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Experimental Study on the Influence of Rice Husk Ash as Supplementary Material on the Performance of Concrete

A THESIS

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(STRUCTURES)

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بِسمِ ٱللهِ الرَحمَنِ ٱلرَحِيمِ

قَالَ رَبِّ اِشْرَحْ لي صَدْري۞وَ يَسّرْ لَي أَمْري۞ وَ احْلُلْ عُقْدةً مِنْ لِسَاني۞ يَفْقَهُوا قوْلي

صدق الله العلي العظيم
سورة طه
الآيه (٢٥- ٢٨)

Dedication

I dedicate this work to…

My Parents

For their help, moral, encouragement, and material support

My sisters

For their encouragement

My Friends

For helping me in my research

My Colleagues

for their help practically

Certification of the supervisor

*I certify that this thesis titled ''**Experimental Study on the Influence of Rice Husk Ash as Supplementary Material on the Performance of Concrete**'' which is being submitted by **(Sajjad Jawad Kadhim)** was prepared under my supervision at the University of Misan/College of Engineering, in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering (Structures).*

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Abstract

Rice husk (RH) is considered a waste material, so there is a way to convert it into useful material in through burn of RH to product rice husk ash (RHA) at temperatures ranging between (500 to 600) °C, therefore production of RHA requires manufacture of a furnace to control the temperature. The furnace had two parts, the top parts contains a burn chamber for burn the husk to produce RHA and the bottom part contains storage place to store the resulting of RHA to keep it until using. The furnace is made of layers of different materials, where the outer layer of steel with a thickness of 1.5 mm, followed thermal insulation (glass wool), then a layer of galvanized iron with a thickness of 2 mm, followed layer of thermal bricks with a thickness of 40 mm to keep the heat inside the furnace.

RHA chemically analysed by X-ray fluorescence device (XRF) and it was found contain a high percentage of silica (SiO2) up to 86.76%, therefore it classified as a pozzolanic material, where minimum pozzolanic limit is 70% of SiO2. RHA used as a replacement material to cement by weight at different percentages (5, 10, 15, 20)% at two mix proportions, (1:1.89:2.64) with w/binder ratio is 0.53 and (1:1.43:2.19) with w/binder ratio is 0.44. Mechanical properties (compressive, splitting and flexural strength) were carried out, whereby sixty cubes, thirty cylinders and thirty prisms were casted. The results showed that the appropriate percentage of RHA is 10% which gave high compressive strength at both mix proportions with w/binder ratios 0.53 and 0.44. The splitting tensile strength increased at addition (5, 10, 15)% RHA at mix proportion with w/binder ratio 0.53, while at mix proportion w/binder ratio 0.44, the splitting tensile strength increased at

addition (5, 10)% of RHA. While for flexural strength, all the percentage of RHA added gave strength higher than reference mix at both mix proportions as well as observed that 15% of RHA gave high flexural strength.

Fourteen beams with dimensions (1200*180*140) mm were casted, ten beams were designed for flexural strength and four beams were designed for shear strength. The tested characteristics of reinforced concrete beams included ultimate load, deflection, ductility, crack patterns and strain distribution. The ultimate load for flexural specimens at addition (5, 10, 15)% of RHA increased by (3.15, 4.05, 0.69)%, respectively at mix proportion with w/binder ratio 0.53, while at w/binder ratio 0.44, the increasing was (3.33, 0.18)% at addition RHA (10, 15)%, respectively. While for shear specimens, percentage of RHA added was 15% for both mix proportions, the results showed increase in ultimate load at beams containing RHA, the increasing were (3.94 and 6.95)% at mix proportions with w/binder ratios (0.53 and 0.44) respectively. The beam for flexural specimens with 20% of RHA showed the maximum deflection increased at both mix proportions with w/binder ratios (0.53 and 0.44) by (3.53 and 7.33)%, respectively. For shear specimens, observed the maximum deflection increased at w/binder ratios (0.53 and 0.44) by (11.47 and 39.21)% respectively. For flexural specimens, at w/binder ratio 0.53, the maximum ductility increased by 11.83% at addition 15% of RHA, while at w/binder ratio 0.44, the maximum ductility increased by 16.74% at addition 5% of RHA. While for shear design, the ductility decreased at addition 15% of RHA at both mix proportions. The strains increased at most the beams containing RHA compared with reference beam.

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List of Abbreviations and Symbols

ACI	American concrete institute
ASTM	American society for testing and materials
BS	British standard
C	Cement
C.A	Coarse aggregate
F.A	Fine aggregate
fcu	Cube compressive strength in MPa
FA	Fly ash
fr	Modulus of rupture in MPa
ft	Cylinder tensile strength in MPa
RH	Rice husk
RHA	Rice husk ash
SiO2	Silicon oxide
XRD	X-ray diffraction
XRF	X-ray fluorescence
W	Water
W/C	Water to cement ratio
W/binder	Water to cement and ash ratios
OPC	Ordinary portland cement
RO	Reverse osmosis

Chapter One

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1: General

Concrete is very generality in the constructions and other purposes related to other civil works, so the most of works related to civil engineering such as column, beam and slab are part of the concrete. Concrete is a composite material composed of different proportions of mixing materials of cement, sand and gravel, and different percentages of water. The world population in year 1950 was 2.5 billion people and increased to 6.9 billion in year 2010, while global construction in year 2012 became 8.7 trillion USD and foresee to reach in year 2025 to 15 trillion USD [1]. Cement is the principal building material where as a binder that utilize in construction industry. The requirements of cement are increase rapidly due to the rapid evolvement and construction worldwide. The world cement produced in year 2011 was 3.6 billion tons and in year 2012 produced 3.7 billion tons, this lead to continuation of the increase in cement production [1]. Ordinary portland cement is presently one of the more widely utilization cement types in the world. In the recent years, some additives have begun to improve the properties of concrete. The additives is considered a pozzolanic material due to contain a high percentage of non-crystalline silica (SiO_2) [2]. The pozzolanic materials include fly ash, burnt shale, volcanic ash, silica fume and rice husk ash (RHA) where the most of the pozzolanic materials are either extracted from natural materials or are industrial residues, so using as an alternative to cement has benefits not only for the environment but for conversion it from a waste materials to materials with positive purposes for concrete properties such as decrease porosity of the hardened cement paste [2].

The rice is main food origin for billions of people in the world, where the rice cover about 1% of surface area of the earth [3]. Annually, approximately 100 million tons of rice husks (RH) procreates in the world [4], which is considered as a waste material, therewith dispose of the husk by burning it to product RHA, which categorizes as a pozzolanic material.

1.2: Rice husk ash (RHA)

In the middle 20^{th} century some of the people are utilize rice husk ash as a fuel for cooking purposes because of shortage of knowledge [5]. In this century, the employment of rice husk ash in concrete by replacing it with cement as a modern trend in concrete technology. Rice husk ash classified a pozzolanic material due to containable highly proportion SiO2 of non-crystalline, whereby utilise as replacement in changeable percentage with cement. The pozzolanic materials have to consist of siliceous or alumino-siliceous materials in finely divided form [6]. Silica is a chemical component of rice husk ash where it possesses cement and pozzolanic properties and fills spaces.

The following interaction will explicates effect the silica that found in RHA [5],

when silicon is burned and oxygen is present, the silica (SiO2) will form

$$Si + O_2 \longrightarrow SiO_2 \qquad \ldots(1\text{-}1)$$

When the cement reaction with water or called hydration of cement then CSH (gel) and calcium hydroxide are form, but calcium hydroxide is soluble and unstable product in concrete

$$C_3S\ (cement) + H_2O \longrightarrow CSH\ (gel) + Ca(OH)_2 \qquad \ldots(1\text{-}2)$$

The silica will reaction with calcium hydroxide that lead to formation CSH (gel) again, therewith will give high strength compared with normal concrete.

$$SiO2 + Ca\ (OH)2 \longrightarrow CSH + SiO2 \qquad \ldots(1\text{-}3)$$

The usage RHA has oligarchic avails for concrete in terms of mechanical characterizations such as compression strength, tensile strength and flexural strength at certain percentages. RHA product as result of burning of the rice husk (RH) as shown in Fig. (1-1) [2], where RH considers as a waste material in natural, so its presence cause a lot of problems for environment, hence burn RH in open pile is unacceptable for environmental reasons, therefore it was disposed by either burned under the ground or burned under controlled condition, but the best way is burning to produce ash which has positive benefits where is burning in a controlled manner and in special places so as not cause problems for the environment due to usually RH is stacked in air and then forsaken or burnt in the fields, consequence in seriously environmental pollution as well as burn RH may be cause fire [7].

Fig. (1-1): Rice husk burned in the furnace [2].

RH burn in specific temperature to production RHA contains high percentage of SiO2, after burning of the husk, the ash left to cool and then the ash is grinding by an electric mill to obtain on high ash fineness. It shows the stages of turning the crust into ash before and after grinding as shown in Fig. (1-2) [8].

Fig. (1-2): Appearance rice husk and ash before and after grinding process [8].

1.3: Statement of the problem

Many factories in Iraq produce cement. The cement production is expensive and requires high energy. It produces a large amount of carbon dioxide gas (CO2), which is known to have a harmful effect on the environment. Since rice husk ash deem as apozzolanic material, therewith have many of benefits in concrete, reduce heat of hydration, high resistance to chemical attack at latish ages due to lower permeability and fewer calcium hydroxide available for reaction [9], as well as the usage of ash not only reduces environmental problems but reduces the emission of carbon dioxide gas (CO2) in the atmosphere by reducing the production of cement. Rice in Iraq is an important food source, whereby most of the Iraqi people taking rice as a daily meal, therefore its cultivation in Iraq is very large, especially in the city of Mashkhab and also was cultivated in some areas of Iraq and the most common type of rice in Iraq is (Amber) which are cultivate in large quantities. Agriculture rice and accomplish extraction it from husk by treadmill particularly, where it was extracted in the city of Amara as shown in Fig. (1-3).

Fig. (1-3): Rice husk (RH) as a waste material in Iraq.

The rice cultivates in large area of Iraq, where the area and production of rice from (2012-2017) year in Iraq as summaries in Table (1-1). It observed that there is a difference between rates area and production rice for each year, where in 2012 year, the area for cultivation of rice was 151500 hector and rice production was 488500 tons. Finally, in 2017 year, area and production of the rice cultivation was 13881.25 hector and 265900 tons. Rice production rate in Iraq from (2012-2017) years was 366151 tons [10]. Since weight of husk is 20% of weight the rice, which indicate that husk output is 73230 tons that deem a waste material, hence get rid of it is necessary, moreover the output ash is (20-25)% of husk, hence average ash production from year (2012-2017) is (14646 to 18307.5) tons.

Table (1-1): The area and production of rice from (2012-2017) year in Iraq [10].

Years	Area (hector)	Production (tons)
2012	151500	488500
2013	193150	626300
2014	198275	402800
2015	96375	173410
2016	12500	240000
2017	13881.25	265900

If the value of ton of cement is about 100 thousand dinars Iraqi, meaning the provision of about (1.4646-1.83075) billion dinars Iraqi every year, since the process of production of ash is burning the peel with a certain temperature for a certain time ranging from (2- 3) hour, where it is easier than the process of production of cement, which passes through multiple stages, so the use of ash will be economically compared to cement. The difficulties that facing the production of ash is the process of burning, must be at temperatures between the temperatures required for the production of ash and the duration of burning, so will burn the material in an furnace at a temperature ranging from 500 °C to 600 °C which is sufficient heat to produce ash containing a high proportion of SiO_2.

1.4: Research objectives

The present study deals with the using rice husk available in Iraq in general by convert it to ash where the cement replaced with rice husk ash at different percentage in the concrete mix and structural members, namely in this research will discuss using RHA as replacement material and its influence on the performance of concrete. The ash added has an economic and environmental benefits in through decreased cost of materials and solve some of the waste problems.

The objectives are as follows:

- Manufacturing a furnace for burning of rice husk to convert it to ash.
- Measurement rate of silica oxide (SiO_2) in the rice husk ash.
- Determine influence of RHA on workability of concrete by work slump test of fresh concrete.
- Investigate the effects of adding RHA on the mechanical properties of concrete to improve its behaviour by determine compressive strength, tensile strength and flexural strength to knowing the optimum ratio of RHA which gives highest strength.
- Knowing the effects of RHA on the characteristics of beam concrete for flexural and shear strength.

1.5: Thesis layout

The research contains five chapter as follows:

- The first chapter presents an overview influence of rice husk on the environmental and disposed of it to converts it to benefit material which contains on a high percentage of SiO_2 in through process of burning, as well as statistics rate of rice production in Iraq.

- Chapter two includes presented the previous researches that used ash and the optimum ratio of ash addition and the temperatures used to burn the husk.

- Chapter three includes details of the furnace, the specification of the materials used, their tests and the mixing percentages are presented, the work steps, the method of preparation and processing, the tests carried out of samples and the equipment used in the research.

- Chapter four presented the results in this research in addition to the discussion of these results.

- Chapter five explain the important conclusions that reached through the present study through the results of the tests, as well as a set of recommendations and proposals that document this study and achieve scientific benefit for future studies.

Chapter Two

LITERATURE

REVIEW

CHAPTER TWO

LITERATURE REVIEW

2.1: General

Rice husk ash was used in many parts of the world. The previous researches and studies have been carried out on the rice husk ash in different countries of the world.

This chapter includes many of researches and studies related to RHA in concrete where the rice husk burns at a certain temperature to produce ash, where the ash was utilized as an alternative to certain ratio with cement.

2.2: Effective RHA on properties of concrete

In 2006, Saraswathy et al. [11], utilised rice husk ash as a partial replacement of cement in the concrete mix in ratios of (5, 10, 15, 20, 25, 30)% by weight and mixing ratio was (1:1.5:3) with w/c was 0.53 at period curing at ages (7, 14, 28) days. The tests were carried out for compressive strength, split tensile strength, pull-out, effective porosity. They were observed that the optimum replacement of RHA which gave higher compressive strength at ages (7, 14, 28) days were (30, 20, 25)% of RHA with compressive strength (33.53, 36.17, 39.55) MPa, while the reference compressive strength was (27.22, 33.29, 36.45) MPa at ages (7, 14, 28) days, where percentage of increasing at 28 days was 8.55%, the optimum replacement of RHA which have high splitting tensile strength at age 28 days was 4.92 MPa when added 15% of RHA, while the reference strength was 4.49 MPa and they were observed that all ratios of RHA gave bond strength higher slightly compared with reference bond strength.

In 2006, Kartini et al. [12], used RHA as partial replacement to cement at ratios (20, 30)% by weight. The mix proportion with and without super plasticizer (SP) was (1:2.76:2.89) with w/c was 0.63, the tests were performed for fresh concrete (slump test) and hardened concrete (compressive strength, flexural strength and split tensile). When the mix without SP, the slump decreased as (RHA) increased, so SP added at variable ratio to obtaining on slump between (120-130) mm. In addition, they showed with and without SP that compressive strength had been decreased when RHA percentage increased where were showed that values of compressive strength were (30.3, 30) MPa at added (20, 30) of RHA where the reference compressive strength was 31.7 MPa, moreover all percentages of RHA didn't improve tensile and flexural strength with and without SP.

In 2007, Oyekan et al. [13], utilised RHA as a partial alternative to cement at percentages of (5, 10, 15, 20, 25, 30)% by weight. The ratio of silica (SiO_2) in RHA was 16%. The compressive strength test carried out for concrete and sandcrete blocks, tests of effective porosity and permeability. The sandcrete blocks dimensions were (450*150*225) mm, observed that compressive strength increased slightly at 5% of added RHA. In addition, the porosity and the permeability of sandcrete block increased as ratio of RHA increased where that sandcrete block with RHA absorbs more fluid and hence fails faster.

In 2008, Marshal et al. [14], utilised RHA as a partial alternate to cement at percentages of (10, 20)% by weight, where the ash was analyzed by X-ray fluorescence machine (XRF) and the analysis revealed that SiO_2 85.77% in the ash.

The tests were carried out of cement paste (normal consistency and setting time), fresh concrete (slump test) and harden concrete (compressive strength). Cement paste with (10, 20)% RHA was required high amount of water compared without RHA to arrive normal consistency. Workability was decreased when RHA increased. The compressive strength decreased slightly at added 10% of RHA, while at 20% of RHA led to that the percentage of decreasing was 44.72%.

In 2010, Chandan et al. [15], utilised RHA as a partial replacement to cement at percentages (5, 7.5, 10, 12.5, 15)% by weight with a maximum size of aggregate being 20 mm and mix proportions of concrete was (1:1.55:3.54) with w/c 0.5 and SP was 1.2 l/m^3. The tests were carried out for hardened concrete (compressive strength, flexural strength) at the ages (3, 7, 28 and 56) days. The results showed that 7.5% of RHA added gave a compressive strength higher than reference compressive strength at age 56 days where percentage of increasing was 3.4%, while flexural strength was decreased slightly at added RHA.

In 2011, Tanvir et al. [16], utilised RHA as shown in Fig. (2-1) as partial replacement to cement at percentages (5, 10, 15)% of RHA by weight. The mix proportion was (1:1.33:2.77) with w/c 0.42. The tests were performed for fresh concrete (normal consistency, initial setting time and final setting time) and for hardened concrete (compressive strength) for period (7, 28) days, they observed that the normal consistency became (32, 35, 40, 43)% at (0, 5, 10, 20) of RHA as well as initial setting time and final setting time increased as RHA ratio increased, in additional compressive strength reduced slightly as RHA increased.

.

Fig. (2-1): Rice husk ash after drying and sieving [16].

In 2012, Deotale et al. [17], utilised rice husk ash (RHA) and fly ash (FA) as partial replacement to cement, where percentage of SiO2 was 78.21% in RHA and 40% in FA. The proportion added started form 30% FA and 0% RHA mix together in concrete by replacement of cement with the gradual increase of RHA by 2.5% and simultaneously gradual decrease of FA by 2.5% until the proportion added up to 15% of FA and 15% of RHA. The mix proportion was (1:1.1:2.85) with w/c was 0.44 and steel fiber used in the mix with diameter was 0.6 mm and length was 30 mm in the mix. The tests were carried out for fresh concrete (slump) and hardened concrete (compressive strength, flexural strength and split tensile strength) at ages of (7, 14, 28, 90) days with and without steel fiber. They observed that workability decreased as RHA increased and when FA increased, the workability increased. They noted that the replacement ratios 7.5% of RHA and 22.5% of FA gave the appropriate compressive and flexural strength, where compressive strength was 46,76 MPa, while reference compressive strength was 49.78 MPa, flexural strength was 7.55 Mpa, while reference flexural strength was 7.22 MPa. The replacement ratios 27.5% of FA and 2.5% of RHA gave the appropriate split tensile strength, where it was 4.10 MPa, while the reference split tensile was 4.38 MPa. They noted all added ratios had strength lower than reference strength except flexural strength where the ratio added gave flexural strength higher than reference flexural strength as well as observed that the addition steel fiber did not improve compressive strength and showed that addition 0.75% of steel fiber by volume fractions improved slightly tensile and flexural strength.

In 2012, Sathish. [18], burned RH at temperature 600 °C to 800 °C for period 48 hour underneath uncontrolled combustion operation to originate RHA that its colour was grey after grinding it for 30 min by ball mill. The chemical characteristics of RHA showed that it contained 65.3% of SiO2. RHA utilised as a partial alternate to cement at percentages of (10, 20, 30)% by weight at mix proportion (1:2:4) with different of w/c was (0.56, 0.58, 0.6) while at w/c of 0.62, ratios of RHA added were (10, 20, 30, 40, 50, 60, 70, 80)%. The samples for all ratio added was cured at (7, 14, 28) days. The tests were conducted for compressive strength and observed that compressive strength decreased as RHA increased, where noted the compressive strength which contains 20% of RHA had range (70-80)% of reference compressive strength.

In 2012, Nagrale et al. [19], burned RH by electric furnace, where the furnace contains on pyrometer which use to monitor. The temperature used to burn RH below was 700 °C. RHA utilized as a partial alternate to cement at percentage of 15% by weight at different mix proportion of concrete and different water cement ratio. The tests were carried out for fresh and harden concrete and noted that weight density was reducing (72-75)% of reference weight density when RHA was added. The use of RHA is economically where percentage of saving was 8.55%. Water absorption of concrete decreased as RHA increased. In addition the compressive strength decreasing slightly when RHA was added where percentage of decreasing was 10.9%.

In 2013, Ettu et al. [20], burned RH at temperature below 650 °C to product RHA where the chemical analysis showed that SiO2, Al2O3 and Fe2O3 did not less of 70%, where ash was used as a partial replacement of cement at different rates started from 5% of RHA and increasing by an steadly increasing every 5% to arrive 50% of RHA in the mix proportion (1:2:4) for concrete while the mix proportion for sandcrete was (blended cement:sand) (1:6) and soilcrete (blended cement: laterite) was (1:6), where the water cement ratio constant for all mix proportions was 0.6 at ages (3, 7, 14, 21, 28, 50, 90) days. The tests conducted for compressive strength where observed that compressive strength for concrete increased by 11% at added 5% of RHA at age 90 days curing, while at 20% of RHA, compressive strength decreased by 38%. Compressive strength of sandcrete, increased by 5% at age 90 days curing, while at 50% of RHA, compressive strength decreased by 43%, while about soilcrete, at age 90 days curing, compressive strength increased by 5% at added 5% of RHA, while at 50% of RHA, compressive strength decreased by 50%.

In 2013, Patnaikuni et al. [21], utilised RHA as a partial alternate to cement at percentages of (5, 7.5, 10, 12.5, 15, 20)% by weight at two mix proportion, the first mix proportion was (1:1.4:2.8) with w/c was 0.4 and the second mix proportion was (1:1.6:2.6) with w/c 0.4 also and all samples cured in water for 28 days. The chemical analysis for RHA found that contain on SiO2 percentage 93.80%. The tests were conducted for harden concrete (compressive strength) where the samples subjected to different temperature (27, 300, 500, 700, 900, 1000) °C. They observed at 27 °C that study on RHA concrete with changeful replacement ratio of

RHA appear that a replacement 7.5% of RHA gave better compressive strength compared with other replacements but the increasing was slightly, but when the temperature was increased, compressive strength with and without RHA decreased, as well as observed when the samples subjected to temperature under 500 °C, compressive strength was higher compared when the samples subject to temperature above 500 °C.

In 2013, Pande1 et al. [22], used RHA as a material pozzolanic to containing on high percentage of SiO_2. RHA utilised as a partial alternate to cement at percentages of (12.5, 25, 37.5)% by weight. The fresh concrete (slump) and the harden concrete (compressive strength) were carried out at ages (7, 28, 90) days and observed that the workability, fresh density, water absorption will reduce as RHA increase, in addition the results showed that the 37.5% of RHA concrete mix reveal higher shrinkage value compared with the reference concrete, while at 25% of RHA had shrinkage close to values of reference concrete, but the shrinkage at 12.5% of RHA was minimal compared with the reference concrete. They observed that strength acquisition became slackest when RHA increased, where the percentage of increasing of compressive strength was 8.5% at added 12.5% of RHA, while at 25% of RHA, compressive strength decreased by 32.5% as well as the percentage of decreasing of compressive strength was 69% at addition 37.5% of RHA.

In 2013, Godwin et al. [23], burned RH at temperature 400 °C to 600 °C for period 48 hour to form RHA, where it was assumed as a material pozzolanic whereat percentage of SiO_2 was (85- 90)%. RHA used as a replacement to cement at ratios of (10, 15, 20)% by weight at ages (7, 14, 21, 28) days. The tests showed that compressive strength decrease slightly as RHA increased but the values was very nearly to reference compressive strength, while noted that no considerable raise in tensile strength when RHA was added. There was decreased slightly in flexural strength when ash was added.

In 2013, Jayanti et al. [24], utilised RHA as a partial alternate to cement at percentages of (5, 10, 15, 20, 25, 30)% by weight. RHA found that contain on high value SiO2 was 83.6%, hence consider as a material pozzolanic. The compressive strength of mortar were carried out and deduce that compressive strength decrease by add RHA, where the percentages of decreasing of compressive strength were (2, 4, 33, 66, 82, 88)% at ratios (5, 10, 15, 20, 25, 30)% of RHA.

In 2013, Deepa et al. [25], collected RHA from rice mill and then burnt in a furnace, then RHA analysed in X-ray diffraction (XRD) device, where the broad band near 22 degrees of the 2-theta scale of the XRD spectrum of the RHA sample as shown in Fig. (2-2). The ash was used as an alternative to cement in concrete mix at variable percentages of (10, 15, 20, 25)% by weight, the mixture of concrete was (1:1.078:1.618) with w/c (0.35, 0.4, 0.5) and SP was variable. The tests performed for hardened concrete, they observed that the maximum compressive strength was obtained when the w/b was 0.4 and the replacement of cement with RHA was 25% percentage, where the percentage of increasing was 4.6%. Splitting tensile strength was decreased slightly as RHA increased. In addition, modulus of elasticity and density decreased as RHA percentage increased.

In 2013, Jinan. [26], added RHA to mortar cement at percentages (5, 10, 15, 20)% of RHA, where observed that the samples having 5%, 10% and 15% RHA showed better results than the OPC mortar at age 90 days.

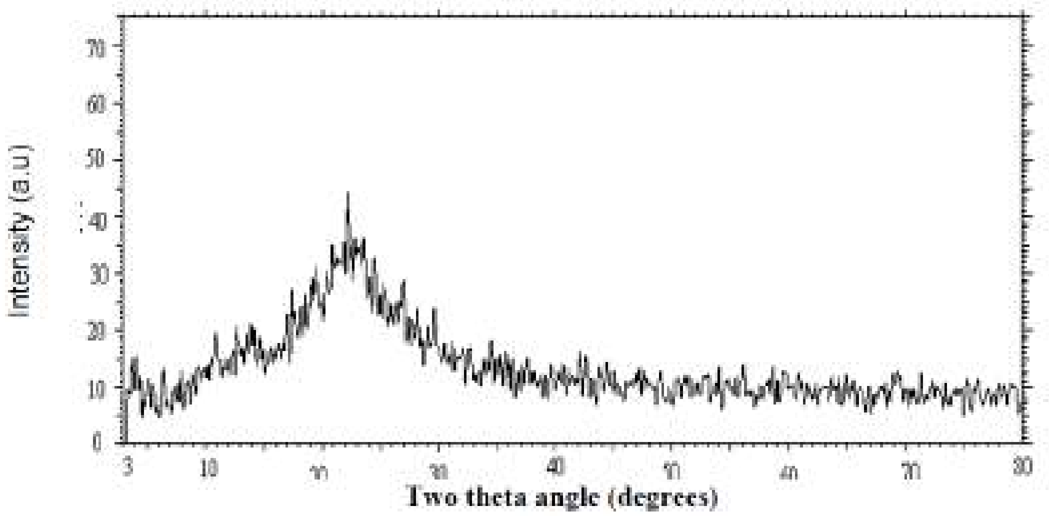


Fig. (2-2): Analysis in X-ray diffraction (XRD) [25].

In 2014, Piyush et al. [27], utilised rice husk ash and marble powder (MP) as a partial alternate to cement (10, 12, 14, 16, 18, 20, 30)% of RHA and constant ratio of marble powder was 5%. The tests carried out for hardened concrete (compressive strength and flexural strength), where they observed that 21 % of cement was substituted by 16% RHA and 5% marble powder led to that compressive strength was more than the reference concrete while percentage 10% of RHA and 5% marble powder were replaced to cement led to that, flexural strength was more than the reference concrete. In addition, the water absorption was decreased at 16% of RHA and 5% of marble powder were replaceable and then water absorption increased as RHA percentage increased slightly.

In 2014, Smita et al. [28], burned RH at temperature 800 °C to originate RHA which its colour was grey. The chemical properties of RHA showed that it contains 93.8% of SiO_2. RHA utilised as a partial alternate to cement at percentages of (5, 10, 15)% at mix proportion (1:1.5:3) with w/c was 0.5 at period curing was 7 and 14 days. The tests execute for harden concrete (compressive strength). They observed at 7 days that the compressive strength increases by 11% at added 5% of RHA and the increasing became 3.98% at added 10% of RHA, while at 15% of RHA, compressive strength decreased by 7.15%, finally at 14 days, the compressive strength increased by 7.92% at added 5% of RHA and when added 10 % of RHA, compressive strength decreased by 3.98% and decreased by 13.69% when added 15% of RHA.

In 2014, Obilade. [29], utilised RHA as a partial alternate to cement at percentages of (5, 10, 15, 20, 25)% by weight at mix proportion was (1:2:4) at ages (7, 14, 28) days. The fresh and harden concrete were performed and observed that workability, the bulk density was decreased when RHA increased. In addition, the compressive strength reduced when ratio of RHA replacement increased, where the percentages of decreasing were (5.04, 28.3, 35.8, 36.2, 54.4)% at (5, 10, 15, 20, 25)% of RHA.

In 2014, Gyanen et al. [30], utilised RHA as a partial alternate to cement at percentages (5, 10, 15, 20, 25, 30)% by weight at ages of days 7 and 28 days, where the samples cured at water normal and water contain a percentage 5% sodium sulphate (Na_2SO_4) and 5% magnesium sulphate ($MgSO_4$) solution at 30 days. The colour of RHA is grey and its chemical analysis found that contains a high percentage of silica 68.12%. The testing of surface water absorption was performed with a cube of concrete with dimensions with size (150*150*150) mm. The tests were carried out for fresh (slump) and harden concrete (compressive strength). The workability, water absorption were reduced as RHA percentage increased. In addition, the compressive strength increases by addition RHA and the optimum percentage of RHA added was 15% at 7 days and 10% at 28 days, where the percentage of increasing was 7.14% that gave higher value compressive strength and the compressive strength of concrete with curing 5% MgSO4 and 5% Na2SO4 showed improve a compressive strength did not appear more strength loss.

In 2015, Archana et al. [31], utilised RHA and fly ash (FA) as a partial alternate to cement at percentages of (10% RHA and 20% FA) and (5% RHA and 20% FA). In addition, stone dust (SD) replacing to sand at ratio (30 and 40)% by weight at mix proportion (1:1.63:2.97) with w/c was 0.64 at ages (3, 7, 14, 28) days. The tests were performed for compressive and flexural strength. They observed that the replacement ratios of cement with (10% RHA and 20% FA) and sand with (30% SD) gave highest value of compressive strength, where the percentage of increasing was 1.13%.

In 2015, Leong. [1], used RHA as a partial replacement of cement in the concrete mixture at ratios of (2.5, 5, 7.5, 10)% by weight and incinerated at the temperature of (600 and 700) °C and the mixing proportion was (1:1.33:2.55) and w/c 0.42, as well as Superplasticizer was 4.69 l/m^3 for both temperatures. Tests were performed to measure pulse speed, where observed that pulse speed increased from 14 to 28 days which mean that the concrete become more homogenous from time to time. They were conducted for fresh and hardened concrete at age (14 and 28) days. They observed that when RHA percentage increase the workability is decreasing. In addition, the compressive strength decreased at all percentages of RHA except 5% of RHA that gave compressive strength higher than reference concrete, where the percentage of increasing was 8.1%.

In 2015, Naveen et al. [32], converted rice husk to ash by burn it at temperature between (500 to 600) °C and observed that RHA contain on high percentage of SiO_2 was 87.20%, which mean that RHA consider as material pozzolanic. RHA utilized as a partial replacement of cement at ratios (5, 10, 15, 20)% with maximum size of aggregate was 20 mm and the mix proportion was (1:1.48:2.63) with w/c of 0.43 and the mix proportion was (1:1.34:2.34) with w/c was 0.35. The tests was carried out for hardened concrete (compressive strength) at ages (7, 28) days, they observed that optimum replacement of RHA was 10%, which gave high compressive strength, where the percentage of increasing were 6.7% and 6.5% for both mixes.

In 2015, Rama et al. [33], utilized RHA in concrete as a partial alternate to cement at percentages (5, 10, 15, 20)% by weight and the samples curing at normal water and variable concentrations of magnesium sulphate solution ($MgSO_4$) (1, 3, 5)%. The tests carried out for fresh and hardened concrete, whereat increase RHA lead to decrease workability, the compressive strengths and split tensile strength increased slightly at ratios (5, 10)% of RHA and decreased slightly at (15, 20)% of RHA which cured in normal water for period (7, 28, 60) days and various concentrations of (1, 3, 5)% $MgSO_4$ at ages (7, 28, 60) days.

In 2015, Nishant et al. [34], studied effectiveness of rice husk ash on the characteristics of concrete, where it utilized as a partial replacement of cement at percentages (5, 10, 15, 20)% of RHA. The tests carried out for compressive strength, where noted that compressive strength decrease slightly as percentages of RHA were increased, while setting time increased as percentage of RHA increased.

In 2016, Taku, et al. [35], produced RHA by burn of rice husk at different temperatures (400, 500, 600, 700, 800) °C for period 180 min in programmable furnace that it has capacity 1300 °C, where they were analysis RHA by X-ray flourescence (XRF) device, where they found that percentage of SiO2 was 48.8% in RH and they observed that RHA contains on SiO2 at temperatures (400, 500, 600, 700 and 800) °C was (71.4, 72.5, 73.1, 73.2, 72.7)%. The output ash from burning at all temperature was added as a partial replacement to cement at ratio 15%. The tests conducted to measure initial setting times and final setting times. They showed that initial setting time was 180 min when adding burnt ash at temperature 700 °C, while at temperature 400 °C, initial setting time was 149 min. Final setting times were (180, 157, 220, 204, 240) min for mix for RHA burned at (400, 500, 600, 700, 800) °C, respectively. The mix for RHA burnt at 800 °C and 500 °C had the high value and low value final setting times.

In 2016 Arvind et al. [36], produced RHA by burning rice husk in the air in an uncontrolled arson with temperature (400-600) °C. Ash was used as a partial replacement of cement by 20% where the testing was for hardened concrete (compressive strength) at ages (7, 14, 21, 28) days where they observed that 20% of RHA give higher strength than reference concrete, where the percentage of increasing was 3%.

In 2016, Sangeetha. [37], burned RH at temperature (550-700) °C for one hour to convert it to RHA, where he was found that ratio SiO2 in the ash was 87.22%. The tests carried out for fresh concrete (slump, workability and setting time) and hardened concrete (compressive strength) where result showed that workability decreased as RHA was increased, while setting time decreased at percentages (10, 20, 30)% of RHA and increased as percentages (40, 50)% of RHA. In addition, testing conducted to compressive strength and observed that compressive strength decreases as RHA increases, where the compressive strength were (8.88, 6.88, 3.88, 2.23)% at percentages (10, 20, 30, 40)% of RHA.

In 2017, Wang et al. [7], convert rice husk to ash by burnt it at temperature 600 °C for period 60 min, where the ash was analysed by XRD pattern and high percentage of SiO2 was obtained up to 84%. RHA was replaced to cement in ratios of (10, 15, 20)% and fly ash replaced to cement a in constant ratio15%, the mix proportion was (1:1.4:2.1) and w/c was 0.3 for all ratios and SP was 10 l/m^3. The tests were carried out for hardened concrete (compressive strength) at different temperature, where tested at temperature (20, 200, 400, 600, 800) °C, the results showed that the compressive strength of RHA concrete at temperature 20 °C was higher than reference concrete and when the temperature reached 200 °C, the compressive strength showed a slight improvement of reference concrete and all ratios of RHA. At 400 °C and 600 °C, the compressive strength was decreased and when temperature 800 °C the compressive strength were (30-40)% of those at room temperature 20 °C. The optimum percentage of RHA at all temperature was 20%, but the percentage of increasing was slightly.

In 2017, Kumar et al. [38], created RHA by burnt the husks at a controlled temperature, where RHA contains on high percentage of SiO2 was 86.91%. RHA utilised as a replacement to cement in mixture concrete at percentages of (5, 10, 15, 20, 25)% and the mix proportion of concrete was (1:1:2) with w/c was 0.42. The tests were carried out for hardened concrete (compressive strength, flexural strength and tensile strength) at ages (7, 28) days. They observed that the optimum replacement ratio for compressive and flexural strength was 5%, where the percentages of increasing of compressive strength was 12.6%. The optimum replacement ratio of tensile strength was 10% of RHA.

In 2017, Sathya et al. [39], utilised three ratio of RHA as a partial alternate to cement (10, 15, 20)% by weight at ages (7, 28, 56) days in self compacting concrete (SCC). The fresh (slump) and harden concrete (compressive strength and splitting tensile strength) were performed. They observed that workability decrease as RHA increase, in addition that increase of compressive and tensile strength up to 15% substitution of cement by RHA where the optimum percentage of increasing was 12.2%, while at 20% of RHA led to decreased the strength but still higher than reference concrete. Porosity was decreased as RHA increased.

In 2017, Akhil et al. [40], utilised RHA as a partial alternate to cement at percentages (5, 10, 15)% by weight and used marble powder as a partial alternate to cement at percentage constant 5% by weight with all percentage of RHA. RHA contains SiO2 90% and the colour was grey. The mix proportion was (1:1.8:2.77) with w/c was 0.34. The highest percentage replacement of (rice husk ash, marble powder) was (15, 5)% which gave the highest compressive strength, where the percentage of increasing was 4.8%. The force caused failure shear of the control beam which its value 112 kN that caused first crack with width 0.05mm and 180 kN which cause the ultimate crack was 0.18 mm as shown in Fig. (2-3) while the force caused failure shear of the RHA-marble powder beam which its value 135 kN that caused first crack with width 0.03 mm and 210 kN which cause the ultimate crack was 0.1 mm as shown in Fig. (2-4). The ductility ratio of control beam was 1.58%, while was 1.69% of RHA- marble powder beam.

Fig.(2-3): Crack pattern for control beam [40].

Fig. (2-4): Crack pattern for RH – marble powder of beam [40].

2.3 Summary

1- From literature used electrical furnace to burn RH and convert it to RHA.

2- Some researches had compressive strength was increased and some researches had compressive strength was decreased, but the ratios of increasing and decreasing were not great compared to the reference strength, the reason for this was due to the burning conditions as well as time of grinding process.

3- The optimum replacement ratio of RHA was 25%, which gave percentage of increasing of mechanical properties was 8.55%, while the optimum percentages of increasing of mechanical properties was 12.6% at 5% of RHA added.

4- In the present study, a natural gas – fuelled furnace was used to burn RH at temperature between (500-600) °C and RHA add to concrete structural (beam) to examine behaviour of beams at RHA added at different percentage and compared with reference concrete.

Chapter Three

EXPERIMENTAL

WORK

CHAPTER THREE

3.1: General

Production of RHA through the burning of rice husk at temperatures ranging from 500 °C to 600 °C in a locally designed furnace that works with natural gas. After RHA formation, the chemical properties of the ash are examined to knowledge the percentage of SiO2 and some chemical compounds other in the ash as well as physical properties of RHA. The physical and chemical properties of material mixtures are determined. RHA are added to the concrete mixture in different proportions. The mechanical properties of the concrete mix are compared with and without the addition RHA, as well as the properties of sample beam with and without RHA and all sample cured to period specific, where all these details are included in this chapter. All tests are executed in the laboratories of the technical institute of Amara. The chapter three is divided into two portion, the first portion includes the manufacture of a furnace with a specific specification for the burning of the crust, which is considered as wastes material for the production of ash and the second portion includes the addition of this ash to concrete mix at different rates to replace the cement and its effective on compressive strength, flexural strength and splitting tensile strength as well as knowledge its effect on properties of beam through flexural, deflection, ductility and cracking.

3.2: Manufacturing of furnace

The production of RHA requires the manufacture of a controlled temperature furnace, therefore a special furnace of a certain size was made to burn the husk and production RHA. The furnace was made of layers of different materials, where the outer layer of steel with a thickness of 1.5 mm, followed thermal insulation (glass wool), followed a layer of galvanized iron with a thickness of 2 mm, followed layer of thermal bricks with a thickness of 40 mm to keep the heat inside the furnace. The burning chamber has certain dimensions, where high of burning chamber is 300 mm and the width of 420 mm as well as the depth of 420 mm. The bottom part contains storage place to store the resulting of RHA to keep it until using. The dimension of storage place is 420 mm height, 420 mm width and the depth of 640 mm, where all these details are mentioned are shown in Fig. (3-1) and (3-2).

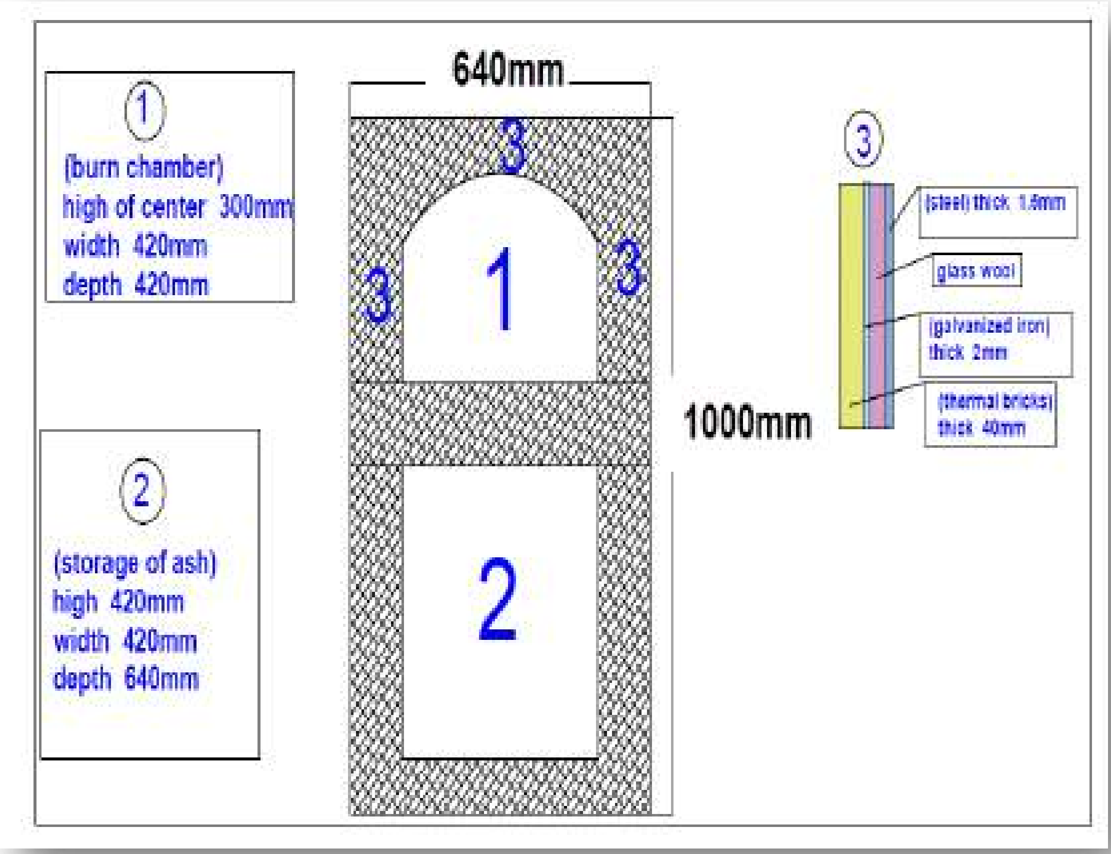
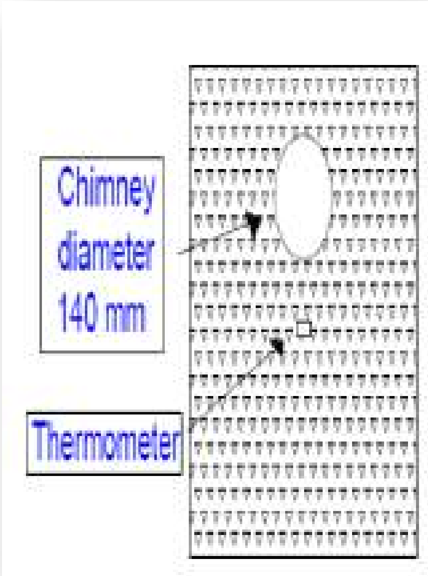


Fig.(3-1): Dimensions and details of layers of furnace.

Fig. (3-2): Front view of the furnace.

The fuel used in the furnace is natural gas where the torch of the fire is located on the side of the furnace and there is an valve in the side of furnace also to control furnace temperature as shown in Fig. (3-3), as well as the top view of the furnace contains chimney with diameter of 140 mm to disposal of harmful burning products and there is a mercury thermometer with capacity to know the temperature of burn chamber as well as there is an electronic thermometer with the mercury thermometer to measure the temperature to ensure that the required heat has been achieved, where the capacity of mercury was 600°C. The temperature 500 °C to 600 °C was used to produce ash as a pozzolanic RHA. These details is shown in Fig. (3-4) and (3-5).

Fig. (3-3): Side view of the furnace.



a) b)

c)

Fig. (3-4): Mercury and electronic thermometer and chimney of the furnace (a-c).

Fig. (3-5): Furnace apparatus.

3.3: Method of burning

The husk burned by bringing a quantity of husk and placed inside the furnace, where the distribution of ash is levelly height to ensure that the heat is distribution on all the husk and then close the furnace after ignition to control the temperature. The husk must be subject to a gradual temperature until reaching to the required temperature for burning, which is 500 °C to 600 °C, and burn it at these temperature for a period of (2 to 3) hours to obtain ash with colour is grey and with a high percentage of SiO_2, where these period of burning contribute to disposal of un-burned carbon, which is harmful to the characteristics of the pozzolanic ash. The ash if subjected directly to a high temperature of 500 °C, its colour remains black and did not change to a grey colour, as well as did not contain high percentage of SiO_2. The output RHA is (20 to 25)% of RH by weight. The colour of the husk is black initially at the beginning of burning until the temperature reaches to 500 °C, the ash convert to grey colour. The burning process of RH is shown in Fig. (3-6). The time required to reach a temperature to 500 °C is (1.5 to 2) hours approximately.

Fig. (3-6): The burning process of RH.

The ash left in the furnace for 24 hours to cool after the burning process was completed. The ash was grinded with a special mill at a speed of 25000 rpm for 5 minutes as shown in the Fig. (3-7).

Fig. (3-7): Mill to grinding RHA.

3.4: Materials

The locally available materials are utilised in this study and optimum proportions should be choose according to the mixture design methods, where this materials are ordinary portland cement, RO water, fine and coarse aggregate and added RHA as a supplementary material, which it used in different proportions. Fig. (3-8) explain experimental work.

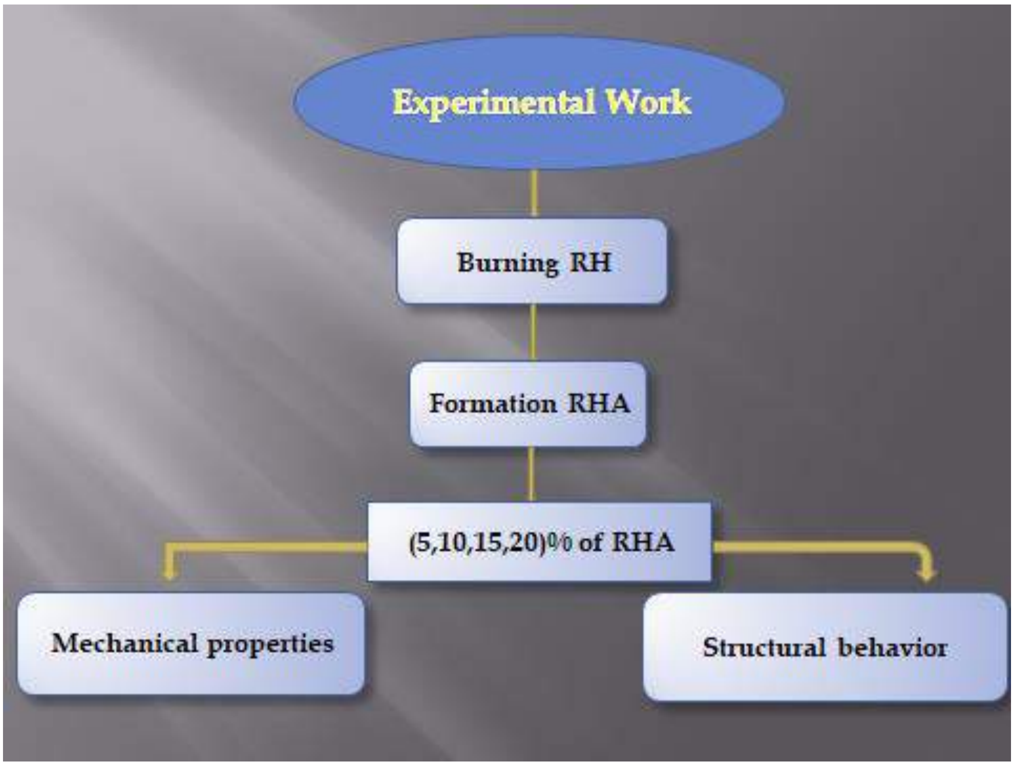


Fig. (3-8): Flowchart for experimental work.

3.4.1: Cement

Ordinary portland cement (Type 1) produced by lafarge company (Kresta Trade name) is utilised in this study. It was putted in a dry locale to keep the characterizations of cement from the effect of moisture. The chemical and physical properties of the cement complies with Iraqi specification No.5/1984 [41] are shown in Tables (3-1) and (3-2). The tests are carried out in the laboratory of construction and material in the technical institute of Amara.

Table (3-1): Chemical composition of cement.

Oxide composition	Abbreviation	Content (percent) by weight	Limit of Iraqi specification No.5/1984 [41]
Lime	CaO	60.4	----
Silica	SiO_2	27.21	----
Alumina	AL_2O_3	5.32	----
Iron Oxide	Fe_2O_3	5.5	----
Sulphate	SO_3	2.6	≤ 2.8%
Loss on Ignition	L.O.I	1.6	≤ 4%
Lime saturation factor	L.S.F	0.68904	0.66-1.02
Tri Calcium Aluminate	C3A	3.4	----

Table (3-2): Physical properties of the cement.

Physical properties	Test result	Limits of Iraqi specification NO.5/1984 [41]
Fineness using blain air permeability apparatus (m^2/kg)	392	≥230
Setting time using victa's method		
Initial (hrs: min.)	1:20	≥ 0:45 min
Final (hrs: min.)	4:40	≤ 10 hrs
The compressive strength of mortar		
3 Days, MPa	21.3	≥15
7 Days, MPa	23.6	≥23

3.4.2: Fine aggregate

Natural sand utilised in this study from the Basra region near sanam mountain in the south of Iraq. The sand cleaned from clay and other impurities. Characterizations of the grading of the sand are shown in Table (3-3), Fig. (3-9) and the specific gravity, sulfate content, and absorption are shown in Table (3-4), according to the Iraqi specification No. 45/1984 [42].

Table (3-3): Grading of the fine aggregate.

Sieve size (mm)	Percent passing %	Cumulative passing % limits of Iraqi specification No.45/1984 zone 2 [42]
10	100	100
4.75	97	90-100
2.36	87	75-100
1.18	70	55-90
0.60	49	35-59
0.3	17	8-30
0.15	8	0-10

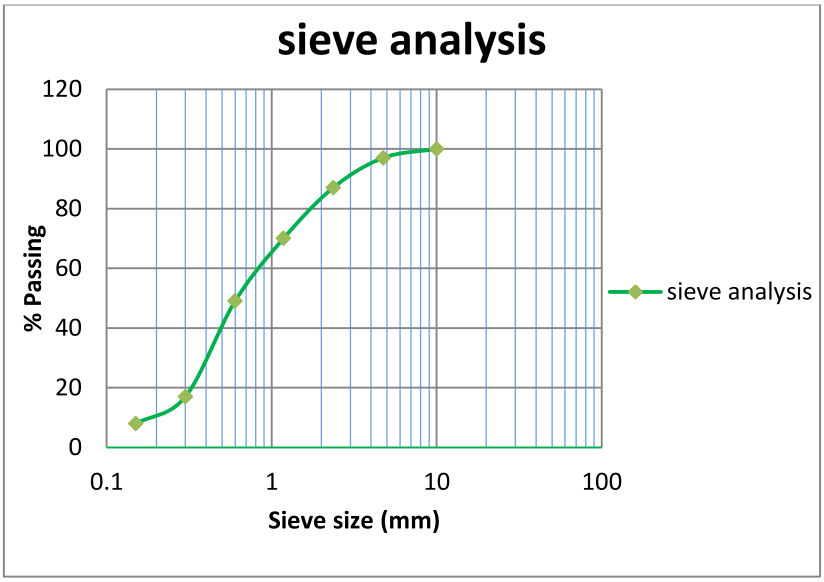


Fig. (3-9): Grading curve for fine aggregate.

Table (3-4): Physical characterizations of fine aggregate.

Physical properties	Test results	Limits of Iraqi specification No.45/1984 [42]
Specific gravity	2.56	-
Sulfate content %	0.38	≤0.5%
Absorption %	0.75	-

3.4.3: Coarse aggregate

The coarse aggregates utilised in this study are naturally available in Misan region. Gravel utilised with a maximum size of 20 mm. The test of grading applied according to the Iraqi specification No. 45/1984 [42] as shown in Table (3-5).

Table (3-5): Grading of coarse aggregate.

NO	Sieve size	%Passing	
		% Coarse aggregate	Iraqi specification No. 45/1984 [42]
1	37.5 mm	100	100
2	20 mm	97	95-100
3	10 mm	33	30-60
4	5 mm	0.63	0-10

3.4.4: Mixing water

The reverse osmosis water (RO) without any additives was utilized for pouring and curing all the samples.

3.4.5: Rice husk ash (RHA)

The type of rice was used was (Amber), which is found in many areas of Iraq. The rice husk (RH) was collected from mill there as in Misan province as shown in Fig. (3-10). The rice husk consider as waste material where collected it and then burn it in a special furnace has previously been mentioned to produce RHA with grey colour as shown in Fig. (3-11). RHA will use in this study as a partial replacement with cement in all concrete mix. The chemical properties was conducted in X-ray fluorescence machine (XRF) as shown in Fig. (3-12) at Baghdad university / college of science / The Iraqi-German laboratory, while the physical properties carried out in the laboratory of construction and material in the technical institute of Amara. The chemical and physical properties as shown in Tables (3-6) and (3-7).

Fig. (3-10): Rice husk extracted from a mill in Misan province.

Fig. (3-11): Rice husk ash produced.

Fig. (3-12): X-ray fluorescence device (XRF).

Table (3-6): Chemical properties of rice husk ash.

Constituent	Composition%
SiO_2	86.76
K_2O	6.119
Fe_2O_3	0.09835
Al_2O_3	0.0038
CaO	2.468
Mgo	0.887
SO_3	1.107
Other constituent	2.786

Where all ratios of constituent are shown in appendix.

Table (3-7): Physical properties of rice husk ash.

Physical state	**Solid**
Appearance	**Fine powder**
Colour	**Grey**
Fineness using blain air permeability apparatus (m2/kg)	**420**

3.4.6: Steel reinforcement

The deformed steel bars of 10 mm diameter were utilized in beams as min reinforcement for tensile strength, shear strength and for anchored top bars to fix the stirrups. Yield stress and ultimate strength were tested. The result of yield and ultimate strength are shown in Table (3-8).

Table (3-8): Properties of steel reinforcement.

Bar type	***Bar diameter (mm)***	***Bar area (mm^2)***	***Yield strength fy (MPa)***	***Ultimate strength fu (MPa)***	***Yield strain***
Longitudinal steel bars	**10**	**78.5**	**498**	**610**	**0.00224**
Longitudinal steel bars					

<u>3.5: Mixture used</u>

Two reference mix were designed according to ACI Recommended Practice 211.1 and inspection by trial batches. The mixture ratios was (1:1.89:2.64) with w/c 0.53 and (1:1.43:2.19) and w/c 0.44, the procedure is in appendix.

3.6: Experimental work

After burning process of RHA are complete then the experimental work included many of added RHA ratio to study the effect of RHA percentages on the concrete characteristics. Four percentages (5, 10, 15, 20)% of RHA were used for each mixture as shown in Tables (3-9) and (3-10) to choose the best percentage by compared with the reference mixture. Then RHA added to beams structural to investigate behavior of beam.

The experimental work included two basic way:

* Effect of RHA on the mechanical characteristics of concrete. Six cubes with dimensions of (150*150*150) mm, three cylinders with dimensions of (150*300) mm and three prisms with dimensions of (150*150*500) mm were poured for each percentage of RHA to measure compressive strength, split tensile strength and flexural strengths.

* Effect of RHA on behavior of the structural beam specimens. Using different percentage of RHA same the percentage that used in mechanical properties. Fourteen concrete beams with various percentage of RHA, ten beams to measure the flexure strength of beams and four beams to test the shear strength were casted and comparison with the reference beam.

Table (3- 9): Concrete mixture proportion (A0%-A20%).

I.D	(RHA)%	Cement (kg/m3)	Sand (kg/m3)	Gravel (kg/m3)	W/binder ratio
A0%	0	386.76	733	1024	0.53
A5%	5	367.42	733	1024	0.53
A10%	10	348	733	1024	0.53
A15%	15	328.76	733	1024	0.53
A20%	20	309	733	1024	0.53

Table (3-10): Concrete mixture proportion (B0%-B20%).

I.D	(RHA)%	Cement (kg/m3)	Sand (kg/m3)	Gravel (kg/m3)	W/binder ratio
B0%	0	466	668	1024	0.44
B5%	5	442.7	668	1024	0.44
B10%	10	419.4	668	1024	0.44
B15%	15	396.1	668	1024	0.44
B20%	20	372.8	668	1024	0.44

3.6.1: Concrete mixture testing

3.6.1.1: Fresh concrete Tests

Workability is one of the substantial properties definition of fresh characteristics of concrete. Concrete consumed is workable when it has handled without segregation, appropriate consistency, pouring with homogeneity concrete and compacted with minimal effort as shown in Fig. (3-13), test was carried out according to ASTM C143 [43].

Fig. (3-13): The slump cone test.

3.6.1.2: Hardened mechanical tests

3.6.1.2.1: Compressive strength test

The compressive strength was carried out by using three cubes with dimensions of (150*150*150) mm at 7 days and three cubes at 28 days each percentage mixture according to BS1881_83 [44]. The tests were done in the laboratory of concrete of the technical institute of Amara. The used machine with capacity of 2000 kN as shown in Fig. (3-14).

Fig. (3-14): The machine used to test the compression.

3.6.1.2.2: Splitting tensile strength test

The tensile strength was performed by using three cylinder with dimensions of (150*300) mm at 28 days according to ASTM- C496 [45].

The tests were done in the laboratory of concrete of the technical Institute of Amara by using compression machine as shown in Fig. (3-15).

Fig. (3-15): Split tensile strength test.

3.6.1.2.3: Flexural strength test

The flexural strength was carried out by using three prism with dimensions of (150*150*300) mm at 28 days according to ASTM- C78 [46]. The tests was done in the laboratory of concrete of the technical institute of Amara by using flexural machine as shown in Fig. (3-16).

Fig. (3-16): Flexural strength test.

3.6.2: Beam molds

Beam casting by using wooden molds as shown in Fig. (3-17). All sides of mold consist of wooden where connected to gather by using a bolts as well as simply supported beam was utilized. All the beam with span 1200 mm length and the cross section is rectangular (b*h=140*180) mm.

Fig. (3-17): Beam molds.

3.6.2.1: Details of beams

In this study fourteen beams was casted with reinforcement. Ten beam was designed for flexural strength and four beams was designed for shear strength. Details of concrete beam include three bars of 10 mm diameter at tension reinforcement, two bars of 10 mm at compression reinforcement for all beams. The stirrups had diameter of 10 mm and distributed as 80 mm c/c for flexural strength and 575 mm c/c for shear strength as shown in Fig. (3-18).

Fig. (3-18): Reinforcement for flexural and shear strength.

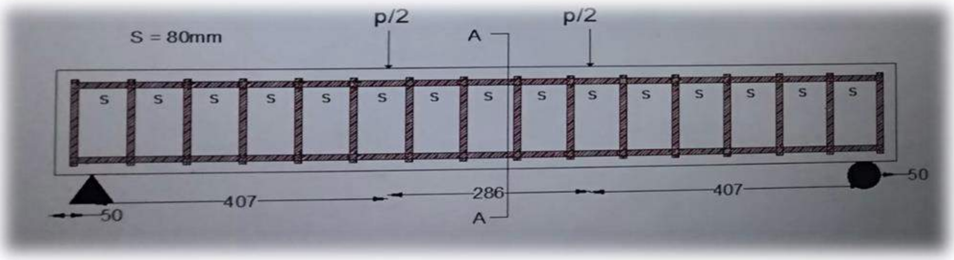
3.6.2.2: Flexural reinforcement

Ten beams were designed to fail by flexural. The procedure of analysis of beam is shown in appendix where all beams are designed through ACI 318-95 Code [47]. The details of beams designed for flexural strength as shown in Table (3-11) and Fig. (3-19).

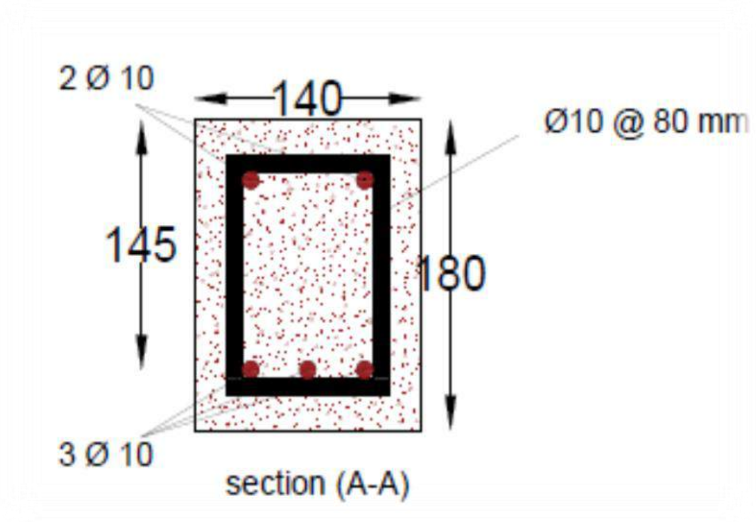
Table (3-11): Details of beams designed for flexural.

I.D	Mix proportion	%RHA	Diameter of reinforcement (mm)	a/d ratio	Spacing of stirrups (mm)
A0%	(1: 1.89: 2.64)	0	10	2.8	80
A5%	(1: 1.89: 2.64)	5	10	2.8	80
A10%	(1: 1.89: 2.64)	10	10	2.8	80
A15%	(1: 1.89: 2.64)	15	10	2.8	80
A20%	(1: 1.89: 2.64)	20	10	2.8	80
B0%	(1:1.43: 2.19)	0	10	2.8	80
B5%	(1:1.43: 2.19)	5	10	2.8	80
B10%	(1:1.43: 2.19)	10	10	2.8	80
B15%	(1:1.43: 2.19)	15	10	2.8	80
B20%	(1:1.43: 2.19)	20	10	2.8	80

a)



b)



c)

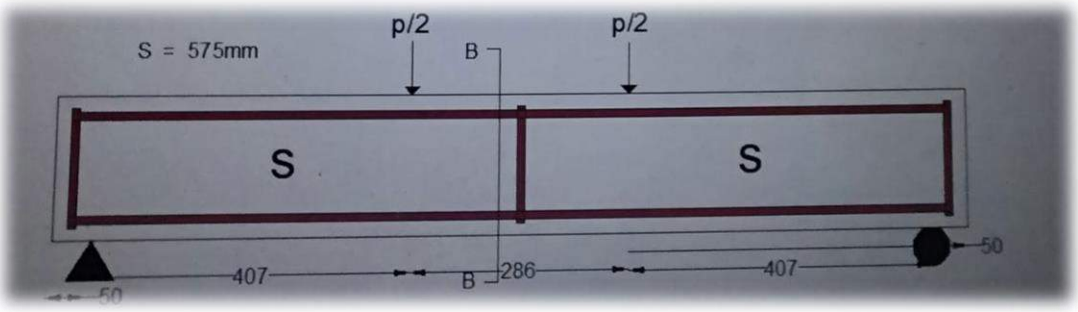
Fig. (3-19): Details of beams designed for flexural strength (a-c).

3.6.2.3: Shear reinforcement

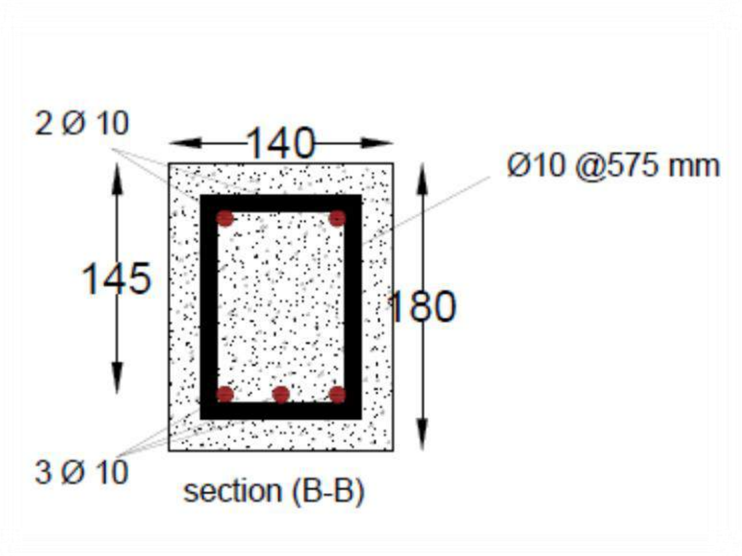
Four beams were designed by reinforcement shear to make-sure that section failure of beam by shear resistance where added 15% RHA for each reference mixture. Beams were designed through ACI 318-95 Code [47]. The details of beams designed for shear strength as shown in Table (3-12) and Fig. (3-20).

Table (3-12): Details design of beams for shear strength.

I.D	Mix proportion	%RHA	Diameter of reinforcement (mm)	a/d ratio	Spacing of stirrups (mm)
C0%	(1: 1.89:2.64)	0	10	2.8	575
C15%		15	10	2.8	575
D0%	(1:1.43:2.19)	0	10	2.8	575
D15%		15	10	2.8	575



a)



b)

Fig. (3-20): Details of beams designed for shear strength (a-b).

3.7: Mixing procedure

The batching carried out in the laboratory of concrete of the technical institute of Amara. The steps of mix are following:

1- All material are weighed according to design the mixture.
2- Sand and gravel are washed by clean water and leave about to dry before mix.

3- The mix are carried out in mixer as shown in Fig. (3-21). Gravel mix with sand, then add cement and RHA, finally the water added gradually to the mixture where period of mix was five minutes.

Fig. (3-21): Methods of mixing.

3.8: Casting and curing

3.8.1: Mechanical properties

Initially forms are grease, then cast the concrete by three layers where each layer compacted by hammer by 25 times, then refine the sample and left 24 hours, finally extract the sample from forms and place in basin contain water RO.

3.8.2: Beams structure

After grease the mold in all inner side, reinforcement install into the mold then concrete casted by three layer as well as using vibrator. Finally, the top concrete surface for each mold was refined. After two days, beams de-molded, then all beams were cured by water as well as used a sheet to cover beams to keep humidity. All beams have been cured for period 28 days and then prepare to testing. All details casting and curing are shown in Fig. (3-22).

a)

b)

c)

d)

e)

Fig. (3-22): Casting and curing the specimens (a-e).

3.9: Concrete beam testing

3.9.1: Testing machine

In the laboratory of construction of technical institute of Amara, a hydraulic manual jack machine was used. The testing set up machine showed in Fig. (3-23). Four point load test were carried to for beams. The distance between loads was 286 mm. Continues apply load until failure the beam. At reading every load, deflection and strains were recorded as well as first crack and draw crack were observed.

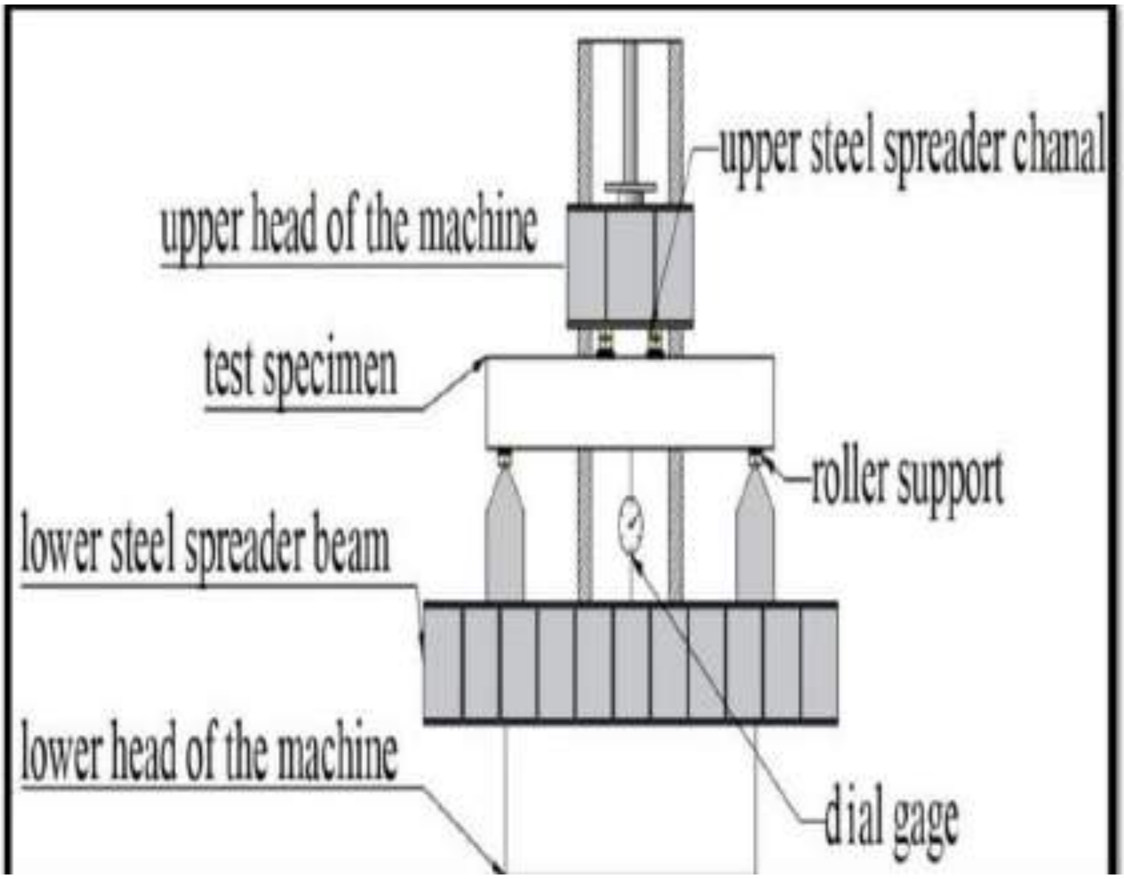
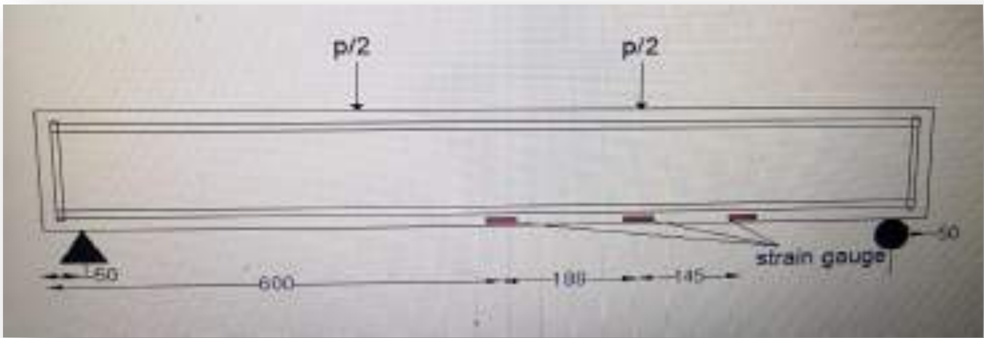


Fig. (3-23): Testing machine for all beams.

3.9.2:Concrete strain

Strain gauge use to measure the strains which happened in beam due to effective a load applied over beam. Smooth the part of beam before strain gauge had been placed by material. Strain gauge used at three zone of each beams at below the load, at center the beam and at distance (d) from a load as shown in Fig. (3-24). The result is measured by special device (data logger), which connect with a computer. Details of strain gauge that effective in all beams as shown in Table (3-13)

a)



b)

Fig. (3-24): Details of strain gauge (a-b).

Table (3-13): Details of strain gauge.

I.D	**Location of strain gauge**		
	At center	**Under load**	**At (d) of load**
A0%	**a-1**	**a-2**	**a-3**
A5%	**b-1**	**b-2**	**b-3**
A10%	**c-1**	**c-2**	**c-3**
A15%	**d-1**	**d-2**	**d-3**
A20%	**e-1**	**e-2**	**e-3**
B0%	**f-1**	**f-2**	**f-3**
B5%	**g-1**	**g-2**	**g-3**
B10%	**h-1**	**h-2**	**h-3**
B15%	**i-1**	**i-2**	**i-3**
B20%	**j-1**	**j-2**	**j-3**
C0%	**k-1**	**k-2**	**k-3**
C15%	**l-1**	**l-2**	**l-3**
D0%	**m-1**	**m-2**	**m-3**
D15%	**n-1**	**n-2**	**n-3**

3.9.3: Deflection reading

Dial gauge placed at mid span of the beam for measure deflection as shown in Fig. (3-25). At reading each load, deflection calculated also by dial gauge. Accuracy of dial gauge is (0.01) mm and the maximum reading is 5 cm.

Fig. (3-25): Dial gauge.

Chapter Four

RESULTS

AND

DISCUSSION

CHAPTER FOUR

4.1: General

In this chapter, results of experimental work that are presented and discussed here in.

4.2: Test of specimens

The result are divided into two parts, the first part was related to fresh and harden concrete properties, where the fresh concrete test includes slump test, while the harden test includes determine, compressive strength, splitting tensile strength, flexural strength. The second part was related to R.C beams tests that included applying load on the beams to calculate the ultimate load, deflection, strains at different zones of the beam, ductility, observed first crack and drawn crack pattern.

4.3: Results of concrete mix

4.3.1 Fresh concrete property

4.3.1.1 Slump test

Slump test was carried out to investigate the workability of fresh concrete the slump test is so simple and easy to handle. Slump test was execution instantly after mixing operation to making sure that mixes satisfy workability requirements with w/binder ratios 0.44 and 0.53. Slump test was carried out for every mix that contains different percentage of RHA. The result was showed that workability decreasing as the percentage of RHA increased as shown in Table (4-1).

Table (4-1): Slump test.

W/binder	% RHA	Slump (mm)	Reduction in slump%
0.44	0	85	----
0.44	5	75	11.7
0.44	10	70	17.6
0.44	15	55	35.2
0.44	20	40	52.9
0.53	0	95	----
0.53	5	90	5.2
0.53	10	75	21
0.53	15	65	31.5
0.53	20	60	36.8

For both water/binder of 0.44 and 0.53, its noted that the workability decreasing when RHA increase, this indicate that presence of RHA led to decrease the slumps. The reason that RHA had high fineness compared with cement, therefore the surface area of RHA increase, so RHA requires more. The relation between RHA% and slump are shown in Fig. (4-1).

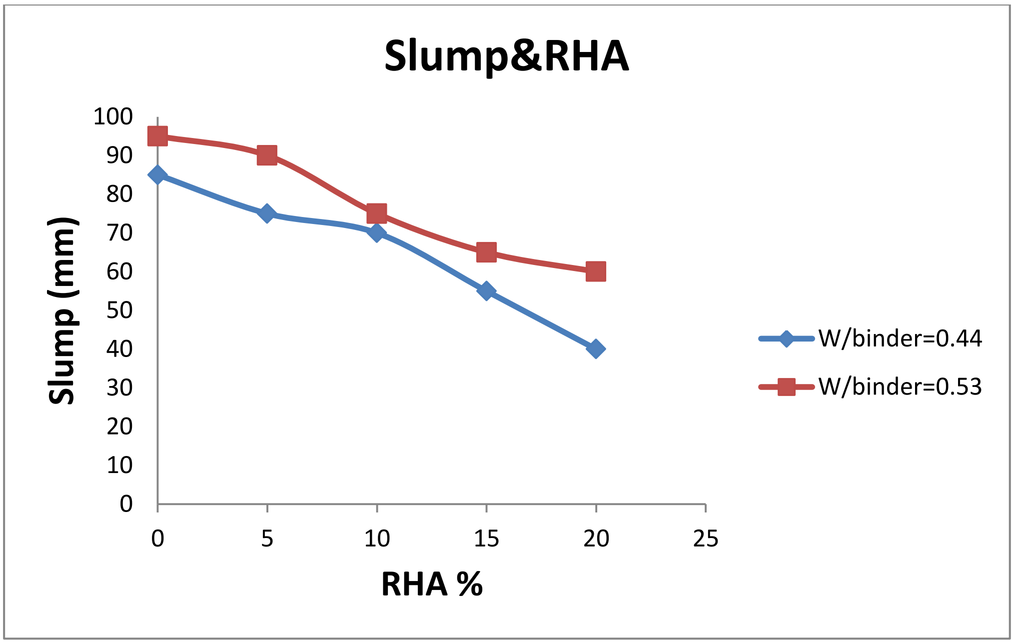


Fig. (4-1): Result of slump test for each percentage of RHA.

4.3.2:Hardened concrete test

4.3.2.1 Compressive strength

Compressive strength is consider one of the important mechanical properties of concrete where define that ability of concrete to resists the compressive force axially. Sixty cubes have been casted with dimensions (150*150*150) mm where six cubes carried out (three cubes for 7 days and also three cubes for 28 days) for each percentage with and without RHA. The results of compressive strength are shown in Table (4-2) and Fig. (4-2) and (4-3).

Table (4-2): Results of compressive strength and density of concrete.

I.D	Mass (kg)	Compressive strength (fcu) MPa 7 days	Average 7 days	28 days	Average 28days	Changing in fcu% at 28 days	7/28 ratio
A0%	8.2 8.16 8.3	31.3 31 32.4	31.5	37.5 36.5 38	37.3	----	0.84
A5%	7.9 8.1 7.8	33.1 30.5 31.6	31.7	36.5 38.6 36.2	37.1	-0.5	0.85
A10%	7.4 7.28 7.7	33.3 30.8 32.1	32	40 38.4 37.8	38.7	+3.7	0.82
A15%	8.02 8.1 7.9	31.4 30.4 31.8	31.2	34.5 35.8 36.7	35.6	-4.5	0.87
A20%	7.8 8.1 8.2	30.8 31.3 30.2	30.7	33.8 34.8 33.4	34	-8.8	0.9
B0%	8.4 8.2 8.5	34.7 39.8 38.3	37.6	38.3 37.8 42.5	39.6	----	0.94
B5%	8.3 7.9 7.78	37.3 36.9 37.3	37.1	44.8 40.3 42.8	42.6	+7.5	0.87

Table (4-2): Continued.

B10%	**7.7** **7.4** **7.2**	**38.2** **37.6** **39.3**	**38.3**	**42.5** **40.7** **39.5**	**40.9**	**+3.28**	**0.93**
B15%	**7.9** **7.5** **7.8**	**34.8** **35.9** **32.1**	**34.2**	**34.5** **36.5** **35.8**	**35.6**	**-10.1**	**0.96**
B20%	**8.1** **7.8** **7.9**	**33.8** **33.5** **32.2**	**33.1**	**33.8** **32.9** **36.1**	**33.8**	**-14.6**	**0.97**

It is observed from Table (4-2) and Fig. (4-2), that samples which contain RHA particles with dosages 10 % show an increase slightly in compressive strength by 3.7% for w/binder ratio 0.53, while at adding (5, 15, 20)% of RHA led to that compressive strength was decreased by (0.5, 4.5, 8.8)%. For w/binder ratio 0.44, observed that compressive strength increased by (7.5, 3.28) at adding (5, 10)% of RHA percentage, while compressive strength was decreased by (10.1, 14.6)% at adding (15, 20)% of RHA.

Compressive strength increased at (5, 10)% of RHA due to the chemical composition of RHA that contain high percentage of silica SiO2 that have pozzolanic property. Also noted that RHA demanded high w/binder ratio due to RHA finer than cement material. Compressive strength decreasing when added more 10% RHA where Ca (OH)2 is being depleted due to it is so essential hydrated of cement must have ph of 13±1 otherwise the hydrated of SiO2 will be destabilized and therefore give rise to weakening of cement structure which clarify the decreasing of the compressive strength as increase in percentage of RHA [48].

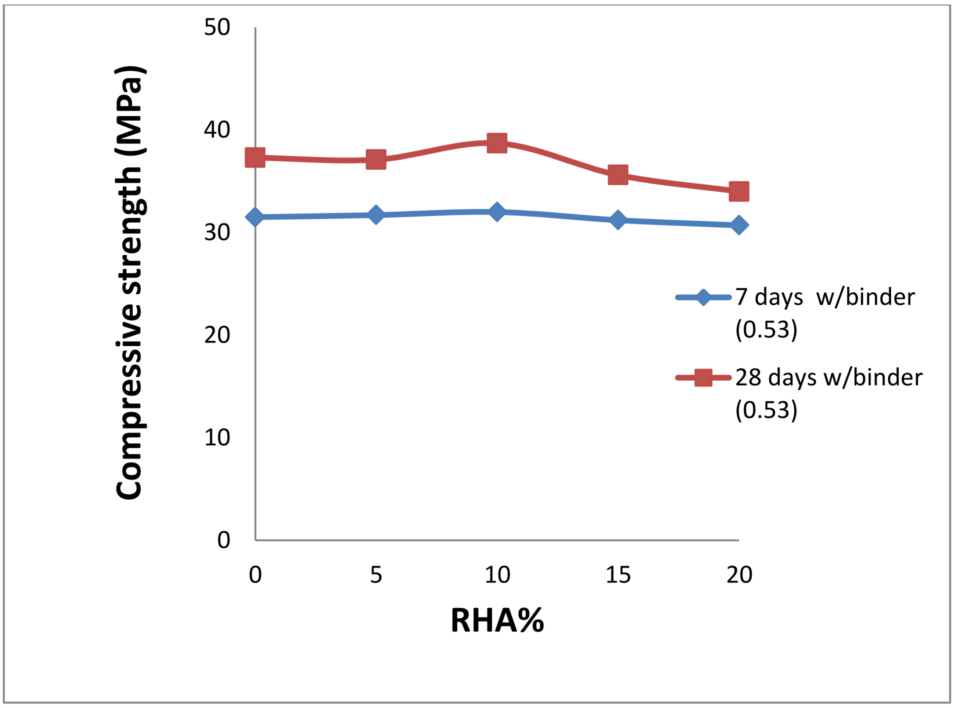


Fig. (4-2): Result of compressive strength (7 and 28) days at w/binder 0.53.

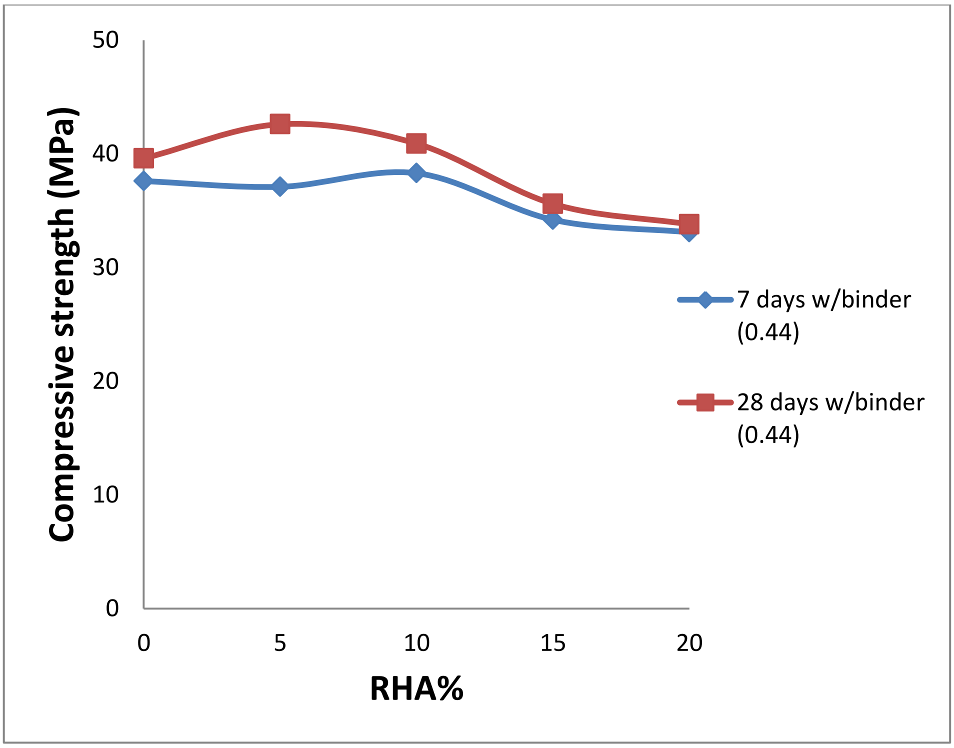


Fig. (4-3): Result of compressive strength (7 and 28) days at w/binder 0.44.

4.3.2.2: Split tensile strength

Three cylinders with dimensions of (150*300) mm were performed to measure the concrete tensile strength by split tensile test at 28 days for each percentage. The results are shown in Table (4-3) and Fig. (4-4).

Table (4-3): Results of tensile strength.

I.D	Tensile strength (ft) 28 days MPa			Average (ft) MPa	Changing in ft %
A0%	3.39	3.34	3.31	3.34	----
A5%	3.72	3.76	3.87	3.78	+13.1
A10%	3.94	3.98	3.93	3.95	+18.2
A15%	3.28	3.5	3.63	3.47	+3.89
A20%	3.32	3.25	3.36	3.31	-0.89
B0%	3.5	3.59	3.64	3.57	----
B5%	4.05	4.01	3.85	3.97	+11.2
B10%	3.93	3.8	3.7	3.81	+6.7
B15%	3.34	3.41	3.38	3.37	-5.6
B20%	3.29	3.09	3.02	3.13	-12.3

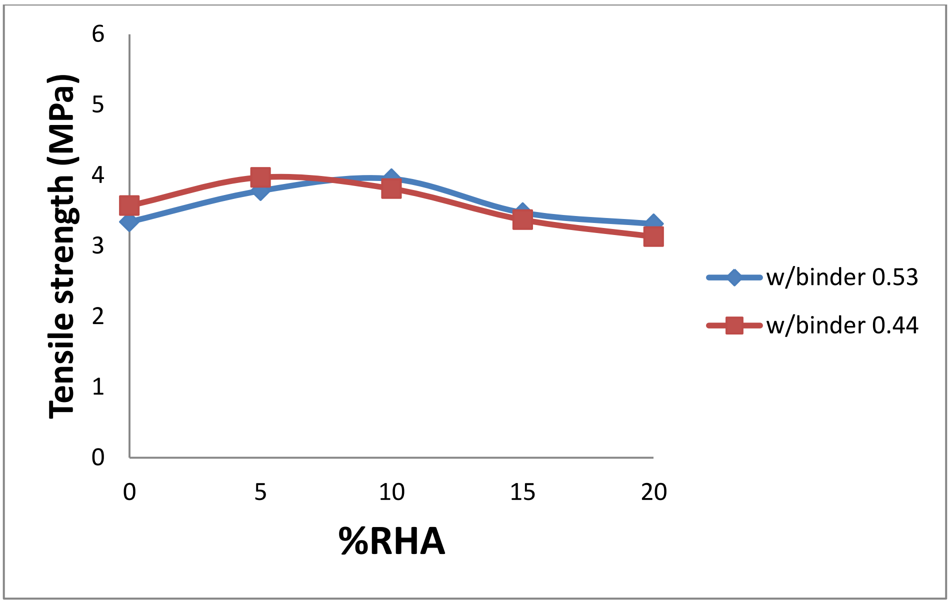


Fig. (4-4): Results of tensile strength for w/binder 0.53 and 0.44.

At w/binder 0.53, it observed that tensile strength increase by (13.1, 18.2, 3.89)% at adding (5, 10, 15)% of RHA, where the optimum tensile strength was at 10% percentage of RHA added, while at 20% of RHA added, observed tensile strength decreased slightly by 0.89%. At w/binder 0.44, it noted that the optimum tensile strength at dosage 5% of RHA and tensile strength began to reduce when adding 10% RHA, but the value of tensile strength remained more than the reference mix, while at (15, 20)% of RHA added, tensile strength decreased by (5.6, 12.3)%, this decreasing in tensile strength due to decreasing in w/binder, where increasing proportion of RHA requires an increasing water ratio due to increase surface area of RHA. The tensile strength decreased because much percentage of RHA was inactive, so didn't reaction with cement materials.

4.3.2.3: Flexural strength

Three prisms (150*150*500) mm were adopted to estimate flexural strength of concrete at age 28 days for each percentage of mixes that contain different percentage of RHA and compared the results with reference mix. The results shown in Table (4-4) and Fig. (4-5)

Table (4-4): Result of flexural strength.

I.D	Flexural strength (fr) MPa			Average (MPa)	Changing in fr%
A0%	4.68	4.81	4.97	4.82	----
A5%	5.1	4.53	5.17	4.93	+2.28
A10%	5.2	4.95	5.11	5.08	+5.39
A15%	6.02	5.94	5.81	5.92	+22.82
A20%	5.52	5.77	5.48	5.59	+15.97
B0%	4.97	5.09	5.05	5.03	----
B5%	5.14	5.30	5.25	5.23	+3.97
B10%	5.17	5.39	5.29	5.28	+4.97
B15%	5.88	5.57	5.69	5.71	+13.51
B20%	5.71	5.26	5.43	5.46	+8.54

It observed from Table (4-4) and Fig. (4-5) that all samples that contain percentage added of RHA have been flexural strength more than reference mix for w/binder 0.53 and 0.44. The results showed when RHA increased, the flexural strength increased until reached to optimum strength at percentage 15% of RHA and began to reduce at 20% percentage of RHA but the strength stayed more than reference mix.

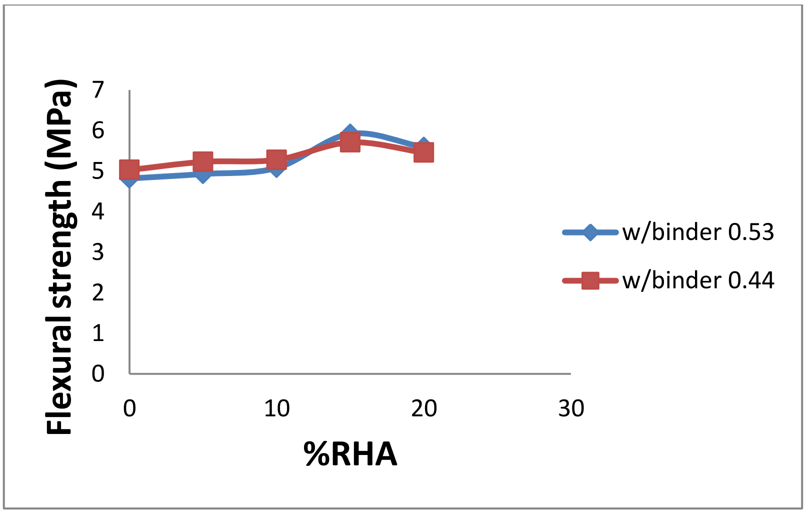


Fig. (4-5): Results of flexural strength for w/binder 0.53 and 0.44.

RHA have been positive effective on mechanical properties of concrete where some the percentage added import the strength as well as RHA economical compared with cement.

4.4: Structural behaviour of beam

The flexural and shear behaviour of beam were investigated via the ultimate load, the crack pattern ,the deflection at mid span, the strains in beam and ductility. For beams (A0%-A20%) and (B0%-B20%) were designed to fail by flexural failure, one reference beam and four beams with different percentage of RHA for two mixes designed were tested, while for beams (C0% and C15%) and (D0% and D15%) were design to fail by shear, one reference beam and one beam with percentage of RHA were tested of two mixes designed. Details design of the beams for flexural and shear strength are shown in appendix. The deflection at mid span was read for each load increment.

4.4.1: The ultimate load

The ultimate loads for flexural behavior of beams are recording and presenting in Table (4-5) and Fig. (4-6).

Table (4-5): Ultimate load of flexural test.

I.D	%RHA	Pu (kN)	Pu/Pu (reference beam)%	Change in ultimate load %
A0%	0	101.3	100	-----
A5%	5	104.5	103.15	+3.15
A10%	10	105.4	104.04	+4.04
A15%	15	102	100.69	+0.69
A20%	20	100.5	99.2	-0.78
B0%	0	108	100	-----
B5%	5	107	99.07	-0.93
B10%	10	111.6	103.33	+3.33
B15%	15	108.2	100.18	+0.18
B20%	20	106.3	98.42	-1.57

The beams (A5%-A15%) which contain different percentage of RHA as a cement replacement with reinforced with steel rebar, observed that have ultimate load failure higher than reference beams by about (3.15, 4.04 and 0.69) % respectively. The beams B10%, gave increase in the ultimate load by 3.33%. The higher ultimate load failure obtained at 10% ratio of RHA. For shear behavior, it observed that 15% of RHA gave ultimate load failure higher than reference beam for w/binder ratio 0.53 and 0.44. The load redistributions and assumptions for the concrete breakout surface that effect on the shear strength. The increasing in strength reached to 3.94% for C15% and reached to 6.5% for D15%, so added different percentage of RHA improve behavior of beams for shear strength. The details of ultimate shear failure are shown in Table (4-6).

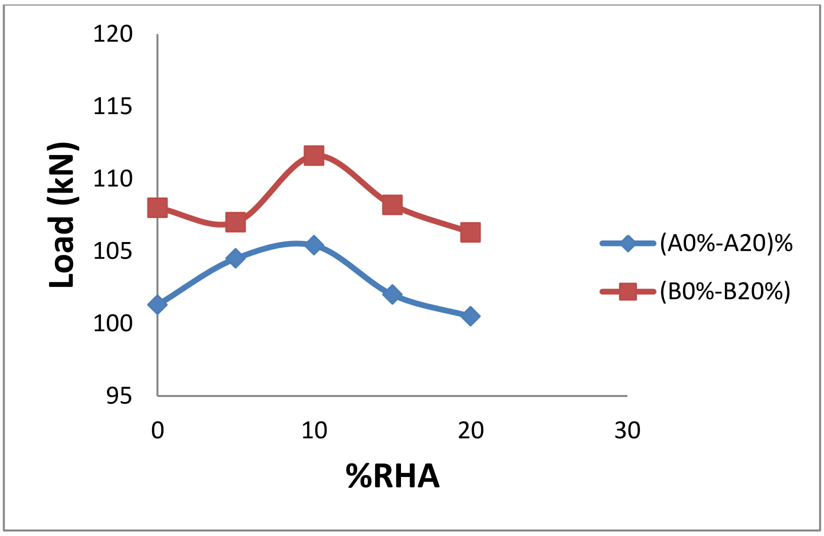


Fig (4-6): Tests of ultimate load failure of flexural behaviour.

Table (4-6): Tests of beams for ultimate shear failure.

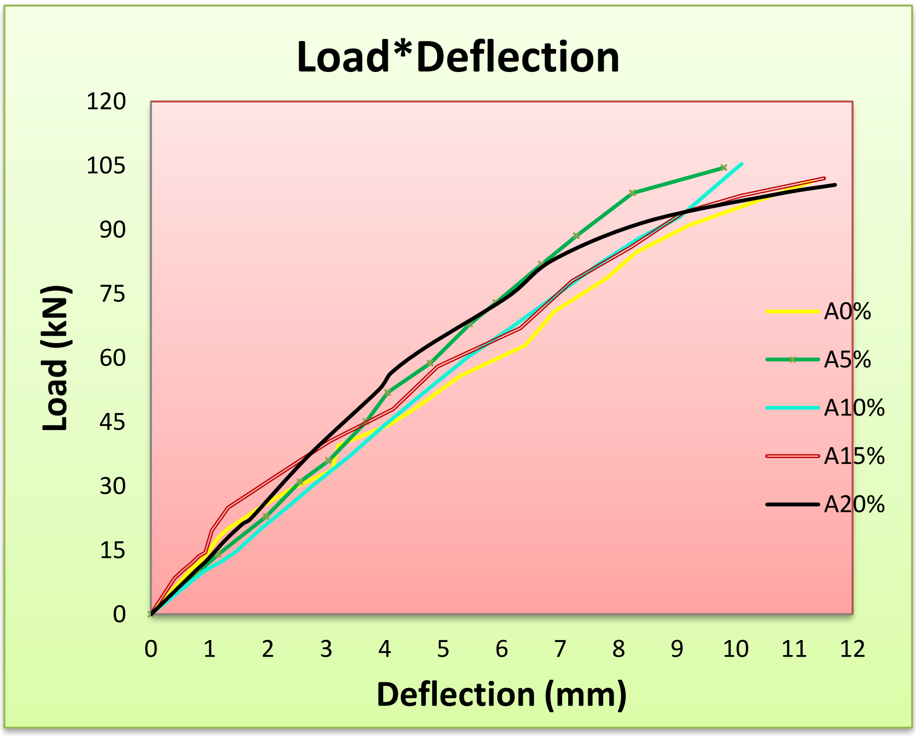
I.D	%RHA	Pu (kN)	Pu/Pu (reference beam)%	Change in ultimate load %
C0%	0	53.2	100	-----
C15%	15	55.3	103.94	+3.94
D0%	0	53.1	100	-----
D15%	15	56.6	106.59	+6.59

4.4.2:Load-deflection behaviour

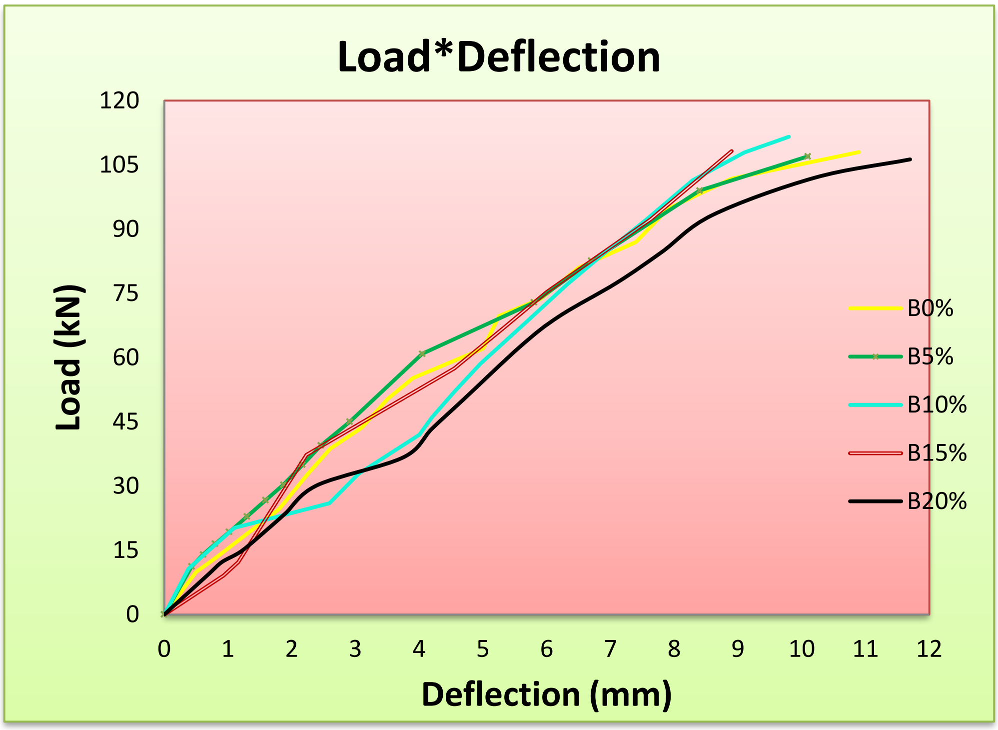
The deflection of all beams structure were recorded at mid span. For flexural behaviour of beam, the result are shown in Table (4-7) and Fig. (4-7).

Table (4-7): Maximum deflection of tested beam for flexural behaviour.

I.D	Ultimate load (pu) kN	Maximum deflection (Δu) mm	Δu/Δu(Reference beam) %	Changing in deflection%
A0%	101.3	11.3	100	-----
A5%	104.5	9.8	86.7	-13.3
A10%	105.4	10.1	89.38	-10.62
A15%	102	11.51	101.8	+1.8
A20%	100.5	11.7	103.53	+3.53
B0%	108	10.9	100	-----
B5%	107	10.1	92.66	-7.34
B10%	111.6	9.8	89.9	-10.1
B15%	108.2	8.9	81.65	-18.34
B20%	106.3	11.7	107.33	+7.33



a)



b)

Fig. (4-7) Load-deflection curve for flexural behaviour (a-b).

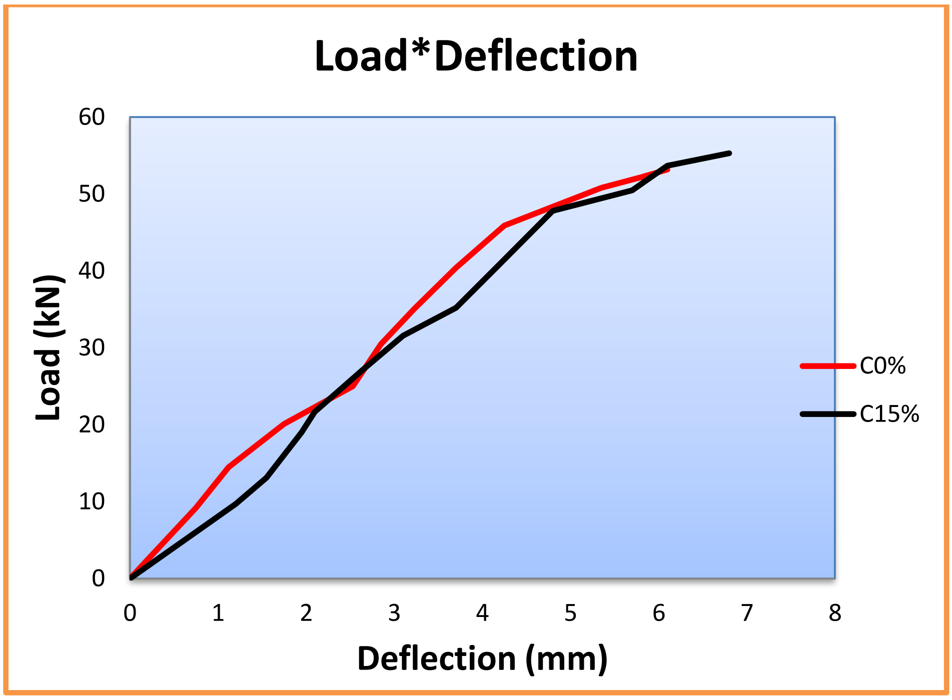
As shown in Table (4-7), (A0%-A20%), observed that reference beam have maximum deflection higher than beams which contained (5 and 10)% of RHA, while the beams which contain (15 and 20)% of RHA that have maximum deflection higher than reference beam. 20% of RHA gave ultimate maximum deflection of (A0%-A20%) beams. For (B0%-B20%) beams, observed 20% of RHA gave ultimate maximum deflection of beam.

From Table (4-7), a slight disparity in the deflection value was observed when adding variable proportions of RHA where some of the beams which containing RHA gave a higher deflection than reference beam and some proportions of RHA have a lower deflection than normal beam, so RHA added has a positive effect despite the convergence of deflection values due to RHA have low cost compared to cement.

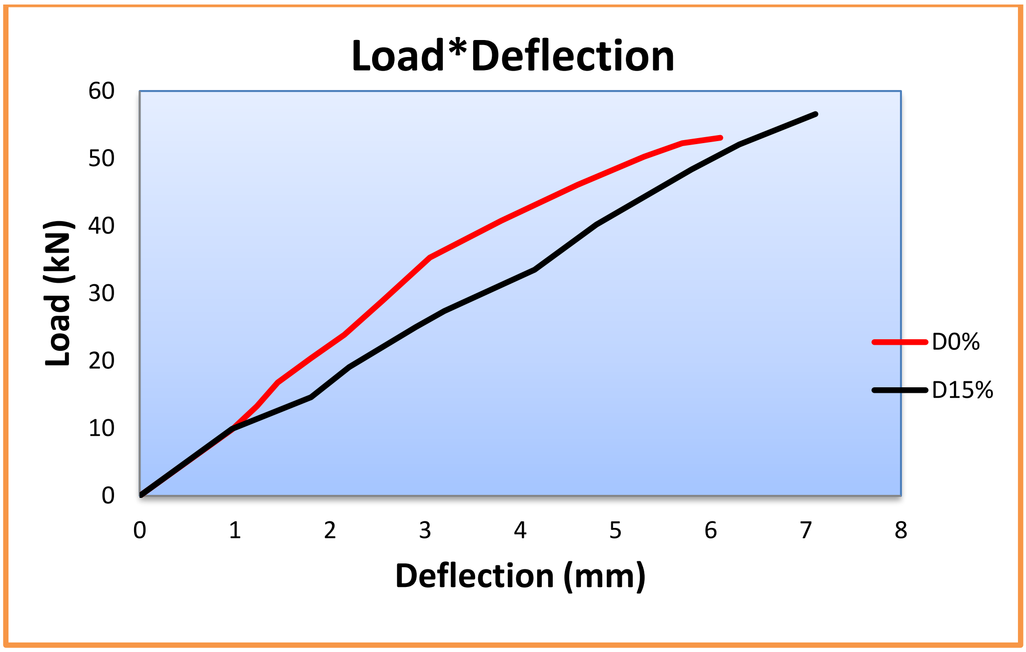
For shear behaviour, the result are shown in Table (4-8) and Fig. (4-8).

Table (4-8): Load-deflection for shear behaviour.

I.D	Ultimate load (pu) kN	Maximum deflection (Δu) mm	Δu/Δu (Reference) beam) %	Changing in deflection%
C0%	53.2	6.1	100	-----
C15%	55.3	6.8	111.47	+11.47
D0%	53.1	5.1	100	-----
D15%	56.6	7.1	139.21	+39.21



a)



b)

Fig. (4-8): Load- deflection curve for shear behaviour (a-b).

From Table (4-8), observed that beam containing RHA gave maximum deflection higher than reference beam. The maximum deflection in case of beam which contain 15% of RHA C15% increased than reference beam C0% by 11.47% and the beam D15% increasing by 39.21% as well as have maximum deflection 7.1 mm.

4.4.3: The ductility

Ductility is a mechanical property used to describe a material that can be deformed without being broken. The ductility can be obtained by dividing the maximum deflection (Δu) on the yield deflection (Δy). The ductility of all beams are showed in Table (4-9) and Fig. (4-9).

$$\text{Ductility} = \frac{\Delta u}{\Delta y} \qquad \text{....(4-1)}$$

Table (4-9): Ductility of tested all beams.

I.D	Maximum deflection (Δu) mm	Yield deflection (Δy) mm	Ductility	Changing in ductility %
A0%	11.3	4.6	2.45	-----
A5%	9.8	3.8	2.57	+4.89
A10%	10.1	3.9	2.58	+5.3
A15%	11.51	4.2	2.74	+11.83
A20%	11.7	4.9	2.38	-2.85
B0%	10.9	4.8	2.27	-----
B5%	10.1	3.8	2.65	+16.74
B10%	9.8	4.1	2.39	+5.28
B15%	8.9	3.9	2.28	+0.44
B20%	11.7	5.3	2.2	-3.08
C0%	6.1	2.3	2.65	-----
C15%	6.8	3.2	2.12	-20
D0%	5.1	2.2	2.31	-----
D15%	7.1	3.4	2.08	-9.95

The beams (A5%, A10%, A15%), observed that the ductility increased by (4.89, 5.3, 11.83)% respectively, the high ductility obtained at addition 15% of RHA, while at addition 20% of, the ductility decreased by 2.85%. The beams (B0%-B20)%, observed that high ductility obtained at addition 5% of RHA, where the percentage of increasing was 16.74%, while at addition 20% of RHA, the ductility decreased by 3.08%. For beam C15%, observed that ductility decreased by 20% as well as that beam D15%, observed decrement in ductility by 9.95%. Thus, the conclusion that high percentage of RHA is 15% which improves the ductility for beams (A0%-A20%), while high ductility obtained at addition 5% of RHA for beams (B0%-B20%), therefore w/binder ratio had effect on the ductility.

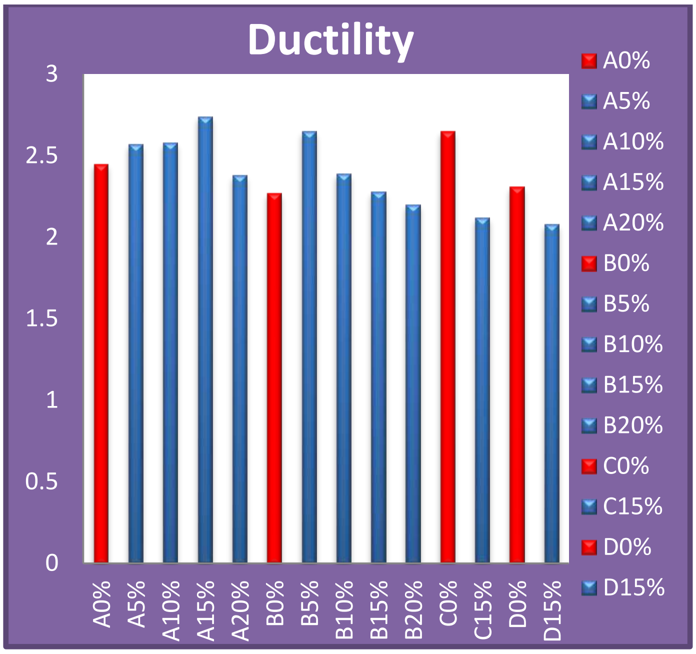


Fig. (4-9): Ductility of tested beams.

4.4.4:Cracking

when applied tensile stress exceed tensile strength of concrete, cracking was developed in concrete. The cracking investigation was accomplished via the following topics:

a. First crack load.

b. Cracking pattern.

4.4.4.1: First crack load (pcr)

The first crack load of all beams specimens were recorded and presented in Table (4-10). As shown in Table (4-10), the beam (A0%) showed the first crack at load 62.9 kN. The results of the first crack are increasing and the values are similar or equal with the reference concrete, where reaction SiO2 activity with Ca (OH)2 in the presence high amount of water had effect positive on concrete in tension zone whereon the load that cause first crack reached (67.9, 67 and 67) kN in case of beam (A5%, A10% and A15%) respectively, where the percentage of increasing were (8, 6.5, 6.5)% but beam A20% have converging values of load cracking with reference beam A0% with percentage of decreasing was 0.7%, thus increasing RHA percentage by more than 15% will reduce first crack load. The beams (B0%-B20%), observed that increase RHA percentage, the first crack load decreasing. For beams reference C0% and D0% the load cracking were 35.1 kN and 35.3 kN, while beams C15% and D15% that contain 15% of RHA, the first crack load decreasing by 10% and 5% respectively.

Table (4-10): First cracking load of all tested beams.

I.D	Pcr (kN)	Pu (kN)	Pcr/Pu %	$Pcr/Pcr_{(reference\ beam)}$ %	Changing in first cracking load
A0%	62.9	101.3	0.62	100	-----
A5%	67.9	104.5	0.64	108	+8
A10%	67	105.4	0.63	106.5	+6.5
A15%	67	102	0.65	106.5	+6.5
A20%	62.5	100.5	0.6	99.3	-0.7
B0%	69.7	108	0.64	100	-----
B5%	72.9	107	0.68	104.5	+4.5
B10%	68.3	111.6	0.61	98	-2
B15%	67	108.2	0.65	96	-4
B20%	62.8	106.3	0.56	90.1	-9.9
C0%	35.1	53.2	0.66	100	-----
C15%	31.6	55.3	0.57	90	-10
D0%	35.3	53.1	0.66	100	-----
D15%	33.5	56.6	0.59	95	-5

4.4.4.2: Cracks pattern

The beams (A0%-A20%) and (B0%-B20%) were designed to fail in under-reinforcement case to fail by the tension failure, the crack started at mid span of the beam at pure bending zone then the crack propagated on left and right of mid span, then the cracks are widen and increasing and up to the compression zone.

For beams (C0% and C15%) and (D0% and D15%), observed the crack started near to supported, which refers to shear failure and then crack started propagated to compression zone. Cracks pattern of all beam failure are shown in Fig. (4-10) and all the beams tested and the device test of beams are shown in Fig. (4-11)

a) A0%

b) A5%

c) A10%

d) A15%

e) A20%

f) B0%

g) B5%

h) B10%

i) B15%

j) B20%

k) C0%

l) C15%

m) D0%

n) D15%

Fig. (4-10): Crack pattern for all beams tested (a-n).

a)

b)

Fig. (4-11): The all beams tested and the machine test of beams (a-b).

4.4.5:Load- strain characteristics

The strains in all beams tested were measured by using data acquisition system. It was measured surface of the beam concrete in tension zones. Three readings of strain for each beam, where the readings was under the load, at mid span of the beam and at distance d from the load. Electrical strain gauges was used to measure the strains. The details of results are shown in Table (4-11) and Fig. (4-12). It was observed that not much difference in the results about the beam with RHA and without RHA. It observed that value the strains in mid span of beam and under the load were higher than the strains at distance d of the load.

Table (4:11):Load-strain characteristics of all tested beams.

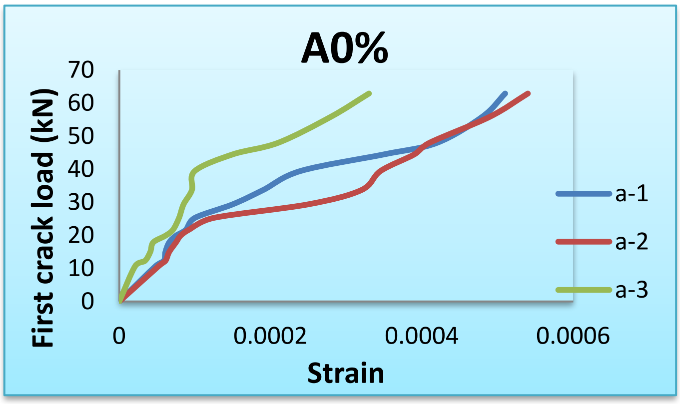
I.D	Symbol	First crack load kN (Pcr)	Maximum strain X 10^{-6}
A0%	a-1	62.9	512
	a-2		541
	a-3		335
A5%	b-1	67.9	492
	b-2		526
	b-3		324

Table (4-11): Continued.

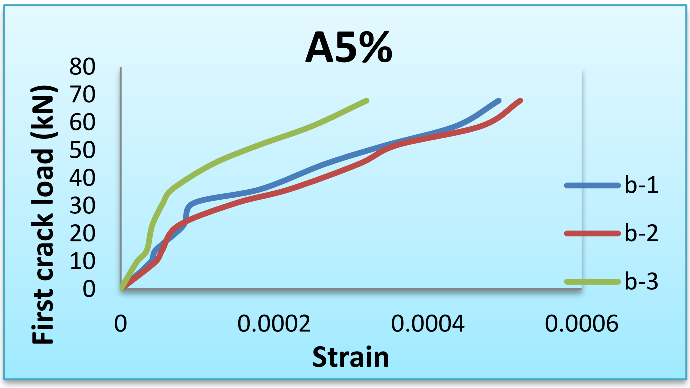
A10%	**c-1**	**67**	**583**
	c-2		**635**
	c-3		**248**
A15%	**d-1**	**67**	**412**
	d-2		**482**
	d-3		**245**
A20%	**e-1**	**62.5**	**249**
	e-2		**315**
	e-3		**215**
B0%	**f-1**	**69.7**	**360**
	f-2		**384**
	f-3		**307**
B5%	**g-1**	**72.9**	**461**
	g-2		**510**
	g-3		**342**
B10%	**h-1**	**68.3**	**448**
	h-2		**485**
	h-3		**236**
B15%	**i-1**	**67**	**312**
	i-2		**323**
	i-3		**245**

Table (4-11): Continued.

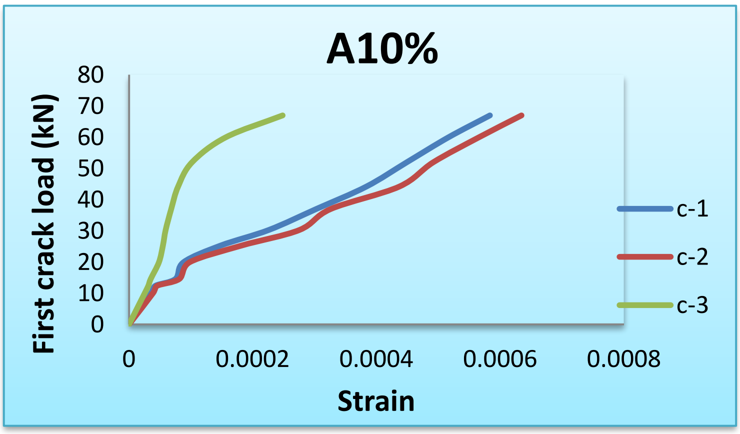
B20%	j-1	62.8	442
	j-2		459
	j-3		215
C0%	k-1	35.1	78
	k-2		85
	k-3		49
C15%	l-1	31.6	82
	l-2		86
	l-3		59
D0%	m-1	35.3	84
	m-2		90
	m-3		64
D15%	n-1	33.5	69
	n-2		75
	n-3		56



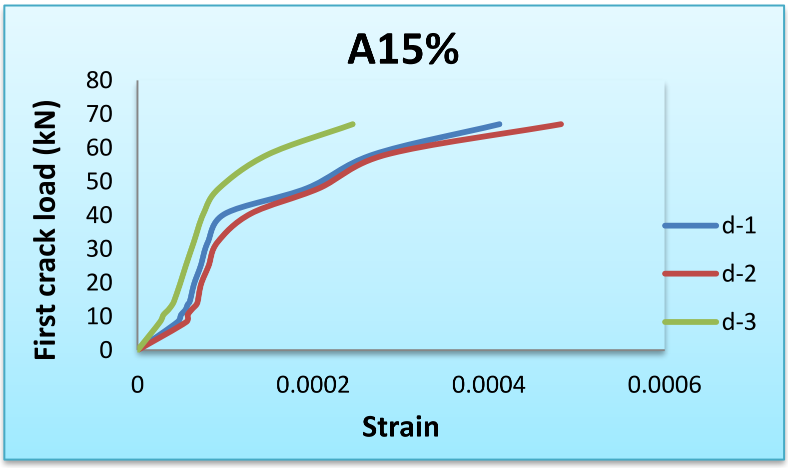
a)


A5%
First crack load (kN)
80
70
60
50
40
30
20
10
0
0
0.0002
0.0004
0.0006
Strain
b-1
b-2
b-3

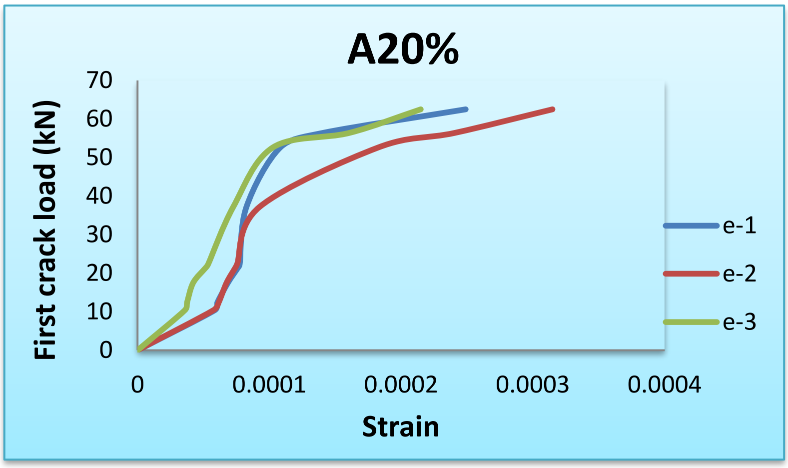
b)


A10%
First crack load (kN)
80
70
60
50
40
30
20
10
0
0
0.0002
0.0004
0.0006
0.0008
Strain
c-1
c-2
c-3

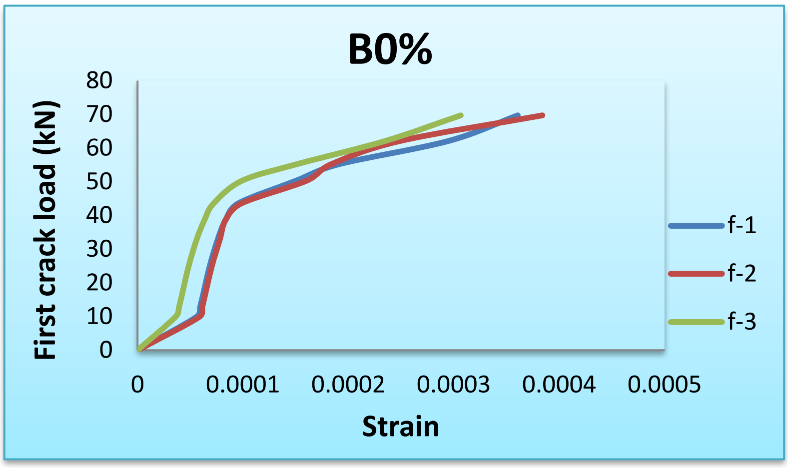
c)


A15%
First crack load (kN)
80
70
60
50
40
30
20
10
0
0
0.0002
0.0004
0.0006
Strain
d-1
d-2
d-3

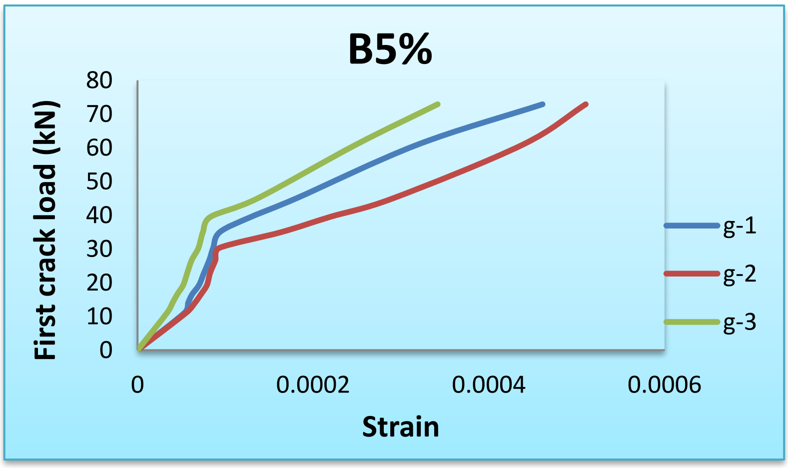
d)


A20%
First crack load (kN)
Strain
e-1
e-2
e-3
0
10
20
30
40
50
60
70
0
0.0001
0.0002
0.0003
0.0004

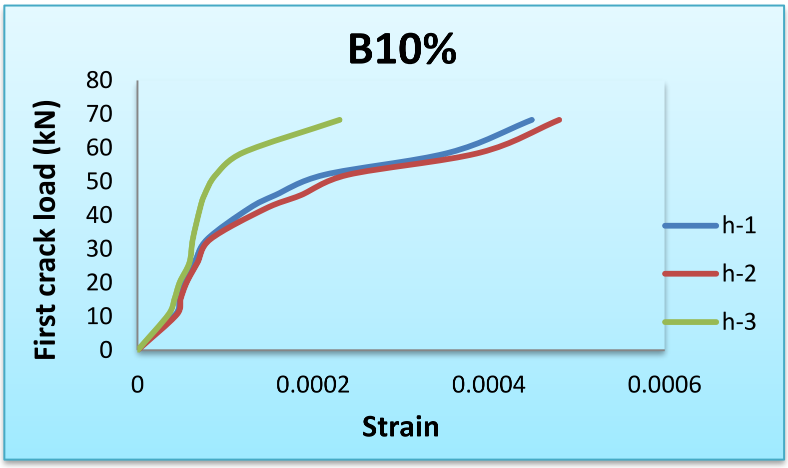
e)


B0%
First crack load (kN)
Strain
f-1
f-2
f-3
0
10
20
30
40
50
60
70
80
0
0.0001
0.0002
0.0003
0.0004
0.0005

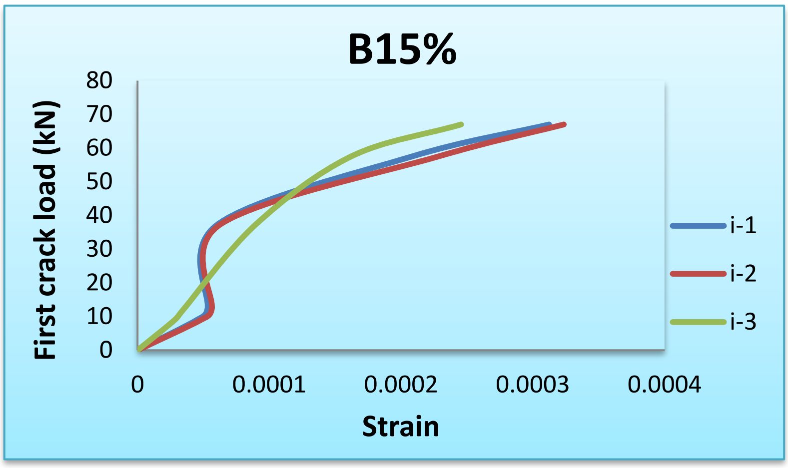
f)


B5%
First crack load (kN)
Strain
g-1
g-2
g-3
0
10
20
30
40
50
60
70
80
0
0.0002
0.0004
0.0006

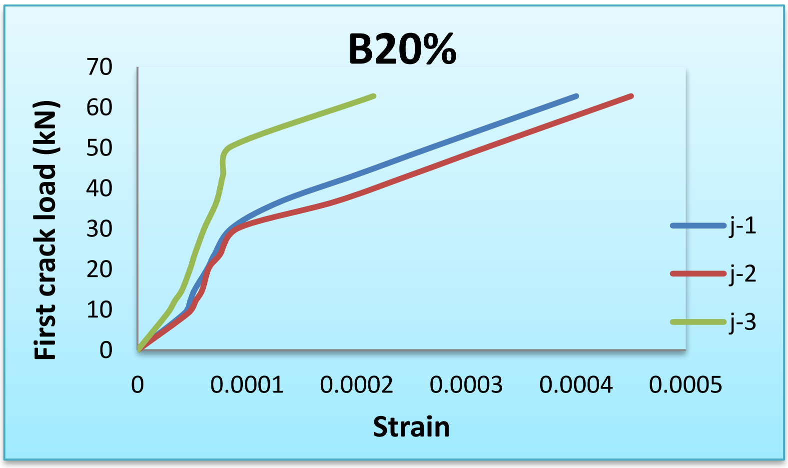
g)


B10%
First crack load (kN)
80
70
60
50
40
30
20
10
0
0
0.0002
0.0004
0.0006
Strain
h-1
h-2
h-3

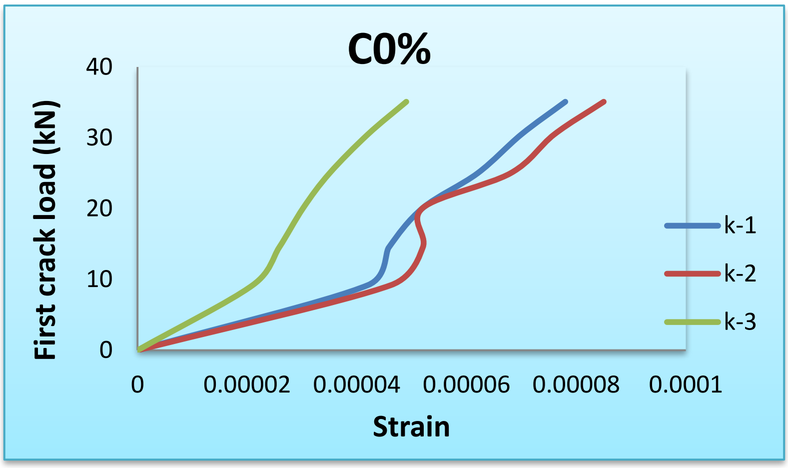
h)


B15%
First crack load (kN)
80
70
60
50
40
30
20
10
0
0
0.0001
0.0002
0.0003
0.0004
Strain
i-1
i-2
i-3

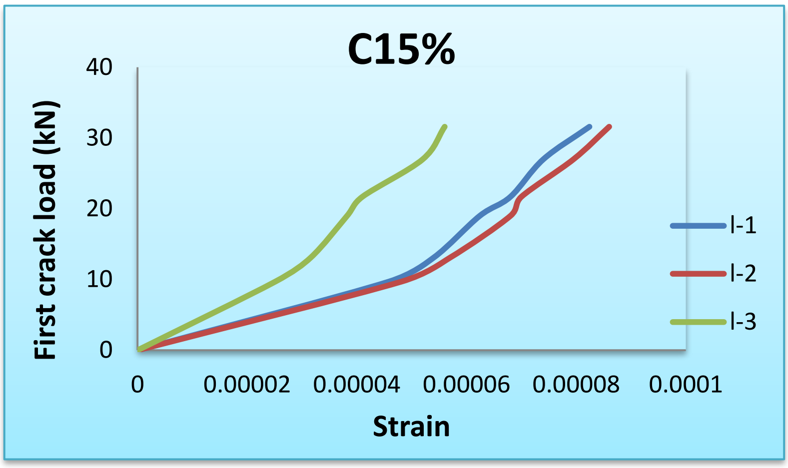
i)


B20%
First crack load (kN)
70
60
50
40
30
20
10
0
0
0.0001
0.0002
0.0003
0.0004
0.0005
Strain
j-1
j-2
j-3

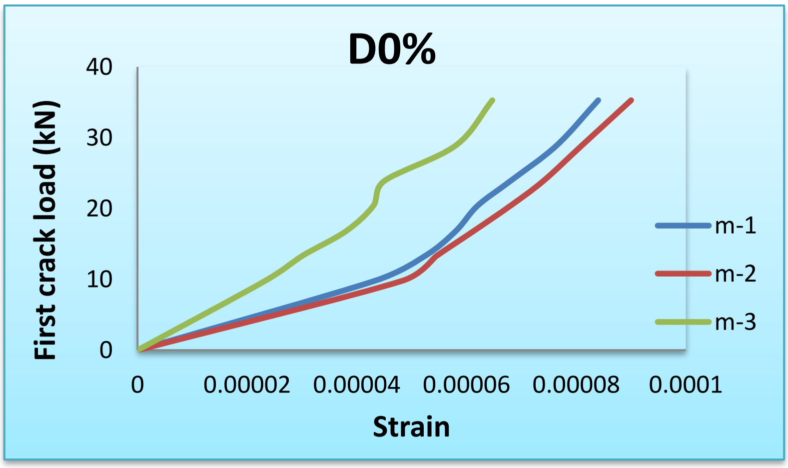
j)


C0%
First crack load (kN)
40
30
20
10
0
0
0.00002
0.00004
0.00006
0.00008
0.0001
Strain
k-1
k-2
k-3

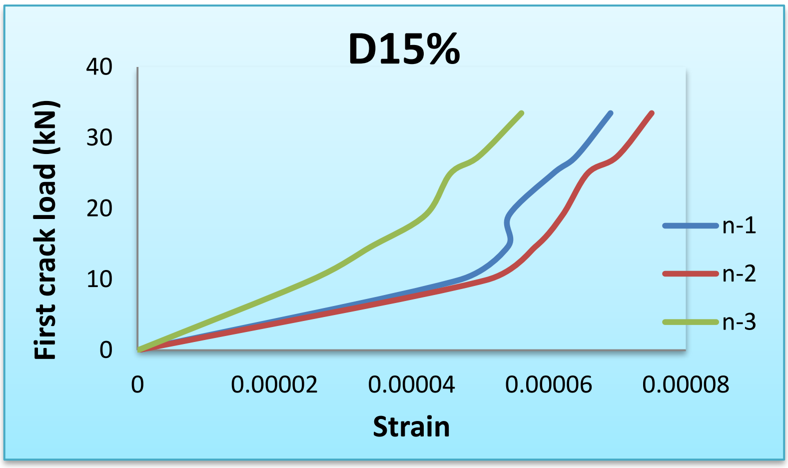
k)


C15%
First crack load (kN)
40
30
20
10
0
0
0.00002
0.00004
0.00006
0.00008
0.0001
Strain
l-1
l-2
l-3

l)


D0%
First crack load (kN)
40
30
20
10
0
0
0.00002
0.00004
0.00006
0.00008
0.0001
Strain
m-1
m-2
m-3

m)



n)

Fig.(4-12): Load-strain curve of tested beams (a-n).

Chapter Five

Conclusions and Recommendation

CHAPTER FIVE

5.1: General

The main conclusion of the experimental work which study effect RHA on behaviour of concrete are presented in this chapter. Also, the recommendations for future work are presented in this chapter.

5.2: Conclusions

Based on the tests results of concrete mixtures with different percentage of RHA, and the results of concrete beams. The main conclusions of the present work are summarized as following:

1- Rice husk ash consider as pozzolanic material due to its contains high percentage of silica SiO_2 up to 86.76%.

2- The workability reduced with increasing of RHA percentage for different w/binder raitos.

3- The compressive strength increased by 3.7% at addition 10% of RHA at w/binder ratio 0.53, while at w/binder ratio 0.44, observed that compressive strength increased by (7.5, 3.28) at addition (5, 10)% of RHA. The optimum percentage of RHA that replaced to cement for both w/binder ratio is 10% that gave appropriate compressive strength.

4- The splitting tensile strength increased by (13.1, 18.2, 3.89)% at addition (5, 10, 15)% RHA at w/binder ratio 0.53, while at w/binder ratio 0.44, noted that the splitting tensile strength increased by (11.2, 6.7)% at dosage (5, 10)%, therefore addition 10% of RHA consider the appropriate percentage.

5- The flexural strength increased by (2.28, 5.39, 22.82, 15.97)% at (5, 10, 15, 20)% of RHA added for w/binder ratio 0.53. Also at w/binder ratio 0.44, the flexural strength increased by (3.97, 4.97, 13.51, 8.54)% at

(5, 10, 15, 20)% of RHA added for w/binder ratio 0.53. The optimum percentage of RHA is 15% that gave high flexural strength.

6- Addition RHA affected positively on ultimate load of concrete ,where most of RHA added were contributed to increase the ultimate load. The beam which contains 10% of RHA gave maximum ultimate load for flexural behaviour at w/binder ratio 0.53 where the percentage of increasing was 4.04%, while at w/binder ratio 0.44, the beam which contains 10% of RHA gave maximum ultimate load, where the percentage of increasing is 3.33%. For shear behaviour, the beam which contains 15% RHA gave maximum ultimate load at w/binder ratio 0.44, where the percentage of increasing was 6.59%.

7- The maximum deflection for flexural behaviour obtained at 20% of RHA for both w/binder (0.53, 0.44), where the percentages of increasing were (3.53, 7.33) respectively, while for shear behaviour, the high percentage of increasing was 39.11% at w/binder ratio 0.44 at 15% of RHA added.

8- The high ductility for flexural behaviour obtained at addition 15% of RHA at w/binder ratio 0.53, where the percentage of increasing was 11.83%, while at w/binder ratio 0.44, the high ductility obtained at addition 5% of RHA, where the percentage of increasing was 16.74%, therefore increasing the amount of water had effective positive on ductility. For shear behaviour, the ductility at addition 15% of RHA decreased by (20, 9.95)% at w/binder ratios (0.53, 0.44) respectively.

5.3: Recommendation

1- Study addition silica fume with rice husk ash for replacement with cement in construction.

2- Study the effect RHA on the mechanical behaviour of self compacting concrete (SCC).

REFERENCES

References

[1] Leong, T. L., ”**Effects of rice husk ash (RHA) produced from different temperature on the performance of concrete**” Faculty of engineering and green technology university tunku abdul rahman, M.Sc thesis, 2015, Malaysia.

[2] Okoya, B. O., ”**Investigation into the cementitious properties of a mixture of rice husks ash with building lime**” M.Sc. (Civil Engineering) University of Nairobi, 2013.

[3] Patnaikuni, C. K. and Nutulapati, V. S. V., ”**X-Ray Diffraction Studies of Rice Husk Ash—An Ecofriendly Concrete at Different Temperatures**” American Journal of analytical chemistry, pp.368-372, 2013.

[4] Oyetola, E. B., and Abdullahi, M., ” **The use of rice husk ash in low -cost sandcrete block production**” Leonardo electronic journal of Practices and technologies, issue 8, pp. 58-70, 2006.

[5] Ramesh, T. S. B. and Neeraja, D., ”**Rice husk ash as supplementary material in concrete- a review**” International journal of chemTech research, vol.9, pp 332-337, 2016.

[6] Piya, G., Penjit, S., Premrudee, K., and Supamas, D., ”**The effects of particle size and content of rice husk ash from textile wastewater treatment on the properties of portland cement-base solidification**”

International conference on biological, environment and food engineering, pp.28-31, 2015.

[7] Wang, W. H., Meng, Y. F., and Wang, D. Z., "**Effect of rice husk ash on high-temperature mechanical properties and microstructure of concrete**" International license pp157−164, 2017.

[8] Ghassan, A. H., and Hilmi, B. M., "**Study on properties of rice husk ash and its use as cement replacement material**" Journal materials research, pp. 185-190, 2010.

[9] Kartini. K., "**Rice husk ash–pozzolanic material for sustainability**" International journal of applied science and technology, vol. 1, pp.169-178, 2011.

[10] Central statistical organization, ministry of Planning, Baghdad, Iraq, in Arabic.

[11] Saraswathy, V. and Ha-Won, S., "**Corrosion performance of rice husk ash blended concrete**" Journal of construction and building materials, elsevier, pp. 1779-1783, 2007.

[12] Kartini, K., Mahmud, H. B., and Hamidah, M. S., "**Strength properties of grade 30 rice husk ash concrete**" Journal Our World In Concrete & Structures, 2006.

[13] Oyekan, G. L. and Kamiyo, O. M., "**Effect of Nigerian rice husk ash on some engineering properties of concrete and sandcrete blocks**" Journal Our World In Concrete & Structures, 2007.

[14] Marshal, G., and Calica, J., "**Influence of rice husk ash as supplementary material in cement paste and concrete**" (NLR) Journal, vol.2, pp. 80-92 , 2008.

[15] Chandan, P. K., and Malleswara, P. R., ”**Benefits of use of rice husk ash in concrete**” International EM Jr. of industrial pollution control, pp. 239-241, 2010.

[16] Tanvir, H., Shuronjit, K. S., and Basak B. C. ”**Utilization potential of rice husk ash as a construction material in rural areas**” Journal of civil engineering (IEB), p. 175-188, 2011.

[17] Deotale, R. S., Sathawane, S. H., and Narde, A. R., ”**Effect of partial replacement of cement by fly ash, rice husk ash with using steel fiber in concrete**” International journal of scientific & engineering research, vol.3, issue 6, 2012.

[18] Sathish, R. K., ”**Experimental study on the properties of concrete made with alternate construction materials**” International journal of modern engineering research (IJMER), vol. 2, issue. 5, pp-3006-3012, 2012.

[19] Nagrale, S. D., Hemant, H., and Pankaj, R. M., ”**Utilization of rice husk ash**” International journal of engineering research and applications (IJERA), vol. 2, issue 4, pp.001-005, 2012.

[20] Ettu, L. O., Ajokou, C. A., Nwachukwu, K. C., Awodiji, C. T. G., and Eziefula, U. G ”**Strength variation of OPC- rice husk ash composites with percentage rice husk ash**” International Journal of Applied Sciences and Engineering Research , vol. 2, issue 4,pp.420-424, 2013.

[21] Patnaikuni, C. K., Nutulapati, V. S. V., and Palli, M. R., ”**Studies on the determination of compressive strengths of different grades of rice husk ash—an ecofriendly concrete**” Journal of environmental protection, pp. 329-332, 2013.

[22] Pande1, A. M., and Makarande, S. G., ”**Effect of rice husk ash on concrete**” International journal of engineering research and applications (IJERA), vol. 3, issue 1, pp.1718-1723, 2013.

[23] Godwin, A. A., Maurice, E. E., Akobo, I. Z. S., and Joseph, O. U., ”**Structural properties of rice husk ash concrete**” International journal of engineering and applied sciences, vol. 3, pp. 57-62, 2013.

[24] Jayanti, R., Yadav, R. K., and Chandak, R. ”**The effect of rice husk ash used as supplementary cementing material on strength of mortar**” International journal of engineering research and applications (IJERA) vol. 3, issue 3, pp.133-136, 2013.

[25] Deepa, G. N., Sivaraman, K., and Job, T., ”**Mechanical properties of rice husk ash (RHA) - high strength concrete**” vol 3, pp14-19, 2013.

[26] Jinan, J., ”**Use of rice husk ash in cement mortar**” Journal of Babylon university ,vol 2, issue 21,2013.

[27] Piyush, R., and Vandana, T., ”**Study of concrete properties using rice husk ash and marble powder**” International journal of emerging technology and advanced engineering , vol 4, issue 8, pp. 680-688, 2014.

[28] Smita, S., and Dilip, K., ”**Alternate and low cost construction material: rice husk ash (RHA)**” International journal of innovative research in advanced engineering (IJIRAE), vol.1, issue 6, pp.214-217, 2014.

[29] Obilade, I. O. ”**Use of rice husk ash as partial replacement for cement in concrete**” International journal of engineering and applied sciences, vol. 5,pp.11-16, 2014.

[30] Gyanen, T., Ravi, P., Savitha, A. L., ”**Experimental study on the properties of cement concrete using rice husk ash**” International journal of engineering science and innovative technology (IJESIT),vol. 3, issue 6, pp.101-107, 2014

[31] Archana, K. and Archana, T., ”**Experimental investigation on flexural behavior of concrete beam by using agricultural and industrial waste materials**” International journal of science and research (IJSR), vol. 4, issue 7, pp.1242-1244, 2015.

[32] Naveen, S. B., and Yogender, A., ”**Effect of rice husk on compressive strength of concrete**” International journal on emerging technologies , pp. 144-150, 2015.

[33] Rama, K. B., Ratnam, M. K. M. V. and Ranga, R. U., ”**Experimental studies on concrete with rice husk ash as a Partial replacement of cement using magnesium sulphate solution**” International journal for innovative research in science & technology (IJIRST), vol 1, issue 7, pp. 333-340, 2015.

[34] Nishant, k., and Vinod, M., ”**Influence of rice husk ash on the properties of concrete**” journal of computer science and engineering(IJRDO), vol 1, issue 5, pp. 075-079, 2015.

[35] Taku, J. K., Amartey, Y. D., and Kassar, T., ”**Comparative elemental analysis of rice husk ash calcined at different temperatures using X-Ray flourescence (XRF) technique**” American journal of civil engineering and architecture, vol. 4, pp. 28-31, 2016.

[36] Arvind, K., Amit, K. T., Shravan, K. G. and Ankit, K., ”**Replacement of cement in concrete with rice husk ash**” International journal of civil engineering (IJCE) , vol 3, issue 7, pp. 127-129, 2016.

[37] Sangeetha, S. P., ”**Rice husk ash sandcrete block as low cost building material**” International journal of engineering research and application, vol. 6, issue 6, pp.46-49, 2016.

[38] Kumar, C. E., and Raju, V., ”**A study on replacement of cement with rice husk ash**” International journal of civil engineering and technology (IJCIET), vol.8, issue1, pp. 723-727, 2017.

[39] Sathya, N. D., Pavani, A. and Venkata, H. R. N., ”**Mechanical properties of self compacting concrete with partial replacement of rice husk ash**” International journal of trend in scientific research and development, vol. 1(4),pp.504-512, 2017.

[40] Akhil, V., Nair and Eapen, P. S., ”**Experimental study on shear behaviour of RCC beam by partial replacement of cement by rice husk ash and marble powder**” International research journal of engineering and technology (IRJET), vol 04, issue 05, 2017.

[41] Iraqi Standard 5/1984 ”**Portland cement central organization for standardization and quality control Iraq**” (in Arabic).

[42] Iraqi standard 45/1984 ”**Aggregates from natural sources for concrete and building construction. central organization for standardization and quality control ”.** Iraq (in Arabic).

[43] ASTM C143, ”**Standard test method for slump of hydraulic cement concrete”**, 2000.

[44] B.S 1881:part116:1983, ”**Method for determination of compressive strength of concrete cubes**”, January 1983, pp.1-8.

[45] ASTM C496/C496M-04, ”**Standars test method for splitting tensile strength**” Cylindrical concrete specimens, vol.4.2,2004,pp.1-5.

[46] ASTM C78, "**Standard test method for flexural strength of concrete**" American society for testing and materials, (2002).

[47] ACI Committee 318M-95 (2008), "**Building code requirements for reinforced concrete**", American Concrete Institute, Detroit.

[48] Dabai, M. U., Muhammad, C., Bagudo, B. U., and Musa, A., "**Studies on the effect rice husk ash as cement admixture**" Nigerian journal of basic and applied science, vol.17,pp. 252-256, 2009.

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APPENDIX

Appendix

1- Chemical composition of RHA

SPECTRO X-LabPro — Job Number 0

Sample Name: 1
Description: Sajad-Maysan
Date of Receipt: 09/17/2019 11:36:55
Method: TurboQuant-Powders

Z	Symbol	Element	Norm. Int.	Concentration	Abs. Error
12	MgO	Magnesium	34.6128	0.887 %	0.025 %
13	Al2O3	Aluminum	0.0000	< 0.0038 %	(0.0) %
14	SiO2	Silicon	27816.6208	86.76 %	0.06 %
15	P2O5	Phosphorus	580.9145	1.184 %	0.003 %
16	SO3	Sulfur	1058.6066	1.107 %	0.002 %
17	Cl	Chlorine	7598.5104	1.459 %	0.001 %
19	K2O	Potassium	971.7940	6.119 %	0.013 %
20	CaO	Calcium	456.7660	2.468 %	0.008 %
22	TiO2	Titanium	2.5976	0.0101 %	0.0013 %
23	V2O5	Vanadium	0.0000	< 0.0036 %	(0.0036) %
24	Cr2O3	Chromium	2.9478	< 0.00015 %	(0.0) %
25	MnO	Manganese	126.7213	0.07988 %	0.00058 %
26	Fe2O3	Iron	262.8631	0.09835 %	0.00050 %
27	CoO	Cobalt	0.4211	< 0.00039 %	(0.0) %
28	NiO	Nickel	14.9045	0.00221 %	0.00006 %
29	CuO	Copper	21.1691	0.00260 %	0.00008 %
30	ZnO	Zinc	110.1229	0.00997 %	0.00008 %
31	Ga	Gallium	2.7680	0.00016 %	0.00004 %
32	Ge	Germanium	0.0000	< 0.00005 %	(0.0) %
33	As2O3	Arsenic	0.1656	< 0.00001 %	(0.00001) %
34	Se	Selenium	0.0000	< 0.00005 %	(0.0) %
35	Br	Bromine	141.6352	0.00380 %	0.00003 %
37	Rb2O	Rubidium	57.7348	0.00099 %	0.00002 %
38	SrO	Strontium	781.7617	0.01311 %	0.00004 %
39	Y	Yttrium	17.2845	0.00024 %	0.00002 %
40	ZrO2	Zirconium	0.0000	< 0.00014 %	(0.0) %
41	Nb2O5	Niobium	0.1705	< 0.00004 %	(0.00004) %
42	Mo	Molybdenum	5.3149	0.00088 %	0.00005 %
47	Ag	Silver	5.1541	0.00138 %	0.00013 %
48	Cd	Cadmium	3.6829	0.00043 %	0.00006 %
50	SnO2	Tin	6.0066	0.00076 %	0.00007 %
51	Sb2O5	Antimony	6.1430	0.00135 %	0.00012 %
52	Te	Tellurium	5.3295	0.00009 %	0.00001 %
53	I	Iodine	4.7205	0.00086 %	0.00016 %
55	Cs	Cesium	0.0000	< 0.00040 %	(0.0) %
56	Ba	Barium	6.9176	0.00324 %	0.00045 %
57	La	Lanthanum	0.0000	< 0.00020 %	(0.0) %
58	Ce	Cerium	0.0000	< 0.00020 %	(0.0) %
72	Hf	Hafnium	1.5425	< 0.00010 %	(0.0) %
73	Ta2O5	Tantalum	30.5566	0.00782 %	0.00017 %
74	WO3	Tungsten	1.8453	0.00009 %	0.00002 %
80	Hg	Mercury	1.8784	0.00009 %	0.00002 %
81	Tl	Thallium	1.7933	0.00008 %	0.00002 %
82	PbO	Lead	6.9980	0.00044 %	0.00003 %
83	Bi	Bismuth	0.0000	< 0.00010 %	(0.0) %
90	Th	Thorium	4.9256	0.00020 %	0.00002 %
92	U	Uranium	8.8102	0.00004 %	0.00001 %
		Sum of concentration		100.23 %	

2- Design of mixture

a- The slump chosen according to mixes, therefore the slump for the case of the beams was between (75 to100) mm.

b- The maximum size was 20 mm of the aggregate.

c- Water content was 205 kg/m^3 for the maximum size of aggregate was 20 mm and slump was between (75 to100) mm according to ACI 211.1-91.

d- In this study the water to cement ratio was 0.44 and 0.53

e- Cement content was 465.9kg/m^3 for W/C was 0.44 as shown in relationship:

The weight of cement = $\frac{\textbf{weight of water}}{\mathbf{W/C}}$ ……………..Eq. (3-1)

$$\frac{205}{0.44} = 465.9 \text{ kg}/m^3$$

1- The coarse aggregate evaluated by depended on maximum size of aggregate = 20 mm and the bulk volume was 0.64. The coarse aggregate is equal by multiplied bulk density with bulk volume

Coarse aggregate content = 0.64 * 1600 = 1024 kg/m^3

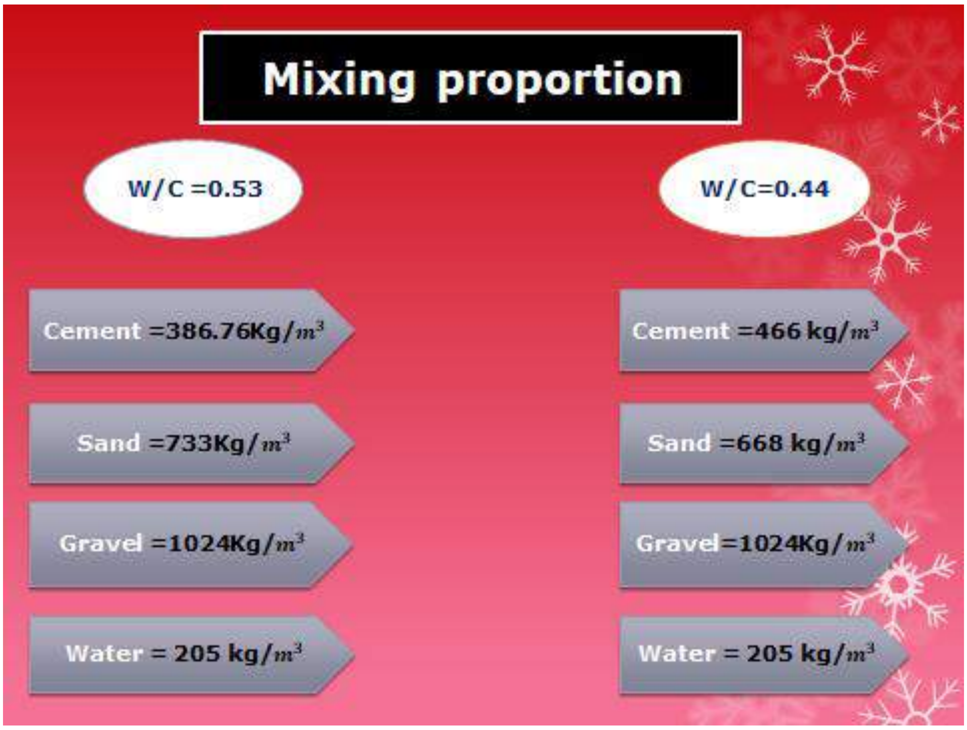
2- The fine aggregate evaluated by utilised the so-called absolute volume method as following :

$$\frac{\boldsymbol{W}}{\mathbf{1000}} + \frac{\boldsymbol{C}}{\mathbf{1000}\, \boldsymbol{Pc}} + \frac{\boldsymbol{F.A}}{\mathbf{1000}\, \boldsymbol{Pf.A}} + \frac{\boldsymbol{C.A}}{\mathbf{1000}\, \boldsymbol{P\, c.A}} = \mathbf{1} \quad \text{………. …Eq. (3-2)}$$

$$\frac{\mathbf{205}}{\mathbf{1000}} + \frac{\mathbf{465.9}}{\mathbf{1000*3.15}} + \frac{\boldsymbol{F.A}}{\mathbf{1000*2.58}} + \frac{\mathbf{1024}}{\mathbf{1000*2.64}} = \mathbf{1}$$

Therefore, the fine aggregate = 668 kg/m^3.

The first mixture (A0%) with ratio (1:1.89:2.64) with w/c 0.53 and the second mixture (B0%) with ratio (1:1:43:2.19) and w/c 0.44.



3- Flexural reinforcement

All beams were designed according to ACI318-95 Code. The steps of analysis of the reference beam as follows **:**

From the design of the beam in Fig. (3-19)

$\because \rho = \frac{As}{bd}$

d =h-cover-ds-$\frac{db}{2}$

Let concrete cover = 20 mm.

So, d =145 mm.

As= 3* $\frac{\pi}{4} * d^2$

As=235.5 mm^2

$\rho = \frac{As}{bd}$, $\rho = \frac{235.5}{140*145}$ =0.0116

∵ ρ max = 0.75 ρb = 0.75 * [0.85 β1*$\frac{f`c}{fy}$ *$\frac{600}{600+fy}$]

β1 = 0.85 – 0.005 $\frac{f`c-28}{7}$ > 0.65 for f`c > 28 MPa

∵ concrete strength f`c equal to 39.9 MPa and yield strength of reinforcement equals 498 MPa

∴ β1 = 0.8417

∴ ρ max =0.0233

∴ $\rho < \rho$ max

P = 0.0116

ρb = 0.85 β1* $\frac{f`c}{fy}$ *$\frac{600}{600+fy}$, ρb = 0.031

So, $\rho < \rho$b

fs = fy

From Whitney Block

C = T

∴ 0.8 * f`c *b *a = As * fy

∵ Mn = C (d- $\frac{a}{2}$) = 0.80 * f`c * b * a *(d- $\frac{a}{2}$) = 15.3 kN.m

Mn = $\frac{p}{2}$ * 407

❖ $P_{flexural}$ **= 75.18 kN**

4- Shear reinforcement

All beams were designed according to ACI318-95 Code.

From the design of the beam in Fig. (3-19)

$$Vu = Ø\ Vn = Ø\ (Vc + Vs)$$

$$Ø\ Vc = Ø * (\frac{1}{6}) * \sqrt{f`c} * bw * d * 10^{-3}$$

$$Ø\ Vc = 0.75 ** (\frac{1}{6}) * \sqrt{39.6} * 140 * 145 * 10^{-3} = 15.9$$

$$Ø\ Vs = \frac{Ø\ Av\ fy\ d}{S}$$

let S = 80 mm

$$Av = 2 * \frac{\pi}{4} * d^2 = 157\ mm^2$$

❖ **Ø Vs = 106.28 kN**

Vu = 106.28 + 15.9 = 122.18 , P_{shear} **= 122.18 kN**

❖ $P_{shear} > P_{flexural}$

From the design of the beam in Fig. (3-20)

let S = 575 mm

Ø Vs = 14.7 kN

Vu = 14.7 + 15.9 = 30.6 kN

- P_{shear} **= 30.6 kN**

- $P_{flexura} > P_{shear}$

الملخص

يعتبر قشر الرز كمادة نفايات لذلك وجدوا طرق لتحويلها الى مادة ذات فائدة عن طريق حرق قشور الرز وتحويلها لأنتاج رماد قشر الرز عند درجة حرارة تتراوح من (٥٠٠-٦٠٠) م°. لذلك انتاج الرماد يتطلب صناعة فرن للسيطرة على درجة الحرارة. يحتوي الفرن على جزأين، تحتوي الأجزاء العلوية على غرفة حرق لحرق القشر لإنتاج الرماد والجزء السفلي يحتوي على مكان تخزين لتخزين الرماد الناتج للحفاظ عليه حتى استخدامه. يتكون الفرن من طبقات من مواد مختلفة، حيث الطبقة الخارجية من الصلب بسمك ١.٥ ملم، يتبع العزل الحراري (الصوف الزجاجي) ، ثم طبقة من الحديد المجلفن بسمك ٢ ملم، يتبع طبقة من الطوب الحراري مع سمك ٤٠ ملم للحفاظ على الحرارة داخل الفرن.

تم تحليل الرماد كيميائيا من خلال جهاز X-Ray fluorescence device (XRF) ووجد بأن رماد قشر الرز يحتوي على نسبة عالية من السليكا SiO_2 تصل الى ٨٦,٧٦% لذلك يصنف الرماد كمادة بوزولانية حيث الحد الادنى للمادة الوزولانية يكون ٧٠%. رماد قشر الرز استخدم كبديل جزئي للأسمنت بالوزن حيث استبدل بنسب مختلفة وكانت النسب (٥,١٠,١٥,٢٠)% عند خلطتين (١:١,٨٩:٢,٦٤) ذات نسبة الماء الى مزيج السمنت والرماد ٠,٥٣ و(١:١,٤٣:٢,١٩) ذات نسبة الماء الى مزيج السمنت والرماد ٠,٤٤ .اجريت الخصائص الميكانيكية وهي مقاومة الضغط والشد والانثناء حيث تم صب ٦٠ مكعب و٣٠ اسطوانة و٣٠ موشور. اظهرت النتائج بأن النسبة المثالية من الرماد هي ١٠% التي تعطي اعلى مقاومة انضغاط عند كلا من نسبة الخلط ذات نسبة الماء الى مزيج السمنت والرماد ٠,٥٣ و٠,٤٤. ازدادت مقاومة الشد عند اضافة (٥، ١٠، ١٥)% من الرماد عند نسبة الماء الى مزيج السمنت والرماد ٠,٥٣ بينما عند نسبة خلط الماء الى السمنت ٠,٤٤ فأن مقاومة الشد ازدادت عند اضافة (٥، ١٠)% من الرماد. كل النسب المضافة من الرماد اعطت مقاومة انثناء اعلى من مقاومة الانثناء المرجعية ولوحظ بأن اضافة ١٥% من الرماد اعطت اعلى مقاومة انثناء لكل نسبتي الخلط.

تم صب ١٤ نموذج من العتبات الخرسانية ذات ابعاد (١٢٠٠*١٨٠*١٤٠) ملم حيث كانت ١٠ عتبات خرسانية صممت ليكون الفشل بالانثناء و٤ عتبات خرسانية صممت ليكون

الفشل بالقص. شملت الخصائص التي تم اختبارها من العتبات الخرسانية المسلحة أنماط الحمل والانحراف والمطيلية وأنماط الشقوق وتوزيع الانفعالات. لوحظ ان نتائج التحمل القصوى بالنسبة لتصميم الانثناء ازدادت بمقدار وكانت نسبة الزيادة (٣,١٥%و ٤,٠٤%و ٠,٦٩%) عند اضافة (٥' ١٠ة ١٥)% من الرماد على التوالي عند نسبة الماء الى مزيج السمنت والرماد ٠,٥٣ بينما عند نسبة الماء الى مزيج السمنت والرماد ٠,٤٤ فأن نسبة الزيادة (٣,٣٣%، ٠,١٨%) عند اضافة (١٠، ١٥) % من الرماد. بينما للعتبات الخرسانية المصممة للقص فان نسبة الاضافة من الرماد كانت ١٥% فقط لكل الخلطتين والنتائج اظهرت زيادة في قابلية التحمل القصوى وكانت نسبة الزيادة(٣,٩٤% و ٦,٩٥%) عند نسبة الماء الى مزيج السمنت والرماد (٠,٥٣ و٠,٤٤) على التوالي. ازدادت قابلية الانحراف القصوى بالنسبة لتصميم الانثناء عند اضافة ٢٠% من الرماد بنسبة (٣,٥٣ و٧,٣٣)% عند نسبة الخاط ذات نسبة الماء الى مزيج السمنت والرماد (٠,٥٣ و٠,٤٤) على التوالي. بالنسبة لتصميم الشير فقد لوحظ بأن قابلية الانحراف القصوى عند نسبة الخلط ذات نسبة الماء الى مزيج السمنت والرماد (٠,٥٣ و٠,٤٤) ازدادت بنسبة (١١,٤٧ و٣٩,٢١) على التوالي. المطيلية القصوى ازدادت ازدادت بمقدار١١,٨٣% عند اضافة ١٥% من الرماد عند نسبة الخلط ذات نسبة الماء الى مزيج السمنت والرماد ٠,٥٣ بينما عند نسبة الماء الى مزيج السمنت والرماد٠,٤٤فأن المطيلية ازدادت بمقدار١٦,٧٤% عند اضافة ٥% من الرماد بينما بالنسبة لتصميم الشير فأن قابلية المطيلية القصوى تناقصت عند اضافة ١٥% عند كلا من نسبتي الخلط. تزداد الانفعالات عند اغلب العتبات الحاوية على رماد قشر الرز مقارنة مع العتبة المرجعية.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة ميسان
كلية الهندسة
قسم الهندسة المدنية

دراسة تجريبية على تأثير رماد قشر الأرز كمواد تكميلية على أداء الخرسانة

رسالة مقدمة الى قسم الهندسة المدنية في كلية الهندسة في جامعة ميسان كجزء من متطلبات نيل شهادة ماجستير علوم في الهندسة المدنية

(إنشاءات)

من قبل

سجاد جواد كاظم

(بكالوريوس- قسم الهندسة المدنية-٢٠١٦)

بأشراف

أ.م.د. محمد صالح عبد علي

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