

## Investigation of the Usability Limestone Sources for Production of Concrete in Çankırı, Türkiye

Houssein Hassan WABER<sup>1</sup>, Abdoulrazack Djama ABDILLAH<sup>2</sup>, Ahmet KAPLAN<sup>3</sup>,  
Başak VARLI BİNGÖL<sup>4</sup>, Ender SARIFAKIOĞLU<sup>5\*</sup>

### Abstract

In this study, the usability of limestone extracted from two different aggregate quarries located in Çankırı province as concrete aggregate was investigated. For this purpose, aggregate samples were taken from the two quarries and on the samples taken, sieve analysis, specific gravity, water absorption, bulk density, very fine material content, flakiness index, methylene blue, disintegration strength, abrasion resistance, freeze-thaw, alkali-silica reactivity, acid soluble sulfate and total sulfur tests were carried out. As a result, the results of the tests performed on aggregates obtained from the limestone quarries around Çapar village (Şabanözü, Çankırı), Seydiköy (Eldivan, Çankırı) and Doğu district (Korgun) were compared with the limit values given in the standards and the usability of these limestone as concrete aggregates was determined. According the tests performed on the aggregates it can be clearly seen that, that all properties of these aggregates are suitable according to the EN standards.

**Keywords:** Limestone, Quarries, Aggregate, Aggregate usability tests.

## Çankırı'da Bazı Kireçtaşı Agrega Kaynaklarının Betonda Kullanılabilirliğinin Araştırılması

### Öz

Bu çalışmada, Çankırı ilinde bulunan iki agrega ocağından çıkarılan kireçtaşlarının beton agregası olarak kullanılabilirliği araştırılmıştır. Bu amaçla iki ocağın agrega numuneleri alınmış ve alınan numuneler üzerinde elek analizi, özgül ağırlık, su emme, yığın yoğunluğu, çok ince malzeme içeriği, yassılık endeksi, metilen mavisi, parçalanma mukavemeti, aşınma direnci, donma-çözülme, alkali-silika reaktivitesi, asitte çözülebilen sülfat, toplam kükürt testleri yapılmıştır. Sonuç olarak, Çapar köyü (Şabanözü, Çankırı), Seydiköy (Eldivan, Çankırı) ve Doğu mahallesi (Korgun) agrega ocaklarından elde edilen agregalar üzerinde yapılan deneylerin sonuçları, standartlarda verilen sınır değerlerle karşılaştırılmıştır ve kireçtaşlarının betonda kullanılabilirliği belirlenmiştir.

**Anahtar Kelimeler:** Kireçtaşı, Taşocakları, Agrega, Agrega kullanılabilirlik testleri.

<sup>1</sup>Çankırı Karatekin University, Civil Engineering Department, Çankırı, Türkiye, [houshassan97@gmail.com](mailto:houshassan97@gmail.com)

<sup>2</sup>Çankırı Karatekin University, Civil Engineering Department, Çankırı, Türkiye, [a.razzack99@gmail.com](mailto:a.razzack99@gmail.com)

<sup>3</sup>Çankırı Karatekin University, Civil Engineering Department, Çankırı, Türkiye, [ahmetkapllan@gmail.com](mailto:ahmetkapllan@gmail.com)

<sup>4</sup>Çankırı Karatekin University, Civil Engineering Department, Çankırı, Türkiye, [basakvarlibingol@karatekin.edu.tr](mailto:basakvarlibingol@karatekin.edu.tr)

<sup>5</sup>Çankırı Karatekin University, Civil Engineering Department, Çankırı, Türkiye, [enders@karatekin.edu.tr](mailto:enders@karatekin.edu.tr)

<sup>1</sup><https://orcid.org/0000-0001-5929-4814>

<sup>2</sup><https://orcid.org/0000-0003-0243-0904>

<sup>3</sup><https://orcid.org/0000-0002-9303-9136>

<sup>4</sup><https://orcid.org/0000-0002-7934-7482>

<sup>5</sup><https://orcid.org/0000-0001-6930-000X>

## 1. Introduction

Concrete is the most used building material in the construction industry. It is obtained by adding water, binder (cement), aggregate and, if necessary, additives. Aggregate is present in the concrete in a very large proportion by volume (Akman, 1990; Poitevin, 1999).

In this period where the construction industry is developing rapidly, the need for concrete and therefore aggregate has increased considerably. It is known that it is very important in terms of the development of the country's economy and the development of existing resources. For that, the use of new aggregates resources has been researched by many researchers and presented to the use of the industry with positive results.

The properties of concrete, which has a non - homogenous internal structure, are determined by the materials that compose it. The quality of the aggregates, which account for approximately 75% of the concrete volume, has a significant impact on the performance and stability of the concrete. It is general knowledge that suitable aggregates must be used in order to produce quality concrete.

Considering the cost of concrete, the fact that aggregate is cheaper than cement makes aggregate a cost-effective and natural filler for concrete. It prevents the volume change of the concrete in the cement paste that hardens as aggregate, skeleton and filling material, increases its resistance against environmental effects and helps the concrete to reach the required strength with its own strength as well as its cheap cost. Limestone is mostly used as concrete aggregate (Koçabay, 1991; Yaşar and Erdoğan, 2003; Gezer, 2009; Tutmaz and Karaman, 2010; Altınsoy et al. 2017).

In this study, the conformity of the crushed stones produced in two different aggregate quarries in Çankırı province with the TS 706 EN 12620 concrete aggregates standard was investigated. The Seydiköy (Eldivan, Çankırı) limestone quarries are about 20 km from the center of Çankırı, 10 km from Eldivan while Çapar village (Şabanözü, Çankırı) limestone quarries are 30 km from Çankırı city center and 12 km from Şabanözü. The limestone quarries of Doğu district are in the Korgun surroundings, far of 20 km from Çankırı.

## 2. Geology Information

The Cretaceous aged Ankara Mélange is commonly observed around the cities of Çankırı-Çorum-Ankara. The quarries located in Eldivan and Şabanözü districts to the west-southwest of Çankırı were opened in the limestone (L) megablocks of the Ankara Mélange. The size of the limestone blocks ranges from a few meters to several kilometers. The Ankara Mélange also contains blocks of basalt (B), diabase, serpentinite (S) and chert (Figure 1-3). Limestone megablocks, in which

the quarries are located, are gray-light gray in color or light pinkish gray in color and have a massive appearance. It is cracked-fractured or karst cavities in places.

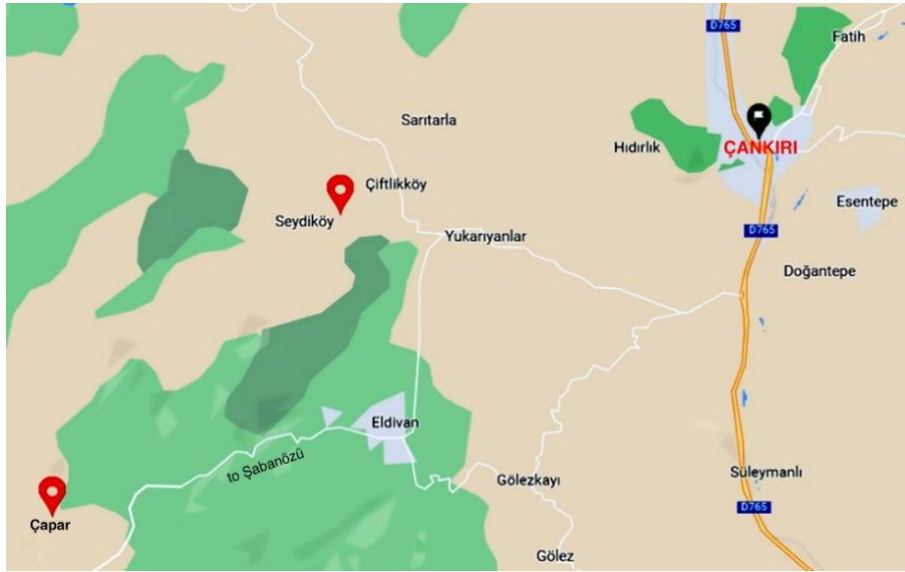


Figure 1. Location on the Seydiköy and Çapar quarries.

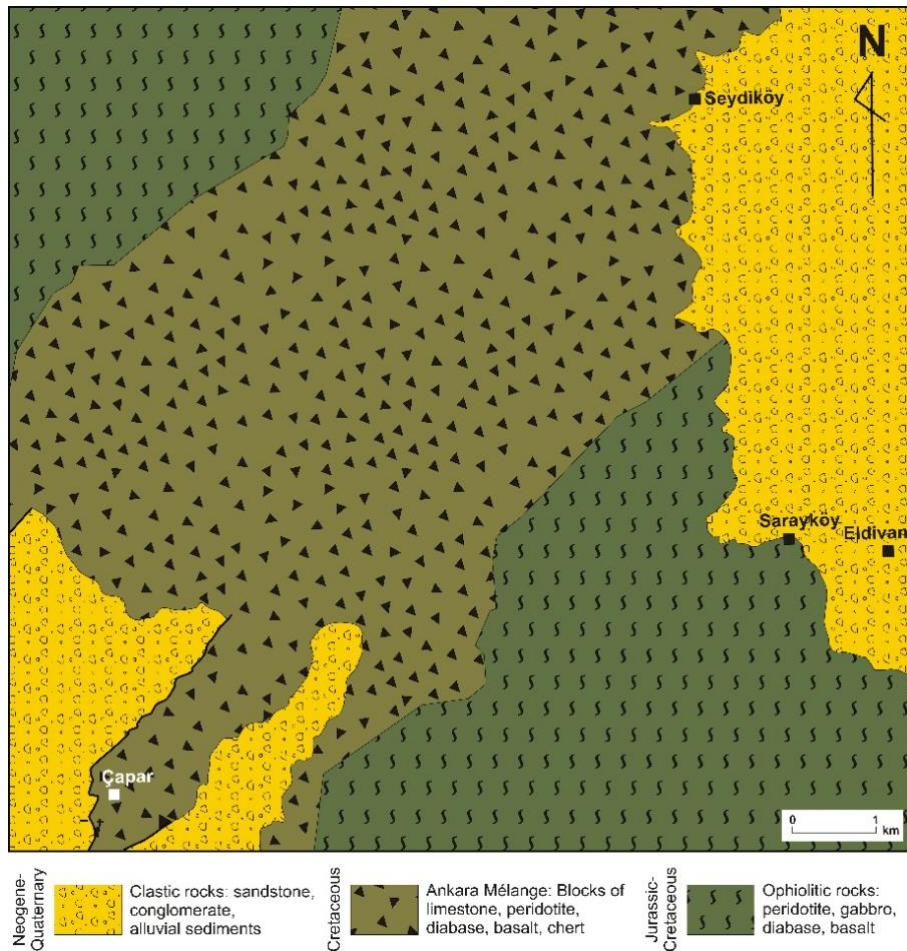


Figure 2. The map of general geology in the study area (simplified from Sarıfakıoğlu et al. 2011).



**Figure 3.** The blocks of Ankara Mélange (B: basalt, L: limestone, S: serpentinite, M: mudstone)

### 3. Materials and Method

#### 3.1. Materials

The samples used in the experiments were taken from quarries near Çapar village (Şabanözü, Çankırı), Seydiköy village (Eldivan, Çankırı) and Doğu district (Korgun). The Samples were procured in accordance with TS 706 EN 12620 standards. The location of the quarries from which the samples were taken is given in Figure 1 and the view of the quarry in the field is given in Figures 4 (a–d). The samples obtained from these aggregate quarries are symbolized as E-1 (Limestone from Şabanözü), E-2 (Limestone from Eldivan) and E-3 (Doğu district, Korgun) (Figure 4).



**Figure 4.** a) E-1 (Limestone aggregates from Şabanözü); b) E-3 (Limestone aggregates, Doğu district, Korgun); c) E-2 (Limestone aggregates from Eldivan)



**Figure 5.** a, b) Views of the Çapar village quarries; c, d) Views of the Seydiköy quarries.

### 3.2. Method

In the limestone quarry, the rocks blasted with dynamite and crushed by construction equipment are loaded onto dump trucks with loader crawler buckets and brought to the crushing-screening facility for size reduction and crushed for using in concrete.

In order to determine the physical, mechanical and chemical properties of the limestone aggregates to be used in preparing concrete specimens according to TS 706 EN 12620 standard. The physical, mechanical and chemical laboratory experiments of this study were carried out in the laboratories of Bulutsan Cement Factory (Çankırı). The laboratory experiments of this study and the standards for these experiments are presented in Table 1.

**Table 1.** Experiments and related standards

Name of the Experiments	Experiment Standards
Grain size distribution	TS EN 933-1
Grain density and water absorption rate	TS EN 1097-6
bulk density	TS EN 1097-3
Very thin material content	TS EN 933-1
Flakiness index	TS EN 933-3
Methylene blue	TS EN 933-9
Los Angeles experiment	TS EN 1097-2
Freeze and thaw resistance	TS EN 1367-1
Alkali silica reactivity (ASR)	TS 13516
Determination of acid-soluble sulfate	TS EN 1744-1
Determination of total Sulphur content	TS EN 1744-1

### 3.2.1. Grain Size Distribution (Sieve Analysis)

The aggregate pile contains grains of varying sizes. Granulometric or sieve analysis is used to evaluate how an aggregate pile should be arranged based on grain size (Figure 6). The granulometric composition indicates the percentage of the aggregate material whose dimensions are within certain limits. Granulometry has a great influence on concrete compaction, strength, durability and the volume of mixing water.

**Figure 6.** Sieve analysis for determining the particle size distribution.

### 3.2.2. Grain Density and Water Absorption Rate

It was made to determine the specific gravity and water absorption rates of the aggregate, which were realized in accordance with TS EN 1097-6 standards. It was carried out by the pycnometer method for aggregate grains. Three experiments were repeated in the laboratory, and the results are given in Table 3 for coarse and fine aggregates. In general, the weights of normal aggregates are 2.4-2.8 mg/m<sup>3</sup>; If the specific gravity is less than 2.4 mg/m<sup>3</sup>, they are light aggregates (Bahattin, 2000). The water absorption rate value is 0.3%-0.4% for coarse aggregate and 0.5%-1.2% for fine aggregate.

### 3.2.3. Bulk Density

It is performed to determine the bulk density value of dry aggregates, which was carried out in accordance with TS EN 1097-3 standards. It was repeated on three samples in the laboratory, and the results are given in Table 4. The coarse aggregates of 11.2-22.4 mm were found to be 1347 kg/m<sup>3</sup> for Çapar village and 1312 kg/m<sup>3</sup> for Seydiköy village. Fine aggregate between 0-4 mm was found to be 1596 kg/m<sup>3</sup> for Çapar village and 1420 kg/m<sup>3</sup> for Seydiköy village. Similar values were found for the aggregates in the Doğu district (Korgun) to those around Çapar village. Loose bulk density is closely related to the grain shape and density of the aggregate. As the rate of defective particles in the aggregate increases, the amount of void increases and the loose bulk density decreases. Since the porous aggregate will adversely affect the resistance of the concrete against external factors, the voids of the concrete can be reduced by making use of the intergranular void volume and the grain granulometry curve to prevent this.

### 3.2.4. Very Fine Material Content

The very fine material content is considered harmless if the total fine material content of the fine aggregate is less than 3% according to TS 706 EN 12620 or another value specified in accordance with the legislation applicable in the place where the aggregate is used. If the very fine material content reaches high ratios, it causes negative effects such as decrease in concrete strength, increase in water requirement in concrete, workability of concrete and shrinkage of concrete. It was carried out according to the method described in the TS EN 933-1 standard.



### 3.2.5. Flakiness Index

The shape of the aggregate particles directly affects the workability of fresh concrete. The upper limit for the flakiness index is 55% and aggregates are not permitted to exceed this value. Determination of the flatness index of aggregates is an important property for aggregates with a grain size between 4 mm and 80 mm. In order to determine the shape of the aggregate particles, the shape index test was carried out according to TS EN 933-3.

### 3.2.6. Methylene Blue

This test was carried out to determine the methylene blue index (MB) of fine aggregates and carried out in accordance with TS EN 933-9 standards. The methylene blue test is used to determine the amount of clay in the aggregate. The maximum value specified in this test, which only applies to fine aggregates, is 1.5%. The material above this value is considered to contain too much clay and cannot be used in the production of concrete. The value of methylene blue, which is the expression in grams of the dye consumed per kilogram, was found to be 25 ml for the Seydiköy village aggregate and 15 ml of methylene blue solution were sufficient to detect the presence of clay in the limestone sample from the Çapar village quarry (Figure 7).



**Figure 7.** The methylene blue test on investigated aggregates.

### 3.2.7. Los Angeles Test

This test was carried out to determine the fragmentation resistance of coarse aggregates, and was realized in accordance with TS EN 1097-2 standards. The wear of the coarse aggregate is determined by the Los Angeles machine using an abrasive load. According to the TS 706 EN 12620 standard in concrete aggregates, the abrasion resistance that occurs as a result of the rotation of the drum for 500 revolutions should be maximum 50%.

### 3.2.8. Freeze and Thaw Resistance

The determination of the resistance of the aggregate when exposed to freezing and thawing effects with Magnesium Sulphate ( $Mg_2SO_4$ ) solution was made in accordance with TS EN 1367-1 standards.

### 3.2.9. Alkali Silica Reactivity (ASR)

Alkali silica reactivity (ASR) is the reaction of reactive silica in concrete aggregates with hydroxyl and alkali ions in the pore solution of hydrated cement paste. This reaction causes the formation of alkali-silica gel, which expands under the influence of moisture in the concrete. Tensile stresses that occur as a result of expansion in concrete lead to cracking (Kambiz, 2013). The higher the alkali content of the concrete, the higher the ASR potential. The increase in ASR causes the effects of sulfate, natural frost, freezing and thawing to increase rapidly (Arslan, 2001).

Many standards have been developed for the determination of alkali-aggregate reactivity. Test Method: Determination of alkali-silica reactivity of TS EN 13516 aggregates by accelerated method of mortar sticks. The ASR test was carried out according to the ASTM C 1260-94 standard and evaluated according to the limitations given in the standard.

It has been carried out in accordance with TS EN 13516 standards and has been evaluated according to the limitations given in the standard.

- If the 16-day expansion is  $<0.1$ , the aggregate is harmless,
- Aggregate is potentially harmful if expansion over 16 days is  $>0.2\%$ ,
- Experiment if expansion over 16 days  $\leq 0.1\% - 0.2\% \geq$ . It is extended to 28 days and petrographic analysis of the aggregate should be done,

With experience, the elongation of limestone aggregates as a function of the expansion resulting from the reaction that can form with the cement paste has been determined.

### 3.2.10. Determination of Acid-Soluble Sulfate

The sulfates extracted from the aggregate test sample piece with dilute hydrochloric acid are determined by the gravimetric method. The sulfate ion content is expressed as a percent by mass of the aggregate. Sulphates in aggregates can cause damage to concrete. Under certain conditions, other sulfur compounds present in aggregates can be reduced in concrete to form sulfates. Acid-soluble sulphates have been determined according to TS EN 1744-1 standard.

### 3.2.11. Determination of Total Sulfur Content

An aggregate test sample piece is treated with bromine and nitric acid to convert the sulfur compound present to sulfates. The sulfates are precipitated as BaSO<sub>4</sub> and weighed. The sulfur content is expressed as a percentage by mass of the aggregate.

## 4. Results

### 4.1. Grain Size Distribution (Sieve Analysis)

The particle size distribution was carried out in accordance with TS EN 933-1 standards. The results of the particle size distribution of the aggregate samples are shown in Table 2. Following the sieving analysis, the granulometry curves of the aggregate to be used in the concrete were drawn (Figure 8). The particle size curves resulting from the sieve analysis are within the particle size curve limits of TS 706 EN 12620 standards. According to these results, it was determined that they are suitable for aggregates in terms of particle size.

**Table 2.** The results of particle size distribution of the aggregates from Çapar village (Şabanözü), Seydiköy (Eldivan) and Doğu district (Korgun).

Sieve size (mm)	Aggregate size (mm)				Lower limit	Upper limit
	Şabanözü	Eldivan	Doğu district			
31.5	100	100	100		100	100
22.4	89	89	99		78	100
16	80	84	83		75	90
11.2	63	69	69		55	78
8	55	59	57		46	66
5.6	47	51	45		40	59
4	40	44	36		34	52
2	30	34	27		22	40
1	17	24	20		14	30
0.5	11	18	15		8	24
0.25	6	10	11		5	18
0.063	3	4	6		0	7

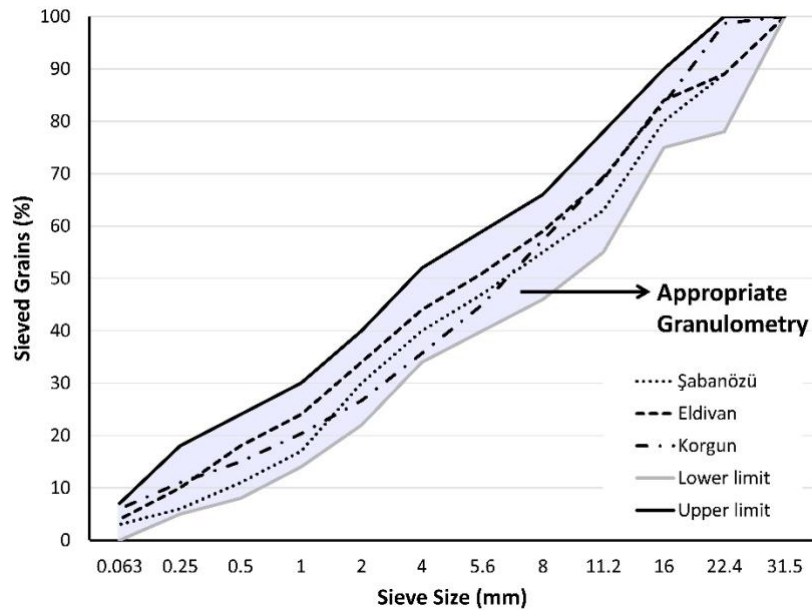


Figure 8. Sieve analysis curves.

#### 4.2. Grain Density and Water Absorption Rate

As a result of the tests, the following values were found, the specific gravity and water absorption rate were calculated by taking the average of these values, and then compared with the limit values given in the standards, the specific gravity and water absorption rate of the aggregates remained within the limit values. It shows that the aggregate is suitable according to TS EN 1097-6 Standards (Table 3).

Table 3. Specific gravity and water absorption rates of coarse and fine aggregates.

Quarry	Aggregate class (mm)	Specific gravity found ( $Mg/m^3$ )			Average	Found water absorption rate %			Average
		1. Experiment	2. Experiment	3. Experiment		1. Experiment	2. Experiment	3. Experiment	
Çapar	0-4	2.71	2.71	2.71	2.71	0.56	0.56	0.56	0.56
	4-12	2.73	3.19	3.06	2.99	0.43	2.09	0.10	0.86
	12-25	2.74	2.28	2.98	2.66	0.40	0.33	0.45	0.39
Seydiköy	0-4	2.81	2.70	2.74	2.75	0.67	0.50	0.50	0.55
	4-12	2.81	2.73	2.76	2.76	0.40	0.40	0.40	0.40
	12-25	2.80	2.75	2.77	2.77	0.50	0.23	0.23	0.32
Doğu district	0-4	2.81	2.80	2.81	2.81	1.43	1.46	1.44	1.44
	4-12	2.80	2.81	2.81	2.81	1.04	0.90	0.94	0.96
	12-25	2.80	2.80	2.80	2.80	0.71	0.65	0.54	0.63

#### 4.3. Bulk Density

The following values were found as a result of the three tests, and the average of these values are then compared with the limit values given in the standards and show that the aggregates comply with TS EN 1097-3 Standard (Table 4).

**Table 4.** Bulk density values.

Quarry	Aggregate Class (mm)	Results				Standard Requested (Kg/m <sup>3</sup> )
		1. Experiment	2. Experiment	3. Experiment	Average	
Çapar	0-4	1.596	1.598	1.595	1.596	<1.740
	11.2-22.4	1.347	1.347	1.348	1.347	<1.418
Seydiköy	0-4	1.420	1.420	1.420	1.420	<1.740
	11.2-22.4	1.312	1.312	1.312	1.312	<1.418
Doğu district	0-4	1.596	1.598	1.595	1.596	<1.740
	11.2-22.4	1.347	1.347	1.348	1.347	<1.418

#### 4.4. Very Fine Material Content

The values found at the end of the very fine matter content test are given in Table 5. The contents of very fine materials were found to be f 1.5 for coarse aggregates and f 22 for fine materials, depending on the category concerned. As it is less than 4% in coarse aggregates and less than 22% in fine aggregates, they have therefore been found to comply with TS 706 EN 12620.

**Table 5.** Very fine material content value.

Quarry	Aggregate Class (mm)	Result (%)	Standard Limit (%)
Çapar	0-4	18.25	22
	11.2-22.4	0.97	4
Seydiköy	0-4	15.09	22
	11.2-22.4	0.4	4
Doğu district	0-4	18.25	22
	11.2-22.4	0.97	4

#### 4.5. Flakiness Index

According to the test results, the flakiness index was found to be 14% for Çapar village, 14.6% for Seydiköy and 10% for Doğu district quarries. According to the test results, the determination of the flakiness index was found to be below the specified standard limit value and complies with TS EN 933-3 standards (Table 6).

**Table 6.** Values with flakiness index and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	14	15
Seydiköy	14.6	15
Doğu district	10	15

#### 4.6. Methylene Blue

As the limit value of methylene blue (MB) (%) is 1.5, this indicates that the aggregates do not contain fines. In addition, the low value of the very fine matter content supports the methylene blue result (Table 7).

**Table 7.** Methylene Blue found values and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	1	1.5
Seydiköy	0.6	1.5
Doğu district	2	1.5

#### 4.7. Los Angeles Test

Experiment results found that the Los Angeles coefficient was 25% for the Çapar village and Doğu district quarries and 30% for of Seydiköy quarries. According to TS EN 12620 standards, LA25 and LA30 categories were determined to be suitable. With these values, the limestone samples are under the limit values and the concrete can be used in production (Table 8).

**Table 8.** Los Angeles Test found value and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	25	50
Seydiköy	30	50
Doğu district	25	50

#### 4.8. Freeze and Thaw Resistance

The freeze-thaw resistance values of the sample with a size of 10-14 mm were found to be 2% on average for aggregates from Çapar village and Doğu district quarries and 4% on average for the Seydiköy aggregates. They are respectively in the F2 and F4 categories according to the TS EN 12620 standards. These values are less than or equal to the value of 4% specified as the upper limit in the standards (Table 9).

**Table 9.** The freeze-thaw resistance values and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	2	4
Seydiköy	4	4
Doğu district	2	4

#### 4.9. Alkali Silica Reactivity (ASR)

The average expansion rate over 16 days was found to be 0.063% for Çapar village and Doğu district aggregates and 0.023% for aggregates from the Seydiköy quarries according to the mortar stick test method. Since these expansion values are less than 0.1%, they are in the safe zone in terms of alkaline silica value (Table 10).

**Table 10.** Alkali silica reactivity test values and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	0.063	0.1
Seydiköy	0.023	0.1
Doğu district	0.063	0.1

#### 4.10. Determination of Acid-Soluble Sulfate

The acid-soluble sulfate content is 0.0425% for Çapar village and Doğu district quarries, 0.0011% for Seydiköy quarries by mass and are in AS02 category. The amount of sulphate soluble in acid should not exceed 0.8% by mass. In the evaluation made according to the TS 706 EN 12620 standard, the aggregates are suitable for use in terms of the amount of sulfate soluble in acid (Table 11).

**Table 11.** The acid-soluble sulfate test values and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	0.0425	0.8
Seydiköy	0.0011	0.8
Doğu district	0.0425	0.8

#### 4.11. Determination of Total Sulfur Content

Total sulfur was determined according to TS EN 1744-1 Article 11 and was found as 0.0452% for Çapar village and Doğu district, and 0.136% for Seydiköy aggregates. These values are below the 2% limit value given in TS 706 EN 12620 and are suitable for use in terms of sulfur content Table 12.

**Table 12.** Total sulfur test values and Standard limit.

Quarry	Result (%)	Standard Limit (%)
Çapar	0.0452	2
Seydiköy	0.136	2
Doğu district	0.0452	2

## 5. Discussion

Limestones are widespread in Turkey. The construction industry utilizes these natural resources for aggregates.

The usability of the aggregate types obtained from different sources within the borders of Çankırı province was examined in line with the standards. In this direction, the sieve analysis has shown that the aggregates from Eldivan is closer to the upper limit, specified in the specification. This shows that the fine aggregate ratio is higher than the aggregates obtained from other sources. All aggregates specific gravities are very close to each other. Significant differences are seen in the methylene blue test results. Aggregates from Doğu Distinct includes more clay and silt. The obtained values were found to be quite close to the other experiments.

Limestone aggregates from Ceyhan (Adana), Çelebili (Mersin), Hafik (Sivas) and Tokat regions were found to be suitable for concrete construction (Kocabay, 1991; Gezer, 2009; Yaşar and Erdoğan, 2003; Tutmaz and Karaman, 2010). The contribution of this study to the literature is to emphasize that the studied aggregate types can be used in concrete mixes.

## 6. Conclusions and Recommendations

In this study, in which the usability of the limestones around Çapar village (Şabanözü, Çankırı), Seydiköy village (Eldivan, Çankırı) and Doğu district (Korgun) as aggregate was investigated, it was determined that the physical, mechanical and chemical properties of the limestones were in accordance with the standards.

The results obtained from the study are summarized below:

- The densities of the limestone determined as a result of the tests were found to be: E-1: 2.66-2.71 mg/m<sup>3</sup>; E-2: 2.75-2.77 mg/m<sup>3</sup> and E-3: 2.81-2.80 mg/m<sup>3</sup>. They are deemed suitable according to TS EN 1097-6 standards.
- As a result of the experiment carried out in the study, the values of the water absorption rate of the limestone samples were: E-1: 0.39-0.56%; E-2: 0.32-0.55% and E-3: 0.63-1.44%. They are deemed suitable according to TS EN 1097-6 standards.
- Bulk Density values of the limestone sample were found to be: E-1: 1.347-1.596 mg/m<sup>3</sup>; E-2: 1.312-1.420 mg/m<sup>3</sup> and E-3: 1.347-1.596 mg/m<sup>3</sup>. They are deemed suitable according to TS EN 1097-3 standards.
- The Very Fine Material Content values of the limestone samples were found to be: E-1: 0.97-18.25%; E-2: 0.4-15.09% and E-3: 0.97-18.25%. They are deemed suitable according to TS EN 933-1 standard.



- The values of the flatness index of the limestone samples as a result of the experiment carried out in the study were found to be: E-1: 14.6%; E-2: 14% and E-3: 10%. They are deemed suitable according to TS EN 933-3 standards.
- The methylene blue values of limestone that we applied as a result of the experiment carried out in the study turned out to be: E-1: 0.6%; E-2: 1% and E-3: 2%. They are deemed suitable according to TS EN 933-9 standards.
- The Los Angeles shear strength (LA) values of the limestone sample were found to be: E-1: 25%; E-2: 30% and E-3: 25%. They are deemed suitable according to TS EN 1097-2 Standards.
- The Freeze-Thaw Resistance value of the limestone sample we applied was found to be: E-1: 2%; E-2: 4% and E-3: 2%. They are deemed suitable according to TS EN 1367-1 Standards.
- The Alkali-Silica Reactivity value of the limestone sample was found to be: E-1: 0.063%; E-2: 0.023% and E-3: 0.063%. They are deemed suitable according to TS 13516 Standards.
- Acid Soluble Sulphate value of the limestone sample was found to be: E-1: 0.0452%; E-2: 0.0011% and E-3: 0.0452%. They are deemed suitable according to TS EN 1744-1 Standards.
- The Total Sulfur value of the limestone sample we applied was found to be: E-1: 0.0452%; E-2: 0.136% and E-3: 0.00452%. They are deemed suitable according to TS EN 1744-1 Standards.

According to the standards, it is proved that two different aggregate quarries located in Çankırı province are usable in concrete mixes. Additional studies can be addressed as comparison of the strength of mixtures prepared by aggregates that is from disparate quarries. Thus, the strength in the concrete mixture will be more clear. However, the feasibility of using materials obtained from the construction waste as an alternative to new aggregate sources may also investigate in future studies.

### **Acknowledgment**

We would like to thank BULUTSAN Cement Factory (Çankırı) for the opportunities provided to carry out laboratory experiments during this study. We would like to thank Selin Kalkan, Editor of The Black Sea Journal of Sciences, and two referees for improving the manuscript.

## Authors' Contributions

All authors contributed equally to the study.

## Statement of Conflicts of Interest

There is no conflict of interest between the authors.

## Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

## References

- Akman M.S. (1990). *Yapı Malzemeleri*. İTÜ İnşaat Fakültesi yayını, sayı.1408, İstanbul, 162s.
- Altınsoy, F., Karahan, N. Ş., Çankaya, R. ve Karabayır, A. (2017). *Çanakkale Elmacık yöresi kalker taşlarının beton agregası olarak uygunluğunun araştırılması*. Çanakkale Onsekiz Mart Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 3(1): 48-58.
- Arslan, M. (2001). *Beton (Dökümü, kalıpları, kusurları, dayanıklılığı)*. İstanbul: Atlas Yayınları.
- Bahattin, K. (2000). *Betonun dayanım ve durabilitesini sağlayan parametreler*. Mühendislik Bilimleri Dergisi, 6, 78-85.
- Gezer, B. B. (2009). *Mersin İli Çelebili Köyü İçmeler Mevkiinde Yüzeyleyen Kireçtaşlarının Beton Ve Asfalt Agregası Olarak Kullanılabilirliğinin İncelenmesi*. Yüksek Lisans Tezi, Çukurova Üniversitesi, Adana.
- Kocabay, N. 1991. *Sivas-Hafik Ocağındaki Agreganın Beton Yapımında Kullanılabilirliğinin Araştırılması*. Yüksek Lisans Tezi. Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Ankara, 40 s.
- Kambiz, R. (2013). *Betonda alkali-silis reaksiyonu bir derleme (Çağrılı Bildiri)*. Beton 2013 Hazır Beton Kongresi, (pp. 289-311). İstanbul.
- Poitevin, P. (1999). *Limestone aggregate concrete, usefulness and durability*. Cement and Concrete Composites, 21: 89-97.
- Sarıfakıoğlu, E., Sevin, M., Esirtgen, E., Bilgiç, T., Duran, S., Parlak, O., Karabalık, N.N., Alemdar, S., Dilek, Y., and Uysal, İ. (2011). *Çankırı-Çorum Havzasını Çevreleyen Ofiyolitik Kayaçların Jeolojisi: Petrojenezi, Tektoniği ve Cevher İçerikleri*. MTA Derleme Rapor No: 11449, Ankara (yayımlanmamış).
- Şimşek, O. (2020). *Beton ve Beton Teknolojisi*. Altıncı Baskı. Ankara: Seçkin Yayıncılık.
- Tutmaz and Karaman, 2010. *Utilization Possibility of Natural Aggregate Resources in Central Town of Tokat as Concrete Aggregate*. Journal of Tekirdag Agricultural Faculty, 7 (1), 71-83.
- TS EN 12620. (2003). *Beton agregaları*. Ankara: Türk Standartları Enstitüsü.
- TS EN 1097-2. (2000). *Agregaların mekanik ve fiziksel özellikleri için deneyler bölüm 2: Parçalanma direncinin tayini için metotlar*. Ankara: Türk Standartları Enstitüsü.
- TS EN 1097-3. (1999). *Agregaların fiziksel ve mekanik özellikleri için deneyler bölüm 3: Gevşek yığın yoğunluğunun ve boşluk hacminin tayini*. Ankara: Türk Standartları Enstitüsü.
- TS EN 1097-6. (2002). *Agregaların mekanik ve fiziksel özellikleri için deneyler bölüm 6: Tane yoğunluğu ve su emme oranının tayini*. Ankara: Türk Standartları Enstitüsü.
- TS EN 1367-1. (2008). *Agregaların ısı ve bozunma özellikleri için deneyler bölüm 1: Donmaya ve çözölmeye karşı direncin tayini*. Ankara: Türk Standartları Enstitüsü.
- TS EN 1744-1. (2013). *Agregaların kimyasal özellikleri için deneyler bölüm 1: Kimyasal analiz*. Ankara: Türk Standartları Enstitüsü.
- TS EN 932-2. (1999). *Agregaların genel özellikleri için deneyler bölüm 2: Laboratuvar numunelerin azaltılması metodu*. Ankara: Türk Standartları Enstitüsü.

- TS EN 933-1. (2012). *Agregaların geometrik özellikleri için deneyler bölüm 1: Tane büyüklüğü dağılımı tayini – eleme yöntemi*. Ankara: Türk Standartları Enstitüsü.
- TS EN 933-3. (2012). *Agregaların geometrik özellikleri için deneyler bölüm 3: Tane şekli tayini – yassılık endeksi*. Ankara: Türk Standartları Enstitüsü.
- TS EN 933-9. (2014). *Agregaların geometrik özellikleri için deneyler bölüm 9: İnce tanelerin tayini – metilen mavisi deneyi*. Ankara: Türk Standartları Enstitüsü.
- TS 13516. (2012). *Agregaların potansiyel alkali reaktivitesinin tayini (harç çubuğu yöntemi)*. Ankara: Türk Standartları Enstitüsü.
- Yaşar, E. and Erdoğan, Y. 2003. *Usability of Ceyhan (Adana) Limestone as Aggregate in Concrete*. III Ulusal Kırmataş Sempozyumu. 3-4 December 2003, Istanbul. Proceedings, 205-211.