JöKULL JOURNAL
JOKULL ISSN: 0449-0576

Vol 67, No.5;May 2017

INFLUENCE OF RICE, WHEAT STRAW ASH & RICE HUSK ASH ON THE PROPERTIES OF CONCRETE MIXES

T. A. EL-SAYED[1*], A. M. ERFAN[2], R. M. ABD EL-NABY[3]

[1,2]Assistant Professor, Civil Eng. Dep., Shoubra Faculty of Eng., Benha University, Egypt

Professor, Civil Eng. Dep., Shoubra Faculty of Eng., Benha University, Egypt

ABSTRACT

Three different types of husks were used, Wheat Straw, Rice Straw, and Rice Husk. The X-ray diffraction and the chemical analysis were carried out on the three wheat and rice husk ashes. The purposes were to verify the pozolanic reactivity and the existence of any harmful ingredients. The percentage of the husk ashes were 5%, 10%, 15%, and 20% of the weight of the cement. The workability was measured by the slump test. The densities of the different mixes were computed. The pulse velocity and the sorptivity were also computed. The compressive and tensile strengths were also estimated.

KEYWORDS

Wheat Straw Ash (WSA), Rice Straw Ash (RSA), Rice Husk Ash (RHA), X-ray diffraction, chemical analysis, slump test, sorptivity.

1. PROBLEM DIFINISTION

Rice straw and husk were an agricultural residue from rice cultivation and milling Process. The annual world rice production for 2007 was estimated by 649.7 million tons, the husk constitute approximately 20 % of It. Rice wastes are residue production in significant quantities on a global basis. While they are utilized in some regions; in others are wastes causing pollution and problems with disposal. When rice straw and rice husk burnt, the ash is highly pozzolanic and Suitable for use in lime-pozzolana mixes and Portland cement replacement.

* Corresponding author. Taha Awad Allah El-Sayed Ibrahim Tel.: +20 1008444985,
Fax: +202 22911118, Official Website: http://www.bu.edu.eg/staff/tahaibrahim3

Email address: taha.ibrahim@feng.bu.edu.eg (T. A. EL-Sayed)

During growth, rice and wheat plants absorb silica from the soil and accumulate it into their structures. It is this silica, concentrated by burning at high temperatures removing other elements, which make the ash so valuable. Amongst the agricultural waste, rice straw, rice husk and wheat straw have a very high potential for the production of very effective secondary raw material. It is mainly due to its random availability, very high silica content and relatively low cost. RHA contains around 85% - 90% amorphous silica which obtains from the soil combines with calcium hydroxide to increase the strength. It is known that cement production is accompanied by the emission of huge amounts of $CO2$, a greenhouse gas, into the atmosphere. It represent 7% of carbon dioxide has produced in the world, so that using rice straw and husk is more beneficial to the environment, the cost of producing Portland cement is very high, so that using rice straw and husk in concrete mixes is more economically.

2. INTRODUCTION

To enhance the durability of concrete, numerous added substances are utilized. These added substances likewise diminish the cost of cement [1–6]. Rice and wheat straw ash is utilized as a pozzolanic added substance [7]. Rice and wheat straw ash remains can be additionally used as a solid added substance because of its high silicium content [8]. For the change of the properties of cement mortar and cement concrete or the development cost to be monetary, admixtures are included with the concrete blend and these are either normally happening mixes or chemicals delivered in mechanical process. The majority of the admixtures are pozzolans. Pozzolan is a powdered material, which when added to the cement in the mix reacts with lime, discharged by the hydration of the cement, to make mixes which enhance the quality or different properties of the concrete or mortar [9]. As per ASTM [10] after chemical analysis if the sum of Iron oxide ($Fe2O3$), Silicon oxide ($SiO2$) and Aluminum oxide ($Al2O3$) is over 70% then the material would be pronounced as a pozzolanic material. It is observed by many researchers that there is an increase of compressive strength of mortar with the use of pozzolanic materials. The increase in compressive strength could be attributed to the reduced water content, the filler effect, and the higher pozzolanic reaction. The fine fineness of pozzolans had a greater pozzolanic reaction and the small particles could also fill in the voids of the mortar mixture, thus increasing the compressive strength of the mortar [11]. The use of supplementary cementitious materials, such as fly ash, silica fume, and blast furnace slag, in concrete construction is widespread. Supplementary cementitious materials may considerably improve the strength and durability of concrete [12], [13].

Different specialists who concentrate on the conceivable utilizations of burned slag have examined building and development materials. Other than tackling transfer issues, monetary, biological, and vitality sparing is another favorable position of burned fiery debris reuse in the development business. As per other reviews [14–16], cremation by-items that could conceivably be utilized as pozzolanic materials in the development business includes paper sludge ash, rice husk ash (RHA), and sewage sludge ash. The utilization of these burned slags as halfway substitutions for bond presents the ecological advantages of waste reuse and CO2 investment funds by diminishing the cement content and change of material mechanical properties. Among these by- products, RHA has pulled in intrigue in view of its high undefined silica content. Several reviews have utilized RHA as a low-cost and superior building material [17, 18]. In spite of the fact that co-combustion of rice husk and sewage sludge gives promising application prospects, just few reviews have been led.

3. RESEARCH SIGNIFICANCE "OBJECTIVES"

1- Studying the effect of using three different ashes as cement replacement or filling materials on the physical and mechanical properties of the concrete mixes.

2- Studying the effect of the percentage of the ashes on the physical and mechanical properties of the concrete mixes.

4. EXPERIMENTAL PROGRAM

4.1 Concrete Mixes

All concrete mixes were designed by absolute volume method according to ACI 211. The mix proportions of the concrete mixes - in kg/m^3 are given in Table (1). All the concrete mixes made with 0.5 w/c ratio. M_0 is the corresponding control Normal weight concrete. Chart 1&2 illustrates the scheme of the experimental program.

Table 1: Mix design

Mix type	W/C	Rice straw powder	Rice husk powder	Wheat straw powder	Cement (kg)	Water (kg)	Sand (kg)	C. Agg. (kg)
M_0	0.5	-	-	-	400	200	725	1075
WSA5%	0.5	5%	-	-	380	200	725	1075
WSA10%	0.5	10%	-	-	360	200	725	1075
WSA15%	0.5	15%	-	-	340	200	725	1075
WSA20%	0.5	20%	-	-	320	200	725	1075
RSA5%	0.5	-	5%	-	380	200	725	1075
RSA10%	0.5	-	10%	-	360	200	725	1075
RSA15%	0.5	-	15%	-	340	200	725	1075
RSA20%	0.5	-	20%	-	320	200	725	1075
RHA5%	0.5	-	-	5%	380	200	725	1075
RHA10%	0.5	-	-	10%	360	200	725	1075
RHA15%	0.5	-	-	15%	340	200	725	1075
RHA20%	0.5	-	-	20%	320	200	725	1075

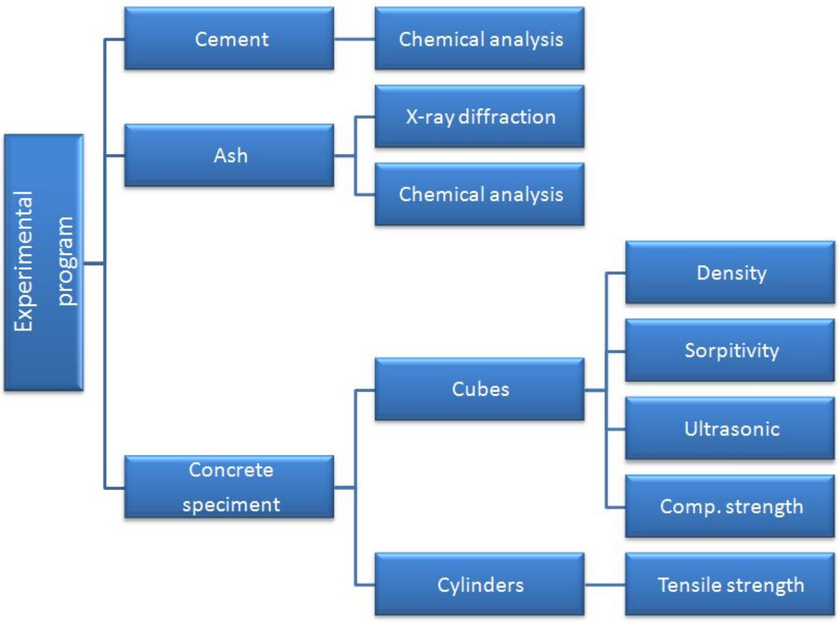


Chart 1: The experimental program

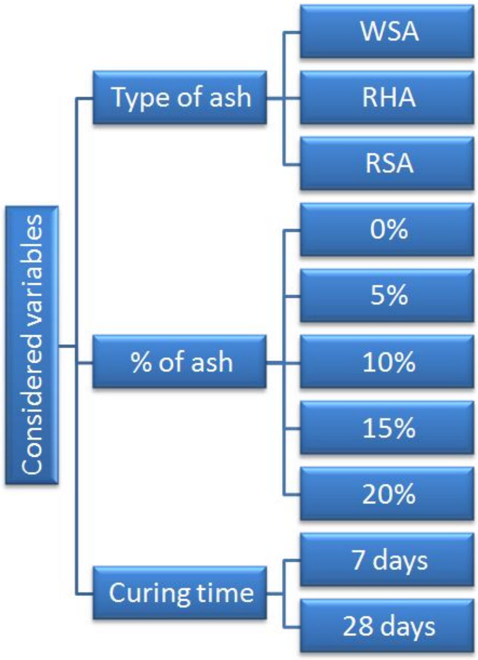


Chart 2: The tested variables

4.2 Testing procedures of Fresh concrete

The slump test was conducted after 20, 40, 60 minutes after mixing to measure the slump loss of the concrete mixes. Figure 1, shows slump test.

Figure 1: Slump test

4.3 Testing procedures of hardened concrete

4.3.1 Compressive strength test

100x100x100 mm cubical specimens were used for determination of compressive strength for concrete mixes. The reported values of compressive strength of concrete cubes represent the average results of three specimens. The load setup is shown in Figure 2.

Figure 2: Compression test machine

4.3.2 Indirect tension strength test

The splitting tensile strength test was carried out on cylindrical specimens of 100 mm diameter and 200 mm height as shown in Figure 3. The test was carried out on SSD condition at an age of 28 days. The reported values of splitting tensile strength of concrete represent the average results of three specimens. The splitting tensile strength was calculated using the following equation:

$T = 2P/\pi LD$ ……………………… Equation (1)

Where;
T = Splitting tensile strength (N/mm^2),
P = Maximum (failure) load (N),
L = Length of the specimen (mm), and
D = Diameter of the specimen (mm).

Figure 3: Splitting test

4.3.3 Ultrasonic pulse velocity

Longitudinal pulse velocity (m/s) is given by:

$V = L / T$ ……………………… Equation (2)

Where:
V is the longitudinal pulse velocity (m/s),
L is the path length (m),
T is the time taken by the pulse to traverse that length (s).

4.3.4 Porosity Test

The porosity can be calculated as follow:

Porosity = volume of the voids/volume of the specimen

= V_v/V_o*100 = (W_1-W_2)*100/V_o ………………………. Equation (3)

Where:

W_1= weight of saturated specimen,
W_2=weight of dry specimen,

4.3.5 Water absorption by capillary action, the sorptivity

The sorptivity test was carried out using a plastic container filled with water to a depth of 20 mm. Steel bars of 18 mm diameter were rested on the bottom of the container such that, the water was just above the top surface of the steel bars as shown in Figure 4. The specimens were weighed using digital electric balance of 0.001 and 0.1 gm accuracy for mortar and concrete specimens respectively.

Sorptivity of the tested specimens was calculated using the following equation. The results were an average of triplicate measurements taken after 28 and 56 days.

$i = St^{1/2}$ ………………………. Equation (4)

Where,

i = increase in mass (g/mm^2).
t = time, measured (min), at which the weight is determined,
S = sorptivity ($mm/min^{1/2}$).

Figure 4: Sorptivity test

5. RESULTS AND ANALYSIS

5.1 X ray diffraction

X-ray diffraction analysis was carried out on three samples of ashes RHA, RSA and WSA. The results of the three ashes are shown in Figures 5, 6 and 7.

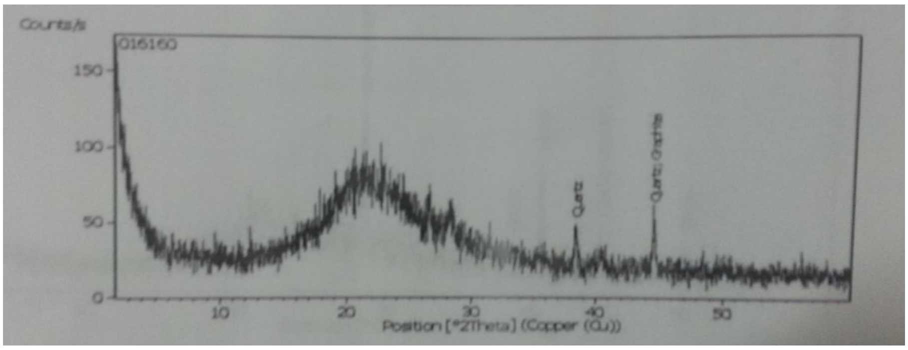


Figure 5: XRD patterns of gray rice husk ash

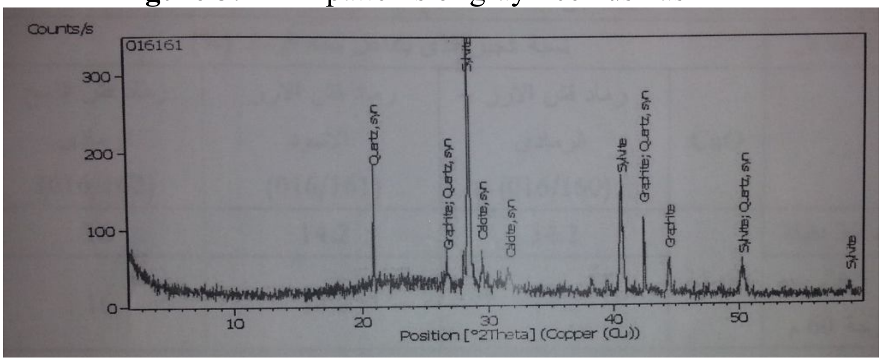


Figure 6: XRD patterns of gray rice straw ash

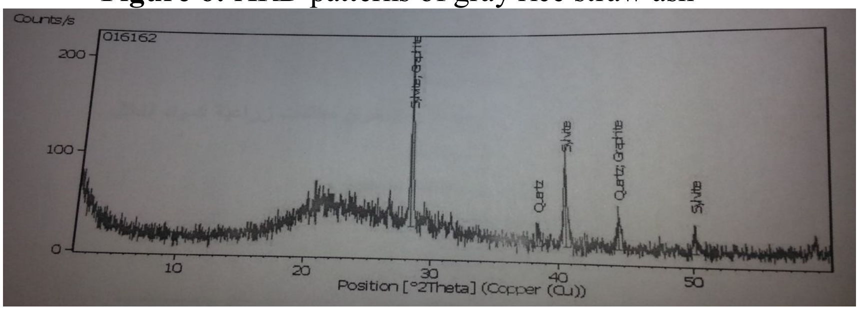


Figure 7: XRD patterns of gray wheat straw ash

5.2 Chemical analysis

Table 2 showed the potential of pozolanic reaction. The results showed that samples of the ashes of rice straw has interacted with 14% of quicklime and the ashes of wheat straw with 16%.

Table 2: Potential of pozolanic reaction

Interaction duration		Quicklime % which interacted with ashes		
	C_ao	Gray rice straw ash RSA (016/160)	Black rice husk ash RHA (016/161)	Gray wheat straw ash WSA (016/162)
After 30 min.	35 ml	14.2	14	16
After 5 days at 60°c		14.2	14	16

5.3 Slump test results

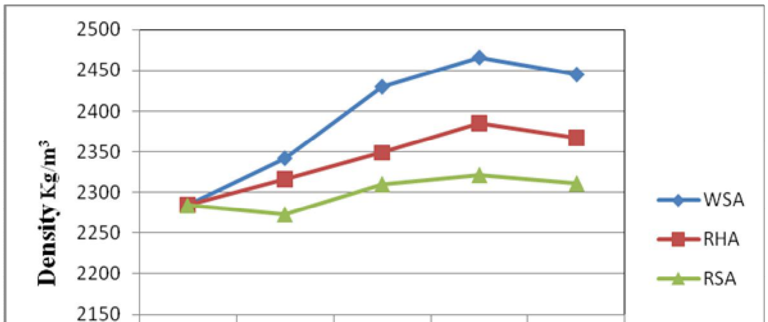
Table 3 shows that slump test results for fresh concrete mixes of (Mo, WSA, RSA and RHA).

Table 3: Slump test results

Sample ID	Percentage of ash	Slump (mm)
CONTROL	0%	6.5
WSA	5%	5
	10%	4
	15%	5.5
	20%	4.5
RHA	5%	3.5
	10%	3.5
	15%	6.5
	20%	4.5
RSA	5%	4
	10%	5.5
	15%	6.5
	20%	5

5.4 Density test results

Figure 8 shows the effect of % of ash on the density of concrete mixes. Figures showed that increasing % of ash from 5% to 15% leads to the increase of the density from 2342 to 2466 Kg/m^2, while increasing the % of ash from 15% to 20% lead the decreasing the density to 2400 Kg/m^2. The highest value of density was observed at 15% WSA as a replacement material.



	0%	5%	10%	15%	20%
WSA	2284	2342	2430	2466	2445
RHA	2284	2316	2349	2385	2367
RSA	2284	2273	2310	2321	2311

Figure 8: Influence of % of ash on density after 7 days of curing

5.5 Hardened concrete

5.5.1 Compressive strength results

Figures 9&10 show the effect of type of ash on compressive strength at 7 & 28 days respectively of concrete mixes. Figure 9 showed that increasing % of ash from 5% to 15% leads to the increase of the compressive strength from 19.80 to 25.61 N/mm^2, while the increasing the % of ash from 15% to 20% lead the decreasing the compressive strength to 23.41 N/mm^2. The highest compressive strength was observed at 15% WSA as a replacement material. Figure 10 showed that increasing % of ash from 5% to 15% leads to the increase of the compressive strength from 37.25 to 45.90 N/mm^2, while the increasing the % of ash from 15% to 20% lead the decreasing the compressive strength to 40.65 N/mm^2. The highest compressive strength was observed at 15% WSA as a replacement material.

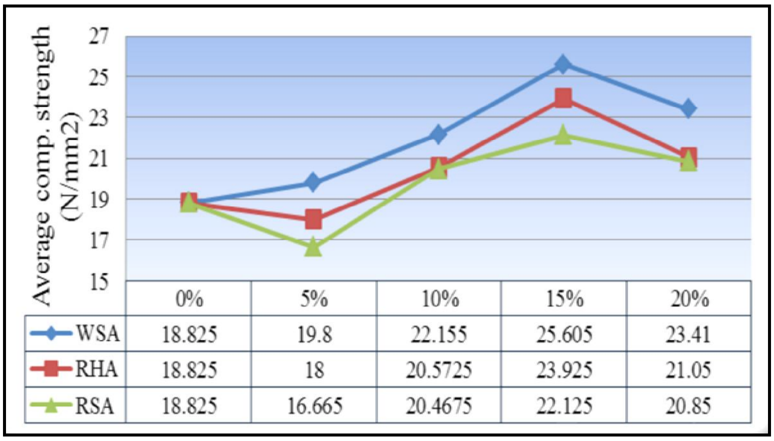


Figure 9: Influence of % of ash on compressive strength after 7 days of concrete mixes

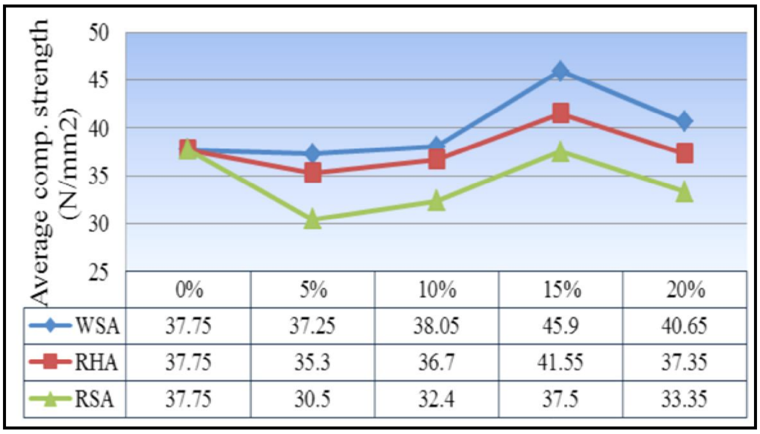


Figure 10: Influence of % of ash on compressive strength after 28 days of concrete mixes

5.2.2 Tensile strength results

Figures 11 & 12 show the effect of type of ash on tensile strength after 7& 28 days respectively of concrete mixes. Figure 11 showed that increasing % of ash from 5% to 15% leads to the increase of the tensile strength from 1.94 to 2.19 N/mm^2. While increasing the % of ash from 15% to 20% leading to decrease the tensile strength to 1.29 N/mm^2. The highest tensile strength was observed at 15% WSA as a replacement material. Figure 10 showed that increasing % of ash from 5% to 15% leads to the increase of the tensile strength from 2.26 to 3.11 N/mm^2. While increasing the % of ash from 15% to 20% leading to decrease the tensile strength to 2.95 N/mm^2. The highest tensile strength was observed at 15% WSA as a replacement material.

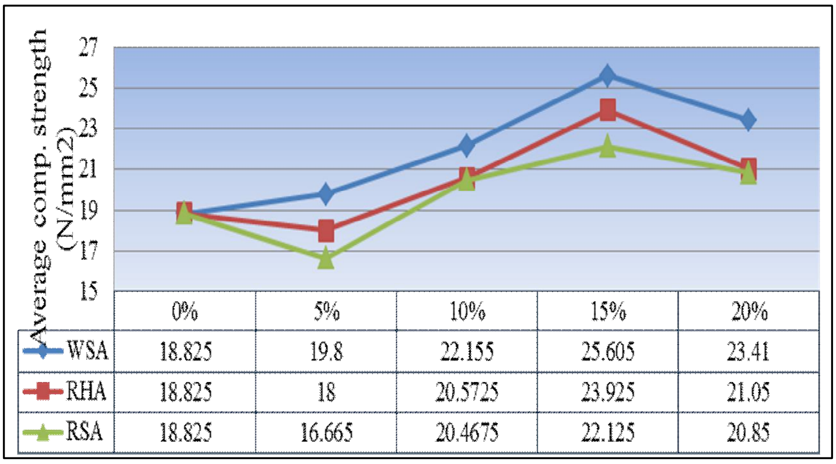


Figure 11: Influence of % of ash on tensile strength after 7 days of concrete mixes

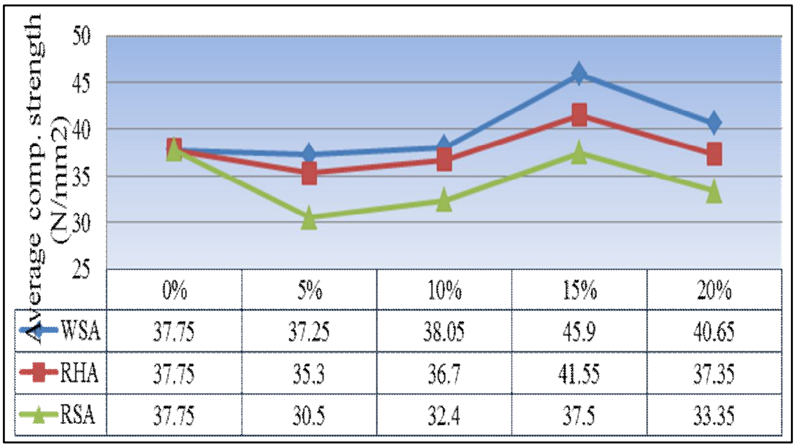
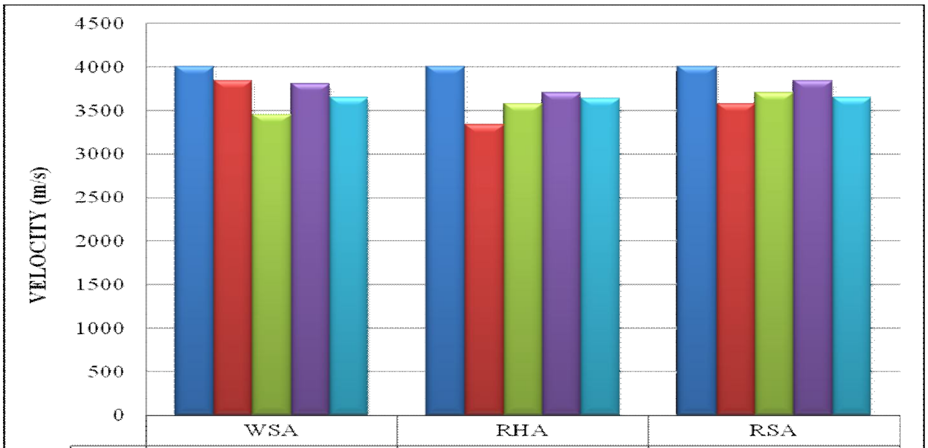


Figure 12: Influence of % of ash on tensile strength after 28 days of concrete mixes

5.6 Ultrasonic test results

Figure 13 shows the effect of type of ash on the pulse velocity of concrete mixes. Figure 13 showed that changing type of ash leads to the increase of the pulse velocity from 3703 to 3846 m/s. The highest value of pulse velocity was observed at 15% WSA as a replacement material.

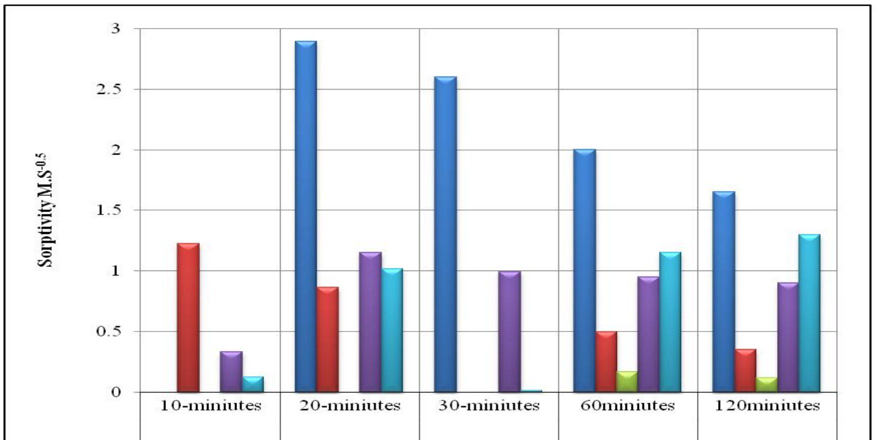


	WSA	RHA	RSA
0%	4000	4000	4000
5%	3846	3333	3571
10%	3448	3571	3703
15%	3805	3703	3846
20%	3647	3637	3649

Figure 13: Influence of % of ash on pulse velocity of concrete

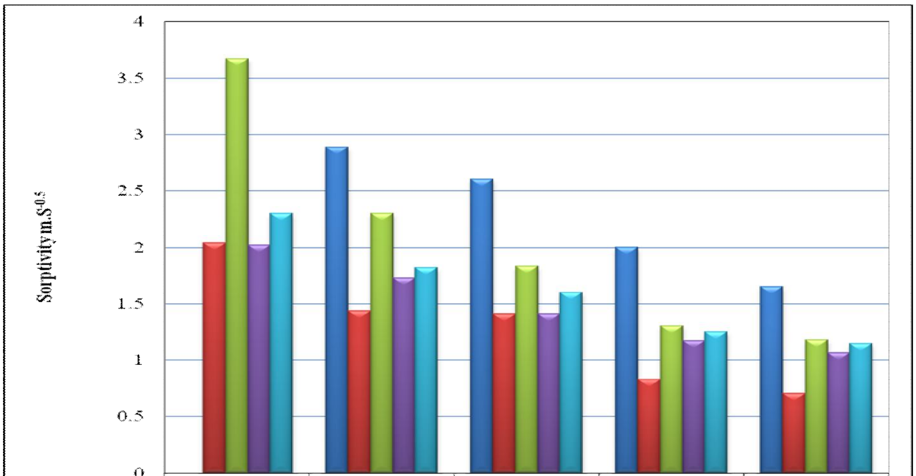
5.7 Sorpitivty test results

Figures 14, 15 &16 show the effect of % of ashes on the sorpitivity of concrete mixes. Figures showed that increasing % of ash from 5% to 15% leads to decreasing sorpitivty from 0.5 to 0.354 m.s$^{-0.5}$, while increasing % of ash from 15% to 20% leads to the increasing of sorptivity from 0.354 to 0.65 m.s$^{-0.5}$. The highest value of sorpitivity was observed at 15% WSA as a replacement material.



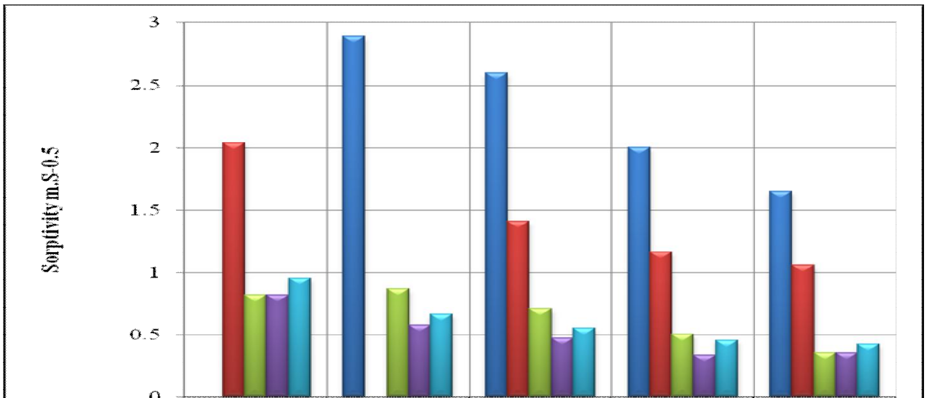
	10-miniutes	20-miniutes	30-miniutes	60miniutes	120miniutes
M0	0	2.89	2.6	2	1.65
RSA5%	1.225	0.866	0	0.5	0.354
RSA10%	0	0	0	0.167	0.118
RSA 15%	0.334	1.15	0.99	0.95	0.9
RSA 20%	0.124	1.02	0.015	1.15	1.3

Figure 14: Influence of % of RSA on sorpitivity of concrete



	10-miniutes After	20-miniutes After2	30-miniutes After3	60miniutes After4	120miniutes After5
M0	0	2.89	2.6	2	1.65
WSA5%	2.04	1.44	1.41	0.83	0.707
WSA10%	3.67	2.3	1.83	1.3	1.18
WSA15%	2.02	1.73	1.41	1.17	1.06
WSA 20%	2.3	1.82	1.6	1.25	1.15

Figure 15: Influence of % of WSA on sorpitivity of concrete



	10-miniutes After	20-miniutes After2	30-miniutes After3	60miniutes After4	120miniutes After5
M0	0	2.89	2.6	2	1.65
RHA5%	2.04	0	1.41	1.16	1.06
RHA10%	0.816	0.866	0.707	0.5	0.354
RHA15%	0.816	0.577	0.471	0.333	0.354
RHA 20%	0.95	0.66	0.55	0.45	0.425

Figure 16: Influence of % of RHA on sorpitivity of concrete

6. CONCLUSION

The main conclusions can be summarized as follows:

1. Using the Wheat and Rice straw Ash and Rice Husk Ash improved the compressive and tensile strength of the concrete specimens.
2. The Wheat Straw Ash showed the highest value of the compressive and tensile strength with respect to the Rice Straw and Rice Husk ash.
3. Adding the ash with 15% of the weight of the cement showed the highest compressive and tensile strength with respect to the 5%, 10%, and 20%.
4. The maximum values of the compressive and tensile strength were shown foe the case of using 15% wheat Straw Ash.
5. The durability of the concrete was significantly improved for the case of using the ash with 15% of the cement and the best result for the durability in terms of density, sorptivity, and strength was obtained for the case of 15% Wheat Straw Ash.

7. Recommendations for future work:

1. The technique of burning the straw and husk should be carried out using well prepared furnace to insure temperature stabilization and complete burning of the straw and husk.
2. Grinding the ash after burning is very important to insure the required surface area.

8. REFERENCES

[1] H. Binici, O. Aksogan, Sulphate resistance of plain and blended cement, Cement Concr. Compos. 28 (2006) 39–46.

[2] J. Tikkanen, A. Cwirzen, V. Penttala, Effects of mineral powders on hydration process and hydration products in normal strength concrete, Constr. Build. Mater. 72 (2014) 7–14.

[3] H. Binici, R. Gemci, O. Aksogan, H. Kaplan, Insulation properties of bricks made with cotton and textile ash wastes, Int. J. Mater. Res. 101 (2010) 894–899.

[4] G.C. Isaia, A.L.G. Gastaldini, R. Moraesl, Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete, Cement Concr. Compos. 25 (2003) 69–76.

[5] H. Binici, O. Aksogan, A.H. Sevinc, A. Kucukonder, Mechanical and radioactivity shielding performances of mortars made with colemanite, barite, ground basaltic pumice and ground blast furnace slag, Constr. Build. Mater. 50 (2014) 177–183.

[6] O. Cakır, Experimental analysis of properties of recycled coarse aggregate (RCA) concrete with mineral additives, Constr. Build. Mater. 68 (2014) 17–25.

[7] H. Biricik, F. Akoz, I. Berktay, A.N. Tulgar, Study of pozzolanic properties of wheat straw ash, Cem. Concr. Res. 29 (1999) 637–643.

[8] J. Bensted, J. Munn, A discussion of the paper: ‘‘Study of pozzolanic properties of wheat straw ash” by Biricik H., Akoz F., Berktay I., Tulgar A.N., Cem. Concr. Res. 30 (2000) 1507–1508.

[9] B. King, A Brief Introduction to Pozzolans. in: Alternative Construction - Contemporary Natural Building Methods, John Wiley & Sons, London, 2000.

[10] Specification for Fly Ash and Raw or Calcium Natural Pozzolona for Use as a Material Admixture in Portland Cement Concrete, ASTM C 618-78, American Standard for Testing Materials, 1978.

[11] G. C. Isaia, A. L. G. Gastaldini, and R. Moraes, “Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete,” Cem. Concr. Compos., vol. 25, Issue 1, pp. 69-76, 2003.

[12] V. Papadakis, M. Fardis, and C. Vayenas, “Hydration and carbonation of pozzolanic cements,” ACI Mater, pp.119– 130, 1992.

[13] B. March, R. Day, and D. Bonner, "Pore structure characteristics affecting the permeability of cement paste containing fly ash," Cem. Concr. Res. pp. 1027– 1038, 1985.

[14] R. García, R.V.D.L. Villa, I. Vegas, The pozzolanic properties of paper sludge waste, Constr. Build. Mater. 22 (7) (2008) 1484–1490.

[15] S.K. Agarwal, Pozzolanic activity of various siliceous materials, Cem. Concr. Res. 36 (9) (2006) 1735–1739.

[16] S.C. Pan, D.H. Tseng, C.C. Lee, C. Lee, Influence of the fineness of sewage sludge ash on the mortar properties, Cem. Concr. Res. 33 (11) (2003) 1749–1754.

[17] J.S. Coutinho, The combined benefits of CPF and RHA in improving the durability of concrete structures, Cement Concr. Compos. 25 (1) (2003) 51–59.

[18] M.H. Zhang, High-performance concrete incorporating rice husk ash as a supplementary cementing material, ACI Mater. J. 93 (6) (1996) 629–636.