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Regression Analysis and Statistical Examination of Knoop Hardness on Abrasion Resistance in Lyca Beige Marbles

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Abstract. Marbles are secondary decomposition products formed by metamorphism of limestone. Effective classification of marble quarries in terms of quality enables the selection of a sustainable production method and safety application. This evaluation is based on physico-mechanical properties of the samples. Obtained results of physico-mechanical properties of the marbles were statistically analyzed using Stata 14 and SPSS 21 software. The marbles indicated mostly normal physical and mechanical properties. A strong inverse relationship exists between Abrasion Value and Knoop Hardness Determination that indicates a significant nonlinear relationship. Samples were distinguished into 3 groups of close similarity and related properties. The estimated value of the parameters is in the 95 % confidence interval. The equation obtained by regression analysis was used for the determination of resistance to abrasion.

1. Introduction

The issue of conservation of natural resources is the subject of political, social, economic and administrative systems, which directly or indirectly affect the services to be made at various level of society. With the contribution of technology and academic studies, the quality and sustainable production relationship of marbles fields has been a scientific subject. Access to natural stone with sufficient quality and required quantity has provided a working environment that can make significant contributions to science in which many disciplines can work together in watershed scale. Strengthening the sustainability of marble quarries by sustainable marble cutting potential is very important to a country and the world. The proper protection and use of a natural stone variety that serves many industrial sectors such as construction, provides benefit to a country's economy [17]. The physical and chemical properties of marbles, which are natural building blocks and its statistical data analysis, have been of high interest for researchers. Mechanical properties such as three-axis stress compressive strength, deformation, stress resistance, friction angle are examined in the determination of a marbles' quality and these data are explained by statistical operations. In the statistical analysis, the reliability of the selected experiments is investigated [4]. The physico-mechanical

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properties of the marble powder were determined and variance analyses (ANOVA) are made to the values found and also correlated with different samples [5][6]. Other studies have been published in which statistical approaches were used [7][8][9][10][12][15][16]. Research projects in marble area have become important for the economies of many countries [3]. Block-marble-travertine import and export data of Turkey in 2016, the country can be seen as an important place in the world market of marble [18]. There are researches in different areas related to marbles of Antalya region [11][12]. The samples were tested for capillary mass water absorption, specific mass, total porosity, compactness, uniaxial compressive strength and mass extinction [3][1]. However, after careful literature review, we have not encountered any study that uses regression analysis to assess Lyca beige marble data. In this study, the effect of abrasion values of Lyca beige marbles on wire cut and block, and the physico-mechanical properties were estimated using regression analysis to determine the linear and nonlinear regression model [14]. Some physico-mechanical properties and classification of the marbles in the study area were analyzed statistically unlike with other studies data.

2. Materials and Method

2.1. Samples and Physico-Mechanical Properties

These 56 sample of 8 different locations taking from Elmali region for statistical analysis [3][1], were tested for their Knoop Hardness Determination (H_k), Real Density (D), Apparent Density (D_a), Abrasion Value (A) and Uniaxial Compressive Strength (UCS) using national standards at the laboratory of the Civil Engineering Department at Akdeniz University. The resulting values establish the physico-mechanical properties of the marble in the study area.

2.2. Regression and Statistical Analysis

The statistical analysis was performed on the physico-mechanical data of Lyca beige marbles using two different kind of statistical software. In this light, the accuracy of the nonlinear and linear models was examined using Stata 14. Hierarchical analysis was conducted to determine the similarities between the data of physico-mechanical properties by using SPSS 21 software [2].

3. Result

The description of the physico-mechanical properties of the samples is shown in Table 1. Maximum values of Knoop Hardness Determination (MPA) are 461.33 MPA and Maximum values of Abrasion Value (mm) is 18.84.

Table 1. Descriptive statistics of Lyca Beige Marble Samples [3][1]

Symbols	Explanation of Symbols	Observation	Mean	StD	Min	Max
A	Abrasion Value (mm)	8	15.98	1.487683	14.39	18.84
D	Real Density (kg/m3)	8	285.875	23.71671	247	318.5
D_a	Apparent Density (kg/m3)	8	2.6075	0.013887	2.58	2.62
H_k	Knoop Hardness Determination (MPA)	8	319.8725	115.2801	204.33	461.33
UCS	Uniaxial Compressive Strength (MPA)	8	158.4	23.62291	118.5	189.47

The normality test to assess the distribution of the physico-chemical properties of the samples was done in accordance with the Shapiro-Wilk test (W) indicated by [14]. The results analyzed with Stata 14 software revealed that p-values of the properties (except H_k) were greater than 0.05, as shown on Table 2, proves the physico-mechanical properties of the samples are normally distributed. The Kolmogorov-Simirnov test results were analyzed by SPSS 21 software and the results are given on Table 3. D, D_a, A and UCS (except H_k) values are all higher than the lower bound value of true significance, "Asymp. Sig (2-tailed)". The also attests the null hypothesis is applicable to the distribution of these properties in the analyzed samples.

Table 2. Shapiro-Wilk W Test of Data

Variable	Obs	W	V	z	Prob>z
D	8	0.95006	0.696	0.559	0.71179
D_a	8	0.83754	2.263	1.468	0.07106
H_k	8	0.80812	2.673	1.813	0.03494
A	8	0.91313	1.210	0.314	0.37665
UCS	8	0.96146	0.537	0.930	0.82387

Table 3. One-Sample Kolmogorov-Smirnov Test of Data

		D	D_a	H_k	A	UCS
Normal Parameters a,b	Mean	2.4549	0.4162	2.4794	1.2020	2.1954
	Std. Deviation	0.03624	0.00232	0.16028	0.03926	0.06688
Most Extreme Differences	Absolute	0.150	0.197	0.260	0.173	0.149
	Positive	0.150	0.185	0.260	0.173	0.110
	Negative	-0.142	-0.197	-0.244	-0.132	-0.149
Test Statistic		0.150	0.197	0.260	0.173	0.149
Asymp. Sig. (2-tailed)		0.200c,d	0.200c,d	0.118c	0.200c,d	0.200c,d
a. Test distribution is Normal.						
b. Calculated from data.						
c. Lilliefors Significance Correction.						
d. This is a lower bound of the true significance.						

The regression analysis of the data, R-Square (R^2), indicated the data used in the analysis were statistically sufficient (Table 4) [13]. Linear and nonlinear regression analysis was performed to measure the relationship between H_k and A. In both equations, the dependent variable is taken as A and the independent variable is taken as H_k. The F-statistic of both models was calculated and their p-value values were significant. The coefficients for both models were significant. All these values are given on Table 4. There was not any heteroscedastic problem for models. Errors are normally distributed and there are no specification errors in the model. Both models are valid. However, considering the RMSE (Root Mean Square Error) and R^2 (R square) values, the R^2 is a better model than the nonlinear model, which is larger and the RMSE value is smaller.

Linear Model:

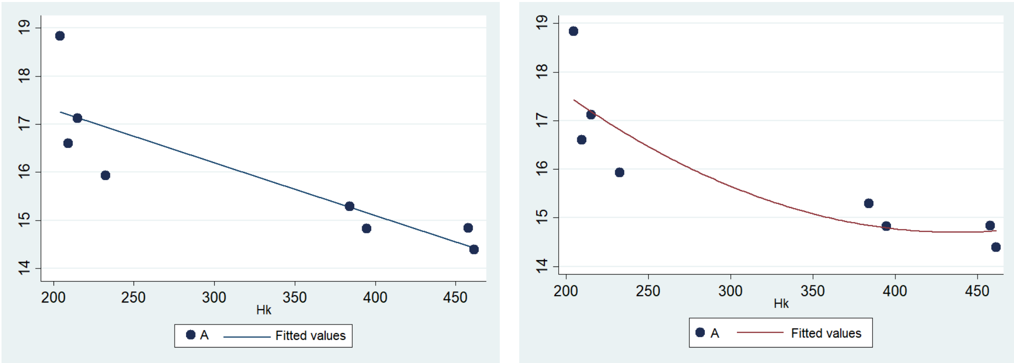
$$A = b_0 + b_1 H_k + e_i \tag{1}$$

Nonlinear Model:

$$A = b_0 e^{b_1 H_k} + e_i \tag{2}$$

Table 4. Regression result of Linear and Nonlinear model

	Linear Model				Nonlinear Model			
		Std.err.	t	p		Std.err.	t	p
b0	19.51*	0.921	21.17	0.000	19.826	0.052	56.28	0.000
b1	-0.011*	0.002	-4.04	0.007	-0.0007	0.0001	-4.38	0.005
RME (Root Mean Square Error)	0.8325				0.0477			
R^2 (R Square)	0.7316				0.761			
F-statistics	16.35			0.006	19.14			0.005
Breusch-Pagan/Cook-Weisberg heteroscedasticity test	P=0.2478>0.05				P=0.251>0.05			
Shapiro_Wilk W Normality test for residual	P=0.356>0.05				P=0.514>0.05			
Ramsey RESET test 0.05 meaningful at error level	P=0.352>0.05				P=0.359>0.05			



Graph 1. Illustration of the Linear (left) and Nonlinear (right) Regression Pattern Fit model of H_k and A Properties of the Lyca Beige Marble Samples

The linear and nonlinear model was evaluated using the graphical illustration; this indicates a better fit (Graph 1).

The Pearson correlation coefficient is used to measure the linear relationship of two continuous variables. In other words, it is used to determine whether there is a significant relationship between the two variables. This result signifies there is a very strong inverse proportional relationship existing between the hardness and abrasion physico-mechanical properties of the samples. The p-value of the variables in Table 2 (except H_k) and Table 3 reveal a normal distribution. In this light, the Pearson correlation coefficients was carried out to test to ascertain the strength of the disparity in the variance of the physicao-mechanical properties (Table 5).

$$\text{Pearson Correlation Coefficient Formula } r = \frac{\sum \sum_{i=1}^{n} X_k X_1 \sum_{i=1}^{n} X_k \sum_{i=1}^{n} X_1}{\sqrt{\left(\sum_{i=1}^{n} X_k^2 \frac{\left(\sum_{i=1}^{n} X_k\right)^2}{n}\right)\left(\sum_{i=1}^{n} X_1^2 \frac{\left(\sum_{i=1}^{n} X_1\right)^2}{n}\right)}} \quad (3)$$

Table 5. Pearson Correlation Coefficients of Samples in SPSS

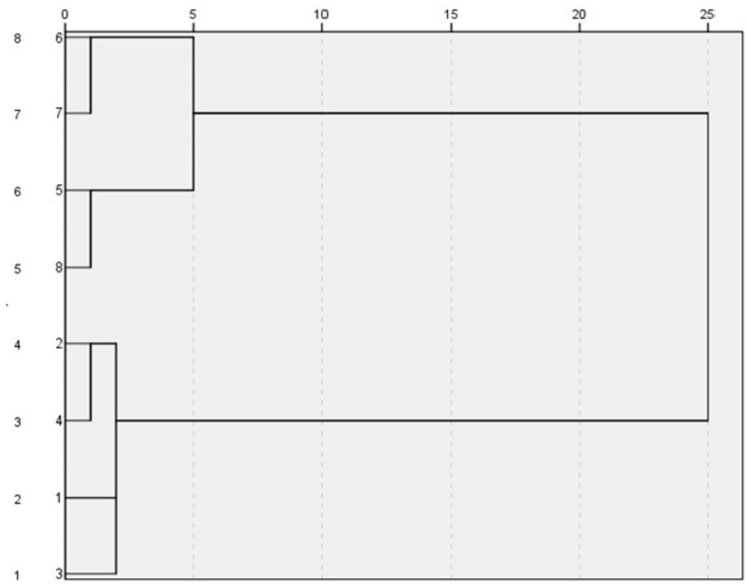
	D	D_a	H_k	A	UCS
D	1				
D_a	-0.230	1			
H_k	0.166	-0.323	1		
A	0.080	0.335	-0.885**	1	
UCS	-0.127	0.331	-0.222	0.017	1

**. Correlation is significant at the 0.01 level (2-tailed)

According to Pearson Correlation Coefficients, there was a very strong negative correlational relationship between the abrasive and knoop hardness properties (Table 5).

The Hierarchical cluster technique illustrated similar characteristics do exist among some samples, such as between samples 6 and 7 (Group 1), samples 5 and 8 (Group 2), and between 1, 2, 3 and 4 (Graph 2). The samples can distinguished into two groups of high dissimilarity in the physico-mechanical properties. That is samples 2, 4, 1 and 3 show close properties similarities to each other and but highly dissimilar properties to samples 6 and 7, and samples 5 and 8 which are relatively closely similar to each other. Samples 6 and 7 are the two most closely related in terms of the physico-mechanical properties, followed by samples 5 and 4, and samples 2 and 4. The same close level of similarities demonstrated by samples 1 and 3, each of them individually demonstrates that same similarities to both samples 2 and 4 (Table 6). From the illustration, the marbles samples from the study area can be distinguish into 3 different qualities based on their properties.

Dendogram using average linkage (Between Groups)
Rescaled distance cluster combine



Graph 2. Graphical illustration of closely related samples in terms of physico-mechanical properties.

Table 6. Clustering Analysis Results of Taking from Lyca Beige Marble Samples

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	6	7	227.091	0	0	6
2	2	4	956.360	0	0	5
3	5	8	2101.164	0	0	6
4	1	3	2841.822	0	0	5
5	1	2	3692.509	4	2	7
6	5	6	7978.034	3	1	7
7	1	5	47142.333	5	6	0

4. Discussion and Conclusion

On the data of the samples obtained from lyca beige marble, descriptive statistics were applied and the results were summarized and discussed above. Shapiro-Wilk and Kolmogorov-Smirnov tests were performed to determine the normal distribution of the data representing physico-mechanical properties of the marble. Linear and nonlinear regressions techniques applied to the data reveal the abrasiveness of the samples is inversely proportional to their knoop Hardness. This is confirmed by the strongly negative Pearson Correlation (r=-0.885). Besides this, every other correlational relationship exhibited between the properties is week but remains significant. D_a, A and UCS all show week relationship among each other. D shows a very week relationship with both H_k and A, and a week negative relationship to D_a and UCS. A week negative correlational relationship also exists between D_a and H_k, and H_k and UCS. Agglomeration schedule of Cluster Combined with Dendogram, indicates samples 6 and 7 are the two most closely related samples in terms of their properties, followed by samples 2 and 4, samples 5 and 8, and samples 3 and 1.

Group 1, samples have closely similar real density, average visible porosity and closely related abrasion value properties. Group 2 samples have average visible porosity property. Group 3 samples have average and closely related abrasive and knoop hardness properties. The most important information obtained as a result of the study is as follows: from the nonlinear regression analysis and the H_k data obtained from the experiments, abrasion resistance can be easily determined by using the established equation 3. The H_k can be determined easily on the field by using a hardness meter machine. By applying the proposed equation 3 with the coefficients obtained of the data from this study area, it is much faster to determine the abrasion value of marble in the area, without using the normal standard method. The estimated value of the parameters is in the 95 % confidence interval.

$$A = 19,82e^{-0,007H_k} \quad (4)$$

References

[1] B. Aydin, Geological, Technological Characteristics, Rehabilitation and Export Of Marble Quarries in Elmali (Antalya) Region Akdeniz University Institute of Science and Technology, Master Thesis, Antalya, 106 pages (Turkish), (2019).

[2] Ş. Kalayci, . SPSS Applied Multivariate Statistical Techniques, Ankara: Asil Publishing, (2009)

[3] B. Aydin, , F. Yalcin, O. Ozer, M.G. Yalcin, "Statistical Classification of Turuncova Marbles With Physical-Mechanical Properties, Finike", Editor Milovanovic, G. Proceedings book of MICOPAM, (2018), 208-212.

[4] Q.Jiang, S. Zhong, J. Cui, X. T. Feng, L. Song Statistical Characterization of the Mechanical Parameters of Intact Rock Under Triaxial Compression: An Experimental Proof of the Jinping Marble. Rock Mechanics and Rock Engineering, (2016), 49(12), 4631-4646.

[5] O. Kelestemur, S. Yildiz, B. Gokcer, E. Arici Statistical Analysis For Freeze–Thaw Resistance Of Cement Mortars Containing Marble Dust And Glass Fiber Materials and Design, (2014), 60, 548-555.

[6] N. Benzannache, A. Bezazi, H. Bouchelaghem, M. Boumaaza, S. Amziane, F. Scarpa, Statistical Analysis of 3-Point Bending Properties of Polymer Concretes Made From Marble Powder Waste, Sand Grains, and Polyester Resin. Mechanics of Composite Materials, (2018), 53(6), 781-790.

[7] G. Sariisik, Determining performance of marble finished products on their usage areas by a new impact-resistance test method Journal of Testing and Evaluation, (2012), 40(6), 945-951.

[8] I. C. Engin, F. Bayram, N. E. Yasitli Experimental and Statistical Evaluation of Cutting Methodsin Relation to Specific Energy and Rock Properties Rock Mech Rock Eng, (2012)., 46:755–766.

[9] E. Hamdi, Z. Lafhaj Microcracking Based Rock Classification Using Ultrasonic And Porosity Parameters And Multivariate Analysis Methods Engineering Geology, (2013), 167, 27-36.

[10] U. Akesson, J. E. Lindqvist, B. Schouenborg, B. Grelk Relationship Between Microstructure And Bowing Properties Of Calcite Marble Claddings Bulletin of Engineering Geology and the Environment, (2005), 65(1), 73.

[11] M. G. Yalcin, O. Akturk, E. Paksu, The Contribution of West Mediterranean Cities (Antalya, Isparta And Burdur) To Turkey's Natural Stones-Marble Export International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology and Mining Ecology Management, 2, (2016), 875-880.

[12] M. G. Yalcin, O. Akturk, "The Importance on Prices of Block Marble and Processed Marble: Antalya, Burdur, Isparta Sample", 9th International Marble and Natural Stones Congress and Exhibition of Turkey, (2017), 617- 622.

[13] E. Yilmazkaya, G. Dagdelenler, Y. Ozcelik, H. Sonmez, Prediction Of Mono-Wire Cutting Machine Performance Parameters Using Artificial Neural Network And Regression Models, Engineering Geology, (2018), 239, 96-108.

[14] P. Royston, A Toolkit For Testing For Non-Normality In Complete And Censored Samples The Statistician, (1993), 37-43.

[15] F. Yalcin, M. Mert, Determination Of Hedonic Hotel Room Prices With Spatial Effect In Antalya. Economıa Sociedady Territorio 18(58), (2018), 697-734.

[16] F. Yalcin, D. G. Nyamsari, E.Paksu, M. G. Yalcin, Statistical Assessment of Heavy Metal Distribution and Contamination of Beach Sands of Antalya-Turkey: an Approach to the Multivariate Analysis Techniques Filomat, 30(4), (2016), 945-952.

[17] M. G. Yalcin, O. Akturk, E. Paksu, Bati Akdeniz Mermer Sektörünün Güncel Durumu ve Gelecek Projeksiyonu, Rapor, Antalya, 164 sayfa (Turkish) (2015).

[18] IMIB., (2016), "Istanbul Mining Exporters' Association Working Report", Istanbul Minerals and Metals Exporters Association.