

Research Article

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Şemsettin Kılınçarslan*, Ebru Yılmaz İnce, Ebru Başpınar Tuncay, Fuzuli Yağmurlu

Clustering Analysis of Normal Strength Concretes Produced with Different Aggregate Types

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Abstract: Concrete is the most commonly used structural material, which is composed of individual base materials. The compressive strength of concrete is important to understand for activities like construction arrangement, prestressing operations, proportioning new mixtures and quality assurance. Concrete has a problem known as Clustering, which is the unsupervised classification of patterns into clusters. The clustering problem has been addressed by several researchers in many contexts and various disciplines; this shows that clustering uses many areas and is an important step in data analysis. In this study, concrete samples with different aggregate types and normal strength were produced. Clustering analysis was performed on the effect of aggregate species for its mechanical strength. According to the result of clustering analysis, it was found that there were three different groups, the study predicts that clustering is not related to the origins of the rocks but is clustered between the strength of the rocks and the mechanical strengths of the concretes produced within these rocks. The common feature of L, RL and SG aggregates in the first cluster is that it is a sedimentary rock. The aggregate of the concrete in the second cluster is that it is a volcanic superficial rock. The common feature of DO and TB rocks in the third cluster is that it has high density. As a result, it was determined that the clay made in normal class concrete is related to the mechanical strength of rocks.

Keywords: Concrete; clustering; mechanical properties; k-means.

1 Introduction

Nowadays, it is possible to confirm the results predicted by experimental data to the results obtained from engineering experiments with artificial intelligence methods [1]. Clustering analysis is a technique used as an unattended learning method for machine education in the field of artificial intelligence. Besides machine learning, It can also be used in statistics; biology; spatial data mining; and image recognition. In this statistical world, packet programs such as S-Plus, SPSS and SAS are intensively used, these programs make use of K-means and clustering analysis methods [2]. Clustering analysis is a classification method, which is used to divide data into groups. There are two types of clustering possible in MATLAB that includes hierarchical clustering and K-means clustering. [3,4]. K-means clustering, was invented by MacQueen in the year 1967 [5] and it is one of the most commonly used unattended learning methods. K means clustering possess an assignment mechanism, which permits each dataset to belong to only one cluster, so that each point in the dataset is assigned to its nearest cluster of nodes [6,7]. The ease of implementation and fast operation in large data sets is the main advantage of K-means clustering [8]. Concrete whose versatility, durability, sustainability, and economy have made it the world's most widely used construction material is basically a mixture of two components: aggregates and paste [9]. Aggregate accounts for 60-80% of the concrete volume and greatly affects the quality, properties and economy of the concrete [10]. The mechanical properties of the concrete are closely related to one another. The strength of concrete is managed by the proportioning of cement, coarse and fine aggregates, water, and various admixtures [11]. A number of methods have been reported in for an estimation of compressive strength of the concrete. There are many recent computing techniques reported for better prediction of concrete compressive strengths. These reported studies were generally based on water/cement ratio, cement types, additive types, additive ratio, recycled aggregates, curing conditions, and mixing designs of concretes [12]. In addition, the compressive strength is related to other properties or performance of

*Corresponding author: Şemsettin Kılınçarslan, Department of Civil Engineering, Faculty of Engineering, Suleyman Demirel University, 32260, Isparta, Turkey, E-mail: semsettin.kilincarslan@sdu.edu.tr

Ebru Yılmaz İnce: Department of Computer Technologies, Technical Sciences Vocational School, Isparta University of Applied Sciences, 32000, Isparta, Turkey

Ebru Başpınar Tuncay, Fuzuli Yağmurlu: Department of Geology Engineering, Faculty of Engineering, Suleyman Demirel University, 32260, Isparta, Turkey

concrete (flexural strength, splitting tensile strength, elasticity modulus, durability) [13]. Scope of the present study is the effect of the aggregate origin in the clustering analysis of normal strength concretes.

2 Material and Method

In this study, six different origin aggregates were used in the mixture concrete, namely, limestone (L), recrystallized limestone (RL), sand and gravel (SG), dolomite (DO), trachybasalt (TB) and tephra-phonolite (TP) (**Figure 1**). Aggregates L, RL, SG, DO are sedimentary rocks, however aggregates TB and TP are igneous rocks. All aggregates were screened through a square sieve and classified into three different size fractions. These are 0/4 mm, 4/8 mm and 16/22.5 mm. CEM I 42.5 R type cement was used in concrete mixtures. Potable water was used in concrete mixes and curing concrete.

Compressive strength of rocks used as aggregates was determined according to TS EN 1926 [14]. According to TS 802 [15] the mixture designs of concretes were given in Table 1 [16] followed by the preparation of concrete samples. After concrete samples were maintained in the curing tank for 27 days, their compressive, flexural, and tensile splitting strength were determined for 28 days according to the principals of standards in TS EN 12390-3 [17], TS EN 1097-2 [18] and TS EN 12390-6 [19], respectively. For each mixture, six cube samples with 150 mm size were moulded to set the compressive strength. On the other hand, three prismatic concrete samples with 100×100×350 mm size were also moulded for determining the flexural strength of concrete. In addition, three cylindrical samples with 150×300 mm size were also casted for determining tensile splitting strength. The classification of normal strength concretes was done by using 4 different variables. These variable include compressive strength of the rocks, compressive strength, flexural strength, tensile splitting strength of concrete samples. Since the data of the analysis were different in the units of measurement, the calculation has been done by z standardization before analysis. Because of few data, gradual clustering methods were preferred. Clustering analysis was performed according to Euclidean distance measure and closest neighborhood methods. Dendograms were used to view clustering analysis results. In addition, clustering analysis was repeated by using a different method, that is by the K-means algorithm but the results obtained were the same.

Ethical approval: The conducted research is not related to either human or animals use.

Table 1: The mixture designs of normal concretes (kg/m³) (water/cement:0,46) [16].

Concrete	Cement (kg)	Water (kg)	Fine Aggregate (kg)	Crushed sand (kg)	Coarse Aggregate (kg)
L30	465	214	56	878	696
RL30	465	214	96	706	831
DO30	465	214	527	700	497
SG30	426	196	586	623	512
TB30	465	214	522	801	434
TP30	465	214	574	745	230



Figure 1: Aggregates RL, SG, L, DO, TP and TB.

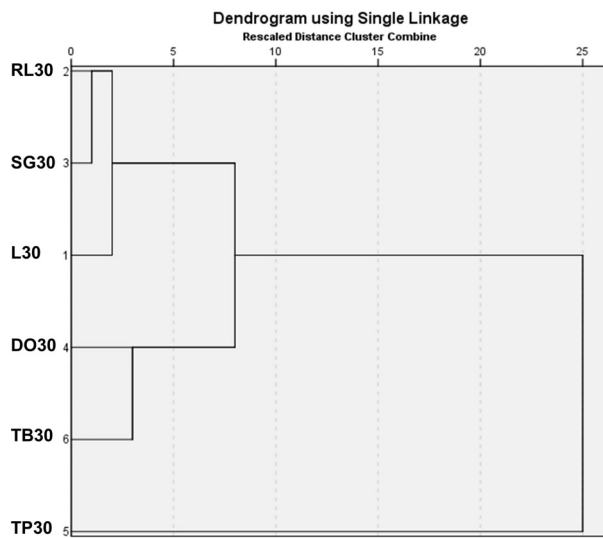
3 Results

Compressive strength of trachybasalt (TB) is the highest as compared to other rocks. However, tephra-phonolite rock is characterized by the least compressive strength than the other rocks. DO has a comparatively higher compressive strength than other sedimentary rocks (L, RL, SG). Generally, compressive strength, flexural strength and splitting tensile strength of concretes are directly proportional to each other as shown in **Table 2**. Compressive strength of TB30 is higher than the other concretes and flexural strength of TB30, which is higher as well. TP30 has the lowest compressive strength as compared to other concrete. However, flexural strength and splitting tensile strength of TP30 is lower than the other concretes. (**Table 2**). Statistical studies of the data obtained are given in the **Table 2**.

According to dendrogram graph obtained (**Figure 2**), R30, L30 and SG30 are in one cluster, TP30 in another cluster, DO30 and TB30 are both in the different cluster. Considering aggregate features such as rock compressive strength, bending strength and splitting tensile strength there are 3 different clusters with similar properties for 6 different experiments normal strength concretes. The same data are obtained from the clustering analysis using the K-means algorithm [20] given in **Table 4**.

Table 2: Minimum, maximum, mean, standard deviation of compressive strength of rocks and concretes [16].

Rocks		L	RL	SG	DO	TB	TP
Compressive Strength of Rocks (MPa)	Min	113,80	109,50	112,36	132,08	149,11	40,57
	Max	124,20	111,77	112,65	145,77	151,16	41,19
	Mean	118,20	110,99	112,47	139,73	150,20	40,83
	Standard deviation	5,38	1,29	0,16	6,99	1,03	0,32
Mechanical Properties of Concrete		L30	RL30	SG30	DO30	TB30	TP30
Compressive Strength of Concrete (MPa)	Min	43,00	45,73	49,14	49,48	54,79	40,81
	Max	44,89	47,96	49,44	53,58	55,74	42,10
	Mean	44,26	47,02	49,29	52,24	55,29	41,58
	Standard deviation	0,72	0,85	0,11	1,78	0,32	0,48
Flexural Strength of Concrete (MPa)	Min	7,50	8,60	10,40	10,50	11,80	8,00
	Max	7,80	9,00	11,00	11,00	12,50	8,80
	Mean	7,63	8,80	10,70	10,77	12,10	8,40
	Standard deviation	0,15	0,20	0,30	0,25	0,36	0,40
Splitting Tensile Strength of Concrete (MPa)	Min	3,31	4,24	4,80	5,18	5,98	3,96
	Max	3,60	4,34	5,49	5,60	6,57	4,09
	Mean	3,50	4,28	5,16	5,38	6,20	4,04
	Standard deviation	0,16	0,06	0,35	0,21	0,32	0,07

**Figure 2:** Euclidean distance measure and clustering analysis according to the closest neighborhood methods.**Table 3:** Clustering relation to K-means method.

States	Experiment	Cluster	Distance
1	L30	1	5.285
2	RL30	1	2.912
3	SG30	1	3.344
4	DO30	3	5.509
5	TB30	3	5.509
6	TP30	2	0,000

L30, RL30 and SG30 are present in one cluster, TP30 in second cluster, DO30 and TB30 in another cluster.

Three different clusters with similar properties were formed for six different aggregates with normal strength concretes, according to rock strength, compressive strength, flexural strength and splitting tensile strength of concretes. The same data were obtained from the clustering analysis using the K-means algorithm, given in **Table 3**. The same groups were obtained as the previous cluster analysis, as shown in **Table 3**. The experiment of concrete samples was divided into 3 clusters and finally the average of the results was given in **Table 4**.

As a result of the study, clustering analysis was performed according to Euclidean distance measure and nearest neighborhood methods of normal strength

When examined Table 4, the same groups were obtained as the previous cluster analysis. Clustering analysis of normal strength concrete was performed according to the Euclidean distance measure, and nearest neighborhood methods. The resulting dendrogram graph is presented in Figure 2. According to the dendrogram graph obtained,

Table 4: Mean of Clusters.

Mechanical Properties of Concrete	Cluster 1 (L30, RL30 and SG30)	Cluster 2 (TP30)	Cluster 3 (DO30 and TB30)
Compressive Strength of Rocks (MPa) Mean	46,86	41,58	53,77
Flexural Strength of Concrete (MPa) Mean	9,04	8,40	11,44
Splitting Tensile Strength of Concrete (MPa) Mean	4,31	4,04	5,79

concrete; the clustering analysis was also repeated with a different algorithm using the K-means method. According to the results obtained, it was determined that the concrete with normal strength is represented by three different clusters for six different aggregates using data.

4 Conclusions

In this study, clustering analysis was performed according to Euclidean distance measure and nearest neighborhood methods of normal strength concrete. In addition, the clustering analysis was repeated with a different algorithm using the K-means method. According to the results obtained, it was found that the concrete with a normal strength is represented by 3 different clusters for 6 different aggregates used in the data.

It is clustered between the strength of the rocks and the mechanical strengths of the concretes produced with these rocks.

The common feature of L, RL and SG aggregates in the first cluster is that it is a sedimentary rock. The aggregate of the concrete in the second cluster is that it is a volcanic superficial rock. The common feature of DO and TB rocks in the third cluster is that it has high density. As a result, clustering in normal class concretes concerns the mechanical strength of rocks.

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Conflict of interest: Authors state no conflict of interest.

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