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# Assessing the effects of mineral content and porosity on ultrasonic wave velocity

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**Abstract.** The influences of mineral content and porosity on ultrasonic wave velocity were assessed for ten hornfelsic rocks collected from southern and western parts of the city of Hamedan, western Iran. Selected rock samples were subjected to mineralogical, physical, and index laboratory tests. The tested rocks contain quartz, feldspar, biotite, muscovite, garnet, sillimanite, kyanite, staurolite, graphite and other fine grained cryptocrystalline matrix materials. The values of dry unit weight of the rocks were high, but the values of porosity and water absorption were low. In the rocks, the values of dry unit weight are related to the presence of dense minerals such as garnet so not affected by porosity. The statistical relationships between mineral content, porosity and ultrasonic wave velocity indicated that the porosity is the most important factor influencing ultrasonic wave velocity of the studied rocks. The values of P-wave velocity of the rocks range from moderate to very high. Empirical equations, relevant to different parameters of the rocks, were proposed to determine the rocks' essential characteristics such as primary and secondary wave velocities. Quality indexes (IQ) of the studied samples were determined based on P-wave velocities of them and their composing minerals and the samples were classified as non-fissured to moderately fissured rocks. Also, all tested samples are classified as slightly fissured rocks according to the ratio of S-wave to P-wave velocities.

**Keywords:** hornfels; mineral; porosity; fissure; wave velocity

## 1. Introduction

The ultrasonic wave velocity test method is today routinely used to estimate the elastic modulus and quality index (IQ) of various rocks. This test that can be carried out for intact rock and rock mass both in the laboratory and field is a common non-destructive testing method used in civil, geotechnical and mining projects. Seismic techniques were commonly used in the field for determining rock mass characterizations and its quality by different researchers (e.g., Yagis 2011, Kakar and Kakar 2016). Ultrasonic P-wave velocity ($v_p$) of a rock is useful to determine the elastic characteristics and rock mechanical properties for various engineering applications such as reservoir subsidence, casing industries and structural damages (Sharma *et al.* 2011, Nefeslioglu 2013, Varun Kumar *et al.* 2017). In the laboratory, seismic techniques are often used for calculating quality index, physical-mechanical properties and dynamic elastic moduli of intact rocks (Karakul and Ulusay 2013, Pappalardo 2015). The ultrasonic wave velocity provides a quick, non-destructive and inexpensive basis to estimate rock properties. The measurement of the ultrasonic wave velocity through rocks is relatively simple, especially when cylindrical specimens are available.

Petrographic and physical properties of rocks such as mineral content, density, water content, anisotropy, temperature degree and the presence of pores, micro-cracks and fissures (porosity) are intrinsic properties which control the engineering behavior of the rock at the fundamental level. Accordingly, the ultrasonic wave velocities of rocks have been found to depend on the intrinsic properties such as mineralogical composition, density, porosity, grain size and shape, texture and anisotropy, and laboratory factors such as water content and temperature degree of rocks. The relationships between petrographic parameters and index properties of rocks have been studied by a great number of researchers (e.g., Ersoy and Waller 1995, Durrast and Siegesmund 1999, Ruedrich *et al.* 2001a, b, Akesson *et al.* 2003, Jeng *et al.* 2004, Sousa *et al.* 2005, Martinez-Martinez *et al.* 2007, Khanlari *et al.* 2014a, b, Fereidooni *et al.* 2015a, Azimian and Ajalloeian 2015, Fereidooni *et al.* 2016). Such interest is due to the fact that intrinsic properties, such as degree of fissuring, porosity, grain size or preferred directions in these elements are the main determining factors behind the physical, index and mechanical properties of rocks (Martinez-Mrtinez *et al.* 2007).

The literature review indicates that most studies on the relationships between the mineralogical, textural, physical properties and ultrasonic wave velocities of rocks are categorized into two separate processes; microscope observations and ultrasonic wave velocities tests, and then correlate the ultrasonic wave velocities to textural properties using suitable regression models. The main step towards obtaining a good relationship is to carry out an effective study of the petrographic features of rocks.

In the laboratory, the value of ultrasonic wave velocity is extremely sensitive to rock micro-fractures and fissures.

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On the basis of laboratory measurements of wave velocity and microscopic observation of fissures, Fourmaintraux (1976) and Tourenq *et al.* (1971) proposed two basic methods for describing the fissuring degree of rock specimens. Based on the first method, fissuring degree of rock specimens can be determined from the ratio of measured P-wave velocity in the laboratory and calculated one from mineral content of rock providing having wave velocity of each mineral. Based on the second method, fissuring degree of rocks can be determined from the ratio of S-wave to P-wave velocities.

In this research, an attempt has been made, (1) to determine petrographic and physical properties of Hamedan hornfelsic rocks, (2) to correlate different rock properties for assessing the influences of mineral content and porosity on ultrasonic wave velocity for the studied rocks and (3) to develop a method for estimating degree of fissuring and quality index (IQ) of intact rocks from ultrasonic wave velocities.

## 2. Site description and geology

The southern and southwestern parts of the city of Hamedan, western Iran, were selected as an area for sampling. Fig. 1 shows a geological map of the area and sampling locations. This area, with a longitude of 48° 10' E to 48° 35' E and a latitude of 34° 30' N to 34° 52' N, contains the most important and interesting plutonic rock mass in Iran, with its metamorphic aureole rocks. This granitic rock mass, called Alvand, is bordered in the north and east by Hamedan, in the south by Touyserkan and in the west by Asad-Abad. It covers an area of about 400 km$^2$, making it the largest plutonic rock mass in Iran (Fereidooni *et al.* 2015b). This region has an irregular morphology related to its geological history, tectonics and lithology. From a geological point of view, the study area is situated in the Sanandaj-Sirjan structural zone, which is the most

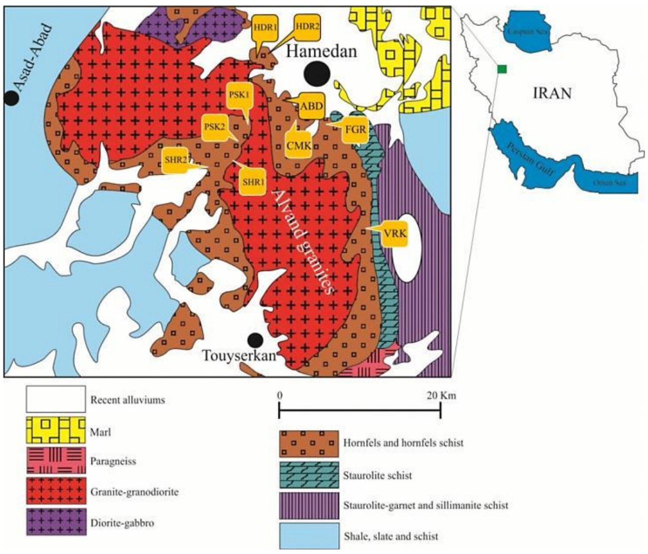



Fig. 1 Geological map of the area indicating sampling locations and its place on the general map of Iran (GSI 1977)

active tectonic zone in Iran. The regional metamorphism of the Sanandaj-Sirjan zone is due to the Zagros orogenic activities. The contact metamorphism in this area is caused by the intrusion of the Alvand plutonic rock masses. The Alvand batholith consists of three parts: a mafic part (gabbro, diorite and tonalite), an intermediate part (granite-granodiorite) and a felsic part (hololeucocratic granitoids). The metamorphic rock masses adjacent to this batholith are pelitic hornfelses. Bordering the north and east sides of the study area are Quaternary alluvial deposits. The area has an elevation of about 2000 m above sea level and a typical continental climate.

## 3. Methods and materials

Ten different samples of contact metamorphic rocks from the southern and western parts of the city of Hamedan have been studied. The reason for selecting such rock samples is both their high mineral content variety as well as economic impact as building materials. The studied hornfelsic rocks are marked as Heydareh1 (HDR1), Heydareh2 (HDR2), Abbas-Abad (ABD), Cheshmeh-Malek (CMK), Faghireh (FGR), Piste-Eski1 (PSK1), Piste-Eski2 (PSK2), Shahrestaneh1 (SHR1), Shahrestaneh2 (SHR2) and Varkaneh (VRK). Sampling was done from the quarries, road cuttings and excavated foundations, and the selected block samples were transferred to the laboratory. The laboratory program was based on determining mineralogical, petrographic and physical properties and also ultrasonic wave velocities. Polished thin sections were prepared for optical microscopic observations in order to identify the mineral composition and texture of the rock samples. Cylindrical specimens were prepared for determining physical properties and ultrasonic wave velocities by a standard coring machine. Then, the cut end-faces of the cores were smoothened and made perpendicular to the core axes using a polishing and lapping machine. Diameters of the prepared rock cores were 54 mm. Size and length to diameter of prepared specimens were accordance to Ulusay and Hudson (2007). A total of 50 specimens were used for various performed tests. Finally, simple regression analyses were performed to develop relationships between different parameters by considering linear and logarithmic functions.

## 4. Results and discussions

### *4.1 Mineralogical and petrographic properties*

Different rocks may be composed of hard or weak minerals. The engineering behavior of rocks is closely related to their mineral content and internal structure. According to Bandini and Berry (2013), the rock texture has an influence on its engineering properties. In the present research, thin sections were prepared and used to investigate the texture and mineralogical composition and petrographic properties of the hornfelsic rocks by optical microscopic observations based on ISRM (2007). The rock samples were composed of quartz, feldspar, biotite, muscovite, garnet, andalusite, sillimanite, kyanite, staurolite, graphite and other fine grained cryptocrystalline

Table 1 Mineral composition of the rocks

| Rock mark | Rock type | Minerals content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Qtz. | Fld. | Bt. | Mt. | Gt. | Ad. | Slt | Kt. | St. | Gpt. |
| HDR1 | Hornfels | 32 | 8 | 30 | 5 | 13 | - | 12 | - | - | - |
| HDR2 | Hornfels | 16 | 9 | 38 | 5 | 13 | 4 | 13 | - | 2 | - |
| ABD | Hornfels | 32 | 7 | 20 | 8 | 15 | - | 4 | 10 | 4 | - |
| CMK | Hornfels | 23 | 7 | 25 | 5 | 15 | - | - | - | - | 25 |
| FGR | Hornfels | 35 | 5 | 25 | 11 | 11 | - | - | 8 | 5 | - |
| PSK1 | Hornfels | 32 | 5 | 30 | 5 | 13 | - | 5 | 5 | 5 | - |
| PSK2 | Hornfels | 32 | 5 | 25 | 8 | 12 | - | 6 | 7 | 5 | - |
| SHR1 | Hornfels | 35 | 4 | 30 | 15 | 10 | - | - | 3 | 3 | - |
| SHR2 | Hornfels | 36 | 4 | 30 | 10 | 8 | - | 4 | 4 | 4 | - |
| VRK | Hornfels | 24 | 10 | 41 | 4 | 10 | 6 | - | - | 5 | - |

Note: Qtz., quartz; Fld., Feldspar; Bt., Biotite; Mt., Muscovite; Gt., Garnet; Ad., Andalusite; Slt., Sillimanite; Kt., Kyanite; St., Staurolite; Gpt., Graphite

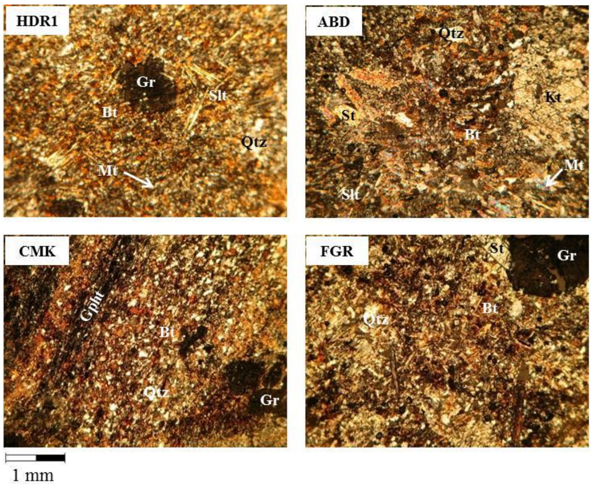
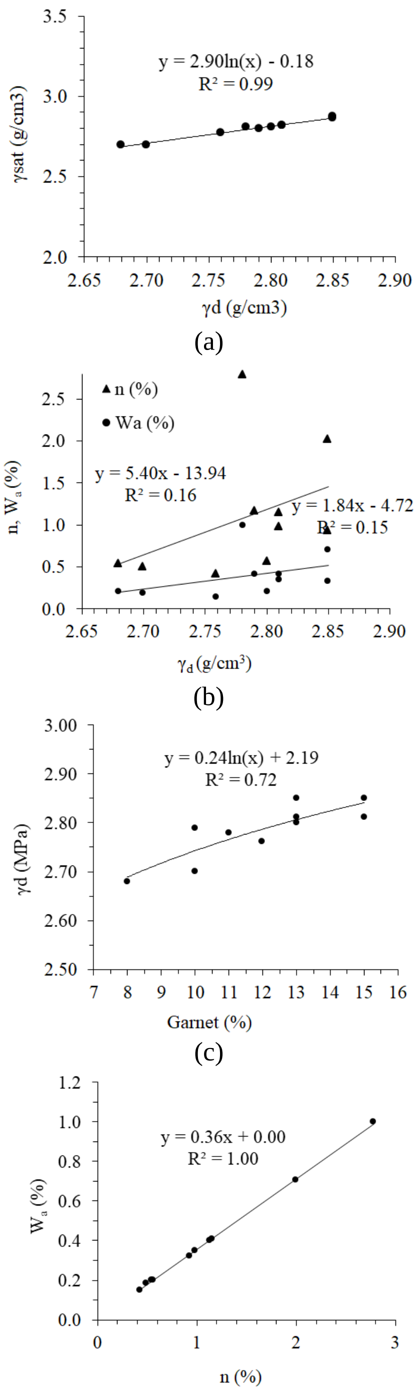



Fig. 2 Microscopic fabric images of the rocks

Table 2 Physical properties for the rocks

| Rock sample | $\gamma_d$ (g/cm$^3$) | $\gamma_{sat}$ (g/cm$^3$) | $G_s$ | n (%) | $W_a$ (%) | Description of $\gamma_d$ (IAEG 1979) | Description of n (IAEG 1979) |
|---|---|---|---|---|---|---|---|
| HDR1 | 2.85 | 2.87 | 2.90 | 2.00 | 0.70 | Very high | Low |
| HDR2 | 2.81 | 2.82 | 2.84 | 1.13 | 0.40 | Very high | Low |
| ABD | 2.85 | 2.86 | 2.87 | 0.92 | 0.32 | Very high | Very low |
| CMK | 2.81 | 2.82 | 2.84 | 0.97 | 0.45 | Very high | Very low |
| FGR | 2.78 | 2.81 | 2.86 | 2.78 | 1.00 | Very high | Low |
| PSK1 | 2.80 | 2.81 | 2.82 | 0.56 | 0.20 | Very high | Very low |
| PSK2 | 2.76 | 2.77 | 2.79 | 0.42 | 0.15 | Very high | Very low |
| SHR1 | 2.70 | 2.70 | 2.72 | 0.49 | 0.18 | High | Very low |
| SHR2 | 2.68 | 2.69 | 2.70 | 0.54 | 0.20 | High | Very low |
| VRK | 2.79 | 2.80 | 2.82 | 1.16 | 0.41 | Very high | Low |

matrix materials. The minerals such as andalusite, garnet, sillimanite, kyanite, staurolite and graphite are crystallized in metamorphic conditions. The rock textures are porphyroblastic. Garnet, andalusite, kyanite and staurolite




(d)

Fig. 3 Correlations between (a) dry and saturated unit weights, (b) porosity, water absorption and dry unit weight, (c) dry unit weight and garnet content and (d) water absorption and porosity for the rocks

are the dominant types of porphyroblasts with sizes range from 0.2 to 1 mm. The matrix consists of fine grains of quartz, feldspar, biotite and muscovite (50-100 $\mu$m dimensions). This pattern defines a fabric characteristic of contact metamorphic rocks. Fig. 2 shows microscopic fabric images of the samples of HDR1, ABD, CMK and FGR as representative rock samples. The rock types and their average modal abundance of the minerals are presented in Table 1. The mineralogical composition of the rock samples

Table 3 The values of laboratory ultrasonic wave velocities for the rocks

| Rock sample | $v_p$ (m/s) | $v_s$ (m/s) | Description of $v_p$ (IAEG 1979) |
|---|---|---|---|
| HDR1 | 4529 | 2844 | High |
| HDR2 | 4987 | 3151 | High |
| ABD | 5065 | 3155 | Very high |
| CMK | 5225 | 3248 | Very high |
| FGR | 3912 | 2486 | Moderate |
| PSK1 | 5478 | 3395 | Very high |
| PSK2 | 5773 | 3566 | Very high |
| SHR1 | 5623 | 3479 | Very high |
| SHR2 | 5615 | 3494 | Very high |
| VRK | 5125 | 3132 | Very high |

was specified through point counting method from thin section studies. As can be seen from the table, quartz is the most abundant mineral, whereas andalusite is the rarest metamorphic mineral of the rocks.

### *4.2 Physical properties*

The physical properties of the different intact rocks depend on their minerals and microstructures. Willard and McWilliams (1969) found that mineral content and the microstructures, including mineral cleavage, grain boundaries, fissures and micro-fractures have an essential effect on engineering properties of rocks. The physical properties of intact rocks are highly influenced by the type, texture, percentage, and fabric of minerals forming the rocks (Shalabi *et al.* 2007).

In this research, physical properties of the rock samples, such as dry and saturated unit weights ($\gamma_d$ and $\gamma_{sat}$), specific gravity ($G_s$), porosity (n) and water absorption ($W_a$), were determined using standard testing methods suggested by Franklin (1972). For this purpose, five sets of experiments were performed on prepared cylindrical specimens. Thus, a total of 50 tests were performed in order to determine their physical properties. Average values of the parameters for the tested rock samples are presented in Table 2.

Results show that the unit weight values of the tested rocks are high, but the values of porosity and water absorption are quite low. The minimum and maximum values of unit weight were obtained for the samples of SHR2 and HDR1, whereas the samples of PSK2 and FGR have minimum and maximum values of porosity, respectively. According to the IAEG (1979) rock classification, the studied samples were classified as the rocks with high to very high dry unit weight and very low to low porosity. Fig. 3 shows the correlations between different physical properties of the tested rocks. A logarithmic relationship exists between dry and saturated unit weights with a high correlation coefficient ($R^2$=0.99) (Fig. 3(a)), whereas, dry unit weight is not related to porosity and water absorption (Fig. 3(b)). With regarding the Fig. 3(c), this correlation is owing to the presence of dense minerals such as garnet. This figure shows that increasing in garnet content results an increasing in the dry unit weight. This overshadows the effect of porosity on dry

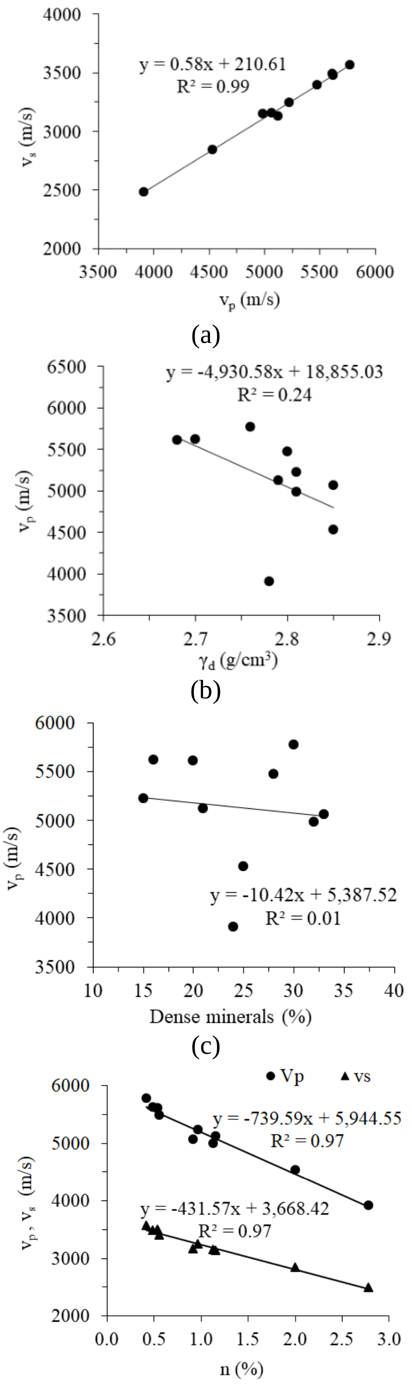



Fig. 4 Correlations between a) P-wave and S-wave velocities, b) P-wave velocities and dry unit weight, c) P-wave velocities and dense minerals (garnet, andalusite, sillimanite, kyanite and staurolite) and c) wave velocities and porosity for the rocks

unit weight. Fig. 3(d) shows good linear correlations between water absorption and porosity in the tested rocks. Therefore, the dry unit weight is controlled by the presence of dense minerals such as garnet and other metamorphic minerals, whereas, the value of water absorption is influenced by porosity.

### *4.3 Ultrasonic wave velocity*

In the laboratory, the ultrasonic wave velocity is determined based on ISRM (2007) suggested method and ASTM (1996). This technique is often employed to determine and characterize the rock quality and its dynamic properties. Based on ASTM (1996), application of ultrasonic wave velocity is the best method to determine dynamic elastic constants of rocks. As this method is non-destructive and relatively easy to apply, it is increasingly being used in geological and geotechnical engineering (Sharma and Singh 2008). The value of ultrasonic wave velocity is depended to various parameters such as elastic properties, mineral content and orientation, foliation, anisotropy, density, porosity, presence of cracks and micro-fractures, stress-strain level and weathering degree (Kossev 1970, Guyander and Denis 1986, Goodman 1989, Kim *et al.* 2012, Jensen and Elming 2013, Li and Tao 2015, Teachavorasinskun and Pongvithayapanu 2016). In this research, the average value of ultrasonic wave velocity was determined from five tests for each sample. The laboratory values for the tested rocks are presented in Table 3. Based on the results, the values of primary or P-wave velocity are from 3912 to 5773 m/s and the values of secondary or S-wave velocity is from 2486 to 3566 m/s. The minimum and maximum ultrasonic wave velocities were obtained for the samples of FGR and PSK2, respectively. According to IAEG (1979), the values of P-wave velocity of the rocks range from moderate to very high.

In the studied rocks, a very good direct linear relationship is obtained between primary and secondary wave velocities (Fig. 4(a)). There is no relationship between P-wave velocity and dry unit weight and percent of dense metamorphic minerals namely andalusite, garnet, sillimanite, kyanite and staurolite (Fig. 4(b) and 4(c)). Instead, based on Fig. 4(d), both P-wave and S-wave velocities are related to porosity by good direct linear equations with high correlation coefficients (0.97). Therefore, the main factor affecting wave velocities is porosity of the rocks.

On the basis of this research, as shown in Fig. 4(a), the empirical equation between primary and secondary wave velocities is

$$v_s = 0.58 v_p + 210.61 \quad (1)$$

where $v_p$ and $v_s$ are in m/s.

Also, based on Fig. 4(d), the empirical equations between primary and secondary wave velocities and porosity are

$$v_p = 5944.55 - 739.59n \quad (2)$$

$$v_s = 3668.42 - 431.57n \quad (3)$$

where $v_p$ and $v_s$ are in m/s and n is in percent (%). The above equations are apparently suitable for predicting both P-wave and S-wave velocities from porosity. But their precision should be checked by a logic method. For this reason, the correlations between results of the experimental and calculated values of P-wave and S-wave velocities using Eqs. (2) and (3) for all tested samples were obtained which are shown in Fig. 5. In order to assess validity of the results, the 45$^o$ lines (y=x) have been plotted in this figure.

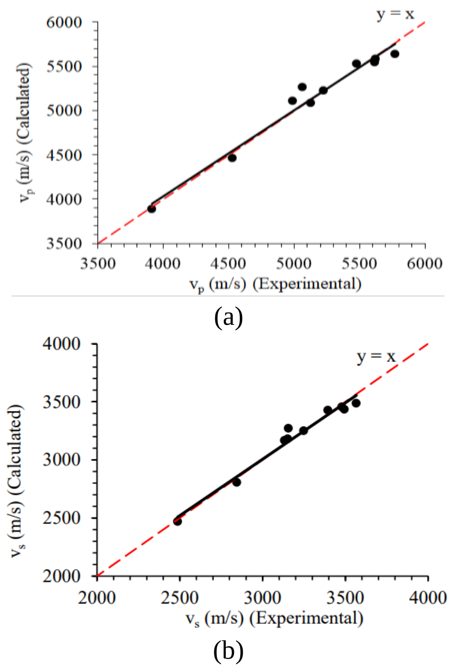



Fig. 5 Correlations between experimental and calculated values of (a) P-wave velocity and (b) S-wave velocity for the rocks

Table 4 The values of P-wave velocity for the mineral composing the studied rocks

| Mineral | $V_{pi}$ (m/s) |
|---|---|
| Quartz | 6050 |
| Feldspar | 6250 |
| Biotite | 5900 |
| Muscovite | 5800 |
| Garnet | 6500 |
| Andalusite | 5750 |
| Sillimanite | 5200 |
| Staurolite | 5700 |
| Kyanite | 5600 |
| Graphite | 4700 |

It is clear that the correlating lines are closely fitted to the lines of 45$^o$. These mean that the experimental and calculated parameters are equal to each other and confirm the validity of the results of Eqs. (2) and (3).

Fissures and micro fractures in intact rocks are among the most important parameters affecting ultrasonic wave velocity. The presence of the fissures and micro-fractures increases rock porosity and decreases ultrasonic wave velocity. Therefore, ultrasonic wave velocity can be determined by accessing the fissures in intact rocks. For this purpose, Fourmaintraux (1976) and Tourenq *et al.* (1971) suggested two methods. Based on Fourmaintraux (1976), the following equation is used for calculating quality index (IQ) of rocks

$$IQ = \frac{v_p}{v_p^*} \times 100 \quad (4)$$

where $v_p$ is the measured P-wave velocity from the experiments and $v_p^*$ is calculated P-wave velocity which can be obtained from the following equation

$$v_p^* = \frac{1}{\sum(\frac{C_i}{v_{pi}})} \tag{5}$$

where $C_i$ and $v_{pi}$ are the percent of rock's composing minerals and their measured P-wave velocities, respectively. The values of $v_{pi}$ for the mineral composing the studied rocks are listed in Table 4.

The calculated values of $v_p^*$ and IQ using Eqs. (4) and (5) are presented in Table 5. The values of IQ are variable from 65.39 to 97.18 for the samples of FGR and PSK2, respectively. IQ is extremely sensitive to rock fissures. On the basis of laboratory measurements and microscopic observation of fissures, Fourmaintraux (1976) proposed plotting IQ versus porosity (Fig. 6) as a basis for describing the degree of fissuring of a rock specimen. Entering the figure with known porosity and calculated IQ defines a point in one of five fields: (I) non-fissured, (II) slightly fissured, (III) moderately fissured, (IV) strongly fissured and (V) very strongly fissured. The studied rock samples are plotted in this figure. According to the classification, the studied samples are classified as non-fissured to moderately fissured rocks. Also, these results indicate that the high or very high values of P-wave velocity of the studied rocks is due to their low or very low porosity. In other words, these results confirm the obtained results from Fig. 4.

Table 5 The values of calculated ultrasonic wave velocities for the rocks

| Rock sample | $v_p$ (m/s) | $v_p^*$ (m/s) | IQ (%) | Rock description based on IQ (Fourmaintraux 1976) |
|---|---|---|---|---|
| HDR1 | 4529 | 5944 | 76.19 | Slightly fissured |
| HDR2 | 4987 | 5905 | 84.45 | Slightly fissured |
| ABD | 5065 | 5973 | 84.80 | Slightly fissured |
| CMK | 5225 | 5666 | 92.22 | Non-fissured |
| FGR | 3912 | 5982 | 65.39 | Moderately fissured |
| PSK1 | 5478 | 5964 | 91.85 | Non-fissured |
| PSK2 | 5773 | 5941 | 97.18 | Non-fissured |
| SHR1 | 5623 | 5989 | 93.88 | Non-fissured |
| SHR2 | 5615 | 5947 | 94.42 | Non-fissured |
| VRK | 5125 | 6001 | 85.41 | Slightly fissured |

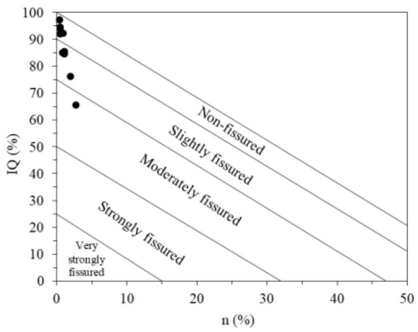



Fig. 6 Classification scheme based on fissuring for the tested rock samples (Fourmaintraux 1976)

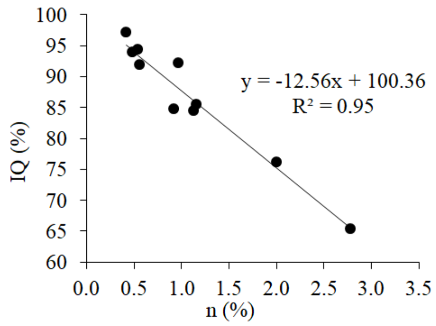



Fig. 7 Correlation between quality index (IQ) and porosity (n) for the rocks

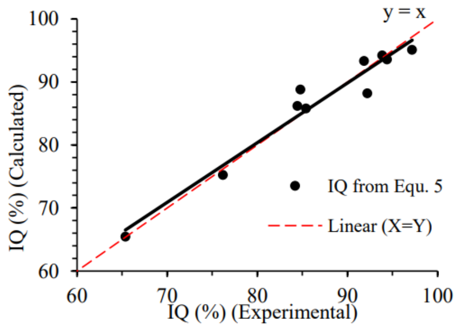



Fig. 8 Correlation between experimental and calculated values of P-wave velocity for the rocks

Table 6 The values of calculated ultrasonic wave velocities for the rocks

| Rock sample | $v_p$ (m/s) | $v_s$ (m/s) | $v_s/v_p$ (%) | Rock description based on $v_s/v_p$ (Tourenq *et al.* 1971) |
|---|---|---|---|---|
| HDR1 | 4529 | 2844 | 62.80 | Slightly fissured |
| HDR2 | 4987 | 3151 | 63.19 | Slightly fissured |
| ABD | 5065 | 3155 | 62.29 | Slightly fissured |
| CMK | 5225 | 3248 | 62.16 | Slightly fissured |
| FGR | 3912 | 2486 | 63.56 | Slightly fissured |
| PSK1 | 5478 | 3395 | 61.97 | Slightly fissured |
| PSK2 | 5773 | 3566 | 61.77 | Slightly fissured |
| SHR1 | 5623 | 3479 | 61.87 | Slightly fissured |
| SHR2 | 5615 | 3494 | 62.23 | Slightly fissured |
| VRK | 5125 | 3132 | 61.10 | Slightly fissured |

Fig. 7 shows correlation between quality index (IQ) and porosity (n) for the tested rocks. Based on this figure, the empirical equation between the parameters is as follows

$$IQ = 100.36 - 12.56n(\%) \tag{6}$$

Based on this equation, for the rocks with porosity lower than 0.286, quality index (IQ) considered to be 100%. This equation is near to the one proposed by Fourmaintraux (1976)

$$IQ = 100 - 1.6n(\%) \tag{7}$$

Also, the above equation is apparently suitable for predicting IQ from porosity. But its precision should be checked by a logic method. For this reason, the correlation between results of the experiments and calculated values of IQ using Eq. (6) for all tested samples was obtained which is shown in Fig. 8. In order to assess the results validity, the $45^o$ line (y=x) has been plotted in this figure. It is clear that the correlating line is fitted to the line of $45^o$. This means that the experimental and calculated parameters are equal to each other and confirms the validity of the results of Eq. (6).

According to Tourenq *et al.* (1971), fissuring degree of rocks can be determined from the ratio of S-wave to P-wave velocities ($v_s/v_p$). For strongly fissured rocks the ratio is higher than 70%, for slightly fissured rocks it is between 60% and 70% and for non-fissured rocks it is less than 60%. Accordingly, all tested samples are classified as slightly fissured rocks (Table 6). These results indicate that the high or very high values of wave velocity of the studied rocks come from their slightly fissuring degree. Therefore, these results confirm the results obtained from Fourmaintraux (1976) classification and Fig. 4.

## 5. Conclusions

The petrographic and mineralogical studies show that the hornfelsic rocks are affected by re-metamorphism processes due to injection of the Alvand batholith. They have high metamorphism degree because of the presence of metamorphic minerals such as garnet, andalusite, sillimanite and staurolite as porphyroblasts in their fabric. Matrix of the rocks consists of quartz, feldspar, biotite and muscovite. The mineral content and porosity of the rocks have influence on unit weight and ultrasonic wave velocity. The values of dry unit weight for the studied rocks are high to very high (between 2.68 for SHR2 sample and 2.85 g/cm$^3$ for HDR1 and ABD samples). But, the values of porosity (between 0.42 and 2.78% for the samples of PSK2 and FGR, respectively) and water absorption (between 0.15 and 1.00% for the samples of PSK2 and FGR, respectively) are very low to low. There are linear and logarithmic relationships between different mineralogical and physical properties with various correlation coefficients. Only, dry unit weight is not related to porosity and water absorption. The minimum and maximum values of P-wave velocity were obtained between 3912 and 5773 m/s for the samples of FGR and PSK2, respectively. Also, the samples of FGR and PSK2 have the minimum and maximum values of S-wave velocity which are between 2486 and 3566 m/s, respectively. This means that, the values of ultrasonic wave velocities of the studied rocks are found to range between moderate to very high. In these rocks, a direct linear relationship was found between primary and secondary wave velocities. Two inverse linear relationships were found between primary and secondary wave velocities and porosity that their validities were confirmed by the validation curves. Therefore, the ultrasonic P-wave and S-wave velocities are affected by porosity and not related to dry unit weight. According to Fourmaintraux (1976) suggested classifications for determining fissuring condition of intact rock, the studied samples are classified as non-fissured to moderately fissured rocks. A linear relationship was found between quality index (IQ) and porosity that its validity was confirmed by the validation curve. Based on Tourenq *et al.* (1971) classification, the studied samples are classified as slightly fissured rocks. This means that the classifications are approximately coordinated with each other for the tested rocks.

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