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Research Article/Araştırma Makalesi

Regression Analysis between Lugeon and V_s in Pulur Metamorphic Rock Masses*

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Keywords
S-wave velocity, Lugeon, Regression.

Abstract
In the determination of the permeability of rock masses, apart from on-site experiments, few experimental relationships have been established for the determination of this parameter due to the very complex geotechnical and geophysical properties that control permeability. In this study, simple regression analyzes were made by comparing S wave velocity (Vs) and Lugeon (LU) values, which are engineering parameters affecting permeability, and experimental equation was obtained for the permeability of rock mass. Then, with the help of the obtained limit values, zoning sections varying with the depth of the study area were created and the permeability of the rock mass was evaluated. While performing simple regression analysis, the highest correlation coefficient (r = 0.67) obtained in the equation between LU and S wave velocity was obtained in the logarithmic equation, and it was found that the relationship between the variables showed a good and negative correlation. As a result, when the S wave velocity values of the metamorphic at the dam axis are examined, it is determined that the rock mass at values varying between 975-1115 m/s is impermeable, while the mass with S wave velocity change between 582-973 m/s is very permeable. The low permeability and high S wave velocity values indicate that the discontinuities in the rock mass do not contain fillings.

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1. Introduction

The permeability of rock masses is one of the most important parameters used in the design of engineering applications. (Sari, 2019). In the determination of this parameter, apart from on-site experiments, because of the very complex geotechnical and geophysical properties that control permeability, very little experimental relationship has been established today for the determination of this parameter. Since on-site experiments are costly, time consuming and performed in the drilling well, such experiments are limited within the scope of possibilities in every engineering structure examined. This situation leads to some engineering deficiencies in the evaluations. These limitations have led researchers to conduct

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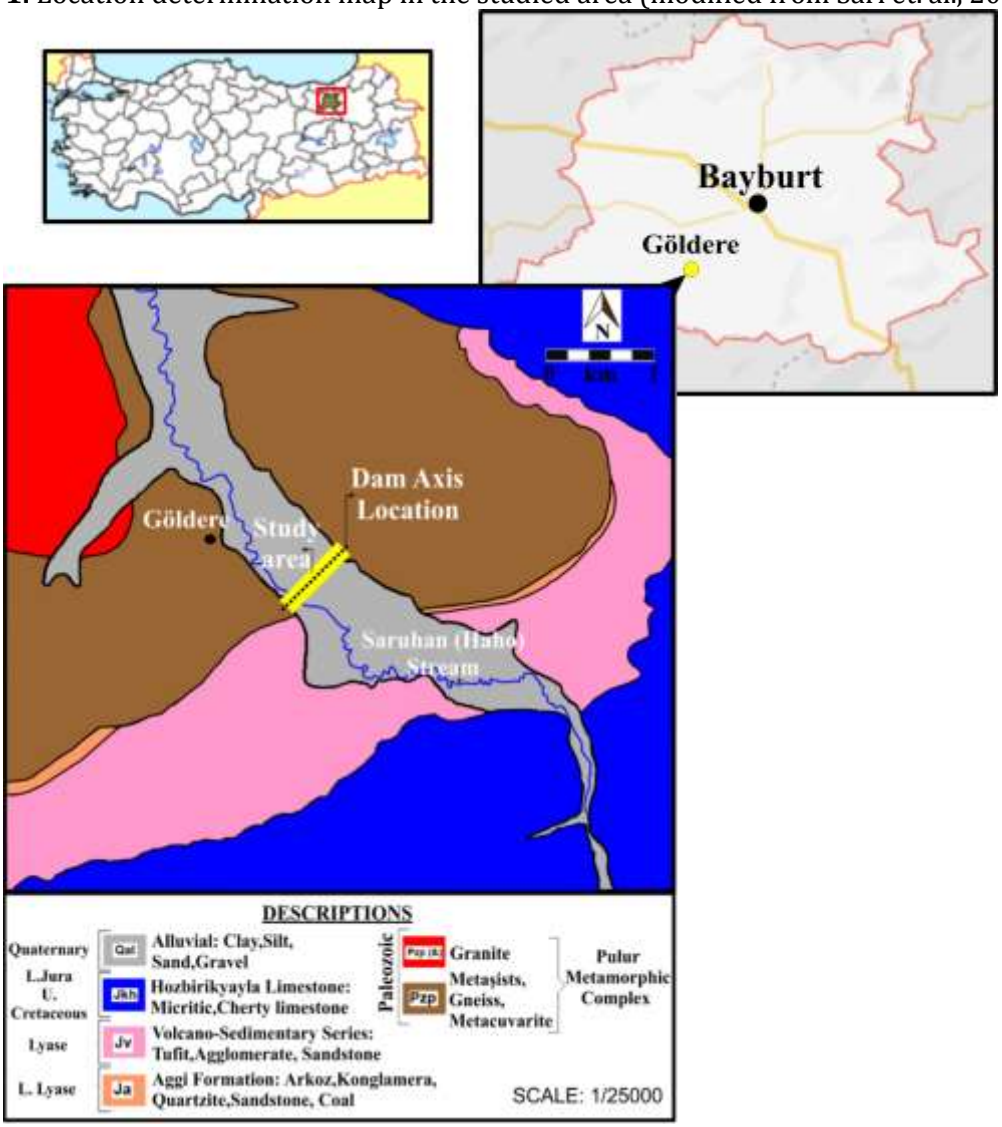
studies to determine the permeability of rock mass with the help of experimental relationships (Adedokun et al., 2016; Öge and Çırak 2019; Kayabaşı et al., 2015; Kargaranbafghi et al., 2018).

In this study, Kırklartepe Dam located approximately 850m southeast of Göldere village of Bayburt central district was determined as the study area (Fig 1). In order to indirectly determine the rock mass permeability of Pulur metamorphics, the Lugeon (LU) values obtained from the Pressurized Water Tests (BWT) performed in-situ and the Vs wave velocity values determined for the existing rock mass were compared with simple regression analysis. While performing simple regression analysis, dependent and independent variables were analyzed separately as linear, logarithmic, geometric and exponential functions, and the equation giving the highest correlation coefficient was preferred.

Fig 1. Location determination map in the studied area (modified from Sari et. al., 2020)

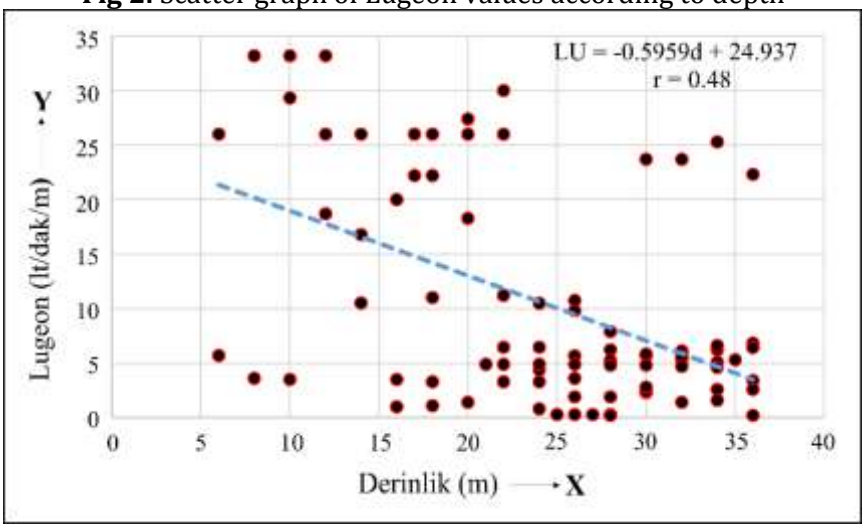


2. Methodology

Simple regression is a mathematical equation that expresses the relationship between two variables, where the value of the dependent variable y is estimated from the value x of a chosen independent variable (Tüysüz and Yaylalı, 2005). To see the shape of the regression, a scatter diagram is prepared first. In this diagram, the independent variable is placed on the X-axis and the dependent variable on the Y-axis, if known (Fig 2).

Regression is calculated in two different ways, depending on whether the independent variable is known or unknown (Morrison, 1983; Draper and Smith, 1981). For example, if the Lugeon change with respect to depth is measured, it can be clearly said that the Lugeon change depends on the depth. That is, the Lugeon dependent (Y) whereas the depth is the independent variable (X).

Fig 2. Scatter graph of Lugeon values according to depth

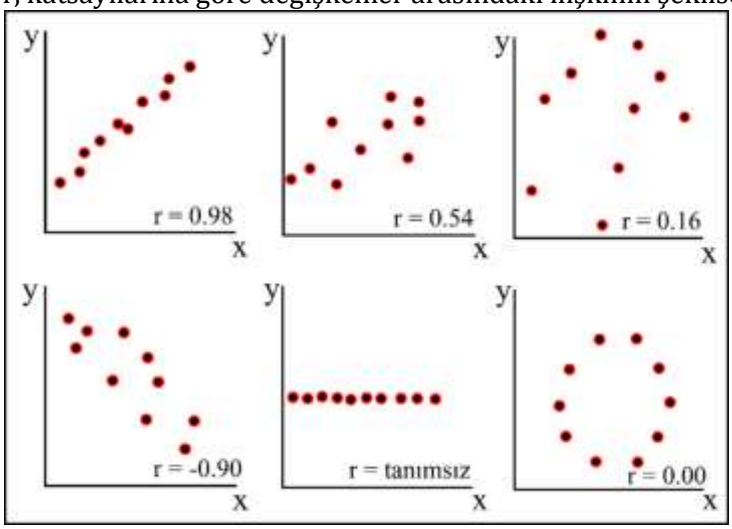


In simple regression analysis, it should always be tested whether the correlation coefficient is significant or not. The correlation coefficient is calculated with the help of the following equation using the t test at a certain significance level and n-2 degrees of freedom.

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

If the t (h) found in this formula is greater than the t (table) values, it is concluded that 'the correlation is significant'. If the correlation coefficient (r) is greater than the correlation coefficient determined by Pearson, it can be said that the relationship is significant (Lindley and Scott, 1995). In addition, the significance coefficients obtained at the 95% confidence level in correlation analyzes were lower than 0.05, indicating that all variables encountered were significant. Correlation coefficient values range from +1 to -1. Therefore, if there is a very good relationship between x and y, or both change at the same rate, r = +1, there is a very good relationship between the two, but if one of them increases by one unit and the other decreases by one unit, then r = -1. In r = 0, it is defined as there is no relationship between two variables (Fig 3), (Tüysüz and Yaylalı, 2005).

Fig 3. Farklı r, katsayılarına göre değişkenler arasındaki ilişkinin şekilsel görünümü



While creating simple regression analyzes, they are evaluated in statistical models, linear ($y = ax + b$), geometric ($y = ax^b$), logarithmic, ($y = a \ln x + b$), and exponential ($y = ae^{bx}$) functions.

3. Results and Discussions

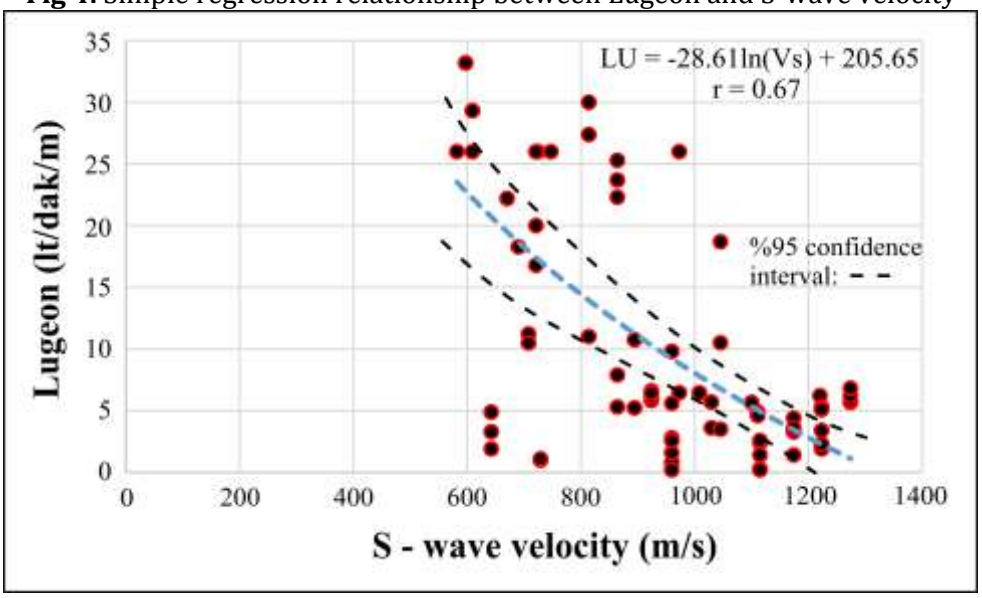
While performing simple regression analysis, the highest correlation coefficient ($r = 0.67$) obtained in the equation between LU and S wave velocity was obtained in the logarithmic equation, and the relationship between the variables shows a good and negative correlation. (Table 1). As a result of statistical evaluations, there is a decreasing relationship between LU and S wave velocity, and the regression analysis graph is given in Fig 4. Accordingly, in the study area, it is seen that the Lugeon (permeability) values decrease with the increase of the S-wave velocity values determined in the Pulur metamorphic rock mass, which is spread at the dam axis location.

Table 1. Equation and critical r value for simple regression analysis between Lugeon (LU) and S wave velocity

Equality Type	Equality	Correlation Coefficient (r)	Pearson's critical r values
Logarithmic	$LU = -28.61\ln(V_s) + 205.65$	0.67	0.207

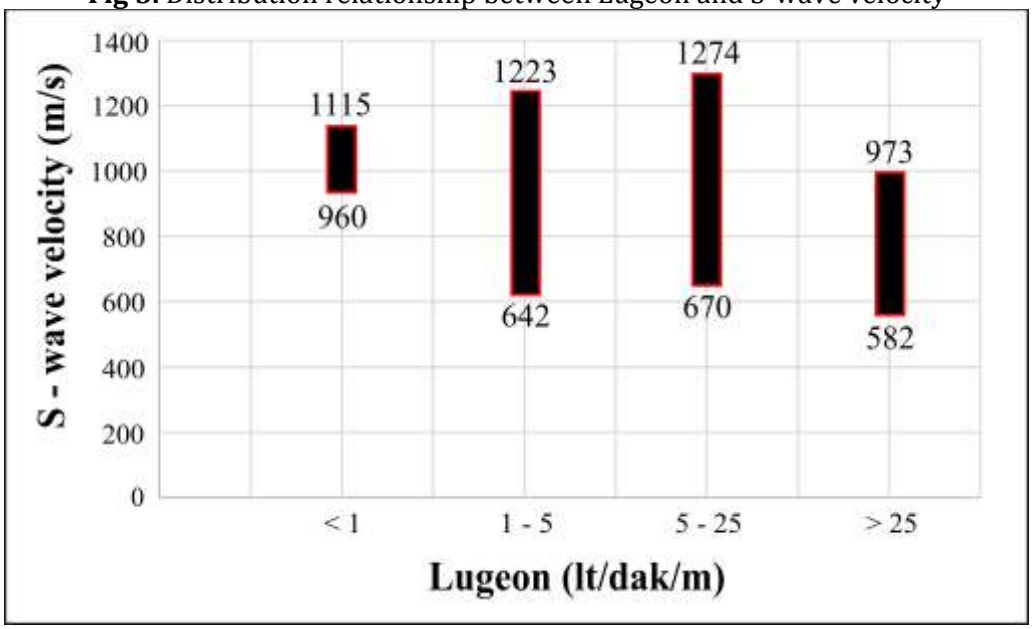
Despite the anisotropic and heterogeneous environmental conditions, there is a significant correlation between the S wave velocity determined by the seismic measurements performed in the area of the dam axis in the study area and the Lugeon values calculated as a result of the BWT tests performed on site.

Fig 4. Simple regression relationship between Lugeon and S-wave velocity



S wave velocity values depending on the Lugeon class intervals are given in Fig. 5, and according to this distribution, the S wave velocity value of the impermeable rock mass is 960-1115 m/s, low-permeable 642-1223 m/s, permeable 670-1274 m/s and It ranges between 582-973 m/s. Due to the overlap of S wave velocity values between permeability classes, rock mass permeability can only be limited in the impermeable and highly permeable region depending on the S wave velocity. It shows transitional feature in permeable and less permeable areas. Accordingly, when the S wave velocity values of metamorphics in the dam axis are examined, the rock mass at values varying between 960-1115 m/s is impermeable, while the mass showing S wave velocity change between 582-973 m/s is highly permeable. The high S wave velocity values with low permeability and permeability indicate that the discontinuities in the rock mass do not contain fillings.

Fig 5. Distribution relationship between Lugeon and S-wave velocity



4. Conclusions

While performing simple regression analysis, the highest correlation coefficient (r = 0.67) obtained in the equation between LU and S wave velocity was obtained in the logarithmic equation, and the relationship between the variables was found to show a good and negative correlation. In addition, it is observed that the Lugeon (permeability) values decrease with the increase of the S-wave velocity values determined in the Pulur metamorphic rock mass, which is spread in the area of the dam axis in the study area.

According to the velocity distribution in the dam axis, it has been determined that the S wave velocity value of the impermeable rock mass varies between 960-1115 m/s, low-permeable 642-1223 m/s, permeable 670-1274 m/s and very permeable 582-973 m/s. Due to the overlap of S wave velocity values between permeability classes, rock mass permeability can only be limited in the impermeable and highly permeable region depending on the S wave velocity. It has been determined to exhibit transitional properties in permeable and less permeable areas.

With this experimental equation, the permeability conditions of these lands can be determined by determining the S-wave velocity in unfavorable land conditions and working areas where drilling is not possible, and reaching the LU value with the equation obtained.

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