LABORATORY EVALUATION OF THE EFFECT OF RICE HUSK ASH AND CANE PULP (BAGASSE) ON MECHANICAL PROPERTIES OF SELF-COMPACTING CONCRETE

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Abstract

Self-compacting concrete (SCC) is an innovative concrete that has been able to improve the problems caused by shaking operations during compaction and concreting in reinforced thin sections compared to conventionally placed concrete. Common pozzolanic materials used in concrete include fly ash, iron smelting furnace slag, rice husk ash, silica fume, pumice, and volcanic tuffs. One of the synthetic pozzolanic materials used in concrete in recent years is bagasse. Bagasse is a substance obtained after extracting the sugarcane stalk extract. Rice husk ash (RHA) produced from the controlled combustion process has a very high pozzolanic property, and this phenomenon is due to the presence of a high percentage of amorphous silica inside the rice husk. This article aims to investigate the mechanical properties (efficiency, compressive strength, and permeability) of SCC containing different percentages of rice husk ash and bagasse according to the variables of concrete age. Also, L-Box, V-Funnel, and Slump tests were used to measure the filling ability, creep, and permeability of the manufactured concrete and confirm the mixing designs' self-compaction. Compressive strength, permeability, and specific, gravity tests were also performed on the self-compacting hardened concrete of the control and modified with ashes. The results indicate that the use of rice husk ash and bagasse increases the compressive strength and specific gravity and decreases the permeability of SCC.

Keywords: Self-reinforced concrete (SCC), Rice husk ash, Sugarcane bagasse ash, Compressive strength, Permeability, Slam.

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1-Introduction

Self-compacting concrete (SCC) is one of the types of high-performance concrete that has been around for two decades, and extensive research has been done on it in these two decades, and it has been used in many countries [1, 2]. With its special features and the use of super-lubricants and more powder and special mixing design, it has provided suitable facilities in the implementation of concrete structures due to its flowability and the problems of lack of proper compaction in places with a high density of rebars [3, 4]. For example, it fixes the joint of the beam and column [5]. Such concrete is compacted under the effect of its weight without the need for any vibrator and has high efficiency and many advantages in pre-making and pre-strengthening and reducing the cost of concrete installation. On the other hand, using agricultural waste materials in concrete can be extremely important for producing durable and high-strength concrete. This article aims to investigate the effect of rice husk ash and bagasse on the mechanical properties of SCC. SCC is an innovative concrete that has been able to improve the problems caused by shaking operations during compaction and concreting in thin reinforced sections compared to concrete placed traditionally [6]. This concrete can flow under the gravitational acceleration of the earth and is also able to fill the surface of the mold and achieve compaction without the need for vibration, and pass through the gaps between the reinforcements. Common pozzolanic materials used in concrete include fly ash, iron smelting furnace slag, rice husk ash, silica fume, pumice, and volcanic tuff [7]. One of the artificial pozzolanic materials used in concrete in recent years is bagasse. Bagasse is a substance obtained after extracting the sugarcane stalk extract. According to the latest information, the area of sugarcane cultivation in Iran is more than 20 thousand hectares , producing about two million tons per year. Rice husk is a major waste in the husked rice mill industry, which is produced in very high volumes. A low-level calculation to estimate the amount of rice husk produced per year in the world proves this claim. It is worth mentioning that in each husked rice grain, 23% of the weight is the husk and 77% of the weight is the rice grain. In the past, rice husk was considered a waste material and had no special use. Then it was used as a fuel due to its energy and high flammability, which is still valid today, the resulting ash had no use, and it was mainly poured into water streams, which is a problem in some countries. It continues to this day. This type of rice husk burning causes the formation of silica ash, whose color changes from gray to black depending on the inorganic impurities and the amount of carbon remaining in it [8]. Rice husk ash is used as filler in concrete. The use of rice husk ash and bagasse as a part of the cement used in concrete (especially SCC) saves money in the construction industry, and with proper implementation and optimal use of it, the resistance properties of concrete can be improved. Improves attention. In this article, an attempt will be made to investigate the mechanical properties (efficiency, compressive strength, and permeability) of SCC according to the variables of mixing design, cement grade, and concrete age [9].

2- Methodology

The rice husk ash used in this study was obtained from a rice factory in Gilan province. First, the rice husk was burned in the open air, then the resulting product is transferred to a special furnace with the ability to discharge CO2 for decarbonization and is placed at a temperature of 650 degrees Celsius. Then the rice husk ash is ground and passed through a 45-micrometer sieve [10].

Figure 1- Ash rice husk

To prepare ash, bagasse was obtained from one of the villages around the monastery and burned in a furnace at a temperature between 600 and 700 degrees Celsius. The color of the resulting ash is gray. Figure 2 shows the bagasse ash used in this research. The obtained bagasse ash has a specific density of 2.01[11]. The chemical composition of bagasse ash meets the requirements of ASTM C618-03 regarding fly ash for use in concrete because the total weight percentage of SiO_2, Al_2O_3, and Fe_2O_3 is more than 70% and its combustion loss is less than 6%. The consumer super lubricant is Poly Carboxylic-Ether type with a specific weight of 13.13 t/m and the number of solid particles is 40% [12].

Figure 2- Bagasse ash used in the research

In this research, L-Box, V-Funnel, and Slump tests were used to measure the filling ability, compaction, and permeability of the manufactured concrete and to confirm the self-compacting ness of the mixing designs. has been [13]. Table (1 and 2) shows the 'stone materials specifications. In the first stage, the samples were evaluated by the slump flow test and T500 in the slump flow, and if the filling ability is suitable, the second part of the tests, including V funnel and L box and V funnel tests at T5min which Other required parameters for SCC (in order of filling, possibility, separation resistance) have been evaluated. These tests were carried out on 7 control and modified SCC mixing plans with different percentages of rice husk ash and bagasse in Table (3) aTableeir average results are given in Table (4).

Table 1- Aggregation of aggregates used in project designs

Sieve size	Cumulative pass percentage (%)			
	ACI 302.1 R		ASTM C33	
	NM	SM	NM	SM
3/4 in	100	100	100	100
1/2 in	99.	99.	100	100
3/8 in	89.	89.	79.7	82.6
No.4	63.	60.	53.2	59.4
No.8	39.	43.	38.4	44.3
No.1	31.	31.	28.1	32.4
No.3	25.	23.	20.6	23.8
No.5	17.	15.	13.7	15.8
No.1	5.7	5.2	4.4	5
No.2	3	2.9	2.4	2.6
	4.2	4.3	5.6	5.34

Table 2- Specifications of different groups of aggregates consumed

Type	Chagali Dry (t/m^3)	Water absorption percentage (percent)	Saturation density (t/m^3)	A dry weight of the mill Eaten (kg/m3)	Modulus Throw
GO	2.52	1	2.54	1543	-
GB	2.5	1.15	2.53	1529	-
GC	2.48	1.3	2.52	1593	-
HIS	2.45	1.4	2.48	-	2.87
SB	2.58	1.6	2.51	-	2.55
Standard Number	ASTM C 127,128	ASTM C 127,128	ASTM C 127,128	ASTM C29	ASTM C136

Table 3- Specifications of the samples of the tested concrete

Mixing Plan	w/c	Water (kg)	Cement (kg)	Super lubricant(kg)	Ash (kg)	Ash rice husk (kg)	Sand (kg)	Waging(kg)
BE(SCC, witness.)	35/0	140	400	-	-	-	850	630
RA10% (SCC 10% ash rice husk)	35/0	140	360	6/5	-	40	850	630
RA20% (SCC 20% ash rice husk)	35/0	140	320	5	-	80	850	630
RA30% (SCC 30% ash rice husk)	36/0	140	280	25/4	-	120	850	630
RA30%+BA15% (SCCed 30% rice husk ash and 15% bagasse ash)	35/0	140	220	805/1	60	120	850	630

RA30%+BA25% (SCC 30% rice husk ash and 25% bagasse ash)	35/0	140	180	805/1	100	120	850	630
RA30%+BA35% (SCC 30% rice husk ash and 35% bagasse ash)	35/0	140	140	805/1	140	120	850	630

Table 4- Results of more concrete experiments mixing different designs

Mixing Plan	**L-shaped mold (height ratio)**	V-Funnel	**Increase the time of funnel V in 5 minutes (s)**	**Diameter of slip flow (mm)**	**Slip flow time up to 50 cm (s)**
BE	81/0	3/10	83/0+	630	43/2
RA10%	81/0	65/9	03/1+	660	65/2
RA20%	83/0	23/9	75/0+	665	58/2
RA30%	86/0	15/9	06/1+	680	51/2
RA30%+BA15%	88/0	87/8	91/0+	730	55/2
RA30%+BA25%	92/0	43/8	78/+	740	61/2
RA30%+BA35%	93/0	89/7	82/0+	760	67/2

According to the results of the slump flow diameter in graph (1), it is evident that in all the mixing designs, samples containing ash have more flowability than the control sample (without ash), which shows the significant effect of using ash on increasing efficiency. Self-compacting mortar, while maintaining its stability. It can also be concluded that by increasing rice husk ash and then adding bagasse ash to SCC containing rice husk ash, the efficiency increases [14]. The increase in mortar efficiency in the presence of rice husk ash and bagasse can be related to its structure and physical properties. Rice husk ash and bagasse have a lower specific weight than cement (about 25% less), as a result, the resulting cement paste has more cement materials. This increase in the volume of cement materials is accompanied by a decrease in dynamic viscosity, which ultimately improves the efficiency of concrete. As a result, the resulting materials are more easily spread and condensed. Also, the small particles in fly ash are absorbed by cement particles, which reduces friction and increases the efficiency of the mixture, and on the other hand, completely spherical particles of rice husk ash and bagasse do not get stuck in each other and in the cement grains, and as a result, they make the concrete greasy and slippery.

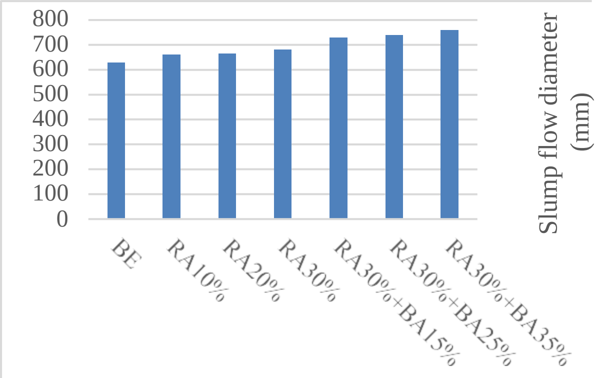

Diagram 1- Diameter of slip flow

As can be seen in graph (2), by adding ash, a decrease in the exit time is observed. The reason for this can be related to the reduction of instability caused by the increase of ash in mixing and the increase of adhesion between the components, in such a way that the reduction of instability causes the aggregate to not separate from the cement matrix and its settling in the opening of the nozzle of the V-shaped funnel and finally It reduces the time of exiting the mixture. Of course, in the present mixtures, despite this reduction in the exit time from the V-shaped funnel, the results are still within the permissible range.

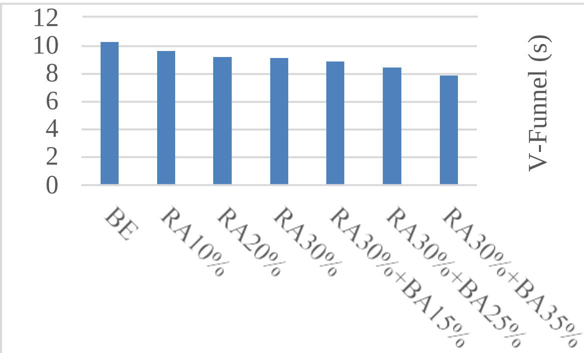

Diagram 2- Changes in the V-shaped funnel test

Carefully in the results of the L-shaped box in graph (3), it can be seen that the filling ability of concrete improves with the increase of ash.

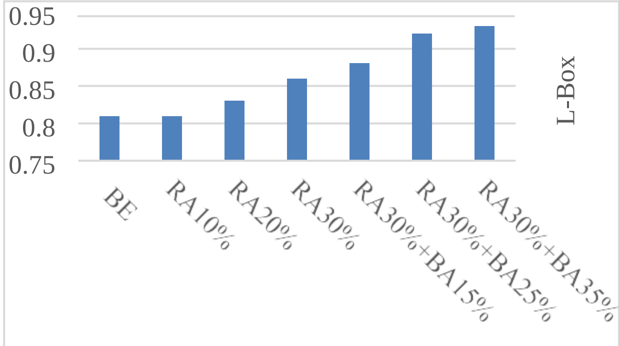

Diagram 3- Changes in L-shaped mold test

3- The results of hardened concrete tests

3-1- Compressive strength

The results of the effect of different percentages of rice husk ash and the combination of a fixed amount of rice husk ash (30%) with different percentages of bagasse ash on the compressive strength of SCC samples made at different ages (7, 28, and 42 days) in Table (2-4) It has been stated.

Table 5- Results of pressure resistance test

Age of concrete (day)	Compressive strength (kg/cm^2)						
	BA	RA10%	RA20%	RA30%	RA30%+BA15%	RA30%+BA25%	RA30%+BA45%
7	172	210	235	251	263	277	265

28	288	340	366	389	401	431	392
42	304	381	412	406	422	478	431

In Figure (4), the results of the effect of rice husk ash and bagasse on the strength of concrete samples aged 7, 28, and 42 days are shown in terms of kg/m3. Based on the results, in all percentages of ash used, the compressive strength of the modified SCC is higher than the control sample. That is, the addition of rice husk ash and the subsequent addition of bagasse ash to SCC containing rice husk ash to the samples has caused a significant increase in compressive strength. So that the highest percentage increase in strength with the addition of rice husk ash, for the SCC concrete sample containing a 30% cement weight ratio, with increasing percentages of 25%, 25%, and 29% for the ages of 7, 28, and 42 days, respectively. The highest percentage increase in concrete strength for the sample containing 30% by weight ratio of rice husk ash cement with the addition of bagasse ash, compared to the control sample, is also related to the sample with 25% bagasse ash by weight of cement with the amount of 34%, 34% and 38% for the ages of 7, 28 and 42 days were obtained. These results indicate the high pozzolanic activity of both ashes in improving the mechanical properties of SCC. By examining the results, it can be claimed that the best and most optimal SCC mixture for improving compressive strength is the addition of 30% by weight of rice husk ash cement and 25% of rice ash.

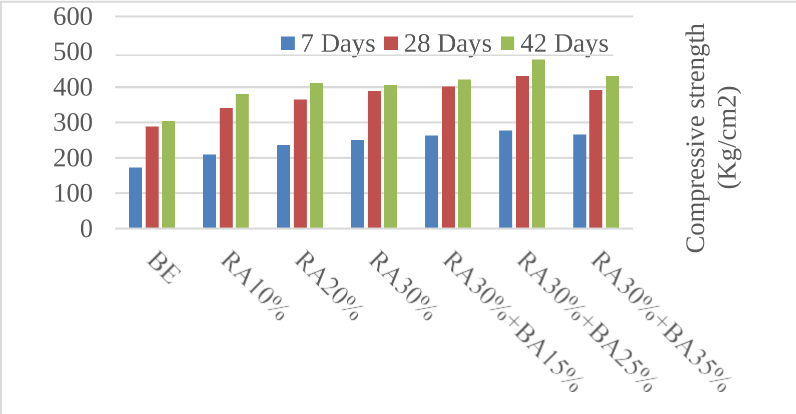

Diagram 4- Effect of ash on compressive strength at different ages

In Graph (5), the results of the effect of the curing age of SCC on the strength of samples with different percentages of rice husk ash and bagasse are shown. Assuming the compressive strength of 42 days as the final strength, it can be seen that the control SCC concrete has 58% and the SCC concretes containing 10, 20, and 30% rice husk ash have 55, 57, and 61% compressive strength, respectively. They earned their final at the age of 7 days. Therefore, it can be concluded that the use of rice husk ash in a larger amount in SCC concrete can speed up the process of obtaining the strength of these concretes at a young age. SCCs containing bagasse ash do not follow a specific trend in obtaining compressive strength at young ages, so for the mixture containing 15, 25, and 35%, this amount is 62, 57, and 61%, respectively.

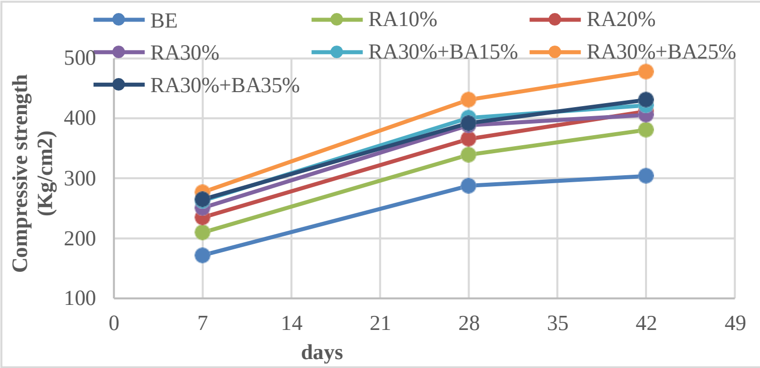

Diagram 5- The process of obtaining resistance in mixtures according to the age of concrete

3-2- Permeability test results

To check the amount of porosity and detect the extent of capillary holes in SCC, a water absorption test was done at the age of 7, 28, and 42 days. The water absorption values of the samples are shown in Table (6).

Table 6- The results of the permeability test

Age of concrete (day)	Permeability (mm)						
	BA	RA10%	RA20%	RA30%	RA30%+BA15%	RA30%+BA25%	RA30%+BA45%
7	70	45	41	34	29	24	23
28	69	32	31	27	21	18	17
42	58	29	20	19	17	16	16

In graph (6), the results of the effect of rice husk ash percentages and subsequently the effect of bagasse ash on SCC-containing rice husk ash on the permeability of SCC samples at different ages are shown. As can be seen from the results in this figure, the addition of rice husk ash and bagasse to SCC concrete causes a decrease in water absorption and permeability, and as a result, it provides a better and more favorable performance of concrete against the attack of external destructive factors and the like... Of course, the role of rice husk ash in reducing permeability is much greater than that of bagasse ash. Adding rice husk ash to the amount of 30% by weight of cement reduces water absorption by 52% (compared to control concrete) and adding 35% by weight of bagasse ash cement to SCC concrete containing 30% of rice husk ash reduces water absorption by 30%. These changes can be due to the significant effect of rice husk ash before adding bagasse ash. Also, by carefully looking at the bar chart below, we can understand that the rate of decrease in permeability increases with age.

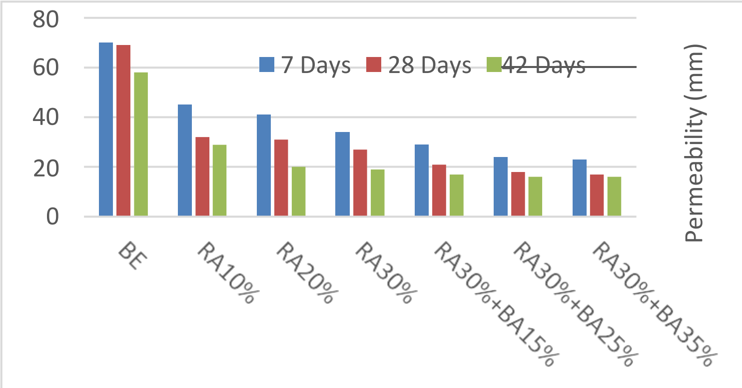

Diagram 6- Effect of ash on the permeability at different ages

Diagram (7) shows the effect of the curing age of SCC on the permeability of the seven samples. The decrease in permeability of SCC from 7-day to 42-day age is 18% and for SCC concrete containing 10, 20, and 30% rice husk ash, it is 36, 52, and 44%, respectively. Therefore, it can be concluded that the use of rice husk ash, in addition to reducing permeability, can help increase the rate of permeability reduction. Also, the rate of reduction of permeability in SCC containing bagasse ash from 7 days to 42 days old decreases with the increase of bagasse ash percentage, so for the mixture with 15, 25, and 35%, this rate is 42, 33, and 31, respectively. It is a percentage.

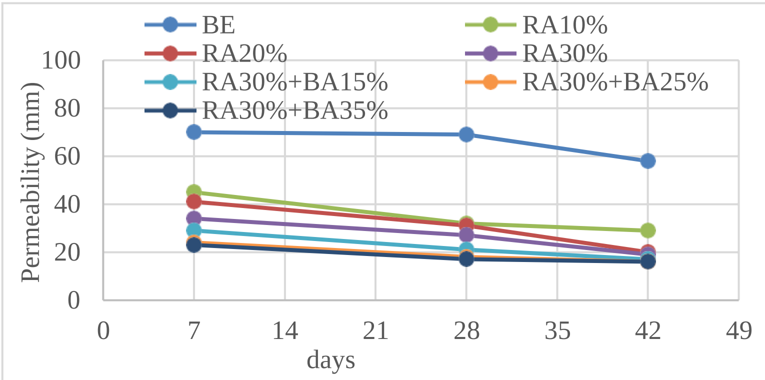

Diagram 7- The trend of permeability changes according to the age of concrete

Considering the use of water penetration depth as a qualitative evaluation of SCC, in which a depth of less than 50 mm is in the impervious category and a depth of less than 30 mm in the impervious category of SCC is under destructive conditions. All modified SCC samples at the age of 42 days and all SCC samples containing bagasse ash at the age of 28 and 7 days and the concrete sample with 30% rice husk ash at the age of 28 days, according to the depth of water penetration is less than 30 mm, in the impenetrable category under destructive conditions, and the rest of the samples, except for the control SCC, with a penetration depth of less than 50 mm are in the impenetrable concrete category.

3-3- Specific weight determination test

The results of the effect of rice husk ash and bagasse ash on the specific weight of SCC samples made at different ages are shown in Table (7). As the specific gravity values of the samples show, all the samples modified with the addition of rice husk ash and bagasse ash have higher specific gravity than the control sample. And in some cases, it has caused an increase in the specific weight of the samples, although it is insignificant.

Table 7- Test results for Specific weight

Age of concrete (day)	Specific weight (ton/m³)						
	BA	RA10%	RA20%	RA30%	RA30%+BA15%	RA30%+BA25%	RA30%+BA45%
7	2.37	2.4	2.41	2.43	2.44	2.47	2.45
28	2.37	2.4	2.42	2.43	2.44	2.48	2.45
42	2.37	2.4	2.42	2.44	2.44	2.49	2.46

Graph (8) shows the results of the effect of rice husk ash on the specific weight of SCC samples. From the results, it is clear that by increasing the percentage of rice husk ash up to 30% by weight of cement, due to its pozzolanic properties, the distance created between the stone materials is reduced, which causes the volume to decrease and the specific gravity to increase. The amount of weight gain is more noticeable at the age of 42 days. Carefully in the figure below, it can be seen that the addition of bagasse ash up to 25% of the weight of cement to the SCC mix containing 30% rice husk ash causes an increase and then a decrease in the specific weight of the concrete sample, as a result of the RA30%+BA25% mixture. The best value for improving the quality of samples is in this section.

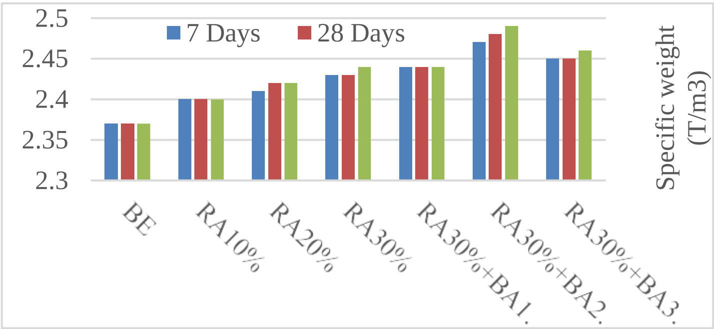

Diagram 8- Effect of ash on the permeability at different ages

Graph (9) shows the effect of the age of SCC on the specific weight of samples. As you can see, the specific weight of SCC does not change much with the age of the concrete, so the specific weight of BE, RA10%, and RA30% + BA15% mixtures does not change during the processing time. By examining the specific weight of the samples at the age of 7 days, it can be concluded that the increase in the specific weight of SCC for the mixture containing 30% by weight of rice husk ash cement compared to the control concrete is more than the lower percentage of this ash.

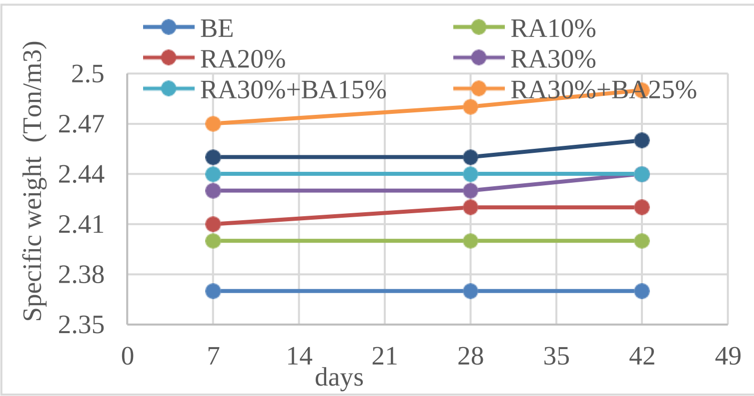

Diagram 9- The trend of permeability changes to the age of concrete

4- Conclusion

-By analyzing the slump results, it was concluded that all samples containing ash have more flowability than the control sample (without ash). Therefore, by increasing rice husk ash and then adding bagasse ash to SCC containing rice husk ash, the efficiency increases.

-The analysis of the results of the V-shaped funnel showed that adding ash reduces the exit time. The reason can be related to the reduction of instability caused by the increase of ash in mixing and the increase of adhesion between components.

-The test output of the L-shaped box also shows that the filling ability of concrete improves with the increase of ash.

-Adding rice husk ash and subsequently adding bagasse ash to SCC containing rice husk ash to the samples has resulted in a significant increase in compressive strength. So that the highest percentage of strength increase related to the sample of 30% rice husk ash and 25% bagasse ash by weight of cement was obtained with the amount of 34%, 34%, and 38% for the ages of 7, 28, and 42 days.

-the results showed that the use of rice husk ash in a larger amount in SCC concrete can speed up the process of gaining the strength of these concretes at a young age.

-Also, the results showed that the use of rice husk ash in a larger amount in SCC concrete can speed up the process of gaining the strength of these concretes at a young age.

-The use of rice husk ash and bagasse in SCC reduces the amount of water absorption and permeability, and as a result, it causes better and more favorable performance of concrete against external factors.

-The highest rate of reduction in the permeability of SCC from the age of 7 days to 42 days is related to the concrete containing 20% rice husk ash by 52%.

-Adding rice husk ash up to 30% of the weight ratio of cement causes the volume to decrease and the specific weight of concrete to increase. Adding bagasse ash up to 25% of the cement weight to the SCC mixture containing 30% rice husk ash increases and then decreases the specific gravity of the concrete sample.

-The specific weight of SCC does not change much with the age of concrete.

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