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Investigation of The Effect of Aggregate Type on Concrete Cost: Example of Adıyaman

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Abstract

Concrete is a building material that is considered as a granular composite. The factor in its acceptance as granular is the aggregate in its content. In addition to forming the vast majority of aggregate concrete volume, it is also extremely important in the development of strength and durability factors. Although cement is the most costly input of concrete, it can affect the cost of concrete in changes in aggregate type. For this purpose, in this study, concrete samples were produced with different types of aggregates from different quarries operating in Adıyaman province. Only the type of aggregate was changed, and cost calculations were made, provided that the cement type and amount and other components in the mixture remained constant. In addition, cost and strength comparisons were made by measuring compressive strength values for 7 and 28 days. It has been determined that with the change of aggregate type, cost and compressive strength value change.

Keywords: Concrete, Aggregate, Cost, Adıyaman.

1. Introduction

Concrete is the most used building material in the world. An average of 10 billion tons of concrete is produced annually in the world. This value is estimated to reach 18 billion tons annually by 2050 [1-6].

Aggregates are the main component that covers the volume of concrete at about 70-80%. Therefore, aggregates are expected to have a significant impact on concrete properties. At the same time, choosing the appropriate aggregate for the type of structure to be produced changes the cost of concrete and structure. The choice of aggregate type in concrete production is a determining factor for concrete quality. Concretes produced with the use of aggregates with the same type and quality cement as well as aggregates with different textural properties and mineralogy may differ, especially the compressive strength [7-12].

There are studies in the literature examining how aggregate variability affects the properties of concrete. Güçlüer [13] determined that the textural properties of aggregate in concrete produced with 3 different types of aggregates, and especially the surface roughness factor, varies in the compressive strength values, and higher compressive strength value are obtained in concretes produced with aggregates with high surface roughness.
Beshr et al. [14] conducted mechanical measurements on concretes produced with aggregates in 4 different mineralogies in their study. They found that aggregate quality was directly related to concrete compressive strength. Özturan and Çeçen [15] stated that the compressive strength value of the concrete test samples produced with different types of aggregates vary depending on the textural and mechanical properties of the aggregate. Yılmaz and Tuğrul [16] found that the strength of concrete produced with different types of coarse aggregate is affected by aggregate mineralogy and surface roughness.
Ahmed and Alghamdi [17] state that in the concrete they produce with basalt and limestone aggregates, the

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compressive strength values of concrete with limestone aggregates are higher than those with basalt aggregates.

For this purpose, in this study, natural (NS) and crushed (CS) stone aggregates obtained from two different aggregate quarries in Adıyaman province and concrete experiment samples were produced. Besides the effects of aggregates on cost, their effects on compressive strength were also investigated.

2. Materials and Methods

CEM I 42.5 R type Portland cement compliant with TS EN 197-1 [18] was used as binder in the study. Physical properties and chemical components of cement are given in Tables 1 and 2.

Table 1. Chemical component of cement.

Oxide	CaO	SiO_2	Fe_2O_3	Al_2O_3	MgO	SO_3	K_2O	LOI
Cement	62,63	19,29	4,25	3,88	3,42	2,58	0,34	2,86

Table 2. Physical properties of cement.

Properties		Results
Specific gravity (g/cm^3)		3.09
Setting time	Firstly (min)	125
	Finish (min)	190
Blaine fineness (cm^2/g)		3420

One of the aggregates obtained from the aggregate quarry is natural stone aggregate and the other is crushed stone aggregate. Physical properties of these two types of aggregates are given in Table 3.

Table 3. Physical properties of aggregate.

Aggregate	Specific Gravity (g/cm^3)	Water Absorption (%)
Natural Stone Aggregate	2.42	2.48
Crushed Stone Aggregate	2.44	3.00

The aggregates to enter the concrete mixture are prepared according to the method of saturation of dry water. The same consistency value was taken as the basis for both aggregate types and the amount of water was arranged according to this value. In addition, it is aimed that the concrete produced from both aggregates will show resistance in accordance with the C30/37 class. Naphthalene sulfonate-based superplasticizer chemical additive was used to facilitate workability in concrete mixtures. Concrete mixing ratios are made according to TS EN 206-1[19] and slump value of 15cm is targeted for both mixtures (Table 4). Compressive strength tests were carried out on concrete samples that were kept in the cure pool for 7 and 28 days in accordance with the TS EN 12390-3 [20] standard on cube samples with 15 cm edges.

Table 4. Concrete mix ratio for $1m^3$.

Aggregate Type	Cement (kg)	0-5mm Aggregate (kg)	5-15 mm Aggregate (kg)	15-22 mm Aggregate (kg)	Water (kg)	SP (kg)
NS Aggregate	308	944	366	626	169	4.6
CS Aggregate	318	988	338	595	175	4.1

The cost calculations of the materials used as concrete components were made according to the unit price method. The unit prices are based on the values used in the enterprises operating in the Adıyaman region.

3. Results

3.1 Compressive Strength Results

7 and 28 days compressive strength findings of concrete experimental samples produced using natural and crushed stone aggregates are given in Figure 1.

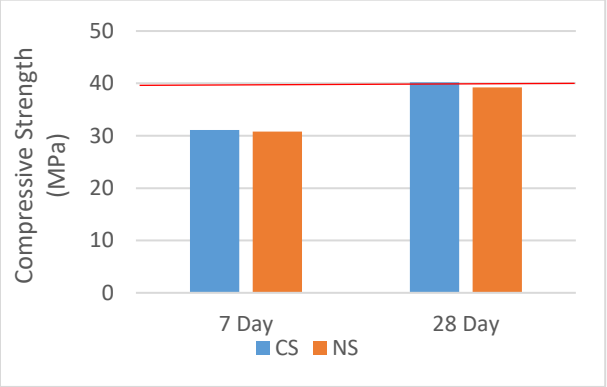

Figure 1. Measured value of compressive strength of concrete samples.

Higher values were determined in the compressive strength data of concrete produced with crushed stone aggregates compared to concrete produced with natural aggregate.

Although there is no effective increase in 7-day curing period, after 28 days curing period, 2.5% increase in the compressive strength value of concrete produced with crushed stone aggregate was found compared to concrete produced with natural stone aggregate. The fact that crushed stone aggregates have higher surface roughness and strengthened adhesion in the cement-aggregate interface area may have been effective in this situation. Aspect ratio and roundness in aggregates are important textural features and are thought to be effective in strength. As the roundness value of the aggregates approaches 1, a perfect roundness is mentioned. The aspect ratio briefly describes the elongation of aggregates (Figure 2).

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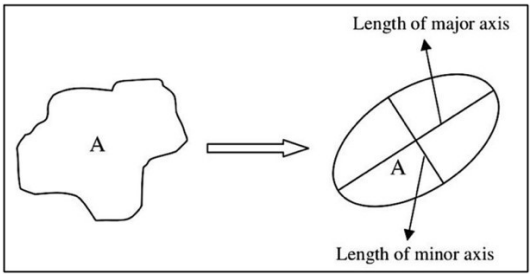

Figure 2. Schematic representation of the aspect ratio [21].

In Figure 3, images of samples taken from natural and crushed stone aggregate pile are given. The roundness of natural aggregates is seen better than crushed stone aggregates. In the study conducted by Güçlüer [7], it was determined that the aspect ratio values of crushed stone aggregates are higher than the natural aggregate and the compressive strength values of the samples produced with crushed stone aggregate are higher. This information supports the higher compressive strength of concrete samples produced with crushed stone aggregates compared to concrete samples produced with natural aggregates.

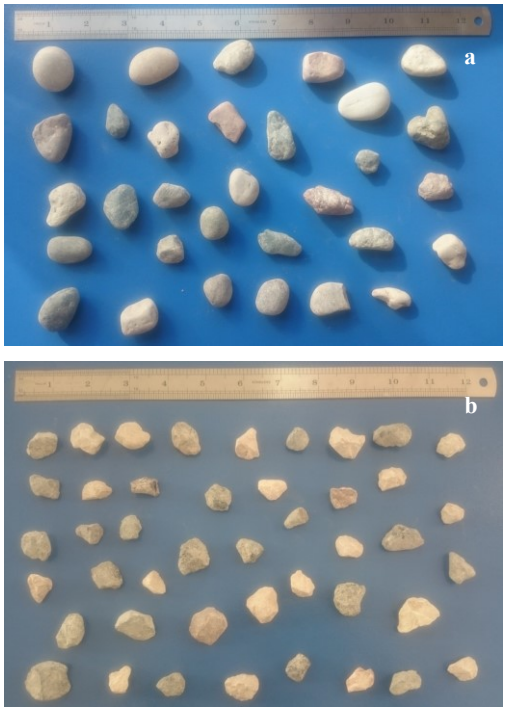

Figure 3. Natural stone aggregate (a), crushed stone aggregate (b).

3.2 Cost Results

Mix ratios and cost calculations of the mixture together with unit prices for C30/37 class concretes produced with natural and crushed stone aggregates are given in Tables 5 and 6.

Cost advantage for C30/37 class concrete produced with natural and crushed stone aggregates has been determined in concretes produced with natural aggregate. When the cost values are examined, the cost of concrete produced with natural aggregate is 10.99% lower than the cost of concrete produced with crushed stone aggregate.

Table 5. Cost rates for natural stone aggregate.

Concrete Class C30/37	Amount (kg)	Unit Price (TL/ton)	Price (TL)
Natural sand 0-5mm	944	₺16,68	₺ 15,75
Natural stone aggregate 15-22,4mm	626	₺16,68	₺ 10,44
Natural stone aggregate. 5-15mm	366	₺16,68	₺ 6,11
Water	169	₺7,20	₺ 1,22
CEM I 42.5 R	308	₺200,00	₺ 61,60
SP	4,6	₺2.000,00	₺ 9,20
Total			**104,31**

*SP= Superplasticizer

However, this situation is inversely proportional to the compressive strength values. Although the cost of concrete produced with crushed stone aggregate is high, compressive strength values are determined higher.

Table 6. Cost rates for crushed stone aggregate.

Concrete Class C30/37	**Amount (kg)**	**Unit Price (TL/ton)**	**Price (TL)**
Crushed sand 0-5mm	988	₺ 22,24	₺ 21,97
Crushed stone aggregate 15-22,4mm	595	₺ 22,24	₺ 13,23
Crushed stone aggregate 5-15mm	338	₺ 22,24	₺ 7,52
Water	175	₺ 7,20	₺ 1,26
CEM I 42.5 R	318	₺ 200,00	₺ 63,60
SP	4,1	₺ 2.000,00	₺ 8,20
Total			**115,78**

Table 7. Aggregate cost ratios in concrete.

Concrete Class C30/37	Aggregate Price (TL)	Percentage of aggregate cost(%)	Concrete Price (TL)
NS aggregate	₺32,30	30,96	₺ 104,31
CS aggregate	₺42,72	36,89	₺ 115,78

Aggregate based cost percentages are given in Table 7. The cost of aggregate in concrete produces with CS aggregate is higher than the cost of aggregate in concrete produced with NS aggregate

4. Conclusion

In the scope of Adıyaman province, the following conclusions have been reached with the research in which the cost analysis of the concrete produced with natural and crushed stone aggregates is made;

•The cost of concrete produced with natural stone aggregate is cheaper than concrete produced with crushed stone aggregate.

•The compressive strength values of concrete produced with crushed stone aggregates are higher than those produced with natural stone aggregate.

• When these data are limited to Adıyaman province, it can be said that concrete production with natural aggregate may be less costly. However, the use of crushed stone aggregates can be recommended at points where strength and durability axis expectations are taken into consideration.

Parameters such as raw material supply, distances of the quarry and concrete batching plant to each other can directly affect the cost of concrete. In this sense, it may be beneficial for the literature and concrete industry to carry out similar studies on different regions.

Author's Contributions

Kadir Güçlüer: Drafted and wrote the manuscript, performed the experiment and result analysis.
Osman Günaydın: Assisted in analytical analysis on the structure, supervised the experiment's progress, result interpretation and helped in manuscript preparation.
Samet Göymen: Assisted in analytical analysis on the structure, result interpretation and helped in manuscript preparation.

Ethics

There are no ethical issues after the publication of this manuscript.

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