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Utilizing of Solid Waste with Different Percentages as Partial Replacement by Cement's Weight

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Abstract: The growth in populated areas lead to accumulate solid waste which is an essential problem in the global. The modren studies moving towards utilizing materials that have less environmental influence. The purpose of this study is to develop an effective and environmentally disposal method of solid Waste Glass Powder (WGP), Waste Paper Ash (WPA) and Waste Sludge of Sugar Industries (WSSI) that collected from different locations to eliminate the disposal problem of these waste, reduce the harmful emission gases result from cement manufacture industry into our environment and thus, substantiate to be environment friendly and examined the performance properties of utilizing these wastes in concrete mixtures. Different percentage (5, 10, 15 and 20%) of WGP, WPA and WSSI are used as a partial replacement by cement's weight for each type of waste and studying their effect on the concrete mechanical properties, after mixing, casting and curing at (7, 28 and 56 days). The fresh and hardened properties of concrete are performed such as (slump, oven dry density, compressive strength, flexural strength and water absorption). Through this, WGP, WPA and WSSI are possibly used in effective way with different percentages.

Key words: Solid waste, environment impact, compressive, water absorption and flexural tensile strength, crushed glass, ash, sludge, paper waste

INTRODUCTION

The waste accumulation in the densely populated areas is a problem in the worldwide. Due to the technology development along with a current lifestyle has directed to an increase in the amount and type of solid waste that being generated. The non-decaying waste materials cause a waste disposal crisis, therefore, contributing to the environmental problems. Most of these wastes are left as landfill material, stockpiles and illegally dumped in areas.

One of the most important environmental problems that the world facing is the solid waste problem. The term "solid wastes" means any non-liquid wastes that generated from human and animals activates and left out by users as useless or unwanted. The major sources of solid wastes are domestic, household, commercial, industrial and construction demolition wastes (Tchobanoglous *et al*., 1977; Worrell and Vesilind, 2011). While the term "solid waste management" is defined as the propriety that are associated with the control of generation, collection, storage, transfer and transport, processing and disposal of solid wastes (Tchobanoglous, 2009).

Solid waste materials are possibly reused as useful materials in concrete, thus, a great noticeable reduction of waste towards sustainable development. The general advantage of utilizing it leads to some important properties such as environmentally friendly, easily available, low-cost concrete. The utilization of solid waste materials as a partially replaced by cement's weight with different percentage is cled to reducing the cost of usages cement also produce concrete with less environmental impact (Okeyinka *et al*., 2015).

Based on Islam *et al*. (2017) the partially replacing milled glass waste in concrete and mortar by cement's weight was considered as a positive step toward the sustainable concrete. The results appeared that by increasing the waste glass mortar, flow test was slightly increased. Besides, the results showed that there was no effect noticed on the concrete workability. The compressive strength was offered a better strength compared to the control mixture until 1 year and indicated a persuasive costly and environmentally at partially replacing 20% glass waste by cement's weight. In addition, the high surface area of milled glass waste variations the kinetics of chemical reaction toward beneficial pozzolanic reaction using the available alkalis, before production of a potential ASR (Alkali-Silica

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Reaction) gel. However, the researchers by Talsania *et al*. (2015) were illustrated the influence of partially replaced powder glass waste by weight of cement in concrete mixture. Based on their experimental work, the (compressive and flexural) strengths of concrete were increased up to 20% when the glass waste replaced by cement's weight. While the outcomes by Aliabdo *et al*. (2016) concluded the effect of partially replacing and addition of powder glass by weight of cement in motars and concrete which appeared powder glass had a pozzolanic characteristic. When using powder glass up to 15% it improved the properties of concrete and mortar as well as increased the compressive strength and improved the concrete performance compared to the partial replacement of cement.

The research by AL-Zubaid *et al*. (2017) was on the effect of incorporate various colors glass such as (neon, green and brown) and partially replacing (11, 13 and 15%) of recycled waste glasses by weight of cement at (7, 14 and 28 days). Their results were showed that increases in (compressive and flexural tensile) strengths when partially replacing 13% neon glass by cement's weight. However, the concrete workability was appeared a decrease with increasing waste content %. However, the research by Mahmood *et al*. (2016) was on the utilization of colorless glass waste in order to transform them into raw materials as alternative method which partially replaced (2, 4, 5, 6, 8, 10, 15, 20 and 25%) by weight of cement. The maximum compressive strength results were only obtained at the replacement 2, 4, 5 and 6%.

Based by Zaki *et al*. (2017) the study waste after treating is used as an addition (5, 10, 15 and 20%) by weight of cement in mortars and concrete in order to produce lightweight mortars and concrete by studying the mechanical properties compared with references mixtures. It was noticed that by increasing the waste paper content, the fresh properties were significantly affected and the (compressive, splitting tensile, flexural) strengths and density decreased when the paper waste content % increased. The outcomes reported that it was a low-cost to be alternative building material and thermal insulation. While the researchers by Ahmad *et al*. (2013) were studied the effect of combination paper sludge ash waste with concrete mixes as a partial replacement (5, 10, 15 and 20%) by cement's weight in concrete and examined its (compressive and tensile) strengths, water absorption and dry density up to 28 days compared to normal concrete. The obtained results were showed that study sludge ash waste possibly replaced up to 5% by weight of cement.

The outcomes by Nazar *et al*. (2014) conducted using paper mill sludge as partially replacement and addition (10, 20 and 30%) in concrete mixes by weight of cement. (Compressive and flexural) strengths and modulus elasticity were examined compared to the control mix which showed a decrease in strength when paper mill sludge content increased. Paper mill sludge waste was appropriate to be used in small quantities of concrete mixes as a replacement of cement. However, the outcomes by Varkey *et al*. (2016) examined the possibility of using paper sludge waste as partially replacement 2.5, 5 and 7.5% by weight of cement in order to produce a low-cost concrete by mixing different ratios of cement with paper sludge which appeared the possibility of replacing up to 5% paper sludge waste by weight of cement without any negative impact on concrete properties. The tests of strengths (compressive, splitting tensile and flexural) up to 28 days were performed and compared with normal concrete.

The researchers by Modani and Vyawahare (2013) focused on utilizing Sugar-cane bagasse from the sugar refining industry, together with ethanol vapor. untreated bagasse ash where partially replaced (10, 20, 30, 40%) by sand's volume in concrete. Fresh and hardened concrete tests were examined such as (compressive and split tensile) strengths and sorptivity. The outcomes appeared that bagasse ash possibly replaced by sand.

MATERIALS AND MATHODS

Research significance: Studying the influence of incorporation different waste materials (Waste Glass Powder (WGP), Waste Paper Ash (WPA) and Waste Sludge of Sugar Industries (WSSI) as partially cementations materials on mechanical properties (oven dry density, compressive strength, flexural strength and water absorption) in concrete mixture to produce a normal concrete.

Experimental procedure: Control specimens included (cubes and prisms) with dimensions (150×150×150 and 400×100×100 mm), respectively. The utilization materials include Portland Limestone Cement (PLC), water, sand and aggregate also the different type of waste that used as a partial replacement by cement's weight.

Materials: The all materials properties are checked according to the standard specifications of (IQS) and of (ASTM).

Table 1: Physical cement properties

Limits of IQS Physical properties	Results	No. 5/1984
Fineness (Blaine method), (m^2 kg)	364	No specified
Setting time (vice apparatus)		
a. Initial setting time (min)	177	≥45 min
b. Final setting (h)	3:377	≤10 h
Compressive strength is not>(mN/m^2)		
For 2 days	21.8	≥20
For 28 days	52.1	≥42.5
Soundness (expansion) mm	0.34	≤10

Table 2: Chemical composition of materials

Compound composition	Abbreviation	(WGP%)	(WPA%)	(WSSI%)	PLC
Silica dioxide	SiO_2	80.06	13.99	2.8	21.1
Calcium oxide	CaO	13.75	46.64	94.18	64.78
Alumina	Al_2O_3	0.83	5.03	0.37	4.78
Iron oxide	Fe_2O_3	0.97	0.84	0.6	3.19
Magnesia	MgO	3.14	1.19	0.7	1.76
Potassium oxide	K_2O	0.16	1.05	-	-
Sulfate	SO_3	0.26	-	0.6	2.45
chlorine	Cl	0.06	-	-	-
Phosphorus	P_2O_5	0.77	-	0.75	-

Aggregate: In this research, the fine aggregate (Sand) that used for mixes is a natural washed sand from (Al-Ekhaidhir) quarry which is a local source in Iraq with zone 3 (0.15-4.75) mm according to have fineness modulus 2.6, specific gravity 2.65 and water absorption 0.74%. While coarse aggregate (gravel) that used for mixes is crushed gravel from (Al-Nebai) Region which is a local source in Iraq with a maximum size of 19 mm.

Water: For all the mixes, the portable water has been used which taken from the water supply network system (tap water).

Cement: The Portland Limestone Cement (PLC) manufactured in Iraq with a commercial name (Karsta) has been used in this study. The physical properties of cement shown in Table 1.

Waste Glass Powder (WGP): The glasses waste that used in this study are collected from some local industrial workshops and landfill ground in Babylon city then washed with water to dispose of unwanted impurities. It has been crushed by ball milling machine known as (loss Angeles crusher). After that it is sieved through 90 μm which is the Iraqi standard sieve, Fig. 1 illustrates the preparation of WGP.

Waste Paper (Ash) (WPA): Waste paper has been collected from administration offices, schools, planning and libraries. Then an open container is used to incineration paper, so as to convert it into ash. The ash is sieved through 90 μm on Iraqi standard sieve. Figure 2 illustrates the preparation of ash.

Waste Sludge of Sugar Industries (WSSI) The waste sludge of sugar industries is collected from the landfill of Etihad Sugar Factory in Babylon City, Iraq. sieved through 90 μm on Iraqi standard sieve. Figure 3 illustrates the preparation of WSSI. The Energy Dispersive X-Ray Fluorescence technology (ED-XRF) has been performed to determine the chemical composition of PLC, WGP, WPA and WSSI which is carried out in Iraqi German Laboratory at Faculty of Science Department of Earth Sciences/University of Baghdad and presented in Table 2.

Mix procedure: A mixer of 0.09 m^3 capacity is used to mixing the concrete as shown in Fig. 4 according to (ASTM., 2016a, b). Adding saturated surface dry aggregates (fine and coarse) to the mixer machine after that starting mixing for about 1 min. Adding approximately half of the required potable water to the mixer machine with aggregates and mixing continues for another 1 min. After that, adding cement to mixer machine on wetted aggregates mixture, adding residue water then mixing continues until the cement paste completely covered the aggregate and the mixing continues for another 2 min until getting a regular color. When the waste is added, the intersperse waste particles are gradually added to mixer machine above the mixture, the addition process of waste usually takes about 1 min and then mixing for 1 min (Fig. 4).

Testing: At the age of 7, 28 and 56 days the concrete specimens of the compressive strength test were performed in this research according to the (BS1881-116, 1997) while flexural tensile strength test according to (ASTM., 2016a, b) and water absorption test according to (ASTM., 2013), slump test according to the (ASTM., 2015) and oven dry density test according to ASTM., (2014) Fig. 5 show the Over view of casting specimen.

Reference and work mixtures: The values of the reference design mixture (without any partial replacement of waste) that is used in this study, content (420 kg/m^3) cement (705 kg/m^3) sand (1024 kg/m^3) gravel and the water to cementsratios (w/c) is (0.47) to produce a normal concrete with (1:1.8:2.4) as explained in (cement, sand, gravel) that has the desirable properties in the fresh and hardened state which is achieved the requirements. It

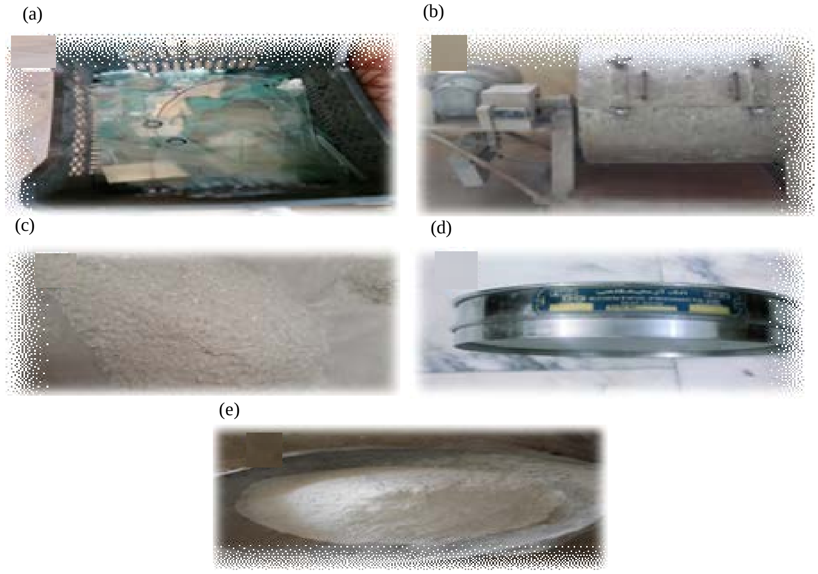

Fig. 1a-e): The preparation of WGP

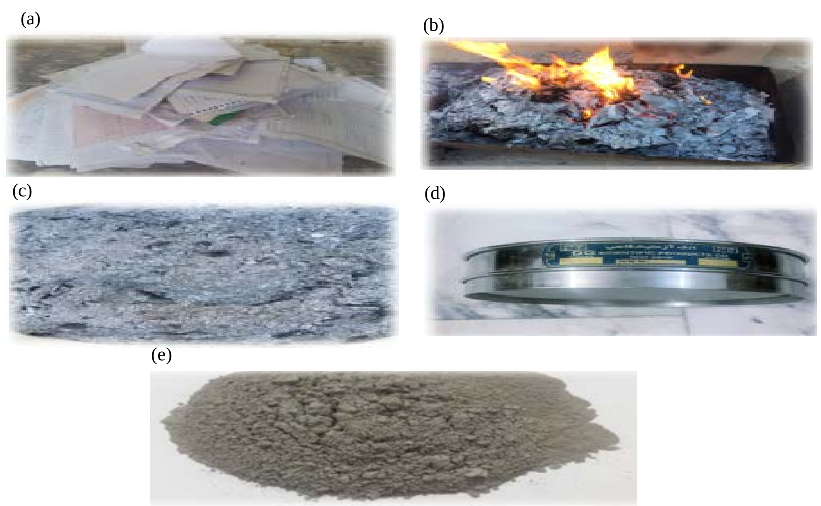

Fig. 2a-e): The preparation of WPA

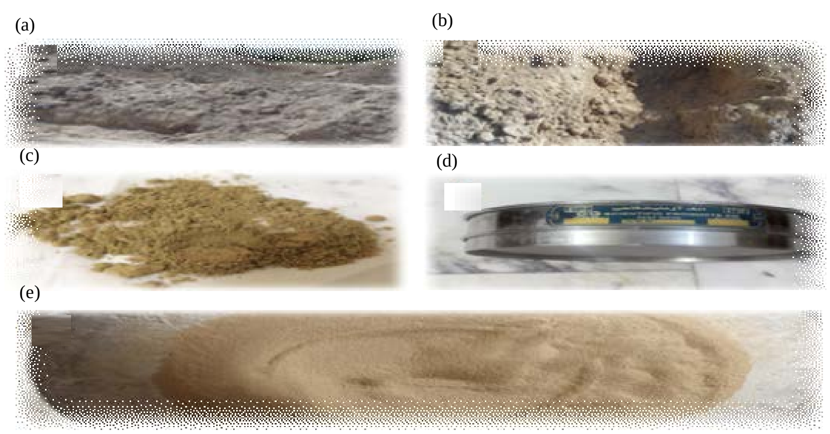

Fig. 3a-e): The preparation of WSSI

(a) (b)

Fig. 4a, b): Mixing machine

Fig. 5: Over view of casting specimen

Table 3: Reference mixture test's results

	Value		
	10		
	Value at		
Test names/slump test (cm)	7 days	28 days	56 days
Oven dry density (kg/m^3)	-	2416.12	-
Compressives strength (MPa)	29.07	41.99	48.38
Flexurals strength (MPa)	4.14	5.83	6.07
Water absorption (%)		3.9%	

Table 4: Symbols of the work mixes

Type of waste/Mixture symbol	Waste (%)	Partially replacing by
Powder glass		
WGP_1	5	Cement
WGP_2	10	
WGP_3	15	
WGP_4	20	
Ash (paper waste)		
WPA_1	5	Cement
WPA_2	10	
WPA_3	15	
WPA_4	20	
Sludge of sugar industries		
$WSSI_1$	5	Cement
$WSSI_2$	1	
$WSSI_3$	15	
$WSSI_4$	20	

is Represented as (Re). The test's results of the reference mixture are recorded in Table 3. Table 4 illustrates the symbols of mixes work.

RESULTS AND DISCUSSION

Slump test: The results showed that slump test of WGP and WSSI concrete mixtures with different percentage (5, 10, 15 and 20%) have a low values than the reference mixture and with fluctuated results with increasing the replacement, the reduction of a slump is (5, 1, 7 and 2%) for WGP_1-WGP_4), respectively and for WSSI (6, 12, 7 and 14%) replacement ($WSSI_1$-$WSSI_4$), respectively. As a result of the surface area and particle size of the wastes that have an angular shape, the workability decreases as mentioned by Keryou and Ibrahim (2014). While the results of WPA concrete mixture iullstrate that increase waste content % causes a decrease in slump values. Correspondingly it is noticed that the decreasing ratio % in a slump % is increased with increasing ash content % due to the fact that the ash has been fine particles (<90 μm) which have a large surface area that can to be absorbed water. All results are shown in Fig. 6.

Oven dry density: The obtained results showed that the oven dry density of WGP, WPA and WSSI concrete mixtures decrease in oven density by increasing waste content %. This decreases in oven dry density of the

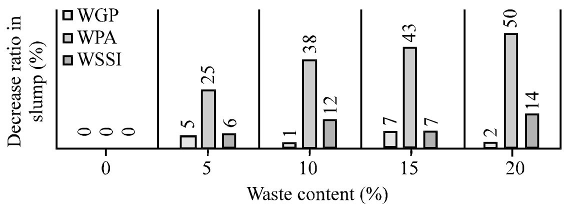

Fig. 6: Decrease ratio in slump (%) verse waste content (%)

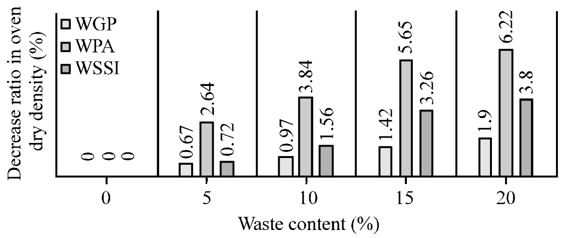

Fig. 7: Decrease ratio in oven dry density (%) verse waste content (%)

specimens has reached to (0.67, 0.97, 1.42 and 1.9%) for mixtures containing (5, 10, 15 and 20%) of WGP compared to Re to (2.64, 3.84, 5.65 and 6.22%) for mixes containing (5, 10, 15 and 20%) of WPA, respectively, compared to Re and to (0.72, 1.56, 3.26 and 3.8%) for mixes containing (5, 10, 15 and 20%) of WSSI compared to the Re. The decreases in the oven dry density possibly attributed to the variances in density between wastes and concrete component. If considering WGP, WPA and WSSI have a low density as follow (1082.7, 382.4 and 538.3 kg/m^3), therefore the concrete specimen's weight become lighter compared to Re. When replacing the waste by cement's weight, the volume of mixture increases and leads to take the volume in the mold as stated by (Keryou and Ibrahim (2016). Figure 7 illustrates that the decreasing ratio in oven dry density % of WGP, WPA and WSSI concrete mixture at 28 days is increased with increasing wastes content % compared to Re.

Compressive strength: The results pointed out that the compressive strength for WGP, WPA and WSSI increases proportionally with curing process because the hydration process still continuous until getting the full strength of concrete which proved by Gluth *et al*. (2014). The maximum compressive strength appeared at 10% of WGP as a partial replacement of cement due to high amount of Calcium Carbonate ($CaCO_3$) that consider the major factor effect on the compressive strength. Besides that WGP contains a high amount of silica which leads to increase the reactions of hydrations concretes in early ages as illustrated by AL-Zubaid *et al*. (2017). The changes in

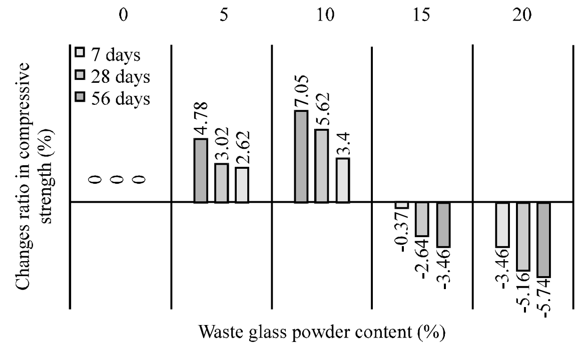

Fig. 8: Changes in compressive strength (%) verse WGP content (%)

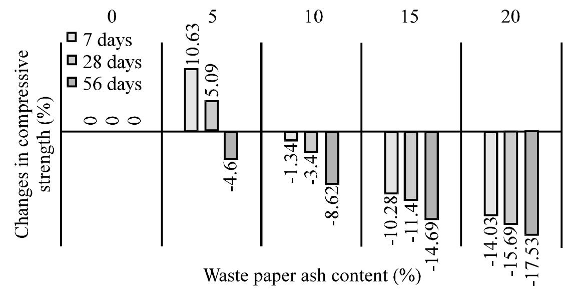

Fig. 9: Changes in compressive strength (%) verse WPA content (%)

compressive strength of WGP concrete mixtures compared to Re at 7, 28 and 56 days of cubes are showns in Fig. 8.

High value of compressive strength appears when partially replacing 5% of WPA by cement due to particle size and chemical composition of WPA which is <90 μm, that leading to research as a filler material as explained by Sharipudin *et al*. (2012). The changes in compressive strength of WPA concrete mixtures compared to Re at 7, 28 and 56 days are shown in Fig. 9.

High value of compressive strength appears when partially replacing 5% of WSSI by cement due to particle size of WPA which is <90 μm that leading to research as a filler material as explained by Sharipudin *et al*. (2012) and this increases is attributed to the chemical composition which is proved by Kumar and Rani (2016) who illustrate that the WSSI contain lime (CaO) which contributes chemically to the Portland cement ingredients. The changes in compressive strength of WSSI concrete mixtures compared to Re at 7, 28 and 56 days are shown in Fig. 10.

Flexural strength: The results pointed out that the flexural strength for WGP, WPA and WSSI increases proportionally with curing process because the hydration

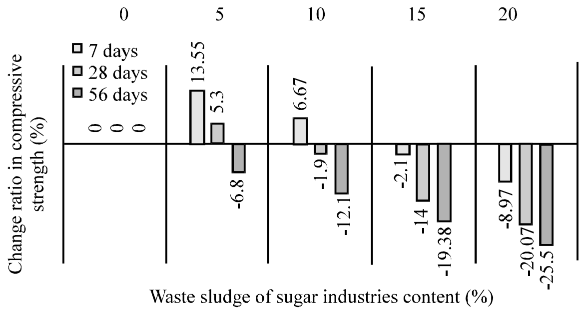

Fig. 10: Change ratio in compressive strength (%) verse WSSI contest (%)

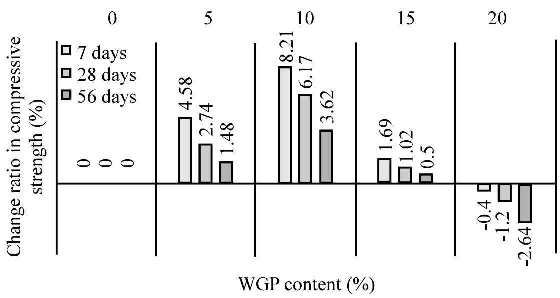

Fig. 11: Change ratio in flexural strength (%) verse WGP content (%)

process still continuous until getting the full strength of concrete which proved by Gluth *et al.* (2014). Results of WGP specimens exhibit significantly a growth in flexural strength when increasing WGP content % until 10% after that it has been decreased, the reason behind that is the hydration progress of the mixture and the effect of powder glass that has a particle size <90 μm, therefore, it has been changed from inert material to reactive pozzolanic material as proved by Taha and Nounu (2008). The influence of curing age (7, 28 and 56 days) on the flexural strength tests of WGP concrete using (100×100×400 mm) prisms are plotted in Fig. 11 compared to Re.

From the testing results, it is concluded that the highest change ratio % has been recorded when WA_3 with partially replacing 10% of WPA which is increased flexural strength compared with other mixes. The reason behind that is particle size of WPA which is <90 μm, that leading to research as a filler material as explained by Mozaffari *et al.* (2009) and chemical composition of WPA that is considered as a cementitious material in which some components hydrate faster than others as proved by Kumar and Rani (2016). The effect of curing age (7, 28 and 56 days) in flexural strength tests of WPA concrete using (100×100×400 mm) prisms are plotted in Fig. 12 compared to Re.

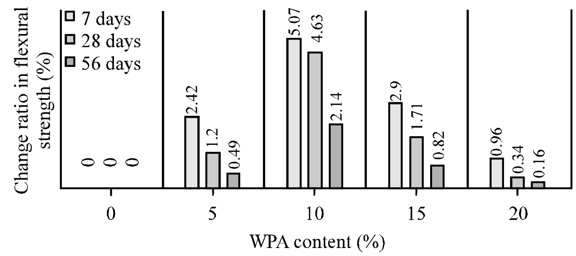

Fig. 12: Change ratio in flexural strength (%) verse WPA content (%)

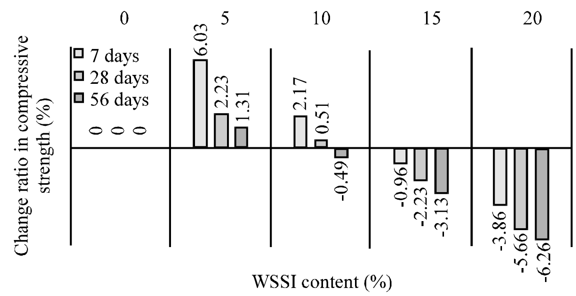

Fig. 13: Change ratio in flexural strength (%) verse WSSI content (%)

From the testing results its is concludeds that thes highest change ratio has been recorded is 6.03% of $WSSI_1$ with partially replacing 5% and it is increased in the flexural strength compared with other mixes. Due to particle size of WSSI which is <90 μm, that leading to reserach as a filler material as explained by Mozaffari *et al.* (2009) and chemical composition of WSSI that is considered as a cementitious material in which some components hydrate faster than others as proved by Kumar and Rani (2016). The effect of curing age (7, 28 and 56 days) in flexural strength tests of WSSI concrete using (100×100×400 mm) prisms are plotted in Fig. 13 compared to Re.

Water absorption: Thes waters absorptions is a good measure of thes concretes quality and its durability once exposed to adverse environments. The values of change ratio in water absorption % compared to Re for WGP, WPA and WSSI concrete mixtures at 28 days age is shown in Fig. 14. The results of WGP concrete specimens withs (5, 10, 15 and 20%) exhibit as decrease in water absorption values by (4.1, 5.89, 7.43 and 8.79%), respectively, compared to Re. This is sattributed to the absorbability of WGP causes the modification of the microstructure of concrete, reduces the capillary pores

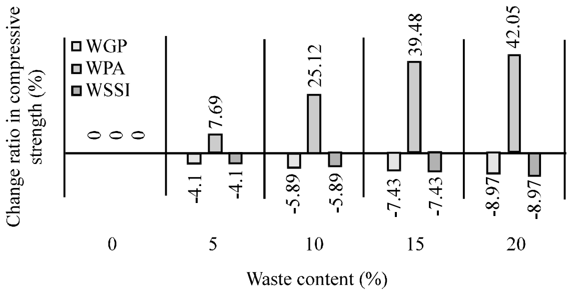

Fig. 14: Change ratio in water absorption (%) compared to Re for (WGP, WPA and WSSI) concrete mixture ats 28 days

which lead to increase the density and reduce in the absorption percentage as proved by Dubey *et al.* (2014).

The results of WPA concrete specimens with (5, 10, 15 and 20%) exhibit an increase in water absorption values by (7.69, 25.12, 39.48 and 42.05%), respectively, compared to Re. These result are similar to the result of (Ahmad *et al.*, 2013) who mentioned that this increasing is attributed to the absorbability of WPA causes a noticeable decrease in the concrete mixture unit weight as a result of the creation voids and the pores in the structure of concrete which leads to an essential increases in thes water absorption inscomparison with Re.

The results of WSSI concrete specimens with (5, 10, 15 and 20%) sludge of sugar industries waste content exhibit a decrease in water absorption values by (4.1, 5.38, 7.69 and 9.49%), respectively, compareds withs their corresponding references mixture. This is sattributed to the WSI absorbability causes the modification of concrete microstructure, reduces the capillary pores which lead to increase the density and reduce in the water absorption percentage as stated by Dubey *et al.* (2014).

The cost analysis: The analysis cost shows that production cost of WGP, WPA and WSSI concrete mixture is reduced by (3.17, 6.34, 9.5 and 12.69%) with replacing (5, 10, 15 and 20%) by weight of cement, respectively compared to Re.

CONCLUSION

On the basis of above results obtained, the following conclusions can be drawn: the slump, oven dry density and water absorption of a concrete mixture containing WGP are reduced by increasing the waste content % while the compressive strength is increased by aincreasing the waste content % compared to Re up to 10%. Flexural strength are increased by increasing the waste content % compared to Re up to 15 but 10% partial replacement is considered as an optimum result. The slump and oven dry density of concrete mixture containing WPA are reduced by increasing the waste content % while the water absorption and flexural strength are increased by increasing the waste content % compared to Re. Compressive strength is increased by increasing the waste content % compared to Re up to 5%. Use of WGP, WPA and WSSI in concrete can be economical. Use of WGP, WPA and WSSI in concrete will eliminate the disposal problem of these waste, reduce the harmful emission gases result from cement manufacture industry into our environment and thus substantiate to be environment friendly. Use of WGP, WPA and WSSI will preserve natural resources that are utilized for cement manufacture, so, make concrete construction industry sustainable.

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