Journal of
Engineering Sciences
Faculty of Engineering
Assiut University
JES
مجلة
العلوم الهندسية
كلية الهندسة
جامعة أسيوط
journal homepage: http://jesaun.journals.ekb.eg

The Optimal Dose of Super Plasticizer (B-V-F) with Optimal Replacement Ratio of Rice Husk Ash (RHA) and with Ordinary Portland cement

Received 26 April 2022; Revised 29 August 2022; Accepted 29 August 2022

Maryam S. Ali[1]
M.M. Rashwan[2]
Kamal A. Assaf[3]

Keywords
RHA, Optimum replacement, Superplasticizer, Optimum dosage, Compressive strength

Abstract

This study aims to an optimal dose of the superplasticizer (B-V-F) with the optimal replacement ratio of the Rice Husk Ash (RHA) and with ordinary Portland cement (OPC) and compares their results. This study generated RHA by burning rice husk in an appropriate iron container for about 24 hours. To improve pozzolanic activity, RHA was ground in a flour mill. The chemical composition and physical properties of RHA were studied. The experimental program consists of seven groups of concrete mixes with different doses of superplasticizer and replacement percentages of RHA. The first group mix contained four mixtures of OPC with different RHA weight replacements (0, 10%, 15%, and 20%). The second group contains six mixtures with a constant slump (15±3) cm and a water-cement ratio (0.51). The compressive strength of these mixtures was studded and compared with a control mixture (PURE OPC). The sixth group A.1 contains six mixtures with optimal RHA replacement (10%) of OPC with a constant slump of 23 cm, and different plasticizing doses were applied. The result shows that the optimum replacement of RHA was 10% which increased concrete compressive strength by about 32%. The optimal dose of superplasticizer with optimal RHA replacement (10%) was 15 L/m^3 which increased compressive strength by about 76%.

1 Introduction

Climate change is considered the central environmental challenge for the world. It is impossible to envisage a modern life without cement. However, Emissions from Cement manufacturing are one of the significant contributors to global warming and climate change

[1] Master student, Dept. of Civil Eng., Assiut University, Assiut, Egypt. Mariam0111275@ eng.au.edu.eg
[2] Professor, Dept. of Civil. Eng., Assiut University, Assiut, Egypt. mohamed.rashwan1@eng.au.edu.eg com
[3] Associate professor, Dept. of Civil Eng., Assiut University, Assiut, Egypt. kamal.abdelrahman@eng.au.edu.eg

https://doi.org/10.21608/JESAUN.2022.135878.1133

(Devi et al., 2017) [1]. If the cement industry were a country, it would be the world's third-largest carbon dioxide emitter with up to 2.8bn (Vidal and Watts, 2019), [2]. The calcination and burning processes of cement production produce both short-term and long-term effect adverse impacts on Air, Water and Land

Rice Husk Ash (RHA) is an agricultural waste product produced in large quantities globally every year, and due to the difficulty involved in its disposal, RHA can become an environmental hazard in rice-producing countries. As the rice husk ash is piling up every day, there is pressure on rice industries to find a solution for its disposal. Therefore, developing eco-friendly concrete from RHA Rice has a dual effect in preserving the environment and has made significant progress in reducing CO2 emissions. However, about 8 million tons of rice are produced annually, leading to large volumes of rice by-products.

Using RHA as a partial substitute for cement reduces the carbon dioxide CO2 air pollution produced from cement manufacturing [2]. Rice husk ash is a highly pozzolanic reactive substance formed by the controlled burning of rice husk [3]. RHA is a super-pozzolan material that possesses (85% to 90%) silica content [5-12]. This type of concrete not only uses waste but also reduces project costs [13]. Several studies reported RHA's mechanical and physical advantages as a concrete additive. These include increased strength and durability properties. Moreover, it has environmental benefits related to recycling waste materials and decreased carbon dioxide emissions [14-16].

For each replacement percentage of RHA, the compressive strength of concrete increases with the increase of the superplasticizer dose and reducing the water content. This increase reached a limit and then decreased at a specific dose of RHA. Therefore, the main objective of this work is to identify these variables. We need to draw a curve describing the association of compressive strength and different doses of plasticizer at each specified % of RHA. There was a gap in knowledge regarding the optimal dose of superplasticizer that needs to be used with the optimum replacement percentage of rice husk ash (RHA). The present study aimed to:

1. Determine the optimal replacement ratio of RHA from cement content.
2. Define the optimal dose of superplasticizer with the optimal replacement ratio of the RHA.
3. Determine the optimum dose of superplasticizer (B-V-F) with ordinary Portland cement (OPC) concrete.

2 Experimental Program

2.1 Materials

2.1.1 RHA Preparation

Rice husk was obtained from the Egyptian rice paddles and burned in a drum incinerator Figure 1 for about 24 hours. The ash was ground using a commercial flour mill, then sieved with a standard sieve no 50. An X-ray fluorescence test identified the chemical composition of RHA in the CEMEX Assiut factory. The NOVA-3000 series apparatus measured the specific surface area. This technique needs approximately 0.3 gm. of the powder and involves measuring the volume of adsorbed nitrogen by the sample.

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. The chemical compositions and physical properties of RHA are shown in Table 1 and Table 2. The materials used in this investigation were obtained from local resources, and they agree with the requirements of relevant Egyptian Standards ESS 1109/2002.

Figure 1: Drum incinerator

Table 1: Chemical composition of RHA

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	K_2O	Na_2O	SO_3	Mn_2O_3	P_2O_5	Cr_2O_3	loss
82.2	0.43	0.0	0.67	0.63	0.3	1.1	0.32	0.39	0.24	0.5	0.01	13.84

Table 2: Physical properties of RHA

Fineness in terms of SSA (cm^2/gm)	Appearance
40301	Dark Gray

2.1.3 Sand

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

2.1.4 Gravel

ASEC ready mix company (ASEC) used two sizes of gravel which have a nominal maximum aggregate size of 20, 10 mm, crushing value 22.5%, 23.8% (samples were passed through a sieve No 20mm, but retained on the sieve No 10mm until an amount sufficient to fill the testing container was obtained). Fineness modulus 6.3, 7.5 and volume weight 1.5, 1.45 t/m^3, 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 concrete mixing and curing all concrete specimens. The Sulphonated naphthalene formaldehyde-based Superplasticizer (ADDICRETE B-V-F), having a density of 1.21 t/m^3, was used to achieve the desired workability.

2.2 Concrete Mixes

The test program consists of seven groups of concrete mixes named A, C, A.13, A.15, A.2, A.1, and B. The first group A includes four mixtures of OPC with 0, 10%, 15%, and 20% replacement percent (by weight) of RHA; all mixtures had a fixed slump of 8±2 cm and different water-cement ratio. The second group C, includes six mixtures with a constant water-cement ratio of 0.51 and a slump of 17±2 cm. The first mixture is the control mix without adding RHA or plasticizer. The second mixture did not contain RHA but contained plasticizer. The remaining four mixtures contained OPC with 10%, 13%, 15%, and 20% replacement percent of RHA and plasticizer.

The third, fourth, and fifth groups are named A.13, A.15, and A.2. Each group contains a fixed percentage of replacing OPC with RHA of 13%,15%, and 20%, respectively. In these groups, plasticizers and different water-cement ratios were applied.

The sixth group A.1, contains five mixtures with optimal RHA replacement (10%) of OPC and a constant slump of 23 cm. In this group, different water-cement ratios and plasticizing doses were applied. The seventh group B consists of three mixes of OPC with different doses of plasticizer and water-cement ratios. All mixes had a constant slump of 23 cm. Details of the studied concrete mixes are listed in

Table *3*.

Table 3: Proportions of concrete mixes for cubic meters.

Group #No	Group code	Mix #No	Cement(kg)	Sand (Kg)	Gravel (Kg)		Water (L)	BFV (L)	RHA		w/c	SLUMP
					Gravel1	Gravel2			Kg	%		
1	A	1	450	623	623	415	202.5	0	0	0	0.45	8
		2	405	580	580	387	247.5	0	45	10	0.55	7.5
		3	382.5	567	567	378	261	0	67.5	15	0.58	8.5
		4	360	537	537	358	292	0	90	20	0.65	7
2	C	5	450	597	597	399	229.5	0	0	0	0.51	15
		6	450	599	599	399	227,5	2	0	0	0.51	18
		7	405	598	598	398	222.5	6	45	10	0.51	17
		8	391.5	597	597	398.6	220.5	7	58.5	13	0.51	17
		9	382.5	598	598	399	217.5	12	67.5	15	0.51	18
		10	360	598	598	399	217.5	12	90	20	0.51	17
3	A.13	11	391.5	628	628	419	185	13	58.5	13	0.44	15
		12	391.5	600	600	400	220.5	9	58.5	13	0.51	12
4	A.15	13	382.5	598	598	399	217.5	12	67.5	15	0.51	18
		14	382.5	620	620	413	195	12	67.5	15	0.46	15
5	A.2	15	360	586	586	391	217.5	12	90	20	0.51	15
		16	360	360	581	387	239.5	8	90	20	0.55	17
6	A.1	17	405	637	637	424	179.5	9.5	45	10	0.42	23
		18	405	641	641	427	174	10.5	45	10	0.41	23
		29	405	654	654	436	159	12	45	10	0.38	23
		20	405	663	663	442	147	15	45	10	0.36	23
		21	405	671.5	671.5	448	135	18	45	10	0.34	23
7	B	22	450	645	645	430	174	6	-	0	0.4	23

		23	450	653	653	421	163	8	-	0	0.38	23
		24	450	662	662	441	152	10	-	0	0.36	23

2.3 Compression Test

Compression tests were performed on the studied concrete specimens at 7, 28, and 60 days using the Testing machine, a 150-ton capacity.

3 Results and Discussion

3.1 Compressive Strength

An investigation was carried out on different concrete mixes to investigate the effect of different replacement ratios of RHA without using a superplasticizer (B-V-F) on concrete compressive strength, and the results are represented in **Table** .

Table 4: The effect of different ratios of RHA replacements on compressive strength

Group #No	Group code	Mix #No	Superplasticizer (B-V-F) (L/m^3)	RHA%	w/c	SLUMP (cm)	Fc (Kg/cm^2)			Strength Ratio
							Fc7	Fc28	Fc60	
1	A	1	0	0	0.44	8.0	280	354	357	1.00
		2	0	10	0.55	7.5	213	285	332	0.80
		3	0	15	0.58	8.5	184	251	288	0.71
		4	0	20	0.65	7.0	171	244	254	0.69

Results in Table (4) indicate that by increasing the ratio of RHA in 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%, and 31% at replacement rate ratio 10%,15%,20%, respectively as shown in Figure 2. The increase in water content that leads to a decrease in compressive strength can be avoided by using a plasticizer.

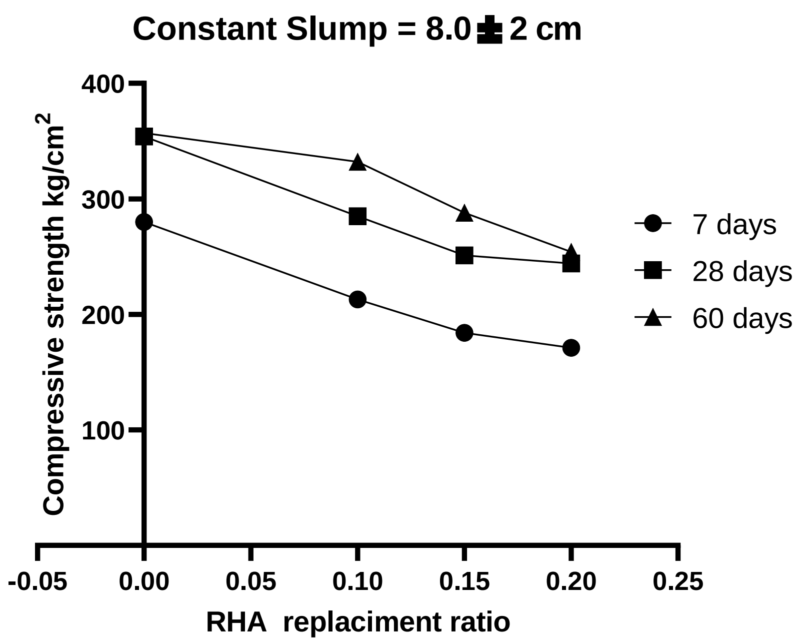

Figure 2: Effect of RHA on concrete compressive strength without using plasticizer

An experimental test was carried out on different concrete mixes with fixed water content and a necessary amount of superplasticizer to keep slump constant to investigate the effect of different replacement ratios of RHA on concrete compressive strength and get the optimum ratio of RHA, which leads to the highest compressive strength of concrete and results are listed in Table 5.

Table 5: Effect of different replacements on compressive strength of concert with constant w/c

Group #No	Group code	Mix #No	BFV L/m^3	RHA% (By weight of cement)	w/c	SLUMP (cm)	Fc (Kg/cm^2)			Strength ratio
							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	1.003
		7	6	10	0.51	17	330	413	450	1.315
		8	9	13	0.51	17	273	358	407	1.140
		9	12	15	0.51	18	260	343	410	1.092
		10	12	20	0.51	17	250	319	393	1.016

The results of Table indicate that with fixed water content and slump, the compressive strength at 28 days increased by 20%, 14%, 1%, and 0% at the RHA replacement rate ratio10%, 13%.15%, and 20%, respectively. Figure 3 shows that the best RHA replacement ratio is 10%, which is agreed upon by the rest of the researchers [18, 19, 20], however, cement can be saved up to 20% while retaining the same compressive strength of the control mix.

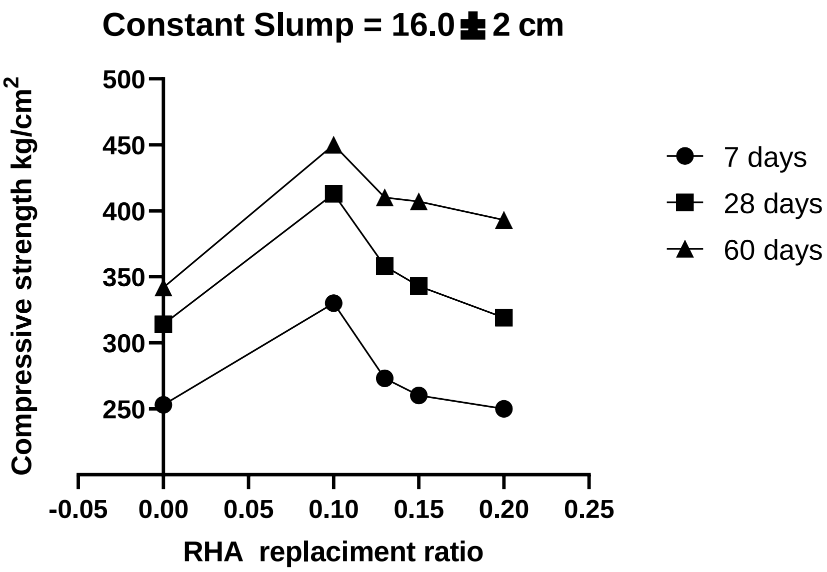

Figure 3: Effect of different RHA content on concrete compressive strength with plasticizer

An experimental test was carried out on different concrete mixes divided into three groups, each containing a fixed percentage of replacing cement ratio with RHA 13%,15%,20% sequentially, and a random dose of superplasticizer (B-V-F), which occurs different compressive strength of concrete, the results are listed in Table ٦, mix 5 is the control one.

Table 4: Effect of superplasticizer on 13%, 15%, and 20 percentage ratios of RHA as cement replacement

Group no	Group code	Mix no	BFV **(L/m³)**	RHA% (By weight of cement)	w/c	SLUMP (cm)	**Fc (Kg/cm²)**			Strength Ratio
							Fc7	Fc28	Fc60	
3	A.13	11	13	13	0.44	15	255	377	443	1.20
		12	9	13	0.51	12	220	376	407	1.20
4	A.15	13	12	15	0.51	18	223	358	377	1.14
		14	12	15	0.46	15	278	370	406	1.18
5	A.2	15	12	20	0.51	15	250	319	393	1.02
		16	8	20	0.55	17	193	281	304	0.90

Results of
Table *4* indicate that for every replacement ratio with different doses of additives and amounts of water, the compressive strength of concrete varies. This leads to the necessity of not only evaluating the optimum percentage ratio of RHA as cement replacement in concrete that leads to the highest compressive strength or the percentage of RHA that provides the maximum amount of cement.

An experimental test was conducted on concrete mixtures, with constant slump and gradual decrease in the water level with increasing the dose of superplasticizer. This study aimed to find the optimal dose of plasticizer with the optimal RHA replacement ratio, 10% on concrete compressive strength. The results of Table ٧ represent the effect of different doses of superplasticizer on the 10%percentage ratio of RHA as cement replacement.

Table 5: Effect of different doses of superplasticizer on concrete compressive strength with an optimum RHA replacement ratio, 10%.

Group no	Group code	Mix no	Superplasticizer (BFV L/m³)	RHA%	w/c	SLUMP (cm)	**Fc (Kg/cm²)**			Strength Ratio[4]
							Fc7	Fc28	Fc60	
6	A.1	17	9,5	0.1	0.42	23	286	415	367	1.32
		18	10,5	0.1	0.41	23	340	428	456	1.36
		19	12	0.1	0.38	23	424	435	473	1.38
		20	15	0.1	0.36	23	430	550	601	1.76
		21	18	0.1	0.34	23	450	509	550	1.60

[4] Strength ratio = FC (28) of mix/ Fc (28) of control mix (mix No. 5).

Results presented in Table 7 indicate that the optimal dose of superplasticizer (B-V-F) was 15 L/M^3, with the replacement rate of 10% of RHA with a water-cement ratio of 0.36, and this mix improves the compressive strength by 75% compared with the control mix as shown in Figure 4. However, the compressive strength decreased at a water-cement ratio of less than 0.36, likely due to insufficient water content to complete the cement reactions. As the water-cement ratio decreased to 0.34, the required consistency (slump 23) cannot be achieved regardless of the superplasticizer ratio.

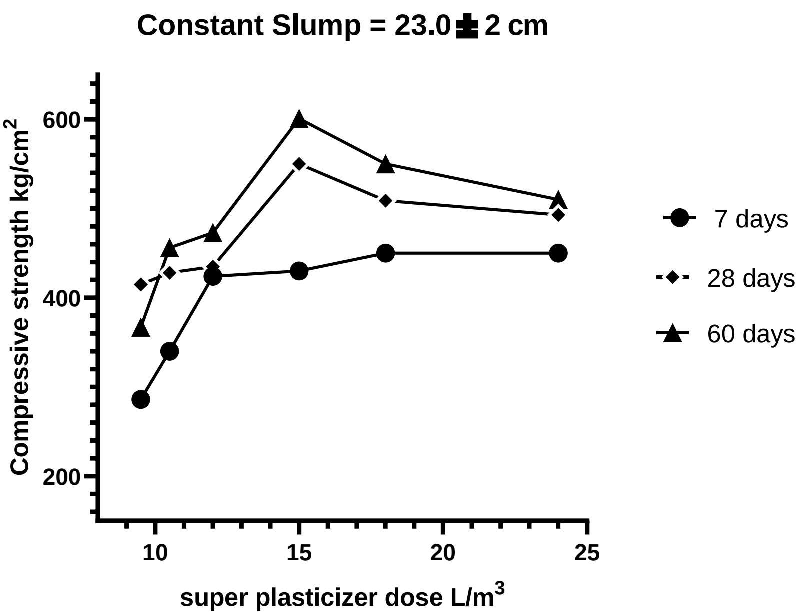

Figure 4: Effect of different doses of superplasticizer on concrete compressive strength with an optimum RHA replacement ratio of 10%

An experimental test was carried out on different concrete mixes to find the optimum dose of superplasticizer (B-V-F) with ordinary Portland cement concrete. The results are presented in Table 8.

Table 6: Effect of different w/c and superplasticizer on compressive strength of concrete.

Group no	Group code	Mix no	Superplasticizer (B-V-F) (L/m^3)	RHA% (By weight Of cement)	w/c	SLUMP (cm)	**Fc (Kg/cm^2)**			Strength Ratio
							Fc7	Fc28	Fc60	
8	B	22	10	0	0.36	23	376	423	501	1.30
		23	8	0	0.38	23	377	455	540	1.40
		24	6	0	0.4	23	338	405	514	1.29

Table 8 & Figure 5 indicate that the optimal dose of superplasticizer (B-V-F) was 8 L/m^3, with a water-cement ratio of 0.38. This led to an increase in compressive strength by 40% compared with the control mix.

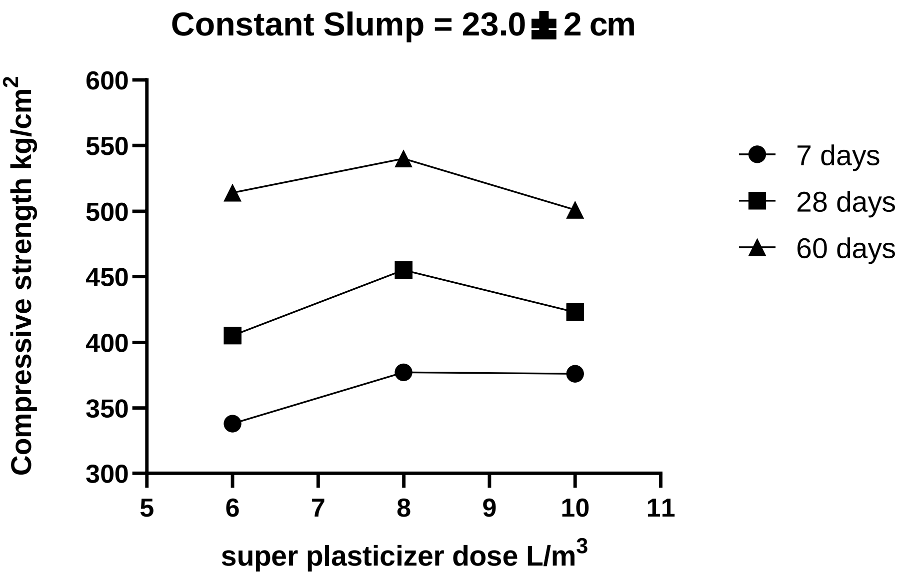

Figure 5: Effect of different w/c and superplasticizer (B-V-F) with (OPC) on compressive strength of concrete

4 Conclusions

The workability of concrete mixes decreases with the increase of RHA replacement, leading to the necessity of using a superplasticizer.

1. The water-cement ratio (w/c) increases with the RHA replacement ratio.
2. The optimum replacement ratio of RHA was documented as 10% by the weight of cement.
   The optimum dose of Superplasticizer (ADDICRETE B-V-F) was identified as 8L/m^3 for ordinary Portland cement (OPC) with w/c=0.38, at which value of the strength ratio reached (1.4) of the control strength value.
3. The optimum dose of (ADDICRETE B-V-F) with the optimum replacement ratio of RHA (10%) was 15 L/m^3 with w/c=0.36, At which the value of the compressive strength ratio reached (1.76) of the control strength.
4. RHA can be used as an economic cement replacement in concrete. About 20% of the cement weight can be saved by replacing it with RHA without fundamentally affecting the compressive strength of concrete.

References

[1] Devi, K.S., V.V. Lakshmi, and A. Alakanandana, Impacts of cement industry on environment-an overview. Asia Pac. J. Res, 2017. 1: p. 156-161.

[2] 2. Vidal, J. and J. Watts, Concrete: the most destructive material on earth. The Guardian, 2019. 25.

[3] DJAMALUDDIN, A. R., CARONGE, M. A., TJARONGE, M. W., RAHIM, I. R. & NOOR, N. M. Abrasion resistance and compressive strength of unprocessed rice husk ash concrete. Asian Journal of Civil Engineering, 19, 867-876, 2018.

[4] BUI, D., HU, J. & STROEVEN, P. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cement and concrete composites, 27, 357-366, 2005.

[5] GAUTAM, N., PATIL, R. & DHAWAD, P. Experimental study investigation of rice husk ash on concrete. AIP Conference Proceedings, AIP Publishing LLC, 030049, 2019.

[6] EPHRAIM, M. E., AKEKE, G. A. & UKPATA, J. O. Compressive strength of concrete with rice husk ash as partial replacement of ordinary Portland cement. Scholarly Journal of Engineering Research, 1, 32-36, 2012.

[7] SMITH, R. & KAMWANJA, G. The use of rice husk for making a cementations material. Proc. Joint Symposium on the Use of Vegetable Plants and their Fibers as Building Material, Baghdad, 1986.

[8] SATA, V., JATURAPITAKKUL, C. & KIATTIKOMOL, K. Influence of pozzolan from various by-product materials on mechanical properties of high-strength concrete. Construction and Building Materials, 21, 1589-1598, 2007.

[9] NUAKLONG, P., JONGVIVATSAKUL, P., POTHISIRI, T., SATA, V. & CHINDAPRASIRT, P. Influence of rice husk ash on mechanical properties and fire resistance of recycled aggregate high-calcium fly ash geopolymer concrete. *Journal of Cleaner Production*, 252, 2020.

[10] BHEEL, N., ABRO, A. W., SHAR, I. A., DAYO, A. A., SHAIKH, S. & SHAIKH, Z. H. Use of rice husk ash as cementations material in concrete. Engineering, Technology & Applied Science Research, 9, 4209-4212, 2019.

[11] HABEEB, G. A. & MAHMUD, H. B. Study on properties of rice husk ash and its use as cement replacement material. Materials research, 13, 185-190, 2010.

[12] BHUSHAN, R., GOCHHE, S., SINGH, H. & BASTOLA, B. Partial Replacement of Cement by Rice husk ash. International Research Journal of Engineering and Technology, 4, 251-256, 2017.

[13] BHEEL, N., MEGHWAR, S. L., SOHU, S., KHOSO, A. R., KUMAR, A. & SHAIKH, Z. H. Experimental Study on Recycled Concrete Aggregates with Rice Husk Ash as Partial Cement Replacement. Civil Engineering Journal, 4, 2018.

[14] GANESAN, K., RAJAGOPAL, K. & THANGAVEL, K. Rice husk ash blended cement: assessment of optimal level of replacement for strength and permeability properties of concrete. Construction and building materials, 22, 1675-1683, 2008.

[15] HWANG, C. The Use of Rice Husk Ash in Concrete. Waste Materials Used in Concrete Manufacturing. Edited: Chandra, S. Noyes Publications, USA,1997.

[16] NEHDI, M., DUQUETTE, J. & EL DAMATTY, A. Performance of rice husk ash produced using a new technology as a mineral admixture in concrete. Cement and concrete research, 33, 1203-1210, 2003.

[17] JOSHI, R., BHATI, R. & KANDPAL, J. 2019. Partial replacement of cement with Rice Husk Ash in concrete Design of Grade M30. International Research Journal of Engineering and Technology, 6,2323-2329, 2019.

[18] RONG, Z., DING, J., CUI, Z. & SUN, W. 2019. Mechanical properties and microstructure of ultra-high-performance cement-based composite incorporating RHA. Advances in Cement Research, 31, 472-480.

[19] SINGH, P., SINGH, T. & SINGH, G. To Study Strength Characteristics of Concrete with Rice Husk Ash. Indian Journal of Science and Technology, 9, 0974-5645, 2016

[20] GARRETT, T. D., CARDENAS, H. E. & LYNAM, J. G. Sugarcane bagasse and rice husk ash pozzolans: Cement strength and corrosion effects when using saltwater. Current Research in Green and Sustainable Chemistry, 1-2, 7-13, 2020.

الجرعة المثلى من الملدن الفائق اديكريت بي في اف مع نسبة الاستبدال المثلى لرماد قش الأرز ومع الأسمن البورتلاندي العادي

الملخص:

تهدف هذه الدراسة إلى الحصول على الجرعة المثلى من الملدن الفائق اديكريت (بي-في-اف) مع نسبة الاستبدال الامثل من رماد قشر الأرز وكذلك مع الأسمنت البورتلاندي العادي ومقارنة النتائج من حيث التأثير على مقاومة الضغط. أنتج رماد قش الأرز في هذه الدراسة عن طريق حرق قشر الأرز في حاوية حديدية مناسبة لمدة ٢٤ ساعة تقريبًا. لتحسين نشاط البوزولاني، تم طحن رماد قشر الأرز في مطحنة دقيق. تمت دراسة التركيب الكيميائي والخصائص الفيزيائية لرماد قش الأرز. يتكون البرنامج التجريبي من سبع مجموعات من الخلطات الخرسانية بجرعات مختلفة من الملدن الفائق ونسب استبدال مختلفة من قش الأرز. احتوى مزيج المجموعة الأولى على أربعة مخاليط من الأسمنت البورتلاندي مع أربع نسب استبدال مختلفة من رماد قش الارز بالنسب التالية (٠٪,١٠٪,١٥٪,٢٠٪)، المجموعة الثانية تحتوي على ستة مخاليط مع نسبة هبوط ثابتة (١٥ ± ٣) سم ونسبة الماء إلى الأسمنت (٠,٥١). تم رصد مقاومة الانضغاط لهذه المخاليط ومقارنتها بمزيج التحكم (يخليط لا يحوي أي إضافات).

المجموعة السادسة تحتوي على ستة مخاليط مع نسبة قش ارز ثابتة ١٠٪ من وزن الاسمنت البورتلاندي ومع هبوط ثابت يبلغ ٢٣ سم، وتم تطبيق جرعات مختلفة من الملدن. أظهرت النتائج أن الاستبدال الأمثل من رماد قش الأرز كان ١٠٪ مما أدى إلى زيادة مقاومة انضغاط الخرسانة بحوالي ٣٢٪. كانت الجرعة المثلى من الملدن الفائق١٥ لتر /م٣ مع نسبة الاستبدال الامثل من قش الأرز (١٠٪) مما زاد من قوة الانضغاط بحوالي ٧٤٪.