock engineering are originated by these brittle faults. The use of fault rock classification and block engineering characteristics in the matrix (BIMROCK) and also the comparison of these characteristics with GSI classification has been done for the first time in this research. Previous researches in the southern Alborz region mostly included structural analysis and paleostress. Guest, based on the slip lines, tensile cracks and mineral strings developed on the fault plane protruding from the North Tehran thrust in the north of Tehran city, consider the oblique movement of reverse slip with a left-strike-slip component for this thrust (Guest et al. 2006). Ballato believes that the southern part of Central Alborz consists of a thick sequence (8-10 km) of sedimentary-volcanic units of the Karaj Formation and the structures in this part form a transpressional duplex (Ballate et all, 2011). Hemmati analyzed the fractures in the north of Tehran. By examining the local faults in the north of Tehran, he concluded that the main force acting on the region is south-southwest-north-northeast (Hemmati 1992). Eliasi has evaluated ancient stress tensors and deformation type based on the analysis of fault slickensides in the southern slope of Central Alborz (Eliasi 2001). Farbod has investigated the impact of fault mechanisms on the evolution of the sedimentary basin of Tehran with a perspective on the evolution of the stress field from the Pleistocene to the present era (Farbod 2005). Haghipour has evaluated the dynamics of the southern margin of the Central Alborz with an attitude on geomorphological indicators (Haghipour 2003). Geological problems related to the brittle faults are mostly caused by the inherent heterogeneity and sudden variation in strong and weak rock components. The inherent heterogeneity of brittle fault zones is clearly due to the accidental presence of more or less un-deformed and un-decomposed units of wall-rock fragments called knocker or horse and are surrounded by weak and soft matrix (Goodman 1993). The deformed rocks in the fault zones, regardless to the type of lithology, are called fault rock (Sibson 1977). The term "block-in-matrix rocks" was first introduced by Loren Raymond (1984) for melange and olistostrome. To concentrate on geomechanical problems and to identify the block-in-matrix rocks, the term "bimrock" was introduced

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(Medley 1994) for melanges and other geological mixtures such as sheared serpantinite, breccia, decomposed granite and tectonically fragmented rocks like fault rocks. The proportion of fine-grained matrix to the blocks with different shapes, sizes and resistances highly vary. Occasionally, the matrix may be cemented by secondary minerals, resulting to a considerable hardening of the fault rocks (Riedmuller et al. 2001). A bimrock is a mixture of rocks composed of geotechnically significant blocks within a bonded (blocks are surrounded by a matrix) matrix of finer-grained texture. The phrase "geotechnically significance" implies the mechanical contrast between blocks and matrix. The minimum strength contrast is suggested based on friction angle ratio ((tan ϕ of weakest block)/ (tan ϕ of matrix)) ≥ 2.0, in the block size between 0.05 LC and 0.75 LC of the characteristic engineering dimensions (the scale of engineering interest like the dimension of a tunnel or a three-axial sample) and range of volumetric block proportion (VBP) between 25% to 75% (Medley 1994). It is worth mentioning that A size range which influences bimrock mechanical properties if block size is characterized by d then a bimrock has a range of blocks that at the scale of engineering interest (as scaled by a characteristic engineering dimension (Lc)) as mentioned conforms to: $0.05\ Lc \leq d \leq 0.75\ Lc$

For example, if Lc = 100m, then blocks < 5 m are assigned to matrix; and blocks > 75 m, are considered blocky rock. In this research, the desired scale is according to the area of the investigated area in centimeter, which is mentioned in the rest of the article. The strengths of faulted rock masses are determined by combination of block and matrixes characteristics in the fault rocks. Consequently, the total resistance of bimrock is higher than the strength of the matrix alone, because the presence of blocks affects the mechanical properties, when block proportion exceeds a threshold limit. Therefore, to estimate the general mechanical properties of bimrocks, determination of volumetric proportion of blocks in the bimrock is very important.

2 Geological backgrounds

Investigation of Active Tectonics (e.g. Khavari et al. 2009, Arian et al. 2012, Arian and Aran 2014, Ehsani and Arian 2015, Aram and Arian 2016) and basement faulting (e.g. Nabilou et al. 2018 and Mansouri et al. 2017 and 2018) show that Iran has a high seismic potential. In terms of lithofacies, especially the role of tectonics in the Alborz Sedimentary Basin, Arian (2015), Razaghian et al. (2018) and Taesiri et al. (2020) divided all rocks in the Alborz into several large tectonic-stratigraphic units. In most areas of the Alborz, Paleozoic-middle Triassic sediments are concordance due to stratigraphic gaps, indicating tectonic movements (Rahgoshay et al. 2018, 2019). In the Western Alborz, structures have north-west-southeast trend, but in the eastern part, the trend of structures is northeast-southwest. These two heterogeneous trends in the Central Alborz reach each other. Recent studies by Nouri et al. (2013a,b) in Tarom, Nouri and Arian (2017) in Takab, Arian (2012) in the SE Tehran, South Gorgan, Kiasar, North Tehran and Talish show clearer facts of mechanisms and the role of thrusts in the Alborz structure (Alavi-Naini 1991). The area under study is located on the southern hillside of central Alborz Mountains in the north and northwest of Tehran, from Darabad to Kan valley where brittle faults are widely developed. Alborz mountain range, with its east-to-west common direction, is a part of active young orogenic alp-Himalia belt, having its newly shape from the last alpine orogenic, and includes east-west folds and thrusts which are driven on each other from Alborz central axis toward north and south. One of the thrusts is related to the North Tehran thrust, which is more than 75 kilometers long in the foothills of the north of Tehran, which continues from the east of the Lashgarak Valley (Deh Sebu) in the northeast of Tehran to Kazem Abad and the west of Karaj city, that the closest seismic fault to the Tehran city. It seems that this fault is a branch of Mosha thrust fault (Berberian et al. 1992). Barbarian et al. (1985) has physiographically divided Tehran domain and its around to four parts from north to south:

1. Alborz high domain including Palaeozoic, Mesozoic, and Tertiary rocks, getting its altitude from great folds and severe thrusts over each other.
2. Alborz corner folds consisting of about 10 km. Eocene volcanic rocks of Karaj Formation, which have been smoothly folded, and Toochal peak is its highest summit.
3. Tehran foothill domain, i.e. the distance between Alborz corner folds and northern subsidence area (basin or Tehran Plain) of centre of Iran, where is affected by numerous east-west fault microzones.
4. Tehran plain with an inclination from north to south where is divided into distinct parts by east-west heights and subsidences.

The time of the last stage of the North Tehran thrust movement is not known due to the lack of the exact age of the alluviums in the Tehran area (Vita-Finzi 1969), If the sedimentation of the alluvial formation of Tehran ended about 4 thousand years ago (Vita-finzi, 1969), the last important movement of the North Tehran thrust and its movement on the alluviums of the north of Tehran was before this date (Berberian et al, 1992). Regarding to Tehran map with the scale of 1:100000, E1tsv unit and E2t unit of sub-formations of Karaj Formation, and Pl-Q ، Q-F units of Hezardareh Formation are stratifically included in the study. E1tsv is a unit consisting of green tuffs and shale. Accompanied with unit E1t shales, E2t unit includes masses of green to blue (greenish blue) tuffs including various kinds of green tuffs e.g. Lithic tuffs, ash tuffs, glass tuffs and other types categorized between them, and tuffites and carbonatic tuffs, gross lime stones and banded tuffs; while it is completely separable from lower layer for its proper bedding and absence of shale and volcanic lavas. PL-Q unit, which is equivalent to the alluviums of segment A regarding to Rieben classification (1955, 1966), consists of homogeneous conglomerate with some sandstone and clay interlayers, while its parts are mostly consist of Karaj Formation rocks and some few Palaeozoic old rocks. The unit's colour is creamish grey and its thickness is more than 1000 meters. The layers are mostly inclined, some of which have inclinations up to 80 degrees. Regarding to Rieben segmentation (1955, 1966), QF unit includes Tehran North Heterogeneous Alluvial Formation (alluviums of unit Bn), clayey siltstones of Kahrizak Formation (alluviums of unit Bs) and Tehran Alluvial Formation (alluviums of unit C). The alluvial layers dips are less than 15 degrees that are unconformably located on the conglomerate and sandstone of Hezar Darreh (Late Miocene-Pliocene) or older units.

3 Study method

3.1 Bimrock classification

Different classifications have been introduced for fault rocks, such as the classification proposed by Brekke and Howard (1973) or Zhang et al. (1986), but the inhomogeneous nature of fault rocks is not clearly determined and classified by these classifications. A distinct engineering classification was finally introduced on the basis of the experience gained from the investigations for, and construction of, rock structures such as dams, slopes and tunnels (Riedmuller 2001) (Fig.1). Unlike the previous classifications, this classification pays more attention to the properties of blocks and matrix and also secondary cementation in fault rocks; because the combined contributions of these components together determine the strength of the faulted rock mass. The basic classification of the rocks produced by brittle faulting, called cataclastic rocks, is based on the differentiation between the cohesive or noncohesive character of the faulted rock (Riedmuller 2001). Strengths of fragments, cement material and also cementation degree are effective on the properties of cohesive cataclastic rocks. However, facing with cohesionless fault rocks, identifying geotechnically significant blocks and calculating the volumetric proportions of the blocks are mostly considered. Some methods have been proposed to determine block volumetric proportions of cohesionless rocks to be used for melanges and similar bimrocks (Medley 2002; Medley and Goodman 1994). In general, three methods are mostly used to calculate volumetric block proportion of bimrocks:

1.One dimensional (scan lines and boreholes).
2.Two dimensional (image analysis on photographs and window mappings).
3.Three dimensional (sieve analysis).

It is necessary to mention that in this study, in order to determine the volumetric block proportion of bimrocks, two-dimensional analysis method has been used. Many of geological disorganised processes have fractal or self-similar natures (Turcotte, 1986, 1992). Lindquist (1991) believes that the block size distribution of melanges conforms to reverse relationships, i.e. the number of large blocks decreases while the number of small blocks is increasing. By plotting size of the blocks relative to their frequency on logarithmic axes, a linear diagram with negative slope is obtained. Lindquist named the absolute value of this slope "the fractal dimension". According to the definition of fractal geometry, the fractal dimension is expected to be the same in all pieces of a block-in-matrix rock regardless of the size of the pieces. Drawings and photography of melanges in the scale of outcrop can describe graphical models of larger-scale melanges, due to the existence of fractal relations in melanges, that these graphical models make possible computational methods for estimating the blocks volumetric proportion and blocks size distribution in melange on different engineering scales (Medley and Goodman 1994). The most comprehensive studies until now for determination of volumetric block proportion have been done on the basis of one and two dimensional methods. The studies which used the stereology method to identify the volumetric proportion of Melange blocks can be named as examples.

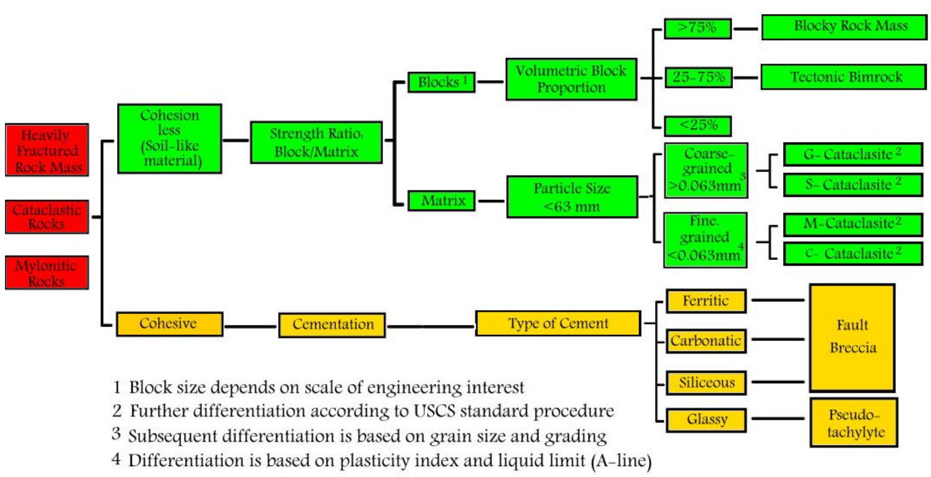

Fig 1. Engineering geological classification of cataclastic rocks (fault rocks) (Riedmuller 2001).

3.2 Measurements of fault rocks

Measurements was done from the foreheads to the ends of each part of the fault, and several stations were evaluated and chosen to be investigated, for identification of the strength properties of fault rocks, and to investigate existence or nonexistence of relation between faults mechanism and characteristics of their fault rocks strength. From each station, photographs of fault outcrops were picked and sampling was performed for further laboratory affairs to obtain strength parameters. At first, seven points were identified on the length of North Tehran fault, on which field studies were done, which includes the areas of Kan, Hesarak, Farahzad Valley, Derkeh Valley, Tochal, Darband and Darabad. but only the trenches on Kan valley and Hesarak showed a typical feature of the fault zone; on the other places most parts of the fault were hidden and inaccessible (Fig.2). Therefore, seven stations on North Tehran fault zone in Kan area, and eight stations in Hesarak area were chosen. Photography of fault rocks outcrops was done in a desired scale and then, due to the considerable effect of volumetric blocks proportion on bimrock mechanical properties, and to gain strength parameters of the block-in-matrix rocks, surface percentage of the blocks in fault rocks of thrust zone was calculated using the Image Analysis software, Image J version (Two-dimensional analysis method). It should be noted that, because the sizes of blocks and matrix obey the desired engineering scale, and for the appropriate conclusion, three frames were prepared in the areas of 300, 600 and 1200 cm2 and used as area of unit for photography of outcrop in fault zones. Considering that fractal dimension was used to calculate the surface percentage of the blocks in fault rocks, each of the frames was placed on a surface of the crushed zone and the related photo was entered into the software for calculations. As a result, the surface percentage of the blocks obtained in the area of each frame is proportional to the surface percentage of the blocks in that part of the fault zone in each possible area. This would also help to recognize probable fractal relation in volumetric proportion and block size distribution.

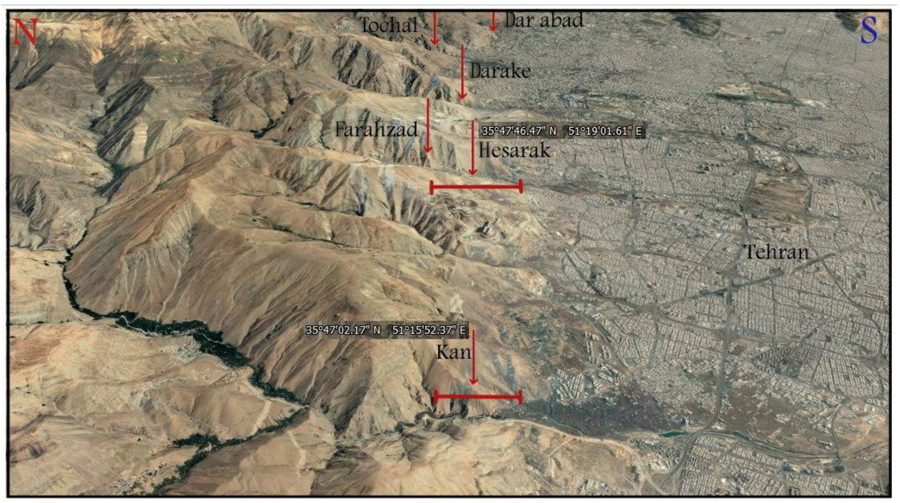

Fig 2. Signs in the shape of arrow are points along the fault that were surveyed during the study, but only the two areas of Kan and Hesarak, whose coordinates are written, were examined as typical sections.

4 Measurement results and analyses

4.1 Measurement results

4.1.1 Profiles in Kan area (seven stations)

The investigations on North Tehran fault zone over both Kan and Hesarak areas indicate that the fault rocks of the forehead of thrust zone, i.e. stations 1 and 2 in Kan zone and stations 1, 2 and 3 in Hesarak zone, block-in-matrix rock structure are not observed, and volumetric block proportion is less than 25% in this area, which according to the Riedmuller (2001) classification, have matrix characteristics (Fig.3). This part of the thrust zone includes footwalls of North Tehran fault (except station 3 in Hesarak area) that mostly consisting of recent deposits accompanied with colluviums and precarious fragment of Karaj formation. Some branches of the thrust can also be seen in the mentioned part implying youth of the thrust and North Tehran fault activations within less than ten thousand years ago. Due to the high fragmentation and the presence young micro-faults in this part of the fault zone, the utmost attention should be paid for constructions and building structures.

4.1.2 Profiles in Hesarak area (eight stations' obsveration)

Fault rocks in the middle part of the study area have block-in-matrix rock structure and having rocky block volumetric proportions between 25 to 75 percentages, which according to the classification of Riedmuller et al. (2001), is considered as Tectonic Bimrock. The volumetric proportions of blocks are about 30% in station no.3 of Kan zone and station no.4 of Hesarak zone (Fig. 4). In Kan's no.4 and Hesarak's no.5 stations, block proportions are about 40% (Fig. 5). Subsequently, block proportions is gained about 50% in Kan's fifth and Hesarak's sixth stations (Fig. 6). Afterwards, in stations no.6 of Kan and no.7 of Hesarak, the obtained block proportions are about 60% (Fig. 7).

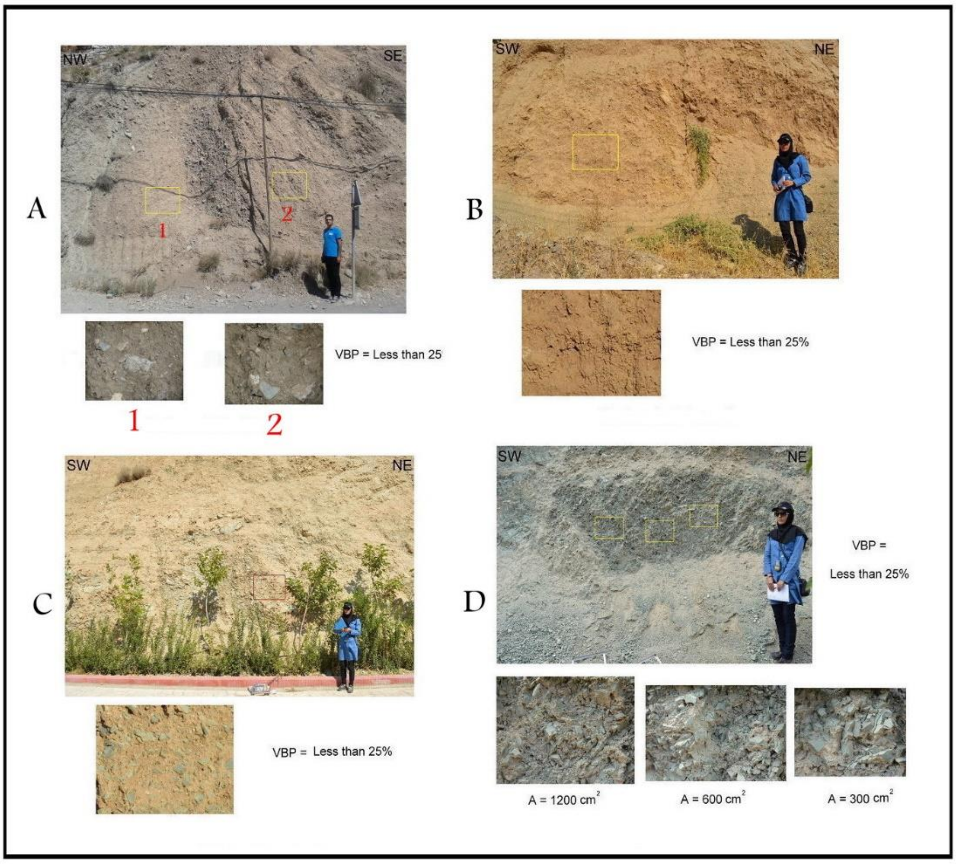

Fig 3. A: Stations 1 and 2 of the North Tehran fault zone in the Kan area, which include the footwall section of the fault and have matrix characteristics. B, C: Stations 1 and 2 of the North Tehran fault zone in the Hesarak area, which include the footwall section of the fault and have matrix characteristics. D: Station 3 of the North Tehran fault zone in the Hesarak area, which includes the hanging wall section of the fault with a high degree of fragmentation and has matrix characteristics. VBP: Volumetric block proportion.

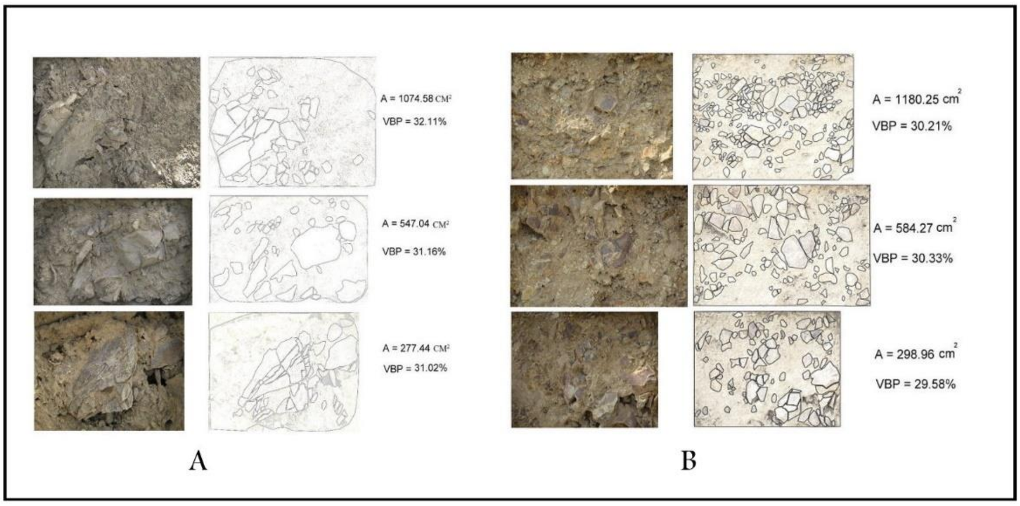

Fig 4. Results of calculating the volumetric block proportion of the fault Rocks in A: station no.3 of Kan zone and B: station no.4 of Hesarak zone in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2. A: Reference area, VBP: Volumetric block proportion

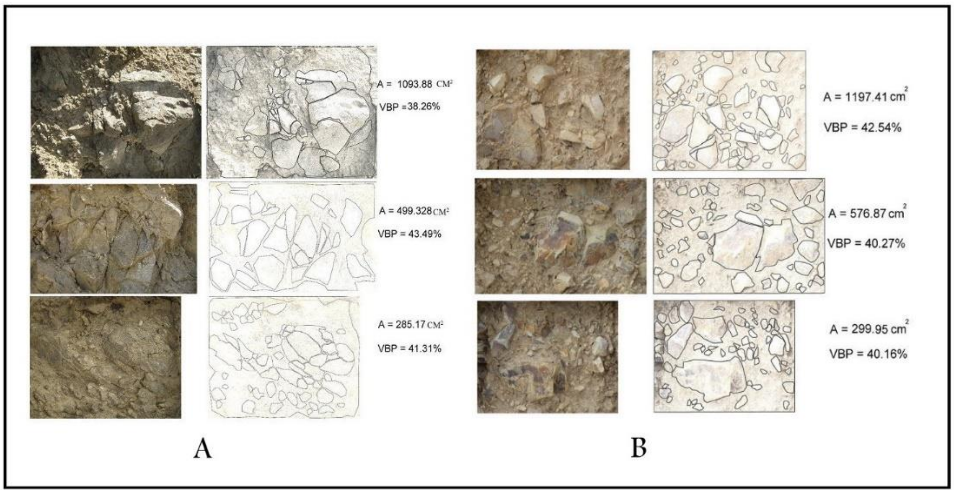

Fig 5. Results of calculating the volumetric block proportion of the fault Rocks in A: station no.4 of Kan zone and B: station no.5 of Hesarak zone in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2. A: Reference area, VBP: Volumetric block proportion

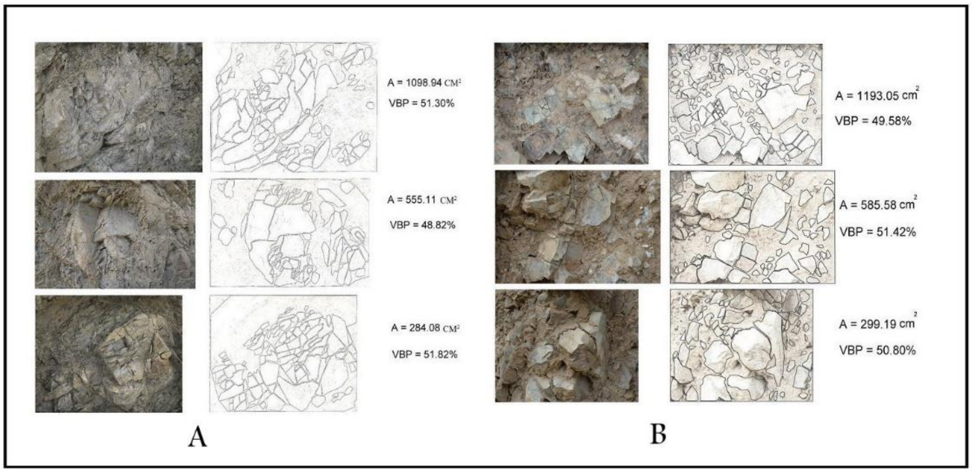

Fig 6. Results of calculating the volumetric block proportion of the fault Rocks in A: station no.5 of Kan zone and B: station no.6 of Hesarak zone in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2. A: Reference area, VBP: Volumetric block proportion

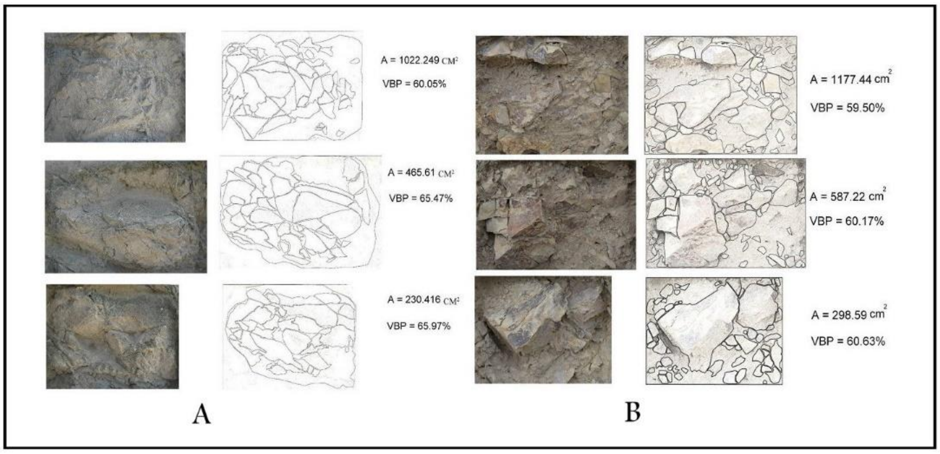

Fig 7. Results of calculating the volumetric block proportion of the fault Rocks in A: station no.6 of Kan zone and B: station no.7 of Hesarak zone in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2. A: Reference area, VBP: Volumetric block proportion

4.2 Data analyses

As it is clearly observed in both study zones (Kan and Hesarak) that placed on the hanging wall of the thrust, by moving from the forehead to the end of the thrust, the volumetric block proportion increases and fragmentation regularly decreases. Achievement to this information by such low expenses and without using borehole methods and only by analysing the observed parts of a trench among the fault width, can be a big step in different constructional decisions and expense estimates in this part of the fault zone. Ultimately, the fault rocks at the end of the North Tehran thrust zone (that is located in the northern part) are less fragmented, in a way that the sizes of the rocky blocks usually exceeds 0.75 of the second root area of the intended area, and therefore, their volumetric block proportion is more than 75%; so according to the classification of Riedmuller et al. (2001), they are considered as blocky rock mass.

Volumetric block proportion of the fault rocks in stations no.7 of Kan and no.8 of Hesarak are higher than 75%, so that the blocks in this zone are much bigger than those three designed frames and their fragmentation decrease (Fig. 8). High volumetric block proportion can be comprehended without doing any especial analysis, so no more software calculating is done on the fault rocks of this part of the fault. As it is observed, the amount of fragmentation gradually decreases while moving in the width of the North Tehran thrust zone from the forehead to the end of the fault. Similarity of the results obtained from the two zones; reduce the risk of errors in calculations to the least probability. Therefore, by matching and overlapping these two typical zones with 5 other study points, which only have limited outcrops of fault zone, the overall fragmentation process of this fault system can be achieved to a large extent throughout the length of fault, and the results of this study can be used for the construction of any structure in other sections.

North Tehran Fault Specifications which were achieved from the samples gathered from Kan zone and Hesarak zone, separately sorted by geographical coordinates of the station, unit geology, the distance from the forehead of fault zone, the volumetric block proportion and their physical-mechanical properties, are shown on tables 1 and 2 respectively. The information obtained from the faults in seven stations of the Kan area and eight stations of the Hesarak area along with the geographical location of those faults are listed in Table 3

Examining the structural elements formed in the fault area shows the reverse movement with a small component of sinistral strike-slip for this fault. (In this research, S-C structural elements and fault lenses are used.) The fault system is duplex and moves in the south direction. A number of S-C structural elements present in the North Tehran fault zone are known in (Fig. 9) and the information related to the measurement of these elements is given in Table 4.

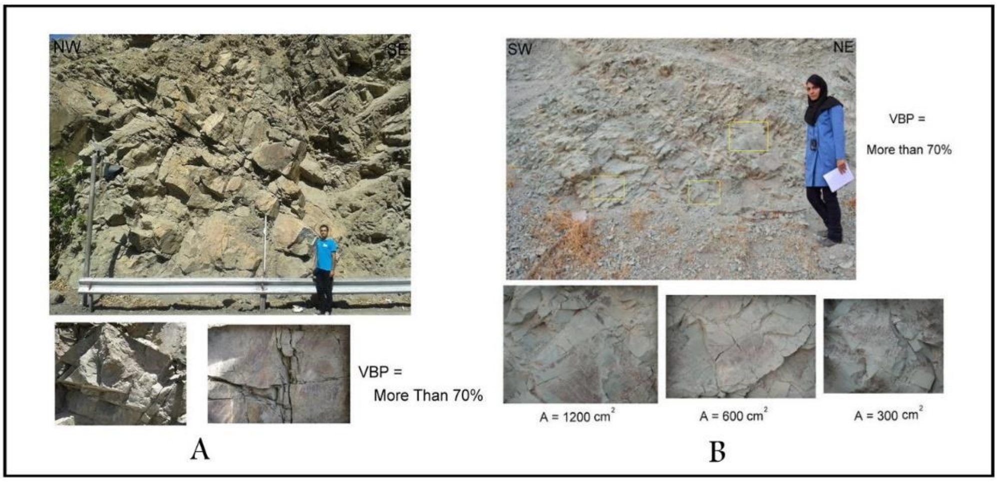

Fig 8. Results of calculating the volumetric block proportion of the fault Rocks in A: station no.7 of Kan zone and B: station no.8 of Hesarak zone in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2. A: Reference area, VBP: Volumetric block proportion

Table 1. Specifications of the rock samples of North Tehran Fault zone (Kan area) by geographical locations, geological units and physical-mechanical characteristics

Station	geographical coordinates		distance from the forehead of fault zone (Meter)	unit geology	volumetric block proportion (%)	uniaxial strength (Mpa)	Dry density (gr/cm³)	Porosity (%)
	Y	X						
Kan1	3959215	0524277	30	Q^f	<25	-	-	-
Kan2	3959232	0524238	90	$Pl-Q$	<25	-	-	-
Kan3	3959277	0524230	126	E_1^{ab}	31	15.18	2.64	5.02
Kan4	3959291	0524228	150	E_1^{ab}	41	29.60	2.64	4.69
Kan5	3959311	0524219	175	E_1^{ab}	51	20.14	2.56	5.50
Kan6	3959396	0524171	240	E_1^{ab}	64	75..53	2.56	2.47
Kan7	3959678	0523809	312	E_1^{tsv}	>75	100.26	2.56	3.60

Table 2. Specifications of the rock samples of North Tehran Fault zone (Hesarak area) by geographical locations, geological units and physical-mechanic al characteristics

Station	geographical coordinates		distance from the forehead of fault zone (Meter)	unit geology	volumetric block proportion (%)	uniaxial strength (Mpa)	Dry density (gr/cm³)	Porosity (%)
	Y	X						
Hesarak1	3960056	0528933	10	Q^f	<25	-	-	-
Hesarak2	3960068	0528955	30	$Pl-Q$	<25	-	-	-
Hesarak3	3960083	0529037	55	E_1^{tsv}	<25	-	-	-
Hesarak4	3960169	0529096	85	E_1^{tsv}	30	-	-	-
Hesarak5	3960194	0529136	160	E_1^{tsv}	40	76.96	2.45	5.55
Hesarak6	3960265	0529233	280	E_1^{tsv}	50	37.77	2.4	4.6
Hesarak7	3960274	0529239	350	E_1^{tsv}	60	43.25	2.32	10.71
Hesarak8	3960329	0529293	450	E_1^{tsv}	>70	82.03	2.38	4.8

Table 3. The geographical coordinates and position of the fault plane related to 7 stations in Kan region and 8 stations in Hesarak region

Station	geographical coordinates		The position of the fault plane	Station	geographical coordinates		The position of the fault plane
	Y	X			Y	X	
Kan1	3959196	0524270	33/325	*Hsarak* 1&2	3960077	0528971	**43/014**
Kan2	3959205	0524262	48/355	*Hsarak* 3	3960086	0529045	**52/025**
Kan3	3959258	0524245	63/349	*Hsarak* 4	3960180	0529102	**45/005**
Kan4	3959292	0524227	40/353	*Hsarak* 5	3960201	0529143	**46/010**
Kan5	3959294	0524221	45/350	*Hsarak* 6	3960270	0529224	**55/025**
Kan6	3959387	0524150	40/353	*Hsarak* 7	3960325	0529283	**47/005**
Kan7	3959430	0523809	46/350	*Hsarak* 8	3960363	0529308	**53/000**

Table 4. Geometric-kinematic characteristics of North Tehran thrust based on the structure of S and C plates

Measurement location	Position of S and C plates		The direction of movement of the hanging wall (Average)	Mechanism
	C	S		
North Tehran Fault Kan	37/295	58/290	115	Reverse with component sinistral strike-slip
	32/330	60/305		
	47/302	71/298		
	26/305	69/301		

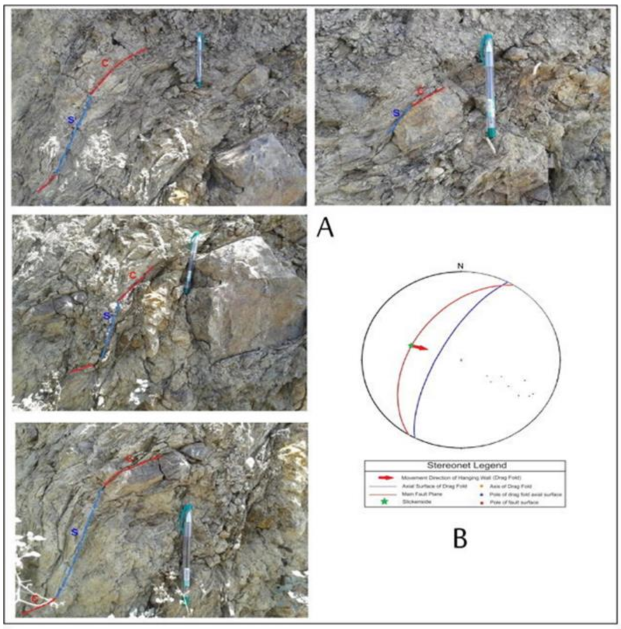

Fig 9. A: S-C structures formed in the North Tehran fault zone B: Stereogram analysis of fault thrust direction

5 Discussion

5.1 Size distribution of blocks from the fault rocks

Logarithmic diagrams of blocks size distribution for the fault rocks of each station in Tehran North fault zone, which were defined in the three scale frames, were drawn and then the fractal dimensions were calculated for all three scales. The results related to each station conforms to the result obtained by Lindquist (1991), showing that the volumetric block proportions are similar in all three studies scales and obey the negative relativity rule, i.e. while the blocks sizes decrease, their number increase (Fig. 10 & 11).

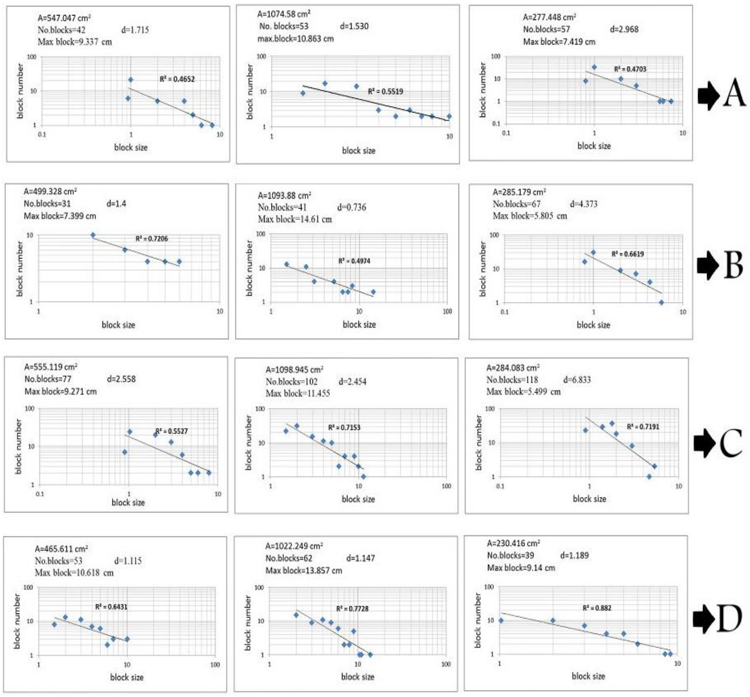

Fig. 10. Logarithmic histogram for the fault rock blocks size distributions of Sk3 to SK6 stations of North Tehran Fault zone in Kan area (respectively A to D) in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2.A: reference area. d: fractal dimension

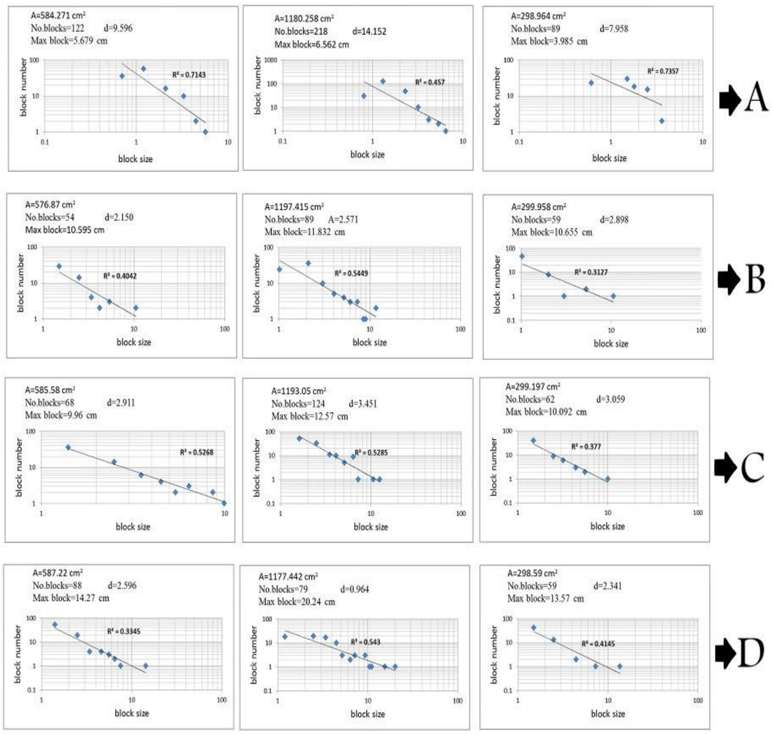

Fig. 11. logarithmic histogram for the fault rock blocks size distributions of Sh4 to Sh7 stations of North Tehran Fault zone in Hesarak area (respectively A to D) in three different scales: a. 1200cm2; b. 600cm2; c. 300cm2.A: reference area. d: fractal dimension.

5.2 Major strength parameters of the fault rocks

To demonstrate the strength parameters of fault rocks in this study, the amounts of porosity, dry density, wet density, water absorption percentage and uniaxial strength of samples (using point load test) were tested and analysed in the laboratory.

Comprehensive laboratory studies on objective samples of melanges (Lindquist and Goodman 1994) show that by increasing of blocks volumetric proportion, while the volumetric proportions are between 25 to 75 percent, the strengths of the objective samples also raise due to increase in tortuosity of the failure surface in Melanges. When the volumetric blocks proportion is less than the mentioned amount (<25%), Bimrock general strength is the same as that of matrix. About higher volumetric proportions (75 %<), the increase in volumetric proportion do not have any effect on Bimrock general strength. In such condition, the block rock mixture in the matrix are considered as block rock masses with wide-filled joints, and common engineering methods for rock fabrics are used to identify them (Lindquist and Goodman 1994).

In this study, due to the lack of drilling core, it was not possible to determine the overall strength of rocks and only the strength characteristics of rock blocks were determined, so it is not acceptable to comment about overall strength of fault rocks according to existing data. However, rock blocks strength data can be used as an idea for the overall strength, and changes in the uniaxial strength of rock blocks can be investigated by changes in the volumetric blocks proportion. As it is shown on (Fig.12), the Uniaxial compressive strength of rocky blocks in this zone increases with increasing the volumetric blocks proportion from the forehead to the end of the zone; because from the forehead towards end of the zone, fragmentation reduces and rocky blocks have higher strengths.

5.3 Comparison of fault rocks engineering classification with GSI classification

In this study, GSI indexes were defined for each zone to compare engineering classification of the fault rocks with GSI classification, and to find probable relation(s) between the fault rocks properties and GSI classification. The classification of Geological Strength Index (GSI) was introduced by Hoek and Brown in 1997 (Hoek and Brown, 1997). This method is based on the field evaluation of the geological characteristics of the rock mass, in which the two appearance characteristics of the rock mass, including structural characteristics and weathering conditions, are examined. The results of classifications for different parts of North Tehran fault area in Kan and Hesarak zones are respectively shown on longitudinal profiles in (Fig 13 and 14).

GSI ranges for different parts of North Tehran Fault in Kan and Hesarak zones are shown in (Fig.15). The limits of changes in GSI index for each zone are indicated by dotted lines. These limits of change are the same as those calculated in the GSI estimate, but can be distinguished based on the study of Bimrocks.

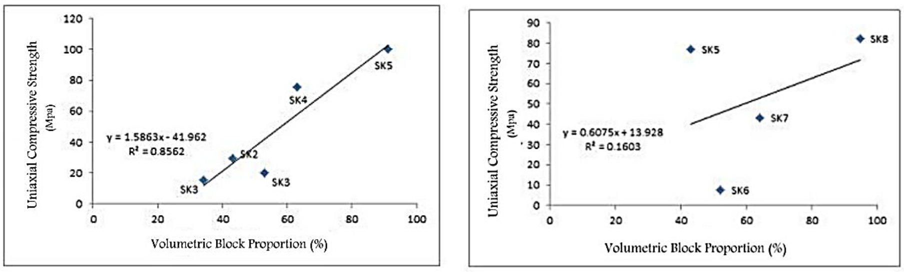

Fig 12. Changes of Uniaxial compressive strength of rock blocks according to the changes in volumetric blocks proportion of Tehran North fault zone in a: Kan area b: Hesarak area

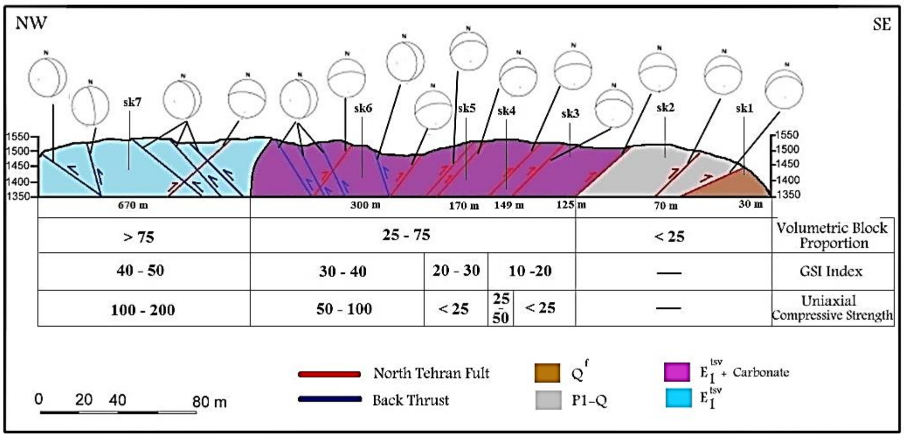

Fig 13. Structural profile of North Tehran Fault in Kan-Suloghan cross section. The places of Sampling are indicated on the picture.

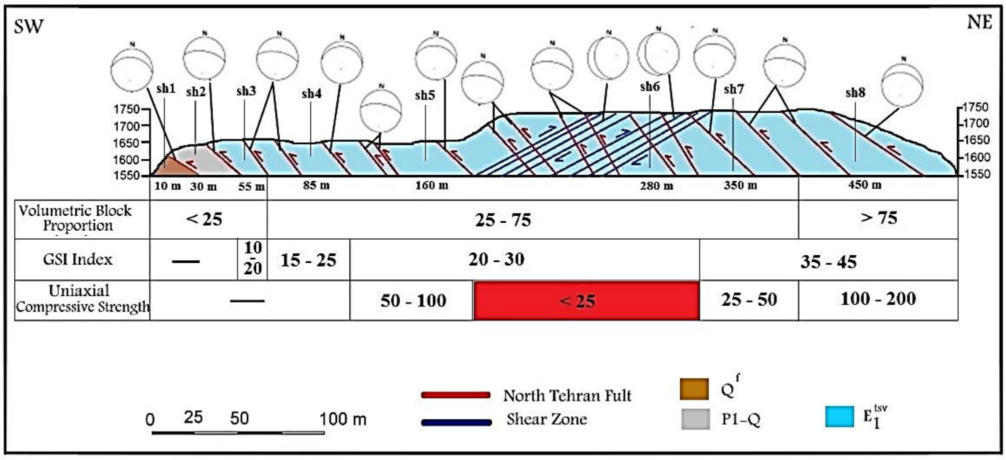

Fig 14. Structural profile of North Tehran Fault in cross section of Ferdous Boulevard placed in Islamic Azad University Science and Research Branch. The places of Sampling are indicated on the picture.

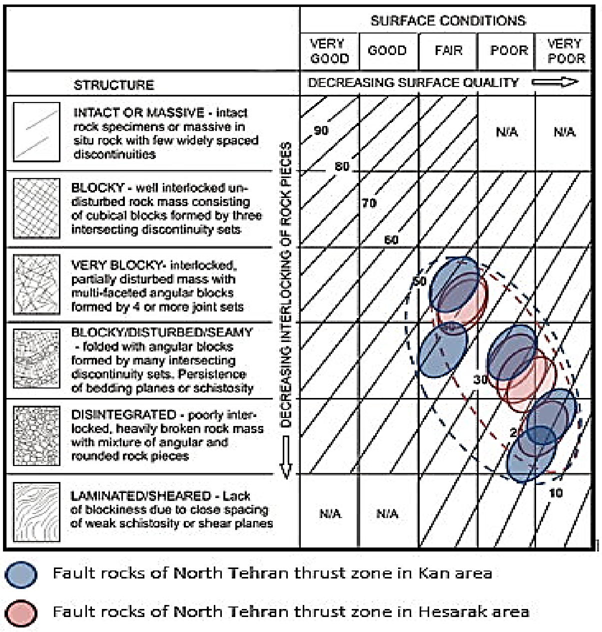

Fig.15. GSI index changes range of fault rocks of North Tehran Fault in Kan and Hesarak zones.

6 Conclusions

1. North Tehran fault has caused Karaj formation units to drive on Quaternary alluviums of Tehran plain, the amount of displacement of this fault is high and accordingly the fragmentation changes in this zone are intense. The results of investigation on the fault rocks outcrops of North Tehran fault zone in Kan and Hesarak areas indicate that, by moving from the forehead towards to the end of the zone, the volumetric proportions and uniaxial compressive strength of the blocks increase and follows a certain order. Therefore, the amounts of fragmentation and intensity of faulting decrease toward the end of the zone. Shear plate spacing relative to each other, presence of micro-faults and the amount of displacement created by the fault affect the mentioned properties.

2. In field studies for engineering projects, engineers commonly refer to different classifications such as RMR, Q, GSI, etc., to specify the behaviour of rock mass. In dealing with fault zones, however, it is not simply possible to use the mentioned classifications; because they require some parameters such as uniaxial compressive strength, information related to the joints, groundwater status, etc., but these parameters are not obtained simply in fault zones. In addition, a fault zone is made of different parts with different strengths; that using the mentioned classifications, a fault zone may only be classified in group of low strength rocks. However, by using fault rocks classification, it would be possible to

divide fault zones into sections with different fragmentation and strength. So, studying the Bimrocks of an area in field researches of fault zones would be a useful idea, when it is not possible to estimate the parameters of engineering classifications like RMR, Q, GSI, etc.

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