**International Journal of Civil Engineering and Technology (IJCIET)**
Volume 11, Issue 10, October 2020, pp. 9-21, Article ID: IJCIET_11_10_002
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=11&IType=10
Journal Impact Factor (2020): 11.3296 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6308 and ISSN Online: 0976-6316



# 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 0.51and (B-V-F) 6 L/*$m^3$*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/m^3 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/m^3 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

**Cite this Article:** M. M. Rashwan, K. A. Abaas and M. A. Ali, Assessment of Using an Optimal Dose of Superplasticizer with the Optimum Replacement of Rice Husk Ash (RHA) on Concrete Compressive Strength, *International Journal of Civil Engineering and Technology*, 11(10), 2020, pp. 9-21.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=11&IType=10

## 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 determent 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | Cao | MgO | $P_2O_5$ | $Mn_2O_3$ | $TIO_2$ | $K_2O$ | $Na_2O$ | $SO_3$ | 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 1cubic 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 |
| 2 | C | 5 | 450 | 597 | 597 | 399 | 229.5 | 0 | 0 | 0 | .51 | 15 | 2.2 |
| | | 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 |
| | | 29 | 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 |
| 7 | B | 23 | 450 | 645 | 645 | 430 | 174 | 6 | - | 0 | .4 | 23 | 2.3 |
| | | 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 concert 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/m 3), 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).

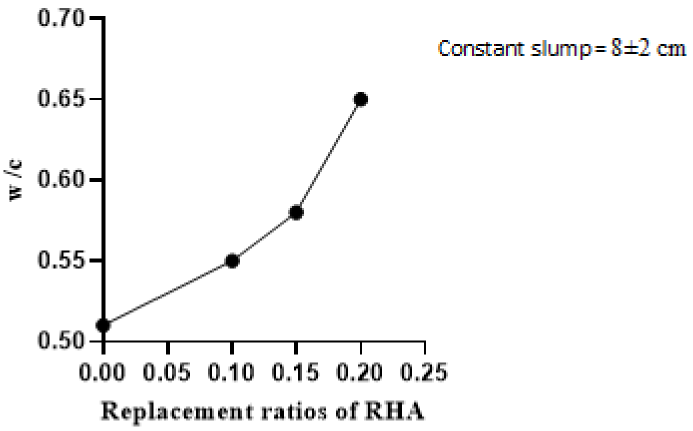


**Figure 5** Effect of replacement ratios on w/c without using superplasticizer admixture

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.

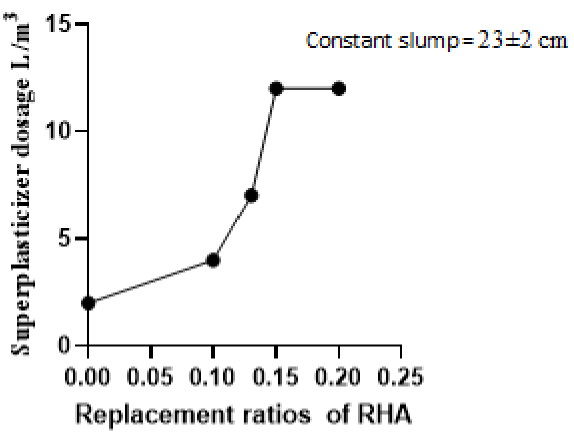


**Figure 6** Effect of replacement ratio on superplasticizer dose

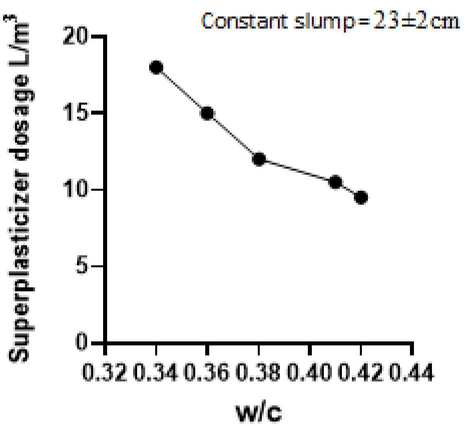


**Figure 7** Effect of amount of w/c on superplasticizer dose

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.

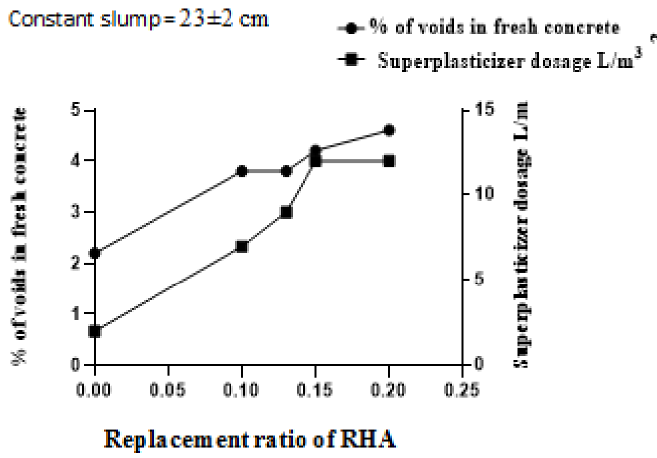


**Figure 8** Effect of RHA replacement and the amount SuperPlasticizer dose on the % of voids in fresh concrete

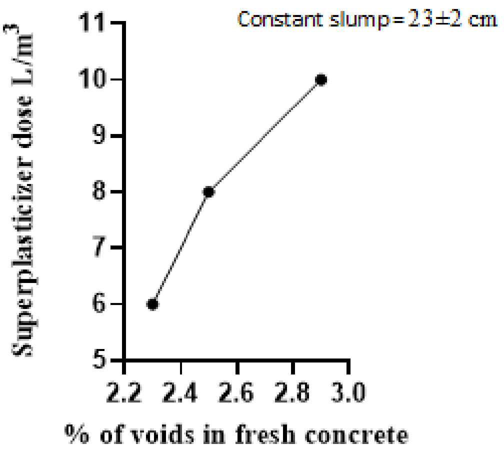


**Figure 9** Effect of the dose superplasticizer on the % of voids in fresh concrete

## 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) ($L/m^3$) | RHA% (by weight Of cement) | w/c | SLUMP (cm) | Fc($Kg/cm^2$) | | | Strength Ratio= $\frac{fc(28)}{fc(28)control}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fc7 | Fc28 | Fc60 | |
| 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 leads to a decrease in compressive strength can be avoided by using a plasticizer as in the previous research.

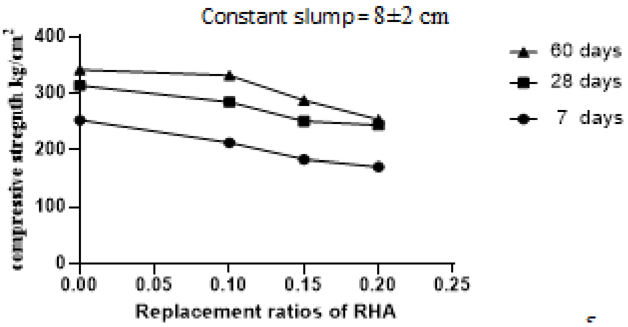


**Figure 10** Effect of different RHA content concrete compressive strength Without using a plasticizer

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.

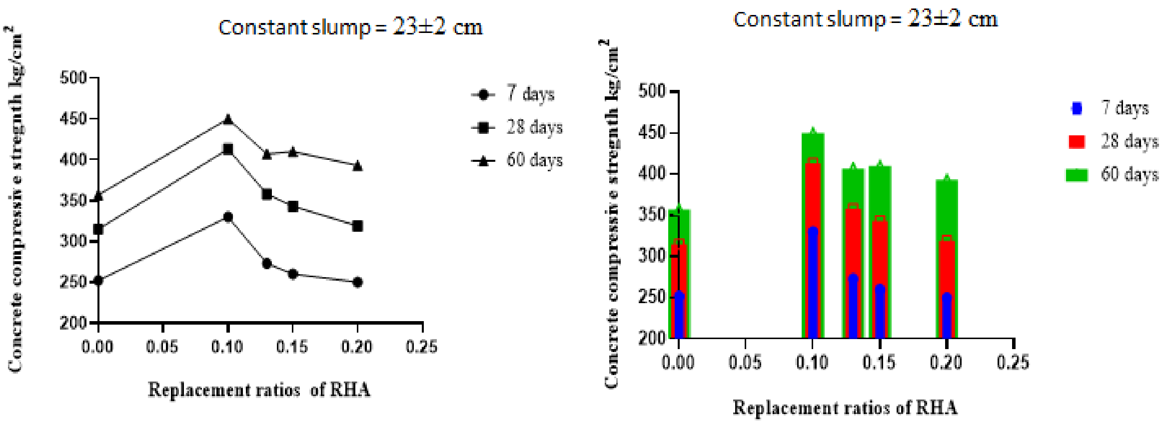


**Figure 11** Effect of different RHA content concrete compressive strength With the use of plasticizer

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= fc(28) / fc(28)control |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fc7 | Fc28 | Fc60 | |
| | | 11 | 13 | 13 | 0.44 | 15 | 255 | 377 | 443 | 1.2 |
| 6 | A.13 | 12 | 9 | 13 | 0.51 | 12 | 220 | 376 | 407 | 1.2 |
| | A.15 | 13 | 12 | 15 | 0.51 | 18 | 223 | 358 | 377 | 1.1 |
| 7 | | 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.

**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/ m$^3$, 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).

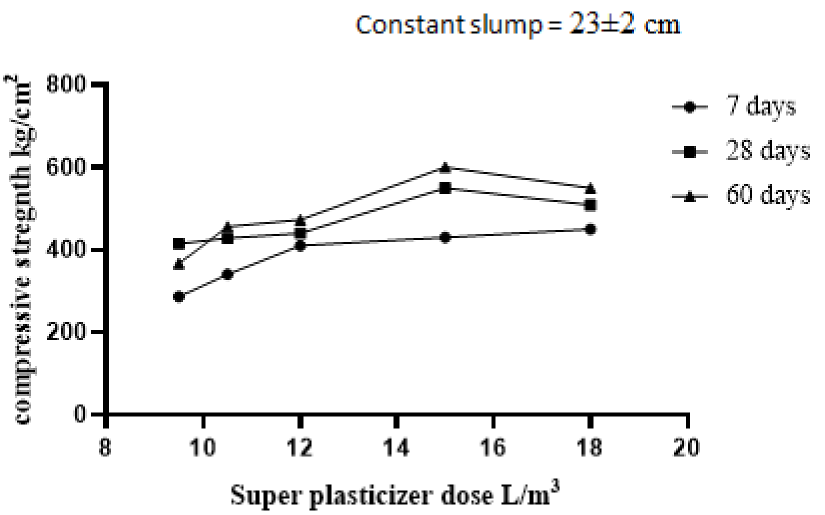


**Figure 12** Effect of different doses of superplasticizer on concrete compressive strength with an optimum RHA replacement ratio (10%).

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).

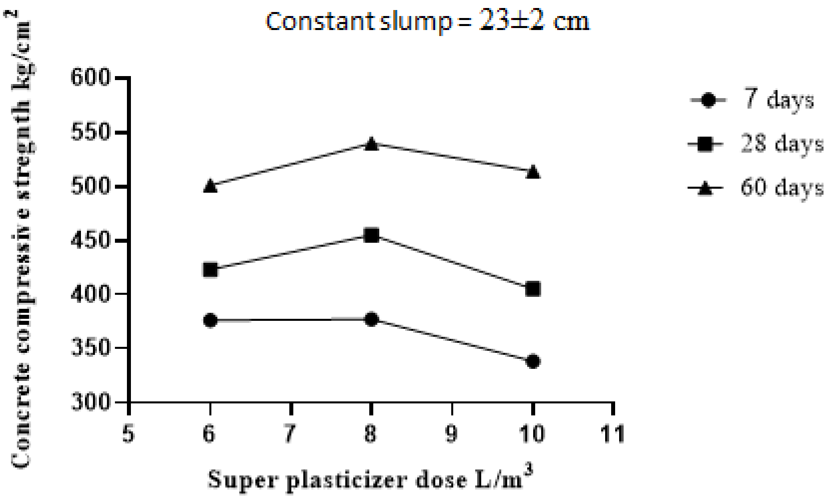


**Figure 13** effect of different w/c and superplasticizer (B-V-F) with (OPC) on compressive strength of concrete.

## 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 8L/$m^3$ for ordinary Portland cement (OPC) with w/c=.38, At which value of the strength coefficient reached (1.4) from the control strength value, the optimum dose of (ADDICRETE B-V-F) withe optimum replacement ratio of RHA (10%) is determined and equals 12L/$m^3$ with w/c=.38, also 15L/$m^3$ when w/c=.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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