Effect of Adding the Rice Husks Residues Remaining from Water Treatment to the Strength of Concrete Mixture Reaching to Zero Residues Level (ZRL)

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Abstract:- The residues of wastewater treatment containing heavy metals in general and copper in particular, specifically treatment using the adsorption technique, are polluted to the environment. It must be disposed of quickly and safe because they still contain the polluted element and are often is very effective. The present paper aims to study the ability of reusing rice husks loaded with copper ions adsorbed from wastewater as an additive to concrete mixture to improve its performance by increasing the compressive strength. The rice husks were loaded with copper was added with a weight ratio ranging from 0.5 to 3% for the cement mixture of 1:2:4 (1 cement: 2 sand: 4 gravel) and water/cement ratio of 0.45. The compressive strength of concrete cubes prepared from reference concrete mixture, concrete mixture with additives of rice husks and rice husks loaded with copper were measured. The results showed that the compressive strength of the concrete is gradually increased until it reaches nearly twice of its value in the reference concrete mixture at a certain rate and then starts to decrease sharply until the cube samples completely fail under initially compression. These results introduce a new approach to the management of toxic waste and propose an easy, simple, useful, economical and environmentally friendly method to get rid of more than one type of waste at the same time reaching the concept of zero residue level (ZRL).

Keywords:- *Concrete, Copper Ions, Adsorption, Rice Husk* And *Zero Residue Level* (*ZRL*).

I. INTRODUCTION

Concrete is a material consisting of cement, sand and water with addition of a kind of aggregates, such as gravel. Concrete is one of the most important building materials in the modern era, especially with iron reinforcement to become reinforced concrete **[1]**. Ancient Romans are the first to use Plain Concrete in history from about 2,000 years ago and have been used in most of their buildings for easy formation and can be implemented with a slightly trained labor **[2]**. Concrete is a mixture of raw materials consisting of sand, gravel (or broken stone) and cement with addition of water to them. When mixed well, a process of cohesion between them is achieved called the setting time **[3]**. Concrete has many characteristics that distinguish it from other materials. It takes a solid form and is durable with time and starts with the initial setting and ends with the final setting. It is also very compressive, but at the same time its tensile strength is very weak **[4]**. Therefore, ordinary concrete is never used in places where tensile stresses occur such as beams **[5]**. To overcome this problem, iron is mixed as an excellent resistance for tensile strength and pressure forces **[6]**. While long iron rods can withstand all tensile forces, the concrete cannot withstand all pressure forces if it's slender. As a result of this buckling concrete is occurred **[7]**. Thence, it is found that a mixture of concrete and iron is given an ideal material to resist the various stresses affecting them. This material is called Reinforced concrete **[8]**. Other additives are materials or composites of multi-substances added to concrete during mixing to improve one or more properties of concrete mixtures **[9]**. Additives are usually classified according to the main purpose of their use as many of these additives affect more than one concrete property **[10]**. Sometimes they affect the desired properties of the concrete in reverse, which may improve a particular property and at the same time have an opposite impact on another property **[11]**. Currently, there are large numbers of additives used for various objectives and those ones who wish to use them have been faced a difficult choice when determining the appropriate additive **[12]**. The work of the additives and their effects are usually described by the manufacturer and the supplier, but the details of its behavior in the mixture must be scrupulousness (especially previously unused additives) before using them in concrete works by making experimental mixtures or performing laboratory tests according to the applicable international standards **[13]**. Several studies have been conducted to study the effect of various additives using on the performance of concrete among these materials are rice husks **[14]**. The use of rice husks – which is a residue of rice production – is helpful when added to concrete in enhancing concrete properties, as well as providing many of important features. Rice husks contain more than 90 percent silica (SiO_2) **[1]**. On the other hand, it poses a danger to the environment because of the damage it causes in the area where it is being disposed. Among the many advantages of concrete containing rice husks is the high resistance capacity since it is a pozzolanic material, showing an increase in compressive strength compared to normal Portland cement, in addition, it has excellent waterproof properties, reduces water penetration by up to 60 percent and reduces water temperature **[15]**. Also it prevents the formation of cracks during preparing and its high resistance to chloride, which prevents the penetration of chloride ions, which cause corrosion of reinforcing steel **[16]**. Moreover to being used as an additive in concrete, rice husks are common adsorbents used as a material in the removal of toxic substances, especially heavy metals, principally copper (which is considered hazardous and toxic to the environment) from contaminated water such as waste from batteries' factories and other industries **[17]**. This study deals with the possibility of using the residues of rice husk loaded with adsorbed copper from the contaminated water as an additive with different proportions to the concrete mixture of (1:2:4). Then study the compressive strength of the concrete mixtures prepared by adding this type of husks and comparing it with reference mixtures for the same mixing ratios.

II. EXPERIMENTAL WORK

➢ *Materials:*

- *Cement:*

Ordinary Portland cement was used as a Tasluja-Bazian type of Iraqi origin and conforming to the Iraqi standard specification (No. 5 of 1984). Tables (1 and 2) below show the results of chemical and physical tests of the cement used in this study respectively.

No.	**Chemical Component**	**Tasluja-Bazian Cement**	**Range of Iraqi standard specification (No. 5 of 1984)**
1	Calcium oxide (CaO)	62.42	69 – 60
2	Silicon Oxide – silica – (SiO_2)	21.30	24 – 18
3	Aluminum Oxide – Alumina – (Al_2O_3)	5.52	8 – 4
4	Ferric Oxide (Fe_2O_3)	4.25	4 – 2
5	Magnesium Oxide (MgO)	2.53	5 – 2
6	Potassium Oxide (K_2O)	0.72	
7	Sodium Oxide (Na_2O)	0.53	
8	Sulfide Triple Oxide (SO_3)	0.83	2.7 – 0.3
9	Free Lime (CaO_F)	1.36	2 – 0
10	Insoluble Residue (I.R)	0.54	
	TOTAL	**%100**	
11	Loss On Ignition (L.O.I)	0.5	0.5 – 0.1
12	Lime Saturation Factor (L.S.F)	0.8935	1.02 – 0.66
No.	Main Chemical Composition	**Tasluja-Bazian Cement**	Range of Iraqi standard specification (No. 5 of 1984)
1	Tri-Calcium Silicate (C_3S)	49.00	65 – 45
2	Di-Calcium Silicate (C_2S)	23.88	25 – 10
3	Tri-Calcium Aluminate (C_3A)	7.57	12 – 07
4	Tetra-Calcium Aluminate Ferrite (C4AF)	13.00	15 – 11

Table 1:- Results of Chemical Tests of Tasluja-Bazian Cement: Percentage of Chemical Components

No.	**Chemical Component**	**Tasluja-Bazian Cement**	**Range of Iraqi standard specification (No. 5 of 1984)**
1	Specific gravity	3.15	---------
2	Standard Consistence	30	26-33%
3	Fineness by Blain Method ($cm^2.g^{-1}$)	3350	≤ 2300
4	Soundness by autoclave (%)	0.30	≥ 0.80
5	Setting Time		
	Initial Setting Time (min.)	120	$\leq 60\ min.$
	Final Setting Time (min.)	360	$\geq 600\ min.$
6	Compressive strength ($N.mm^{-2}$)		
	3 days	17.6	($N.mm^{-2}$)≤ 15
	7 days	25.3	($N.mm^{-2}$)≤ 23
7	Flexural Strength ($N.mm^{-2}$)		
	3 days	8.25	---------
	7 days	12	---------

Table 2:- Physical Tests Results of Tasluja-Bazian Cement: Percentage of Chemical Components

- *Fine Aggregate:*

Fine aggregate (or sand) used in this study was brought from Al-Ukhaidir region about 200 km south-west of Baghdad. The content of sulfur salts was 0.12%, softness was 2.674 and the specific gravity was 2.63. Table 3 shows the grading test of the sand, which is identical to the Iraqi standard (No. 45 of 1984).

- *Coarse Aggregate:*

Coarse aggregate (or gravel) used in this study was brought from Al-Nebai region about 65 km north-west of Baghdad. Its nominal size was (5-20) mm, the content of sulfur salts was 0.046% and the specific gravity was 2.67. The gravel was identical to the Iraqi standard (No. 45 of 1984). Table 4 shows the grading test of the gravel.

Sieve size (mm)	**Passed percentage (wt%)**	**Range of Iraqi standard specification (No. 5 of 1984) area 2**
10	100	100
4.75	94	100 - 90
2.36	84	100 – 75
1.18	78	90 – 55
0.6	56	59 -35
0.3	27	30 – 8
0.15	3	10 – 0
Soft materials passing through sieve No. 200	0	< 5%

Table 3:- Gradation of Al-Ukhaidir Fine Aggregate (Sand)

Sieve size (mm)	**Passed percentage (wt%)**	**Range of Iraqi standard specification (No. 5 of 1984)**
37.5	100	100
20	99	100 – 95
10	42	60 – 30
5	2	10 – 0
Materials passing through sieve No. 75 µm	0	< 3%

Table 4:- Gradation of Al-Nebei Coarse Aggregate (Gravel)

- *Rice Husks Loaded with Copper Ions:*

The rice husk residues used in this study were brought from Iraqi rice growing fields in Al-Shinafiyah area located in Al-Qadisiyah governorate, 300 km southern of Baghdad. These rice husks were used as adsorbent media to remove copper from wastewater solutions by adsorption technique at different operating conditions as described in [1]. When the adsorption process was ended, the adsorbents material (rice husks) was loaded by (8.61-22.12 mg of copper /g of rice husks). To prepare the concrete mixture, rice husks of 10 mg/g were used. The rice husk selected were sun dried for 24 hours, then sieved by sieve analysis and the powdered passed from sieve 200 µm. The rice husks powder was collected in moisture proof bags for further used. Table 5 explains the chemical structure of rice husks used in this paper.

No.	**Chemical Component**	**wt%**
1	Calcium oxide (CaO)	0.610
2	Silica oxide (silica) (SiO_2)	90.70
3	Aluminum oxide (Alumina) (Al_2O_3)	0.130
4	Ferric Oxide (Fe_2O_3)	0.060
5	Magnesium Oxide (MgO)	0.250
6	Potassium Oxide (K_2O)	2.640
7	Sodium Oxide (Na_2O)	0.090
8	Titanium Oxide (TiO_2)	0.015
9	Phosphorus tetroxide (P_2O_4)	0.730
10	Loss On Ignition (L.O.I)	4.710
11	Copper loaded on rice husks after adsorption (mg/g)	10 mg of Copper ions/g of rice husks

Table 5:- Chemical Composition of Iraqi Rice Husk used in this Study

- *Water:*

Drinking water of the specifications explained in Table 6 was used for mixing, casting and maturation of prepared concrete cubes.

No.	Chemical ion	Concentration (mg/l)
1	Calcium (Ca^{+2})	12.00
2	Magnesium (Mg^{+2})	5.200
3	Sodium (Na^{+2})	3.500
4	Potassium (K^{+})	0.500
5	Ferric (Fe^{+3})	0.008
6	Bicarbonates (HCO_3^{-})	10.52
7	Nitrate (NO_3^{-})	1.800
8	Sulfides (SO_3^{-2})	10.90
9	Chlorides (Cl^{-})	5.100
10	Fluoride (F^{-})	0.010
11	Total Dissolved Solids (TDS)	110.0
12	pH	7±0.2

Table 6:- Chemical Composition of Iraqi Rice Husk Used in this Study

- *Preparation of Concrete Mixtures:*

In the current study, three types of concrete mixtures were prepared. The first one is a reference concrete mixture of 1:2:4 (1 cement: 2 sand: 4 gravel) and water to cement ratio (w/c) of 0.45. The second and third types of concrete mixtures were prepared using the same previously ratios in reference mixture but added an amount of rice husks powder alone and rice husks powder loaded with copper ions. The weight percent of loaded rice husks were ranged between (0.5-3.0%) of the total weight of concrete mixture. Table 7 shows the details of concrete mixtures used in this investigation.

- *Preparation of concrete samples (cubes):*

- *Mixing*: At the beginning, the fine and coarse aggregates were washed with drinking water to dispose of any dust or impurities stuck with them and then left in the sun until drying. After making certain that the two types of aggregates were dry, cement and fine aggregates (sand) (in the reference mixture) and copper loaded-rice husks (in the addition mixture) were firstly drying mixed. The mixture was place in a 25-kg mini electric portable concrete mixer then adds two-thirds of the total amount of water required continuously and mix two thirds of the weight of the coarse aggregate (gravel) with the blended materials until acceptable homogeneity. Finally the amounts water and gravel rest were added with continuous blended by the concrete mixer until obtained a homogeneous concrete mixture.
- *Casting and maturation of cubes:* According to British standard (**B.S.1881: part 113: 1983**) steel cube molds of (150×150×150) mm dimensions were used for casting and maturation of concrete cubes for Compressive Strength Test. The cubic steel molds were packed with concrete mixtures by three layers and compacted mechanically using the vibrator for 10-15 seconds to obtain homogeneous concrete. After finishing the casting process, the steel molds were covered with small layers of nylon-6 for 24 hours. The molds were then removed from the molds and placed in specially equipped drum filled with tap water at a temperature of 20-25°C for the purpose of maturation. The different cubes were left in the maturation drums until tests were carried out.
- *Compressive Strength Test:* The compressive strength of concrete used for structural works is usually expressed by the unit of force (stress) required to cause rupture in Newton divided by the area unit in (mm^2). To determine the compressive strength of the concrete mixture, a cube sample of 150×150×150 mm or a cylindrical sample, its height is equal to twice the diameter. The treatment is performed by wet method for 7 days and 28 days according to the Iraqi specification at lab temperature. The sample is then loaded by putting it in a standard concrete compressive strength testing machine with a specific velocity until it is ruptured. The loaded was achieved usually within 2-3 minutes. In this study the compressive strength test was carried out according to British standard specification (B.S. 1881: part 116) for 7 and 28 days concrete cubes prepared using compressive strength testing machine (WeKob) of 2500kN capacity and $15MN.m^{-2}.min^{-1}$ until the rupture of sample starts. Cubes of reference concrete mixture and additive concrete mixtures for every age (i.e. 7 and 28 days) were tested for to identify the best compressive strength. The dependent compressive strength was the average of three cubes for each test in each age.

No.	Types of Concrete Mixture	Cement (kg.m^{-3})	Fine aggregate (Sand) (kg.m^{-3})	Coarse aggregate (Gravel) (kg.m^{-3})	Rice husks Powder and Rice husks Powder loaded with copper ions (kg.m^{-3})	Water to cement ratio (w/c)
1	Reference	300	600	1200	0	0.45
2	Rice husk Additive	300	600	1200	(10.5-63) (0.5-3)% (35.45-213.625)*	0.45
3	Loaded rice husks Additive	300	600	1200	(10.5-63) (0.5-3)% (35.45-213.625)*	0.45

Table 7:- Details of Concrete Mixtures Prepared in this Study

* *The amount of rice husks loaded with copper ions (measured in grams) added to each cube of dimensions* (150×150×150) mm

III. RESULTS AND DISCUSSION

Figures 1 and **2** show the results of the compressive strength test for the cubes of reference concrete mixture, the cubes of rice husks additive mixtures and the cubes of rice husks loaded with copper ions additive mixtures. Generally, it's clear that from **Figure 1** the compressive strength increased from the initial value of 21.35 and 24.42 kN.mm^{-2} for 7 and 28 days, respectively with increasing the ratio of rice husks added until reach to its maximum value 26.87 and 28.36 kN.mm^{-2} for 7 and 28 days respectively at 0.2. The addition of any kind of fine granules, including powder rice husks (alone), to concrete mixture by a limited ratio lead to enhance the compressive strength simply. This may be due to the fact that the fine grains of rice husks may have overlapped with fine and coarse aggregate granules. Both types of aggregates are many times heavier coarser, which may let to reduce the voids in the concrete structure and enhancing the nature of the interstitial area, which is usually full of pores. Therefore, the use of powder rice husks will result in filling and as a result reduce these pores and increase the homogeneity of the interstitial area. Thus increase its compressive strength. With increasing the ratio of rice husks added to concrete mixture beyond 0.2 the compressive strength was decreased sharply until completely sample cracked at the ratio of 0.6. This result may be due to when the rice husks added beyond the optimum ratio, the concrete mixture requires an increase in the amount of water added to the mixture and thus reduce the compressive strength.

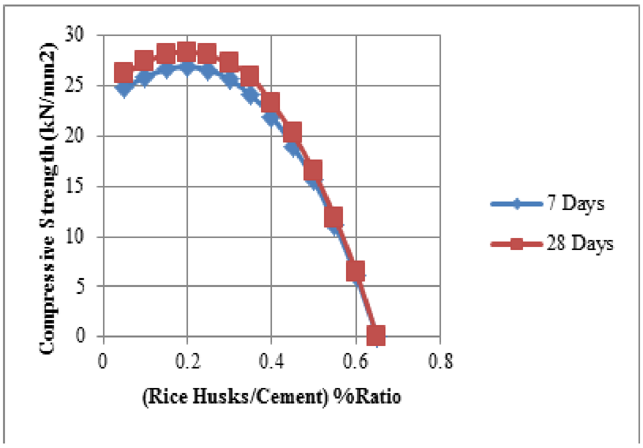

Fig 1:- Effect of Rice Husks Additive on the Compressive Strength of Concrete Mixture

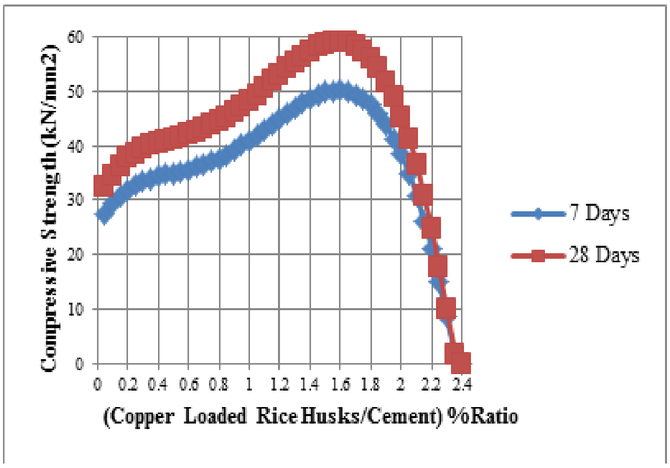

Fig 2:- Effect of Copper Loaded Rice Husks Additive on the Compressive Strength of Concrete Mixture

From another hand, it is obvious from **Figure 2** the enhanced effect of copper loaded rice husks to concrete mixture behaviour. The compressive strength of cubes increased gradually from 27.43 kN.mm^{-2} at a ratio of 0.05 to maximum value 50.15 kN.mm^{-2} at a ratio of 1.6. The increase in the compressive strength of concrete mixture due to the addition of the rice husks loaded with copper ions was may be due to the increased the strength of adhesion between the powder loaded rice husks and the concrete cement. The adhesion depends on some physical and chemical properties resulting from the metal structure of the rice husks. It is obvious that from the comparison of **Tables (1)** and **(5)**, the chemical composition of rice husks is very similar to the chemical composition of cement. So, this similarity may lead to increase the compressive strength. Moreover, the compressive strength for this case was increased due to existence of copper ions on the surface of rice husks. The presence of copper (which is a high-density element) by a quantity that cannot be ignored certainly increases the compressive strength of concrete due to copper penetration in the pores and voids of concrete mixture because they are loaded by rice husks. Beyond the loaded rice husks ratio of 1.6 the compressive strength begun decrease gradually until the completely fails of samples at a ratio of 2.4. This result can be explained by the same reasons illustrated in addition of rice husks alone.

IV. CONCLUSIONS

The results obtained from the present study indicate that the rice husks and loaded rice husks wasted from adsorption of heavy metals process (including copper) can be used as an effective additive to enhance the compressive strength of concrete mixtures. Rice husks alone gave a slight increase in compressive strength compared with the reference mixture. While the increase in compressive strength was nearly twice its value when using rice husks loaded with copper ions. The method used in this research can be considered as a useful and economical technique for the disposal of residual toxic waste by an eco-friendly method, accessing to zero residues level (ZRL).

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