ASSESSMENT OF USING AN OPTIMAL DOSE OF SUPERPLASTICIZER WITH THE OPTIMUM REPLACEMENT OF RICE HUSK ASH (RHA) ON CONCRETE COMPRESSIVE STRENGTH

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ABSTRACT

Rice straw is one of the best sources of huge waste where governments try to get rid of it because it is harmful to the environment as the irregular burning of it by farmer's causes a lot of damage to the environment. This study aims to find the optimal dose of the plasticizer with the optimal replacement ratio of the Rice Husk Ash (RHA) and the optimum dose of superplasticizer (B-V-F) with ordinary Portland cement (OPC) concrete and comparing their results. Following is noted all researches agreed on the inevitability of using RHA without using a plasticizer, but no one studied the effect of added different doses of the plasticizer to RHA concrete or in other hand added it to different replacement percentages of RHA. In this study RHA generated by burning rice husk straw in a huge iron container for 24 hours. To improve pozzolanic activity, RHA was grinding in a flour mill. After the preparation of the material, we studied its chemical composition and physical properties. the Program consists of seven groups (A, C, A.13, A.15, A.2, A.1, and B) The first group mix (A) contained four mixtures of OPC (by weight replacement (0, 10%, 15%, and 20%) from RHA, the second group contains six mixtures with a constant slump (15 ± 3) and water-cement ratio (0.51), The first mixture is the control mix without any added of RHA or plasticizer the second mixture did not contain RHA, but it contained a dose of the plasticizer, the remaining four mixtures contained OPC by weight replacement (0%, 10%, 13%, 15%, and 20%) from RHA and different doses of the plasticizer. The

group (A.1) contains six mixtures with a constant replacement cement ratio RHA and a constant slump of 23 cm, except the last mixture No(21) that has a slump 8, and each mixture contains a different water-cement ratio and plasticizing doses. The seventh group (B) consists of three mixes of (OPC) cement with different doses of plasticizer and different water-cement ratio, all of which had a constant slump of 23cm. The result shows that the optimum replacement of RHA is equal to 10% at W/C ratio 0.51 and (B-V-F) 6 L/m³ which increased concrete compressive strength by about 32% compared to the control mix. The optimum dosage of superplasticizer with optimal replacement was found to be 15 L/m³ at W/C ratio 0.36, at which an increase in compressive strength by about 76% as compared to the control mix: The optimum dosage of superplasticizer (B-V-F) with (OPC) is 8 L/m³ at W/C ratio equals 0.38 achieves an increase in compressive strength by 58% compared to (OPC) mix (control mix).

Keywords: RHA, optimum replacement, superplasticizer, optimum dosage, compressive strength

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1. INTRODUCTION

The rice industry produces millions of rice husk waste around the world annually. The manufacture of rice husk ash to be used it in civil works as a partial substitute in concrete is not only a way to preserve the environment from the pollution but also to reduce the cost and improving the efficiency of concrete. Using RHA as a partial substitute for cement reduces the carbon dioxide CO₂ air pollution produced from cement manufacturing (Djamaluddin et al., 2018). Rice husk ash is a highly pozzolanic reactive substance formed by controlled burning of rice husk (Bui et al., 2005). This type of concrete not only uses waste, but also reduces project costs (Bheel et al., 2018). Several studies were reported on the mechanical and physical performance of RHA-blended concrete these researches have concluded that the use of rice husk as a pozzolanic substance in cement and mortar has many advantages, such as increased strength and durability properties, decreased construction costs due to cement production, and environmental benefits related to the recycling of waste materials and decreased carbon dioxide emissions. (Ganesan et al., 2008, Hwang, 1997, Nehdi et al., 2003) RHA is a super-pozzolan material possess (85% to 90%) of silica content (Gautam et al., 2019, Ephraim et al., 2012, Smith and Kamwanja, 1986, Sata et al., 2007, Nuaklong et al., 2020, Bheel et al., 2019, Habeeb and Mahmud, 2010) Rice husk Ash is an Agricultural waste that which rice husk straw is burnt into ashes. (Bhushan et al., 2017).

2. METHODOLOGY

The work consists of four Stages and 25 mixtures Each of the 25 divides into seven groups and modeled into nine standard cubes 15*15*15 cm and each mix will be tested just after mixing for, %of voids, and slump test. The Nine specimens from each mixture were used to determine the compressive at 7, 28, and 60 days.

The first one deals with the definition of RHA manufacturing and processing.

The second includes a study about the effect of different percentages of RHA on the necessary amount of water (water-cement ratio w/c) keep the slump constant, the percentage of voids in fresh concrete, and the compressive strength of concrete without using superplasticizer.

The third deals with the case of fixed the water content during adding the necessary amount of superplasticizer to keep slump constant for two reasons:

1st Evaluate the optimum percentage ratio of RHA as a cement replacement in concrete which leads to the highest compressive strength of concrete.

2nd determining the maximum amount of cement at the expense of RHA keeping the compressive strength constant.

The fourth aimed to evaluate the optimum dose of (OPC) and with the optimum replacement ratio of RHA at which occur maximum compressive strength of concrete (10%).

Superplasticizer (B-V-F) dissolved in the mixing water with the necessary amount to get the target slump for every group, even the group (A) mixture and control mix presented in the group (C).

2.1. Materials and Methods

2.1.1. RHA

Method of RHA Preparation

Rice straw was collected from the Egyptian farms and prepared for the burning process by using a huge iron container designed at the bottom of a small room to light a fire with a Kerosene Stove shown in figure (1) for one day. RHA was ground by using a flour mill (ASSIUT /Walidia Street Mill) figure (2), then sieved with a standard sieve no 50mm. The chemical composition of RHA was identified by an X-ray fluorescence test in the CEMEX Assiut factory. The Specific surface area was determined by the NOVA-3000 series apparatus figure (3). This technique needs approximately 0.3 g of the powder and involves measuring the volume of adsorbed nitrogen by the sample.

Figure 1 Drum incinerator

Figure 2 Walidia Street flour Mill

Figure 3 NOVA-3000 instrument

2.1.2. Cement

Ordinary Portland Cement (OPC) type CEMI 32.5 produced by Assiut cement company (CEMEX) complying with the Egyptian Standard Specifications (ESS 1-4756/2007) was used in this study. Chemical compositions and physical properties of ordinary Portland cement (OPC) and RHA are shown in Table (1).

Table 1 Chemical composition and physical properties of cement and RHA.

Material name	Chemical analysis (%)												(S.S.A) (Cm ² /g)	Appearance
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	P ₂ O ₅	Mn ₂ O ₃	TiO ₂	K ₂ O	Na ₂ O	SO ₃	total		
OPC	20.8	4.82	4.0	62.6	1.40	---	---	---	1.1	0.32	2.54	96.4	10100	Gray
RHA	82.52	0.43	00	0.67	0.63	.5	.24	0.3	1.76	0.58	0.39	92.6	444540	Dark Gray

The materials used in this investigation were obtained from local resources and they agree with the requirements of relevant Egyptian Standards ESS 1109/2002.

2.1.3. Sand

Clean Local natural siliceous medium sand from Assiut was chosen as fine aggregates for all concrete mixes in all experiments. It has water absorption of 0.72%, fineness modulus of 2.6, a specific gravity of 2.5, volume weight of (1.66t/ m³), and amount of clay and fine dust equals to 2.4%.

2.1.4. Gravel

ASEC ready mix company (ASEC) two grads of aggregate were obtained which have a maximum aggregate size of (20, 10) mm, crushing value (22.5%, 23.8%) fineness modulus (6.3, 7.5) and Volume weight for gravel (1.5, 1.45) (t/ m³) respectively. Both have the same specific gravity of (2.56) and water absorption of 0.58%.

2.1.5. Water and admixture

Potable water was used for molding and curing of all concrete specimens. The Sulphonated naphthalene formaldehyde-based Superplasticizer (ADDICRETE B-V-F) having a density of 1.21t/m³ was employed to achieve the desired workability.

3. GROUPS OF CONCRETE MIXES:

The test program consists of seven groups (A, C, A.13, A.15, A.2, A.1, and B).

The first group mix (A) contained four mixtures of (OPC) by weight replacement (0, 10%, 15%, and 20%) from RHA, all mixtures had fixed slump (8±2) cm and different water-cement ratio.

The second group contains six mixtures with constant water-cement ratio (0.51) and slump (17±2) cm. The first mixture is the control mix without any added of RHA or plasticizer the second mixture did not contain RHA, but it contained a dose of the plasticizer. The remaining four mixtures contained OPC by weight replacement (0%, 10%, 13%, 15%, and 20%) from RHA and different doses of the plasticizer.

The third, fourth, and fifth groups (A.13, A.15, A.2) each contains a fixed percentage of replacing cement ratio with RHA (13%,15%,20%) sequentially and different doses of the plasticizer additive and different water-cement ratio.

The sixth group (A.1) contains six mixtures with a constant replacement cement ratio RHA and a constant slump 23 cm, expect the last mixture No. 21 that has a slump 8, and each mixture contains a different water-cement ratio and plasticizing doses.

The seventh group (B) consists of three mixes of (OPC) cement with different doses of plasticizer and different water-cement ratio, all of which had a constant slump of 22 cm.

Different groups of concrete mixes are shown in Table (2).

Table 2 proportions of concrete mixes for different groups for 1 cubic meter of fresh concrete.

Group no	Group cod	Mix no	Cement (kg)	Sand (kg)	Gravel (Kg)		Water (L)	Superplasticizer (B-V-F) (L)	RHA			w/c	SLUMP (cm)	Percentage of voids in fresh concrete
					Gravel 1	Gravel 2			Kg	% RHA (by weight Of cement)				
1	A	1	450	623	623	415	202.5	0	0	0		0.45	8	2.1
		2	405	580	580	387	247.5	0	45	10		.55	7.5	2.2
		3	382.5	567	567	378	261	0	67.5	15		.58	8.5	2.2
		4	360	537	537	358	292	0	90	20		.65	7	2.3
		5	450	597	597	399	229.5	0	0	0		.51	15	2.2
2	C	6	450	599	599	399	227.5	2	0	0		0.51	18	2.2
		7	405	598	598	398	222.5	6	45	10		0.51	17	3.8
		8	391.5	597	597	398.6	220.5	7	58.5	13		0.51	17	3.8
		9	382.5	598	598	399	217.5	12	67.5	15		0.51	18	4.5
		10	360	598	598	399	217.5	12	90	20		0.51	17	4.6
3	A.13	11	391.5	628	628	419	185	13	58.5	13		.44	15	4.4
		12	391.5	600	600	400	220.5	9	58.5	13		.51	12	3.8
4	A.15	13	382.5	598	598	399	217.5	12	67.5	15		.51	18	4.2
		14	382.5	620	620	413	195	12	67.5	15		.46	15	4.2
5	A.2	15	360	586	586	391	217.5	12	90	2		.51	15	4.6
		16	360	360	581	387	239.5	8	90	2		.55	17	4.2
6	A.1	17	405	637	637	424	179.5	9.5	45	10		.42	23	4.3
		18	405	641	641	427	174	10.5	45	10		.41	23	4.4
		19	405	654	654	436	159	12	45	10		.38	23	4.5
		20	405	663	663	442	147	15	45	10		.36	23	4.5
		21	405	671.5	671.5	448	135	18	45	10		.34	23	3.2
		22	405	681	681	454	120	24	45	10		.32	23	3.6
		23	450	645	645	430	174	6	-	0		.4	23	2.3
7	B	24	450	653	653	421	163	8	-	0		.38	23	2.5
		25	450	662	662	441	152	10	-	0		.36	23	2.9

4. TEST PROCEDURE

4.1. Fresh concrete Properties

Early age properties of concrete, including slump and air content. Was measured according to (ESS 1658/1989). AIR content of fresh concrete measured (BY USING PRESSURE METHOD) and registered in Table (3), figure (4) shows the Volume Air Meter.

Figure 4 Volume Air Meter

4.2. hardened concrete Properties

4.2.1 Compressive Strength Test

Compressive strength tests were performed at 7, 28, and 60 days using the Testing machine (150-ton capacity) for all the concrete cubes.

5. EXPERIMENTAL RESULTS AND DISCUSSIONS

5.1. Properties of Fresh Concrete

5.1.1. Slump, air content

The amount of Superplasticizer (B-V-F) (L/m³), slump, and % of voids for each mix are recorded and shown in Table (2).

As shown in the group (A) and figure (5) that the amount of water increases by increasing RHA replacement to maintain the slump equals (8±2)cm, this is due to RHA is a highly porous material and higher surface area, which is agreed upon by the rest of the researcher's as (Ephraim et al., 2012, Bui et al., 2005, Joshi et al., 2019).

Figure 5 Effect of replacement ratios on w/c without using superplasticizer admixture

From the group (C) and figure (6), it was found when the RHA replacement ratio increased superplasticizer dosage rates increase to maintain that required slump. From group (A.1) and figure (7), we can know that the decrease in the amount of water leads to increases in the amount of superplasticizer dosage to maintain the slump (23±2) cm.

Figure 6 Effect of replacement ratio on superplasticizer dose

Figure 7 Effect of amount of w/c on superplasticizer dose

From group(C) and figure (8), it can be noted that the air content increases by increase superplasticizer and RHA replacement. This is maybe due to an increase in the reactant's material. Table (2) Group (A) shows slight increases in air content by increase RHA replacement. It may be due to increased water content.

From group (B) and figure (9), it is clear that the increases in superplasticizer dosage cause an increase in air content also increase the slump causing the same effect. The reason may be due to the increase of cement hydration with superplasticizer, and that the cement paste increases in size with the increase of slump, or maybe due to the increase in the volume of cement paste due to the increase in the reactants.

From the results shown for groups A.1, A.13, A.15, and A.2, we note that by adding both the plasticizer and there was a big jump in the air content, this may be due to the increase in the cement beast volume.

Figure 8 Effect of RHA replacement and the amount SuperPlasticizer dose on the % of voids in fresh concrete

Figure 9 Effect of the dose superplasticizer on the % of voids in fresh concrete

5.2. Concrete Hardened Properties

5.2.1. Concrete Compressive Strength

Experimental test was carried out on different concrete mixes to show the effect of different replacement ratio of RHA without using superplasticizer (B-V-F) on concrete compressive strength and the results are shown in Table(3).

Table 3 the effect of different replacement on the compressive strength of the concrete.

Group NO	Group cod	Mix no	Superplasticizer (B-V-F) (L/m³)	RHA% (by weight Of cement)	w/c	SLUMP (cm)	Fc(Kg/cm²)			Strength Ratio= $\frac{f_c(28)}{f_c(28)_{control}}$
							Fc7	Fc28	Fc60	
1	A	1	0	0	0.44	8	280	354	357	1
		2	0	0.1	0.55	7.5	213	285	332	.8
		3	0	0.15	0.58	8.5	184	251	288	.71
		4	0	0.2	0.65	7	171	244	254	.69

Table (3) shows that by increasing the percentage ratio of RHA in the group (A) as a cement replacement in concrete, the water-cement ratio w/c increases to maintain a steady consistency, so compressive strength decreased by (20%,29%,31%) at a replacement rate ratio (10%,15%,20%) respectively as shown in figure (10). The increase in water content that

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leads to a decrease in compressive strength can be avoided by using a plasticizer as in the previous research.

Figure 10 Effect of different RHA content concrete compressive strength Without using a plasticizer

Experimental test was carried out on different concrete mixes has fixed water content and the necessary amount of superplasticizer keep slump constant to show the effect of different replacement ratio of RHA on concrete compressive strength and get the optimum percentage ratio of RHA which leads to the highest compressive strength of concrete and the maximum amount of cement at the expense of RHA keeping the compressive strength constant results are shown in Table (4).

Table 4 Effect of different replacement on compressive strength of concert when w/c constant.

Group No	Group cod	Mix no	Superplasticizer (B-V-F) (L/m ³)	RHA% (by weight Of cement)	w/c	SLUMP (cm)	Fc(Kgcm ² /)			Strength Ratio= $\frac{fc(28)}{fc(28)control}$
							Fc7	Fc28	Fc60	
2	C	Control mix (5)	0	0	0.51	15	253	314	342	1
		6	2	0	0.51	18	252	315	357	1
		7	6	1	0.51	17	330	413	450	1.3
		8	9	13	0.51	17	273	358	407	1.14
		9	12	15	0.51	18	260	343	410	1.1
		10	12	20	0.51	17	250	319	393	1.01

Table (4) showed that with fixed of both water content and slump it was found, compressive strength increased by (30%,14%,10%,0%) at replacement rate ratio(10%,13%.15%,20%) respectively. Figure (11) the best RHA replacement ratio is 10%; which is agreed upon by the rest of the researcher's as (Habeeb and Mahmud, 2010, 2017, Rong et al., 2019, Singh et al., 2016, Garrett et al., 2020), however, cement can be saved up to 20% while retaining the same compressive strength of the control mix.

Figure 11 Effect of different RHA content concrete compressive strength With the use of plasticizer

Experimental test was carried out on different concrete mixes divided into 3 groups each contain a fixed percentage of replacing cement ratio with RHA (13%, 15%, 20%) sequentially and a random dose of doses of the superplasticizer (B-V-F) which occurs different compressive strength of concrete, the results are shown in Table (5).

Table 5 effect of different doses of superplasticizer on (13%, 15%, 20) percentage ratio of RHA as a cement replacement.

Group no	Group cod	Mix no	Superplasticizer (B-V-F) (L/m ³)	RHA% (by weight Of cement)	w/c	SLUMP (cm)	Fc (kg/cm ²)			Strength Ratio= $\frac{fc(28)}{fc(28)control}$
							Fc7	Fc28	Fc60	
6	A.13	11	13	13	0.44	15	255	377	443	1.2
		12	9	13	0.51	12	220	376	407	1.2
7	A.15	13	12	15	0.51	18	223	358	377	1.1
		14	12	15	0.46	15	278	370	406	1.2
	A.2	15	12	2	0.51	15	250	319	393	1
8		16	8	2	0.55	17	193	281	304	.9

In table (5) group (A.13, A.15, A.2) shows that for every replacement ratio when different doses of additives and amount of water, the compressive strength of concrete varies, this leads to the necessity of not only evaluate the optimum percentage ratio of RHA as a cement replacement in concrete that leads to the highest compressive strength, or was the percentage of RHA that provided the maximum amount of cement. As is the case in most of the previous research; Rather it's necessary to study a curve for each replacement ratio of RHA with different addition of doses and amount of water to determine the amount of addition and the water content that gives the best compressive strength to each RHA replacement ratio, as happened in this research with the optimal replacement ratio (10%).

Experimental tests were carried out on different concrete mixes to found the optimum dose of superplasticizer (B-V-F) on concrete compressive strength with the optimum replacement ratio of RHA which occurs maximum compressive strength of concrete (10%), the results are shown in Table (6) effect of different doses of superplasticizer on (13%, 15%, 20) percentage ratio of RHA as a cement replacement.

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Table 6 Effect of different doses of superplasticizer on concrete compressive strength with an optimum RHA replacement ratio (10%).

Group no	Group cod	Mix no	Superplasticizer (B-V-F) (L/m ³)	RHA% (by weight Of cement)	w/c	SLUMP (cm)	Fc (Kg/cm ²)			Strength Ratio= $\frac{fc(28)}{fc(28)control}$
							Fc7	Fc28	Fc60	
5	A.1	21	9,5	0.1	0.42	23	286	415	367	1.3
		22	10,5	0.1	0.41	23	340	428	456	1.36
		23	12	0.1	0.38	23	424	435	473	1.38
		24	15	0.1	0.36	23	430	550	601	1.76
		25	18	0.1	0.34	23	450	509	550	1.6
		26	24	0.1	0.32	8	450	493	510	1.57

Table (6) indicates that the optimal dose of superplasticizer (B-V-F) was 15L/ m³, in the replacement rate of 10% of RHA with a water-cement ratio is 0.36 this mix improves the compressive strength by 75% Compared with the control mix as shown in figure (12).

Moreover, when the water decrease more than 0.36 the result obtained was unprofitable on the effect of compressive strength, this is maybe due to the water content was less than the content needed to complete the concrete reactions, also if the water decrease than 0.34 the superplasticizer increase could not reach the same consistency (slump 23).

Figure 12 Effect of different doses of superplasticizer on concrete compressive strength with an optimum RHA replacement ratio (10%).

An experimental test was carried out on different concrete mixes to found the optimum dose of superplasticizer (B-V-F) with ordinary Portland cement concrete which occurs maximum compressive strength of concrete; the results are shown in Table (7).

Table 7 effect of different w/c and superplasticizer; to evaluate the optimum dose of superplasticizer (B-V-F) with (OPC) on compressive strength of concrete.

Group no	Group cod	Mix no	Superplasticizer (B-V-F) (L/m ³)	RHA% (by weight Of cement)	w/c	SLUMP (cm)	Fc (Kg/cm ²)			Strength Ratio= $\frac{fc(28)}{fc(28)control}$
							Fc7	Fc28	Fc60	
4	B	14	10	0	0.36	23	376	423	501	1.3
		16	8	0	0.38	23	377	455	540	1.4
		17	6	0	0.4	23	338	405	514	1.29

As shown in table & figure the optimal dose of superplasticizer (B-V-F) was 8 L/m^3 , with a water-cement ratio is 0.38 this led to an increase in compressive strength by 40% Compared with the control mix as shown in figure (13).

Figure 13 effect of different w/c and superplasticizer (B-V-F) with (OPC) on compressive strength of concrete.

6. CONCLUSIONS

- RHA contains a high percentage of silica hence prefer RHA use in concrete those other additives.
- The workability of concrete mixes decreases with the increase of RHA replacement, this leads to the necessary using superplasticizers.
- Water-cement ratio (w/c) increases with the increase of RHA replacement ratio Because it's a highly pours material.
- The optimum replacement ratio of RHA equals to (10%) by weight of cement.
- Compressive strength of concrete increases with the increase of the super plasticizer dose which leads reducing the water content, for each replacement percentage of RHA, But this increase begins to decrease at a certain dose. This leads to necessary need of drawing a curve between compressive strength and different doses of plasticizer with a constant slump to find the optimum dose for each replacement ratio of RHA and this not concern only RHA But also with all pozzolanic substances.
- The optimum dose of Superplasticizer (ADDICRETE B-V-F) is determined and equals 8 L/m^3 for ordinary Portland cement (OPC) with $w/c=0.38$, At which value of the strength coefficient reached (1.4) from the control strength value, the optimum dose of (ADDICRETE B-V-F) with the optimum replacement ratio of RHA (10%) is determined and equals 12 L/m^3 with $w/c=0.38$, also 15 L/m^3 when $w/c=0.36$ At which value of the compressive strength coefficient reached (1.72,1.75) from the control strength.
- RHA addition has enhanced the strength of concrete for up to 60 days.
- At 20% RHA level, the concrete mix achieved the required strength compared to that of the control. Therefore a 20% replacement of ordinary Portland cement can be substituted with RHA without reducing its compressive strength.

- Increasing of superplasticizer dose shows an increase in air content, RHA replacement increase causes slightly increasing in air content But using both RHA and superplasticizer making a big jump in air content.

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