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Investigating the Curing Conditions on the Mechanical Properties of Concrete Containing Brick Waste

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Abstract:-Today, the increase in construction has caused a shortage of building materials all over the world. On the other hand, the need to remove construction debris, environmental protection, optimal use of resources and recycled materials, and economic construction have made it possible to propose recycled materials as a suitable alternative source. Among the different recycled materials, we can mention recycled brick waste. In this study, concrete samples containing recycled brick waste were processed in 6 different conditions, then the samples were subjected to compressive strength, tensile strength and impact strength tests and their performance was evaluated.

The results show that the samples made with waste bricks with different replacement percentages with coarse-grained materials gain their compressive strength and tensile strength in the conditions of 3 days wet curing and the concrete samples made with waste bricks and replaced with materials Fine grain, they get their compressive strength and tensile strength in wet curing conditions of 7 days. Also, the results showed that the compressive strength and the tensile strength of waste bricks are decreasing.

The impact resistance of concrete with different percentages of replacing coarse-grained materials in the laboratory environment (dry curing conditions) showed better performance than other curing systems. Concrete samples with different percentages of replacement of waste bricks with fine grains showed higher impact resistance in fully wet conditions than other curing systems. The impact resistance with the presence of recycled brick has decreased in most cases compared to the control concrete.

Keywords: *Environment, Recycled Brick Waste, Concrete, Compressive Strength, Tensile Strength, Impact Strength.*

1. Introduction

Nowadays, the use of recycled concrete has become one of the most important issues in the field of construction, and the economy pays great attention to the use of concrete with recycled grains. In recent years, many studies and researches have been conducted in the field of using waste materials in concrete. In general, the wastes used in concrete are divided into two groups, there are a group of wastes that have pozzolanic properties and replace some of the cement materials in concrete and the other group is the wastes that play the role of filling and replace the aggregates in concrete. Every year, millions of tons of rubble are used to produce sand. Now, if this high volume of stone materials could be recovered from the past materials, the sand mines would not decrease rapidly. Therefore, the use of bricks from worn structures to make concrete with recycled granulation may not be able to completely help in keeping reserves and natural resources, but it can help to avoid wasting a large amount of these God-given resources.

Also, the use of recycled concrete containing brick waste will help to prevent the destruction of the environment. In his study, Cachim evaluated the mechanical properties of concrete containing crushed bricks replaced with coarse grains. The used recycled aggregates were of two types of bricks, the compressive strength of the bricks before crushing was equal to 1.7 MPa for type A brick and 2.55 MPa for type B brick. The results of the research showed that the compressive strength of the samples containing type B bricks at all curing ages was higher compared to the samples containing type A bricks, and the replacement of part of the coarse grain with type B bricks reduced the compressive strength compared to the control concrete does not show. The results of the compressive strength of samples containing 50% coarse-grained replacement waste brick were almost the same compared to the control concrete. But by replacing 100% of waste bricks with coarse grains, the compressive and tensile strength of concrete decreases. After the curing time of 90 days, the samples containing waste brick showed more resistance than the control concrete[1].

In another study, researchers investigated the mechanical properties of concrete containing recycled concrete aggregate (RCA) and crushed clay brick (CCB) as coarse aggregate substitutes.

They observed that with the replacement amount of CCB=20%, the compressive strength of the manufactured concrete decreased by about 8% at the age of 7 days and 11% at the age of 28 days, and with the replacement amount of CCB=50%, the reduction of the compressive strength of recycled concrete was higher. And the compressive strength decreased about 14% at the age of 7 days and 20% at the age of 28 days. Also, the tensile strength of cylindrical samples decreased with the increase of RCA and CCB substitution in the composition[2].

In another study, the researchers used different proportions of recycled bricks as a substitute for coarse grain to investigate the permeability of recycled concrete containing fly ash and brick waste, and the samples were subjected to compressive strength tests and water absorption, water penetration, air penetration and chloride ion diffusion tests. They found that the use of recycled brick increases the permeability of the samples and increases the penetration of water, air and chloride ions. Due to the mixing and replacement of waste brick with coarse grain part, the strength of concrete also decreases. In addition to increasing porosity, recycled concrete containing clay brick waste increases the permeability of samples by forming a loose paste[3].

Past studies have shown that the type of processing has a significant effect on the properties of concrete containing recycled aggregates. In their study, Zhao et al. studied the effect of curing conditions on the properties of self-compacting concrete (SCC) and used six systems to cure samples (Three regimes were kept in water for 3, 7, and 14 days, and in the remaining three regimes, the samples were in continuous full water (FW) curing condition, continuous full standard (FS) curing condition and continuous full room (FR) curing condition).

The mechanical properties and durability of SCC such as carbonate depth, chloride ion diffusion coefficient of concrete were evaluated under different curing conditions. The results of their experiments showed that it is necessary to process the samples for 7 days in water for the occurrence of pozzolanic activities of the samples. Concrete subjected to FR processing conditions shows higher compressive and bending strength and carbonate depth and lower chlorine ion diffusion coefficient than concretes subjected to FS and FW processing conditions[4].

Researchers in a study investigated the performance of different curing conditions on the strength and permeability of concrete. The results of their tests showed that the compressive strength of samples treated in water for 3 and 7 days is higher than the compressive strength of samples treated in water for 28 days and this is due to the removal of moisture from the inner layer of cement gel[5].

Researchers investigated the effect of curing conditions on the performance and durability of concrete made with plastic waste. In this research, plastic-polyethylene terephthalate (PET) particles were used in proportions of 0, 7.5, and 15 percent by weight and replaced with sand particles in the concrete mixture, and the effects of fine and coarse particles were investigated separately. Factory concrete samples were placed in the curing systems of open environment, laboratory environment and humid chamber. Shrinkage, water absorption by immersion, water absorption by capillary action, carbonation and chloride penetration tests were performed on the samples. The results of their tests showed a reduction in the properties of concrete made with plastic particles in terms of durability compared to conventional concrete. All samples did not perform well in dry curing conditions. They found that under dry curing conditions, the performance reduction of concrete containing plastic waste is less compared to normal concrete[6].

In a similar study, researchers used three types of plastic waste in ratios of 0, 7.5, and 15 percent by weight and replaced with sand particles in the concrete mixture, and the effect of processing conditions (laboratory conditions, humid chamber, and outdoor environment). They investigated the mechanical performance of concrete. They found that by increasing the proportion of plastic waste and increasing their size, the compressive and tensile strengths of concrete decrease and this decrease increases with the w/c ratio of the mixtures. However, the wear resistance is improved. Drier curing conditions produced higher compressive strength at younger ages, while the wettest regimes did the same in the medium/long term, and the regime with the highest relative humidity resulted in higher modulus of elasticity than other curing conditions[7]. Therefore, to know the properties and performance of concrete, the environmental conditions governing them should be further investigated. Further research has been carried out and in order to resolve some existing ambiguities, in this research the effect of 6 curing systems on concrete containing brick waste has been studied and compressive strength, tensile strength and impact resistance tests have been performed on the samples.

2. Materials and mixing method

2.1. Water

In order to make test samples in this study, drinking water from Lahijan city was used, which was suitable for making concrete due to the quality of drinking water.

2.2. Cement

The cement used in this study was Portland Type 2 produced by the Dillman Cement Factory in Gilan. The specific weight of the cement used is 3.15 gr/cm³ and the specific surface area is 3020 cm2/gr. The chemical composition of this cement is given in Table 1.

Table 1: Chemical characteristics of type 2 Portland cement

Iran'sstandard test results	ISIRI389 Iranian standard	Chemical composition
22.45	>20	SiO_2
4.85	<6	Al_2O_3
3.55	<6	Fe_2O_3
-	-	CaO
0.85	<5	MgO
1.25	<3	SO_3
-	1 -0.5	K_2O
-	0.4 -0.2	Na_2O
0.9	<3	L.O.I
-	-	Free CaO
0.4	<0.75	I.R
3020	>2800	Blaine (cm2/gr)
312		3 days
507	>175	7 days
739	>315	28 days

2.3. Gravel

The gravel used in this study is the broken material of Sefidroud riverbed, with a maximum size of 19 mm, a specific weight of 2650 kg/m³, and a water absorption percentage of 1.01. The sieve analysis test of the used gravel was done according to the ASTM C33 standard, and its grading curve is shown in Figure 1.

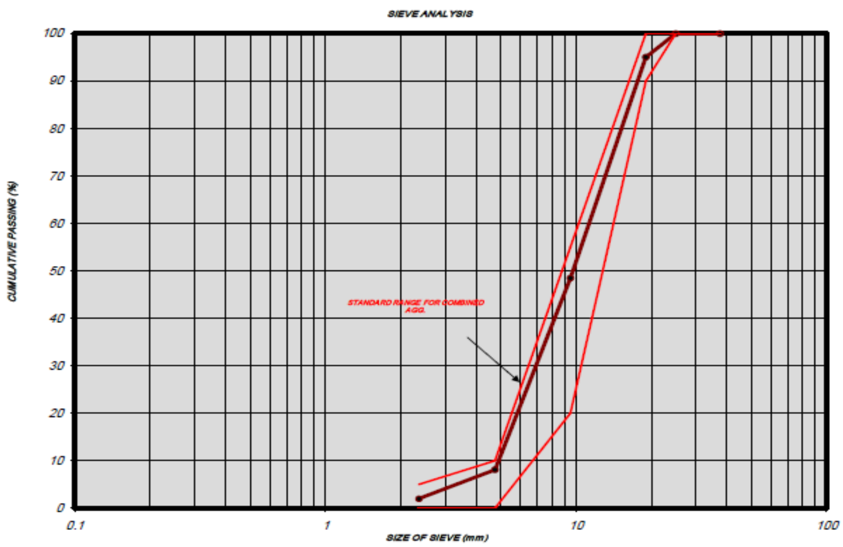


Figure 1: Grading curve of used gravel

2.4. Sand

The sand of the Sefidroud River bed with a modulus of elasticity of 2.84 according to the ASTM C-125 standard was used to make the test samples. Its apparent specific weight was equal to 2600 kg/m3 and its water absorption percentage was 2.31. The grading curve of the used sand based on the ASTM C33 standard is shown in Figure 2.

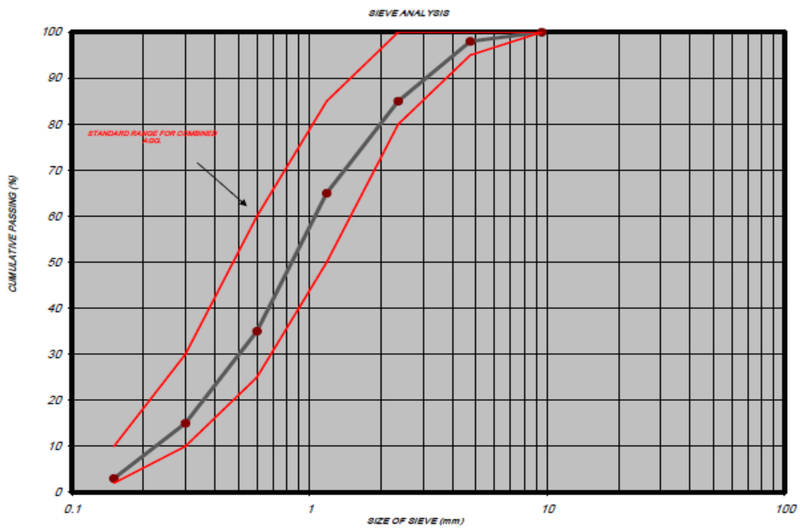
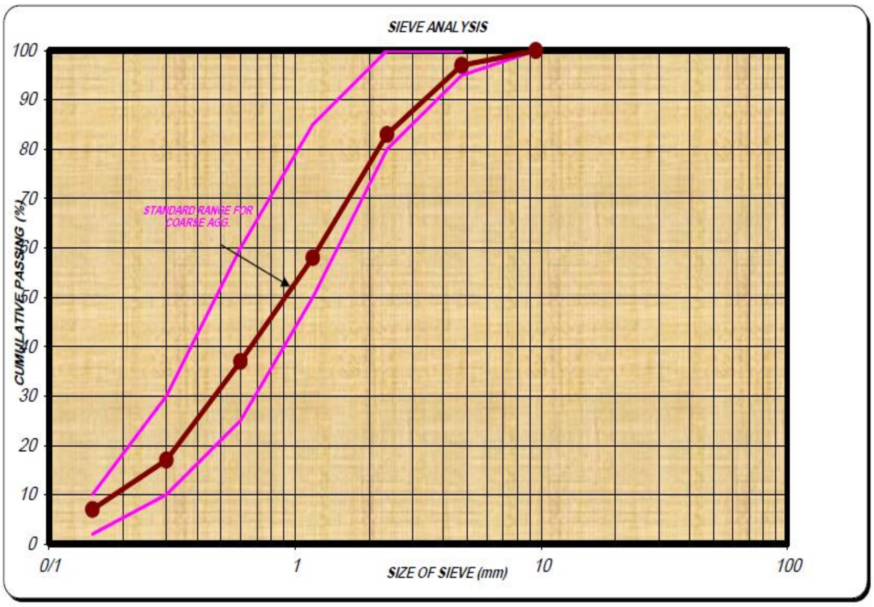


Figure 2: Grading curve of used sand

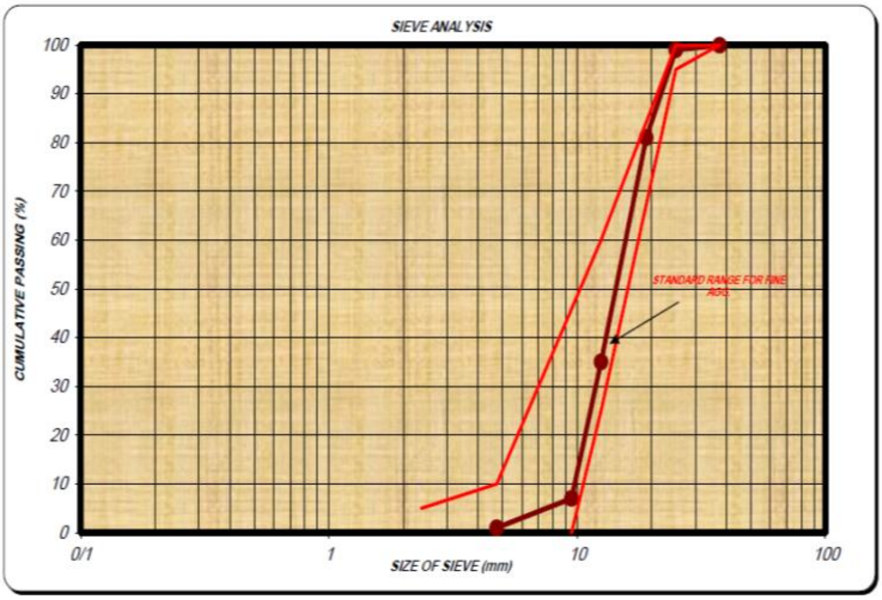
2.5. Waste brick

In this research, construction brick waste was used as a substitute for part of fine and coarse grains in concrete. After preparing used bricks from construction waste, in order to achieve the permitted range of fine and coarse grain size, it was crushed and in order to achieve the appropriate size (ASTM C-33 standard), the size modification was done on it.

Crushed waste brick is within the permitted range of ASTM C-33 for fine grain and for coarse grain with the largest diameter of 19 mm and water absorption of 28.2%. The specific weight is 1/2 (cm/m3) and the modulus of elasticity is 2/9. The grading curve of waste brick for fine and coarse grain is shown in Figure 3.



(a)



(b)

Figure 3: Grading curve of alternative waste brick a) fine grain, f) coarse grain

2.6. Mixing plan

Determining the proportions of concrete mixing is a step that can be used to achieve the appropriate combination of cement, stone materials, water and additives to make concrete with relevant specifications. The purpose of determining mixing ratios is to obtain concrete that meets performance requirements at the lowest cost. In order to evaluate the engineering properties of concrete containing waste brick and compare its performance, firstly, a sample of control concrete was made according to the ACI 211.1-81 standard, the mixing plan of which is shown in Table 2.

Table 2: Specifications of the control concrete mixing plan

Concrete characteristics	Gravel (kg/m3)	Sand (kg/m3)	Cement (kg/m3)	Water (kg/m3)	w/c
C	1000	840	400	160	0.4

In all mixtures, the ratio of water to cement was kept constant (0.4) and recycled bricks were used instead of stone materials. In order to investigate recycled concrete made with construction brick waste, 6 mixing designs with different amounts of brick chips with replacement percentages of 10 [10s], 20 [20s], 30 [30s] for sand and 30 [30G], 50 [50G], 70 [70G] was used for gravel. The samples were processed for 90 days in 6 different environments, which are: dry curing conditions [D], submerged in water [W], dry and unprotected curing [ND] and submerged in water until 3 [3W] and 7 [7W] and 14 [14W] days and then processed in a dry environment until the age of 90 days. The details of concrete curing and mixing plan are shown in Tables 3 and 4, respectively.

Table 3: curing details

Curing Description	Duration (In Days) and Place of Curing			
	Mold	Immersed in water	Laboratory environment (dry curing)	Outdoor environment (dry curing without protection)
ND	1	0	0	90
W	1	90	0	0
3W	1	3	87	0
7W	1	7	83	0
14W	1	14	76	0
D	1	0	90	0

Table 4: Mixing plan table

Concrete characteristics	Gravel (kg/m3)	Sand (kg/m3)	Cement (kg/m3)	Water (kg/m3)	w/c	Waste brick (kg/m3)
C	1000	840	400	160	0.4	0
S10	1000	756	400	160	0.4	55
S20	1000	672	400	160	0.4	110
S30	1000	588	400	160	0.4	164
G30	700	840	400	140	0.4	193
G50	500	840	400	160	0.4	321
G70	300	840	400	160	0.4	450

2.7. Mixing materials and molding samples

To make concrete, first, coarse grains (gravel) and fine grains (sand or waste) were poured into the mixer and mixed dry for one minute. In order to better absorb the water of the aggregates, about half of the water needed for the design is added to the mixture and we continue mixing for one minute. Then, the desired amount of cement is gradually added to the mixture until the cement and aggregates are well mixed, and in the last step, we add the rest of the design water to the mixture and then continue mixing.

After mixing the materials, we pour the concrete into the corresponding molds (cubic samples 15x15x15 cm to perform the compressive strength test and cylindrical samples 30x15 cm to perform the tensile strength test) and then compact it until Air out of it.

After pouring concrete into the mold and compacting it, the molds were placed in the laboratory environment for 24 hours. Then the samples were removed from the mold and examined in 6 curing systems (water temperature for samples immersed in water is 20 ± 2).

3. Test method

3.1. Impact test

In this experiment, a hammer with a mass of 4.54 kg from a height of 457 mm is alternately dropped on a hard steel ball with a diameter of 63.5 mm. To reduce the effect of restraint and friction between the bottom plate and the sample, the bottom plate is coated with grease. The standard samples for the impact test are cylindrical samples with dimensions of 15 x 30 cm, which are converted to 15.6 x 35 cm by cutting. The number of blows required to create the first crack on the surface of the sample is called the impact strength of the first crack (N1), and the number of blows required to create and spread the crack until the final rupture is called the final impact strength (N2). The values related to the initial and final rupture are determined in each sample. The impact test device is according to the regulations of the ACI-544 committee[8]. A view of the device is shown in Figure 4.

Figure 4: The device used to impact test

3.2. Compressive strength test

The compressive strength test was performed according to BS EN12390 standard on cubic samples of 15 x 15 x 15 cm[9] and for the test, the samples were placed on their flat sides (perpendicular to the direction of concreting inside the mold) in contact with the plates of concrete breaker jak. The compressive strength and tensile strength tests on the samples were repeated 3 times and finally the average of the samples was reported as the compressive and tensile strength.

3.3. Tensile strength test

This test includes applying a compressive force in the direction of the diameter and in the longitudinal direction of the cylindrical samples in which failure occurs. This loading leads to the creation of tensile stresses in the plane of application of the load and the creation of relatively high compressive stresses near the applied load.

To perform this test, a standard cylindrical sample of 30x15cm is placed horizontally along axis of the concrete breaker jack, and a metal rod along the axis of the cylinder above and a metal plate below the cylinder are used to evenly distribute the load and both sides of the cylindrical sample are restrained at the bottom. Then the load is continuously applied and the applied compressive stress causes a uniform tension in the perpendicular direction along the diameter and when the tensile strength of the sample is reached, the sample is split in half. The tensile strength of halving is obtained from the following relationship:

$$fct = 2p/\pi L D$$

In the above relationship, fct is the tensile stress, P is the breaking load, L is the length of the sample, and D is the diameter of the sample.

4. Results and discussion

The tests performed in two cases of fresh and hardened concrete were investigated. Testing of concrete in fresh state includes slump test and in hard state it includes tests of compressive strength, tensile strength and impact strength in different curing conditions.

4.1. Slump test

Slump test has been used in order to investigate the effect of using recycled brick debris instead of sand and gravel. In all designs, the ratio of water to cement is 0.4 and the only variable is the amount of sand or gravel. According to Table 5, by replacing recycled brick debris in concrete as a part of sand or gravel, the efficiency of the design increases compared to the control concrete.

Table 5: Slump values in different ratios of replacement of recycled brick debris

Sample	C	10S	20S	30S	30G	50G	70G
Slump (cm)	7.8	8.3	8.8	9.5	9	9.5	9.8

4.2. Compressive strength test

In Figure 5, the compressive strength of control concrete and waste brick concrete samples with different percentages of fine grain replacement and in different curing conditions and at the age of 90 days are shown. According to the figure, the presence of bricks in most samples has reduced the compressive strength of concrete.

Figure 5: 90-day compressive strength of samples in different percentages of fine grain replacement and in different curing conditions

According to the figure, the process of gaining compressive strength in dry curing conditions for control concrete and waste concrete samples is slower in comparison with moist curing conditions. Hydration of cement is possible only in capillary cavities filled with water and in completely saturated conditions. In the samples stored in dry curing conditions, internal water loss occurs in concrete, this causes the water in the capillary pores to decrease, and as a result, cement hydration slows down, and finally, the compressive strength of concrete decreases. This result has also been mentioned in other researches[10, 11].

According to the figure, the strength of some samples containing bricks has increased in dry processing conditions, which is probably due to the internal processing of concrete samples containing waste bricks. Considering the effect of different processing conditions, the highest compressive strength is observed in the samples kept in humid conditions for 7 days. Similar results have been shown for self-compacting concrete in another study (outdoor conditions performed better compared to dry conditions)[4].

The compressive strength of control concrete samples and brick waste concrete with different percentages of coarse grain replacement and in different curing conditions and at the age of 90 days are shown in Figure 6.

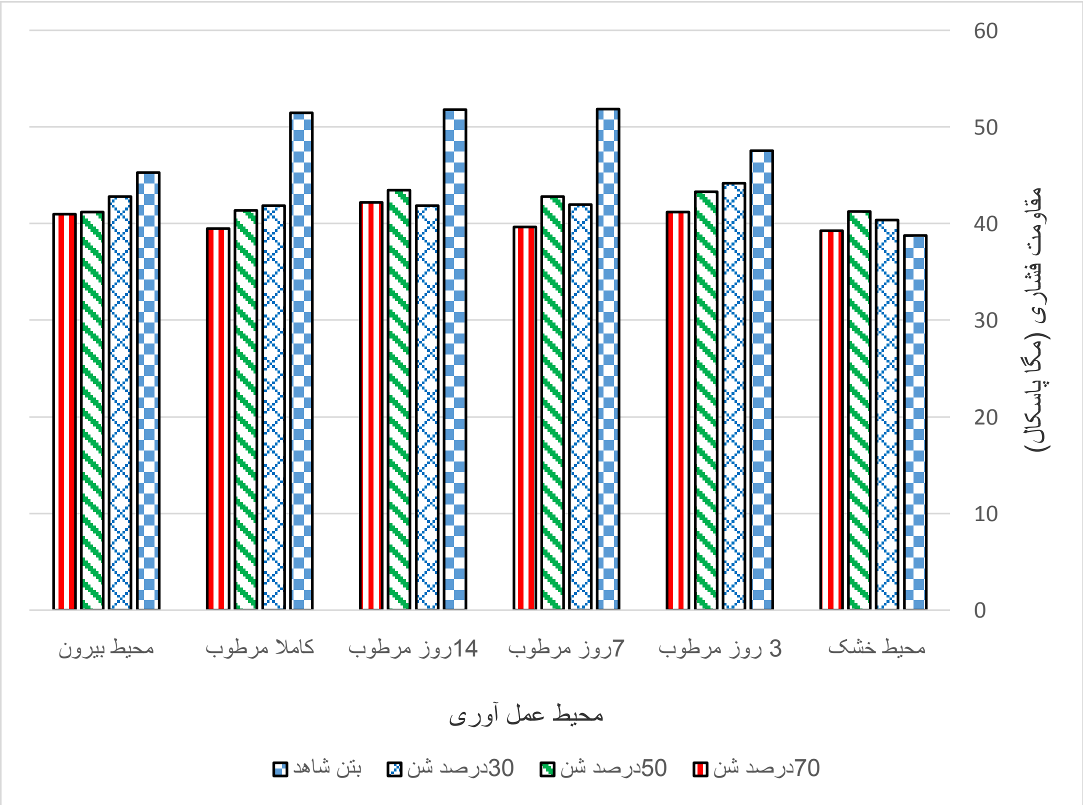


Figure 6: 90-day compressive strength of samples in different percentages of coarse grain replacement and in different curing conditions

The results show that the compressive strength of the samples increased by replacing aggregates with waste bricks and in three wet curing conditions, and no significant changes were observed after that. While the witness concrete after seven days, its compressive strength is almost close to each other. The reason for reducing the compressive strength of concrete by replacing waste brick with gravel can be attributed to the weakening of the bond between the cement paste and aggregates and due to the high porosity of the brick. This result has also been mentioned in other researches and they have stated that the reason for the decrease in resistance is the removal of moisture from the inner layer of the cement gel[5, 10, 11].

According to the figure, the curing conditions of the outdoor environment show better performance compared to the conditions of the dry curing. In addition, concrete samples with 70% replacement of gravel with waste bricks and in 14 days wet curing conditions show more resistance than other curing conditions.

4.3. Tensile strength test

In Figure 7, the tensile strength of control concrete and brick waste concrete samples with different percentages of fine grain replacement and in different curing conditions are shown. In general, it can be said that the presence of bricks in concrete has reduced the tensile strength of concrete, and these results have also been mentioned in other researches[4, 10, 11].

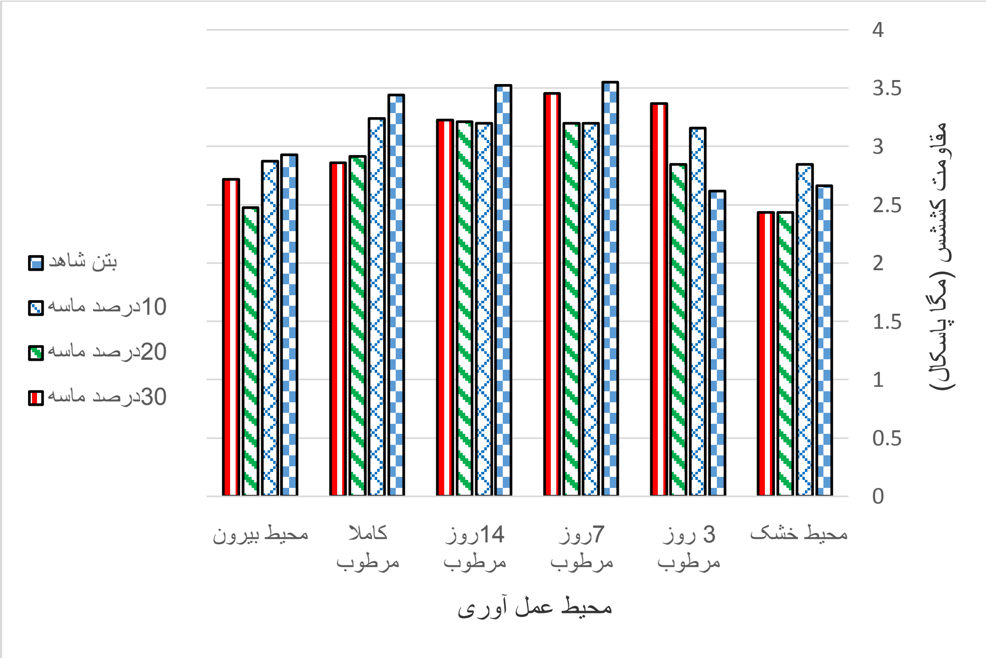


Figure 7: Tensile strength of 90 days of samples in different percentages of fine grain replacement and in different processing conditions

According to the figure, the tensile strength of the control concrete and waste concrete samples increased the most during seven days of processing. After that, not many changes are observed. In 7-day wet, 14-day wet and completely wet curing systems, the tensile strength of the witness concrete is higher compared to waste concrete. According to the shape, the curing conditions in the outdoor environment show better tensile strength results than the curing conditions in the dry curing.

The sample made with 10% replacement of fine-grained materials and in dry curing conditions showed higher tensile strength than other percentages, and the sample made with 30% replacement of fine-grained materials in wet curing conditions for 3 days showed higher tensile strength than others. It shows the percentages and the control sample. Taking into account the effect of curing conditions and in all replacement percentages, the highest resistance is observed in the cured samples in humid conditions of 7 days.

The tensile strength diagram of control concrete samples and brick waste concrete with different percentages of coarse grain replacement and in different curing conditions is shown in Figure 8.

According to the form of waste concrete containing bricks with different percentages of replacing coarse-grained materials, they gain their tensile strength within 3 days of processing, and after that the concrete strength does not show much change. But the witness concrete has obtained its tensile strength in wet conditions of 7 days. Similar results were observed by Tan, who stated that the reason for this was the removal of moisture from the inner layer of the cement gel[5].

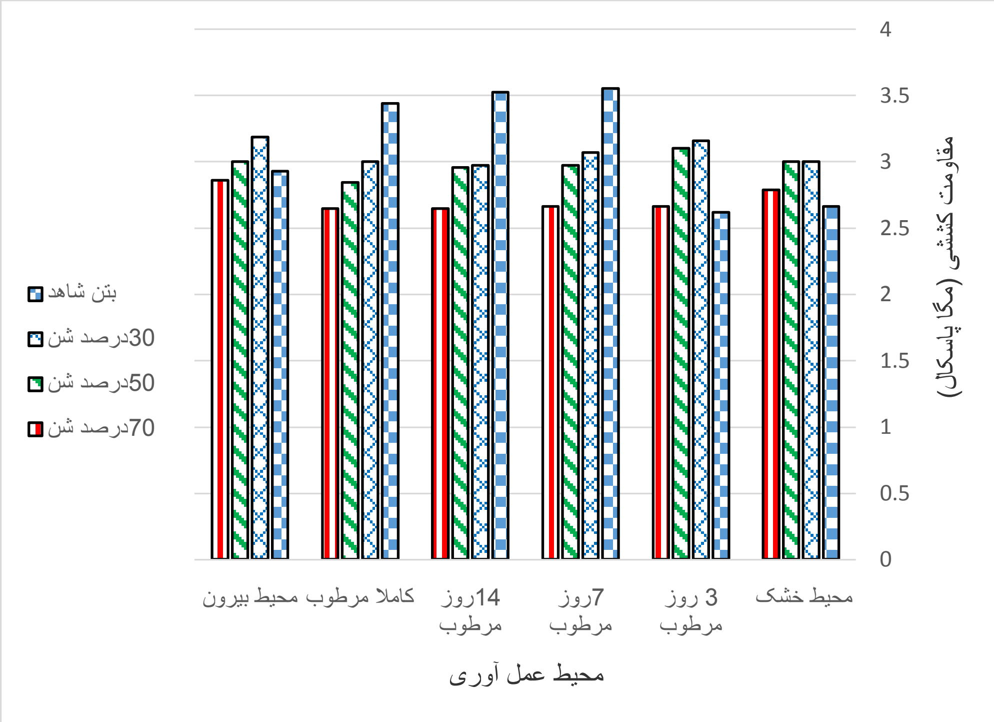
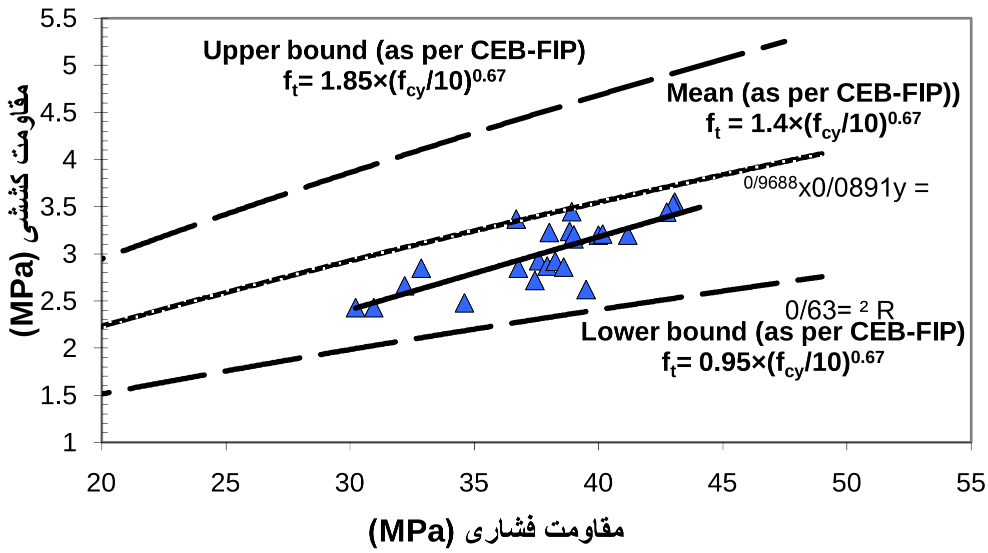


Figure 8: Tensile strength of 90 days of samples in different percentages of coarse grain replacement and in different curing conditions

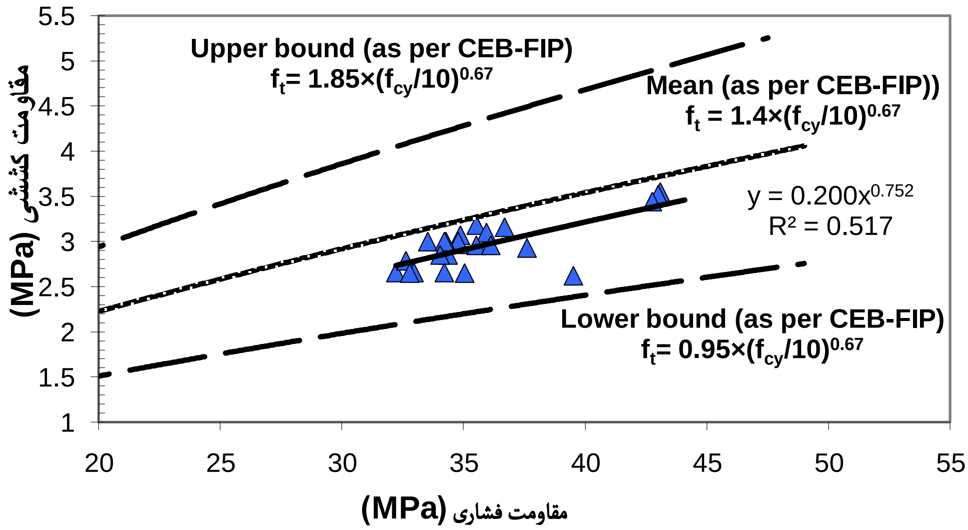
According to the figure, the curing conditions in the outdoor environment show better tensile strength results than the curing conditions in the dry environment. Also, the samples made in 70% replacement ratio and in the outdoor environment have obtained higher tensile strength than other curing conditions. Waste concrete containing bricks with the replacement of different percentages of fine grains, as well as control concrete, reach their compressive and tensile strength at the age of 7 days, and after that, the increase in compressive and tensile strength is not significant. While the waste concrete containing bricks by replacing different percentages of coarse grains reaches its compressive and tensile strength at the age of 3 days, and after that the process of increasing the compressive and tensile strength is not significant.

4.4. The relationship between tensile and compressive strength of concrete

Figure 9 shows the relationship between compressive strength and tensile strength of waste concrete replaced with fine and coarse grain according to CEB-FIP regulations [12].



(a)



(b)

Figure 9: Tensile-compressive strength diagram of concrete samples containing recycled brick debris replaced with a) fine grain b) coarse grain

In Figures 9, it can be seen that the numbers are within the range recommended by CEB, however, the numbers for the presented relationship were below the mean estimate.

4.5. Impact resistance test

4.5.1. Replacement of brick waste with fine aggregate

In Table 6, the values of the number of first crack and final crack blows for control concrete and waste concrete samples with 10, 20 and 30% replacement of fine-grained with bricks and in different curing conditions are shown, and the graph of final crack blows in different processing conditions is shown in Figure 10.

Table 6: Impact resistance results of concrete with fine-grained materials

curing type	Cracktype	Control	10%	20%	30%

		concrete	sand	sand	sand
Laboratory environment (dry curing)	N1	14	14	11	18
	N2	20	25	26	28
Immersed in water (3 days)	N1	44	36	31	30
	N2	50	41	35	33
Immersed in water (7 days)	N1	49	40	30	45
	N2	52	44	36	35
Immersed in water (14 days)	N1	51	38	41	39
	N2	55	43	45	44
Completely moist	N1	36	46	44	42
	N2	43	52	55	47
Outdoor environment (dry curing without protection)	N1	28	12	15	11
	N2	34	16	20	17

According to the figure, in the dry curing conditions, with the increase in the percentage of replacement of brick waste instead of fine-grained materials, the number of blows for breaking the concrete sample has increased and the impact resistance has also increased. In the condition of 14 wet days, the impact resistance of the control concrete sample is higher than the samples made of brick waste with different percentages.

Roughly, it can be said that the impact resistance of the sample with 20% recycled brick debris is equal to the samples with 30% replacement of recycled brick debris and in conditions of 3 days and 7 wet days.

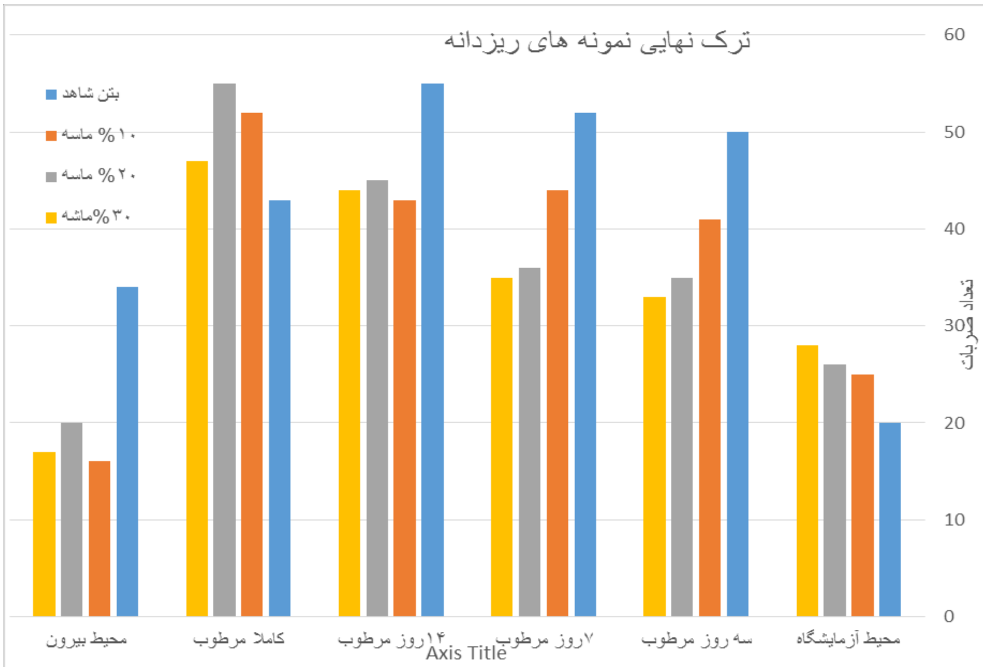


Figure 10: The graph of the number of final cracks (rupture) of concrete with fine-grained materials

By increasing the curing time of the samples in wet conditions, the impact resistance of the samples has also increased. So that in completely wet conditions, the number of samples breaking blows in all percentages of brick waste replacement is higher than the number of blows in other curing conditions and they show better impact resistance. While in the conditions of dry curing and without protection, the impact resistance reached its lowest value and the control concrete shows more resistance than other samples and with different replacement percentages.

The impact resistance of the control concrete in dry curing conditions is lower than the impact resistance of the witness concrete in a dry and unprotected environment. While the waste concrete samples in dry curing conditions show more resistance than the samples processed in a dry and unprotected environment. Figure 11 shows the waste concrete samples with 10, 20 and 30% replacement of bricks with fine grains in the impact test.

Figure 11: Waste concrete samples in different percentages of replacing bricks with fine grains a) control concrete b) 10%, b) 20% and c) 30%

4.5.2. Replacement of brick waste with coarse grains

In Table 7, the values of the number of first crack and final crack for control concrete and waste concrete samples with 30, 50 and 70% replacement of coarse-grained with bricks and in different curing conditions are shown and the graph of final crack blows in different curing conditions is shown in Figure 12.

Table 7: Impact resistance results of concrete with coarse aggregates

curing type	Cracktype	Control concrete	30% gravel	50% gravel	70% gravel
Laboratory environment (dry curing)	N1	14	43	42	35
	N2	20	54	50	39
Immersed in water (3 days)	N1	44	42	40	38
	N2	50	47	45	43
Immersed in water (7 days)	N1	49	33	28	22
	N2	52	38	34	27
Immersed in water (14 days)	N1	51	33	28	28
	N2	55	35	34	31
Completely moist	N1	36	28	28	28
	N2	43	34	35	34
Outdoor environment (dry curing without protection)	N1	28	16	14	11
	N2	34	23	18	13

According to the figure, in the dry curing conditions, with the increase in the percentage of replacing recycled brick debris instead of fine-grained materials, the number of blows to break the concrete sample has decreased and the impact resistance has also decreased. In all curing conditions (except dry environment), the impact resistance of the control concrete is higher than the waste samples with different percentages of brick waste.

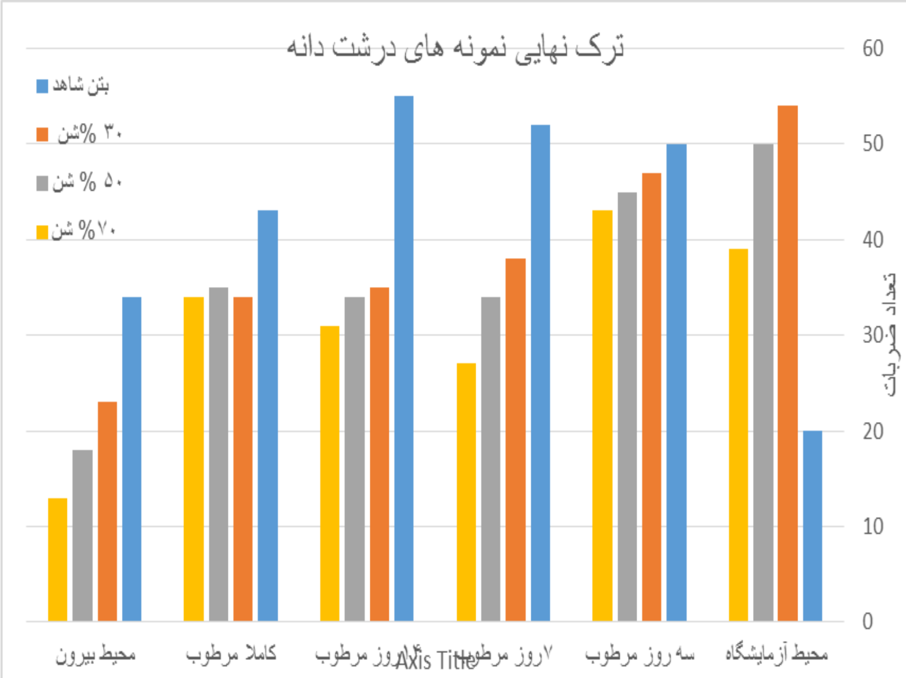


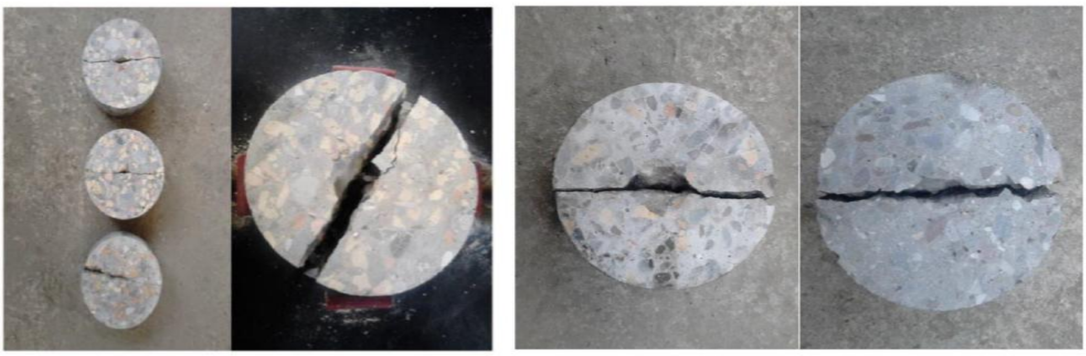
Figure 12: The graph of the number of final cracks (rupture) of concrete with coarse-grained materials

In water-immersed conditions, the number of breakages of the samples in the control concrete is higher than that of the waste concrete samples in different percentages, and the change in the replacement percentages of waste bricks does not show much change in the impact resistance of the concrete, and the concrete sample with the replacement of 50 The percentage of coarse-grained with brick waste has the best impact resistance.

In the dry and unprotected environment, the concrete has a higher impact resistance than waste concrete samples, and with the increase in the amount of brick waste instead of coarse-grained materials, the impact resistance decreases.

While in the dry environment, the waste concrete samples have better resistance than the control concrete and show more impact resistance than the curing conditions in the dry and unprotected environment. By increasing the curing time of the samples in wet conditions, the impact resistance of the samples also decreased.

Figure 13 shows waste concrete samples with 30, 50 and 70% replacement of coarse-grained with bricks in the impact test. According to the figure, the samples are cracked in one direction and then broken. It is expected that by placing the fibers in the concrete, the direction of the cracks will change and turn into microcracks.



د) نمونه ۷۰% شن   ج) نمونه ۵۰% شن   ب)نمونه ۳۰ % شن   الف) نمونه بتن شاهد

Figure 12: Waste concrete samples in different percentages of brick replacement with coarse grain a) control concrete b) 30%, b) 50% and c) 70%

The control concrete and the waste concrete containing bricks in different percentages of replacement with fine grains reach their ultimate impact strength in the conditions of curing immersed in water, while the control concrete and waste concrete containing bricks in different percentages of replacement with coarse grains, in conditions 3 wet days reaches its ultimate impact strength.

5. Conclusion

In this study, in order to evaluate the strength of recycled concrete containing brick waste, various tests such as impact strength, compressive strength and tensile strength were performed on concrete samples and the following results were obtained:

1- Recycled concrete containing brick waste and replaced with fine-grained materials has a better impact resistance than normal concrete in a dry curing environment, and in a fully wet curing environment, the impact resistance of the samples is higher than other curing systems.

2- In the fully wet curing environment, the number of blows to break the samples in all percentages of replacing brick waste with fine grains is more than the number of blows in other curing conditions, which indicates better impact resistance.

3- The impact resistance of control concrete in laboratory conditions (dry curing) is lower than the impact resistance of waste concrete containing brick waste replaced with coarse-grained materials and in other curing systems. But in the condition of 14 days immersed in water, the strength of the control concrete is higher than that of the waste concrete samples.

4- Waste concrete with different percentages of replacing brick waste with coarse-grained materials has better impact resistance in the laboratory environment than other curing systems.

5- The optimal combination for replacing brick waste with coarse-grained material (sand) is 30% suggested according to different curing conditions and impact test.

6- Optimum composition for replacing brick waste for fine-grained materials (sand) is 20% suggested according to different curing conditions and impact test.

7- Waste concrete with different percentages of brick slag replacement with fine-grained materials and control concrete reach their compressive and tensile strength after 7 days of immersion in water, and after that the process of increasing compressive and tensile strength is not significant.

8- The strength of concrete containing brick waste in different curing systems is almost similar to the strength of natural concrete and the reduction of its strength is insignificant.

9- Waste concrete with different percentages of brick slag replacement with coarse-grained materials reaches its compressive and tensile strength after 3 days of immersion in water, and after that the process of increasing compressive and tensile strength is not significant. While the control concrete reaches its strength after being immersed in water for 7 days.

10- In all the concretes made in this study, the outdoor curing conditions (dry and unprotected curing) show better compressive and tensile strength results than the curing conditions in the dry environment.

11- In the dry curing environment, the compressive and tensile strength of concrete containing brick waste and replaced with coarse-grained materials is better than the control concrete sample.

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