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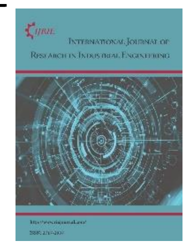

Proposing the Use of Fine Stone Cutting Factory as Recycled Materials in Concrete and Study of Design Economy and Environmental Protection

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A B S T R A C T

During the past years, extensive studies have been performed on concretes containing rice husk ash and recycled aggregates, which have shown the advantages of those concretes. Comparison of recycled concrete materials from the aggregates of quarrying plants for use in laboratory mixtures is the difference between this study and previous studies in this field. In addition to mechanical tests and evaluation of the performance of recycled concrete and comparison of ordinary concrete, the evaluation of the design economy and environmental protection are also examined. The main purpose of this study is to achieve and introduce the most optimal conditions for the use and application of recycled stone materials in concrete production. Evaluate and compare the effectiveness of each of the hardened concrete parameters such as mechanical properties and engineering properties (compressive and tensile strength) as a result of using recycled aggregate replacement values, as well as conserving environmental resources that are non-renewable in many industries. Or renewed over very long periods of time, reducing construction waste and environmental pollution, creating employment and economic benefits are other goals pursued in this study.

Keywords: Mechanical performance, Rice husk ash, Microsilica, Recycled grain, Compressive and tensile strength of concrete.

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1. Introduction

Concrete is one of the most common construction materials in the world, which is produced in large quantities and is one of the main components of Portland cement concrete, so the amount of cement production in the world has increased significantly. During the production of a cement, about one ton of carbon dioxide gas is released into the atmosphere. For this reason, it is necessary to consider alternative materials that are environmentally friendly as an alternative to part of cement in the manufacture of concrete. By substituting cement, these materials reduce cement production and thus reduce the emission of carbon dioxide into the atmosphere [1]. These additives are called cement additives. Rice husk ash and recycled aggregates are among the cement additives that replace some of the cement and aggregates and have many environmental benefits [2].

Recycled concrete aggregates of fine-grained or coarse-grained part can usually be replaced as well as fine-grained or coarse-grained and total replacement or both be considered. Aggregates of recycled concrete is mainly attract higher water and less resistant to stone flakes normal because the resistance mortar sticking out of the resistance of aggregate is lower than the same mortar on the stone flakes recycled because of porosity greater than the aggregate, has more water.

Ajdukiewicz and Alina [3] investigated the effect of recycled aggregates on high-strength concrete. In this research, the mechanical properties of recycled concrete with high strength concrete made of natural aggregates have been compared and during a series of experiments, concretes with a life of 2 to 7 years with medium and high strength were used. They were crushed at least three months before reuse.

In a study conducted by Ehsani and Shaabani [4] in 2017, despite the use of the highest quality recycled brick aggregates in the manufacture of concrete, the test results showed that the concrete obtained from recycled brick aggregates is of lower quality than it was made of concrete with stone and natural aggregates. It was suggested that concrete from brick aggregates be used for low-load-bearing walls or for partition walls such as partitions.

D'angelo et al. [5] in 2011 investigated the superplasticizing and hollarizing effects of alkaline sodium hydroxide solution on the performance, microstructure and compressive strength of Self-Compacting Geopolymer Concrete (SCGC), the results showing that performance and strength compression is improved by increasing the superplasticizer dose.

Vejmelková et al. [6] in 2015 analyzed the engineering properties of concrete containing natural zeolites as biomaterials and studied the mechanical, physical, and durability properties of concrete. Experimental results show that 95% zeolite in concrete mix is the most suitable amount.

Hamad [7] in 2017 with the initial and inevitable interest in using partial alternatives or by-products as additives mainly led to the implementation of air pollution control by the cement industry. Increasing the husk of the by-product obtained from the rice milling process, by about 200 kg per ton of rice, reduces it to 40 kg, even at high temperatures. This paper presents the advantages of different ratios of Rice Husk Ash (RHA) on concrete indices through 5 mixed designs with ratios of 5, 10, 15, 20 and 25% RHA to cement weight in addition to 10% Micro Silica (MS) mixed compare reference with 100% Portland cement. The test results showed that a positive correlation between 15% RHA replacement with an increase in compressive strength of about 20%, the optimum level of strength and durability properties generally increases with the addition of 20%, beyond that with a slight decrease in strength parameters of about 5, 4% is accompanied. Similar results for water absorption ratios are likely to be unpleasant. The diffusion of chloride ions increases by increasing the rate of cement replacement by about 25% compared to the initial values (about one-fifth).

Zareei et al. [8] in 2017 experimentally investigated the effects of Nano-Sio2 on the properties of cement paste.

Mohamed in 2016 [9], in a study, the current efforts and situation and the impact of nano-silica on the properties of cement mortar to better understand the materials and their applications were examined. This paper also shows the effect of S-Glass fibers on the mechanical properties of concrete.

In the present study, using the replacement of rice husk ash instead of cement in concrete production reduces production costs in concrete production because rice husk ash naturally has silica and pozzolanic properties. On the other hand, rice husk ash, due to its natural silica, is safe from the damage caused by pozzolans with artificial silica, and in fact, it is possible that if ash is used, a better result than cement be taken in concrete. Then, by using recycled aggregates as consumables such as (sand, gravel) in concrete, a significant percentage of the volume of consumables (sand, gravel) in concrete is reduced, which reduces the cost. Concrete is made as if we used a type of recycling in the manufacture of concrete that may enter the environment and cause pollution and destruction.

2. Laboratory Program

The materials used to perform the tests are as follows:

2.1. Cement

Cement used in all tests portland cement is a medium anti-sulfate (type two) products of Bojnourd factory in Iran. According to the tests performed, all the specifications of the consumed cement are in full compliance with the required standards. Preliminary tests of cement that can be done in the concrete technology laboratory have also been performed on cement.

Table 1. Specifications of cement used.

Test number in the relevant standard	Result	Type of experiment
ASTM-C188-89	15/3gr/cm^3	Specific weight of cement
ASTM-C191-82	After 3 hours	Initial setting time of cement
ASTM-C187-86	26/0	Normal concentration of cement

2.2. Water

The water used in making concrete is from drinking water in Chalous city of Iran, which is not a problem due to its drinking water for making concrete. In addition, the optimal amount of water consumption in this concrete is 3.4 kg/m3.

2.3. Stone Grain

The sand used in this research is of crushed rock type of factory. Maximum 21 mm has a water absorption of 1.03% and a specific weight of 2710 kg / m3.

Table 2. Sand granulation table.

Alec number	Full weight	Empty weight	Net weight
$1\frac{1}{2}$	384.52	384.52	0
1	471.47	471.47	0
$\frac{3}{4}$	713.14	445	268.14
$\frac{1}{2}$	853.96	462.02	445.11
$\frac{3}{8}$	598.23	408.85	180.38
4	612.47	445.13	167.35
The last dish	314.25	208.85	105.40

2.4. Sand

The sand used is prepared from the riverbed and its maximum grain size is 80.4 mm, has a water absorption of 5.12% and a specific weight of 2570 kg/m3.

Table 3. Sand granulation table.

Alec number	Full weight	Empty weight	Net weight
8	1121/12 gr	451/45gr	669/67 gr
16	612/23 gr	316/16gr	296/07 gr
30	423/43 gr	292/38gr	331/05 gr
50	412/25 gr	288gr	124/25 gr
100	298/89 gr	254/82gr	44/07 gr
200	300/12 gr	255/93gr	44/19 gr
The last dish	261/10 gr	208/91gr	52/19gr

The modulus of softness is a single number obtained from the results of a sand granulation test and is equal to the sum of the cumulative percentages remaining on sieve No. 100 and its sieves above, divided by one hundred and indicating the average size of the sand grains. Low modulus of softness indicates fine-grained sand and high modulus of softness indicates coarse grain [10-12]. ASTM C33 stipulates that the modulus of softness of the sand used to make concrete should be between 1.3 and 3.2.

2.5. Rice Husk Ash and Microsilica

The ash characteristics of rice paddy husk consumption are given in ***Table 4***. There is also a picture of rice paddy husk ash in ***Figure 1*** and consumed microsilica in ***Figure 2***.

Table 4. Characteristics of rice paddy husk ash.

Powder	Structure
Brown	Color
2/30 gr/cm^3	Density
12 % or 15 % of weight of cement used	Optimal consumption rate

Microsilica is a by-product of electric furnaces of the type immersed in the production of silicon or silicon alloys, especially ferrosilicon alloys. Microsilica particles are usually spherical in shape with an average diameter of about 0.1 to 0.2 microns in a non-crystalline state. Its silica content is 85% to 95%, which depends on the type of product and the silica plant. The main purpose of using microsilica was initially to replace part of the cement with these wastes to reduce the cost of cement consumption, but today with the increase in the price of microsilica in most countries, the above application is no longer cost-effective, so microsilica as an alternative It becomes part of the cement, is added to the concrete mix to obtain the required properties.

The microsilica used in this research is produced by Iranian ferrosilicon factories which has a specific mass of 2.2 g/cm3 and a blain surface of 2.20 m2/gr. Its chemical test is presented in ***Table 5*** and the characteristics of microsilica are presented in ***Table 6***.

Table 5. Chemical properties of microsilica used in this dissertation.

Chemical compounds	Microsilica
SiO_2	94.77
Fe_2O_3	0.87
Al_2O_3	1.32
CaO	0.49
MgO	0.97
Na_2O	0.37
K_2O	1.01
P_2O	0.16
SO_3	0.1

Table 6. Specifications of consumed microsilica.

Spherical and non-crystalline	Structure
Whiteish gray	Color
2/12gr/cm^3	Density
7	PH
12 %by weight of cement	Consumption rate
0.05 to 0.15 of Micron	Grading
11% by weight of cement	Micron

Figure 1. Consumption microsilica.

Figure 2. Ashes of rice paddy husk used.

2.6. Garbage from the Stone Cutting Factory

After being transferred to the laboratory, the rubble of the stone cutting factory was separated by large parts and fragments, and also the pieces smaller than 25 mm were separated and sieved by sieving on a one-inch sieve. Recycled aggregates are to be replaced by percentages of sand in concrete in several different mixing schemes according to a pre-determined schedule. Therefore, it is necessary to obtain the grain size of the aggregates according to ***Table 7***.

Table 7. Grading table of recycled aggregates.

Alec number	Full weight	Empty weight	Net weight
$1\frac{1}{2}$	384.52	384.52	0
1	517/16	471.47	45.69/42
$\frac{3}{4}$	1214/98	445	769/98
$\frac{1}{2}$	613/14	462.02	151/12
$\frac{3}{8}$	498/86	408.85	90/43
4	465/12	445.13	19/99
The last dish	300/14	208.85	91/29

3. Mixing Plan

According to the predetermined plan, a mixing plan for the primary concrete (control sample) must first be considered. ***Table 8*** shows the mixing scheme of the control sample.

Concrete strength	Color	Cement	Sand	gravel
250 Kg/cm^2	178 kg/m^3	350kg/m^3	820kg/m^3	1140kg/m^3

It is necessary to explain that the values mentioned in ***Table 8*** are considered for one cubic meter of concrete and for the desired volume percentage in this experiment, a ratio of it should be considered. ***Figure 3*** shows a sample of the control mixing scheme.

Figure 3. Construction of a control sample.

After making the control sample, in this step we seek to obtain the ideal percentage of rice husk ash or microsilica. In different samples, one with 12% and the other with 15% cement substitute, two different concrete samples have been made for rice husk ash and also to obtain the ideal percentage. ***Table 9*** shows the mixing scheme of samples containing rice husk ash and microsilica. It should be noted that due to the addition of ash or microsilica to the design, a percentage of lubricant should be added to the designs.

Table 9. Concrete mixing plan containing rice husk ash or microsilica.

No.	Water kg/m^3	Lubricant kg/m^3	Ash or microsilica kg/m^3	Cement kg/m^3	Sand kg/m^3	Gravel kg/m^3
12%	175.33	2.67	42	308	820	1140
15%	175.33	2.67	52.5	297.5	820	1140

It is necessary to explain that the values mentioned in ***Table 9*** are considered for one cubic meter of concrete and for the desired volume in this experiment, a ratio of it should be considered. ***Figure 4*** shows a sample of a mixture of rice husk ash and microsilica.

Figure 4. Sample construction with rice husk ash and microsilica.

After testing on samples containing rice husk ash and microsilica, the interpretation of which is mentioned in ***Table 10***, the sample with 12% rice husk has better strength and performance than other samples. Therefore, this ideal percentage of rice husk in this dissertation is 12, and as a result, its corresponding mixing plan will be considered for coarse-grained recycled concrete. In the following, two different mixing schemes are considered for concrete with 12% rice husk and recycled aggregate, the first containing 30% and the second design containing 40% recycled aggregate replacing sand. The purpose of selecting the ideal mixing plan for concrete is two different types of recycled aggregate percentage based on laboratory results for concrete containing rice husk.

Table 10. Mean compressive strength of samples containing rice husk and microsilica.

Title	7 day Kg/cm^2	28 day Kg/cm^2
12 % ash	209	353
15 % ash	189	263
12 % microsilica	216	310
15 % microsilica	205	256

Figure 5. An example of concrete with rice husk ash containing recycled aggregate.

Table 11 shows the mixing scheme of samples containing rice husk ash with two different percentages of recycled aggregates.

Table 11. Concrete mixing plan containing rice husk ash and recycled sand aggregate.

Recycled aggregate samples	Water kg/m^3	Lubricant kg/m^3	Ash kg/m^3	Cement kg/m^3	Sand kg/m^3	Gravel kg/m^3	Recycled aggregate kg/m^3
30%	175.33	2.67	42	308	820	797	342
40 %	175.33	2.67	42	308	820	684	456

The ultimate goal of this study, after idealizing the control sample with rice husk ash, is to investigate the appropriate percentage of replacing recycled aggregates in quarrying plants with sand. Then, by presenting the laboratory results, the best percentage of recycled aggregate will be presented.

4. Slump Test

According to ACI116-R90, performance is a property of freshly mixed concrete or mortar that determines the ease and uniformity of mixing, pouring, compacting or polishing its surface. According to the ASTM C125 standard of performance, the properties determine the work required to move freshly mixed concrete with minimal reduction in its uniformity.

To perform the slump test, fresh concrete is poured into three layers inside the slump cone and each layer is pounded 25 times using egg so that the height of each layer after compaction is approximately one third of the height of the formwork and if after compacting the upper layer of concrete surface it should be placed below the edges of the mold, pour some concrete on it again and smooth the surface with a rod by rolling movements. The lifting operation of the formwork should be performed in approximately five seconds with a continuous upward motion without applying lateral or rotational motion to the formwork or concrete. ***Table 12*** shows the results of the slump test.

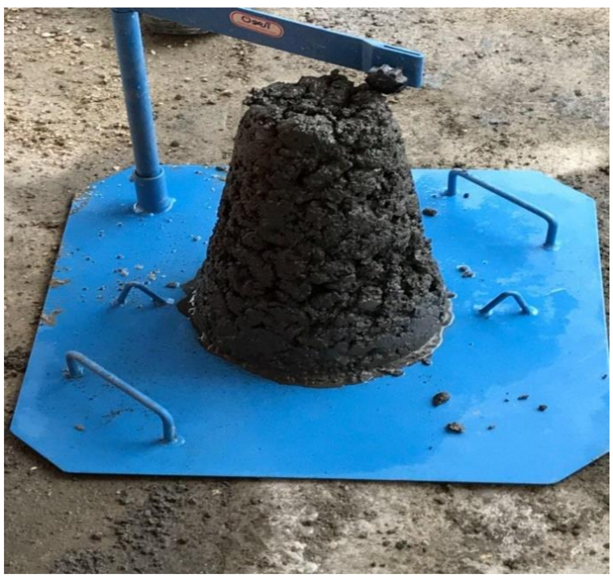

Figure 6. Performing a slump test.

Table 12. Slump test.

40 %recycled aggregates and rice husk ash	30 %recycled aggregates and rice husk ash	The experiment
10	9	Islamp

As can be seen in ***Table 12***, the results of the slump test are in the range of 7 to 10 cm, which is acceptable considering the grade of cement and the ratios of water to cement used.

5. Hardened Concrete Tests

5.1. Compressive Strength Test

The samples are taken out of the pool before the test and their surface is dried. The tested cubic specimens are then placed between the two plates of the device in such a way that the surface of the specimen is in contact with the cubic mold (***Figure 7***), and a vertical force is applied to the cubic specimen by the device at a constant speed. The compressive force is broken and the maximum applied load is recorded at the time of rupture, and by dividing this force by the surface of the cube, the compressive strength of the sample is obtained. ***Table 13*** shows the average compressive strength of the samples.

$$\sigma = \frac{P}{A}. \qquad (1)$$

σ = Compressive stress

P= Load applied to the sample

A = The area of a cube face

Figure 7. Performing compressive strength test of concrete.

Table 13. Average compressive strength of samples.

Title	7 days (Kg/Cm^2)	28 days(Kg/Cm^2)
30 % recycled aggregate	201	253
40 % recycled aggregate	206	282

According to ***Table 13***, it can be seen that in both 7-day average strength and 28-day average strength, concrete with an ideal percentage of rice husk containing 40% recycled aggregate results are not much better, for example containing 30% recycled aggregate.

5.2. Tensile Strength Test

The tensile strength test is performed by halving the cylindrical specimen in such a way that a compressive force is applied uniformly from the lateral surface of the cylinder to the specimen placed horizontally between the two plates of the test apparatus until rupture occurs along the specimen and the maximum applied load is recorded at rupture. This experiment was performed at the age of 7 and 28 days on two cylindrical specimens with a diameter of 15 and a height of 30 cm in accordance with the C496 ASTM standard (28). The amount of tensile stress is obtained from 2 relations. ***Table 14*** shows the tensile strength of the specimens.

$$F = \frac{2P}{\Pi \cdot L.D}. \qquad (2)$$

D: Diameter (cm).

L: Sample length (cm).

P: load applied to the sample (kg).

F: Tensile strength halved (kg / cm^2).

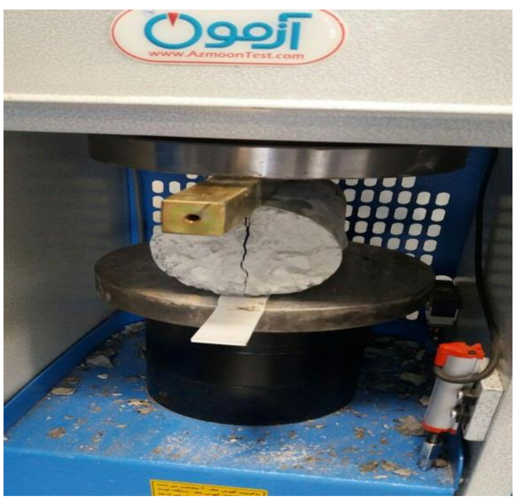

Figure 8. Performing compressive strength test of concrete.

Table 14. Tensile strength of samples.

Tensile strength in kg / cm^2	
Title	28 days
30 %	37
40 %	43

According to the tensile strength test, ***Table 14***, which shows the test result, shows that the tensile strength is 40% more than 30%.

5.3. Modulus of Elasticity Test

Another important test in determining the mechanical properties of hardened concrete is the modulus of elasticity test. To perform this test, the strain of a cylindrical specimen is determined by different forces by installing a high-precision strain gauge on cylindrical specimens with a diameter of 15 and a height of 30 cm and placing the specimen vertically between the loading plates. According to ASTM 469 C, modulus of elasticity is defined as the ratio of stress to strain values for hardened concrete at any age and under any processing conditions. The modulus values obtained in this way are usually less than the modulus values obtained under the application of fast loads such as dynamic loads. This experiment was performed on two samples for each mixing scheme at the age of 28 days.

The results of the static modulus of elasticity test are shown in ***Figures 9*** and ***10***. The modulus of elasticity of concrete increases with the change and increase of strength, and since the modulus of elasticity of concrete is affected by the modulus of elasticity of its components, including aggregates, so the modulus of elasticity increases with the change of aggregate material with decreasing porosity. Cement paste is associated with an increase in compressive strength, obviously, the higher the strength, the more brittle the concrete will be.

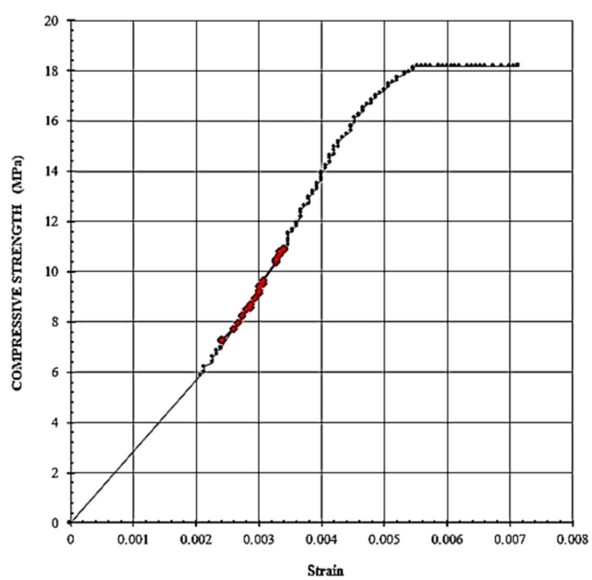

Figure 9. Elastic modulus of 30% recycled aggregate.

Figure 9 shows the modulus of elasticity of a concrete design containing 12% of rice husk ash and 30% of recycled aggregate, which shows that its modulus of elasticity is 18.53 MPa.

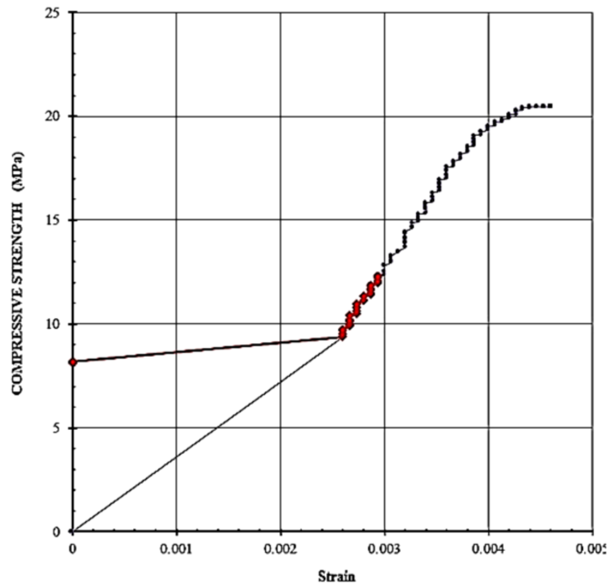

Figure. 10. Elastic modulus of 40 %recycled aggregate.

Figure 10 shows the modulus of elasticity of the two-concrete design containing 12% of rice husk ash and 40% of recycled aggregate, which shows that the modulus of elasticity is 20.36 MPa.

6. Conclusions

According to the results obtained in this experiment, the best percentage of mixing between rice husk and microsilica is related to rice husk ash, by replacing 12% by weight of ash instead of cement. The results of slump test are in the range of 7 to 10 cm, which is acceptable according to the grade of cement and water to cement ratios used. In addition, slump 40% of concrete containing recycled aggregate and rice husk ash. It is more than 40%. The average 7-day compressive strength of concrete containing 40% of recycled aggregate and rice husk ash is 206 and the average of 30% is 201, which indicates that the sample is more than 40%.

The average compressive strength of 28 days of concrete containing 40% of recycled aggregate and rice husk ash is 282 and the average of 30% is 253, which indicates that the sample is more than 40%. The 28-day tensile strength of concrete contains 40% of recycled aggregate and rice husk ash is 43 and the average of 30% is 37, which indicates that the tensile strength of the sample is 40%. The average modulus of elastic concrete containing 30% of recycled aggregate and rice husk ash is 18.53 and the average modulus of elasticity of concrete containing 40% of recycled aggregate and ash of rice husk is 20.36, which indicates that the elastic modulus of the sample is higher. It is 40%.

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