# Investigation of the optimum percentage of RHA to obtain maximum compressive strength of concrete

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## Abstract

Rice Husk Ash (RHA) is a byproduct of paddy rice. At the moment it is not taken a considerable use from that by product. So RHA adds as another waste to the environment. But now there is a trend to find the pozzolanic properties of RHA to enhance the properties of concrete. As a result, there are many researches were done to test the properties of RHA mixed concrete. And found that compressive strength of the RHA mixed concrete is increased in at any proportion of RHA mixing. But until today any one has not recommended that what is the optimum percentage of mixing RHA to concrete for gain maximum compressive strength with better durability performance. This research it is expected to find the optimum percentage for the mixing RHA to the OPC concrete as replacement basis to gain higher compressive strength and simultaneously it is expected to find corrosion performance and shrinkage performance of RHA mixed concrete. According to previous studies it has been found that with about 20% RHA replacement level is giving higher compressive strength. So here we expected to find the increment of compressive strength of 20%, 25% and 30% RHA replacement levels. At the moment we found 25% percentage of RHA replacement is also giving higher compressive strength. Also we expect compare the increment of 20% and 30% percentage replacement levels with above results. Also we are checking the shrinkage performance of RHA mixed concrete and normal OPC concrete in both indoor and outdoor condition. At the moment shrinkage performance of both RHA mixed and control sample has not significant difference and we expect to check for 90 days. Further we are checking the corrosion performance of RHA mixed concrete by using 'Accelerated corrosion Test ' but after 45 days there is no any crack appeared either control sample or RHA mixed sample. So it expected that corrosion performance of RHA mixed concrete is also very close to the normal OPC concrete. Also we expected to do the 'Rapid Chloride Penetration Test' to find the corrosion performance of RHA mixed concrete. Finally we hope to recommend optimum RHA mixed proportion to gain higher compressive strength with sufficient reliability.


**Keywords:** Rice husk ash, compressive strength, brick kiln, corrosion

## 1. INTRODUCTION

The rice husk is a byproduct of de-husking operation of paddy rice. Annually about 115 million tons of rice husk is produced all over the world. The total amount of rice produced in Sri Lanka over 2002 is 2.79 million metric tons and the total amount of rice needed in Sri Lanka over the year 2005, 2010 and 2020 are estimated at 3.23, 3.46, and 3.83 million metric tons respectively and approximately 20 kg of rice husk are obtained for 100 kg of rice [1].

But most countries don't have a proper method to utilize rice husk. Sri Lanka also doesn't have a proper method to utilize this waste. But in some areas in Sri Lanka rice husk is used as a fuel for some other products. When the rice husk is burned Rice-Husk-Ash (RHA) remains as another byproduct. However there is no any proper way to utilize RHA in a productive and efficient manner.

Rice Husk Ash (RHA) has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone (ITS) between the cement paste and the aggregates in high performance concrete [3]. It is also reported that the microstructure of the cement paste can be significantly improved by adding pozzalanic materials such as, fly ash, silica fume, metakaolin and rice husk ash.

The utilization of RHA as a pozzalanic material in cement and concrete provides several advantages such as; improved strength and durability properties, reduce material cost due to cement saving and environmental benefits related to the disposal of waste materials and to reduced Carbon Dioxide emissions. It is found that the compressive strength increases with blending percentage and with age and higher concentration of RHA can be used without strength loss.[2] Also durability of OPC concrete also increases due to adding RHA to the concrete. RHA is essential in production of high strength concrete due to its incorporation is beneficial in improving the durability of concrete.[3]

In the present study RHA was blended with Ordinary Portland Cement (OPC) at various percentages by replacing amount of cement and investigate the compressive strength of concrete containing RHA. In addition realistic assessments of the corrosion resistant properties and shrinkage performance have been made and the results were compared with OPC concrete.

# 2. Methodology

## 2.1 Production of Rice Husk Ash

### 2.1.1 Open burning

Open burning is the simplest method to produce RHA. The advantage of this method is it can be used to produce huge amount of RHA during one burning cycle. But it is needed at about 24 hours for complete one burning cycle. So it is needed huge amount of energy and the usable RHA percentage is very low. The worst case is required temperature (600 $^0$C) is also not possible with the open burning. The maximum temperature rise in the open burning process was around 350 $^0$C. Therefore the suitability and efficiency of this process is not adequate for process of producing RHA.

*Figure 1: Paddy cultivation in Sri Lanka and open burning of rice husk*

## 2.1.2 Controlled burning

This method is much better than open burning process. It has some control of burning than the previous case. In this method rice husk is burning inside a barrel. So that energy loss can be minimized and also the energy that dissipate during the burning can be used for another appropriate work. But in this method RHA produce in one burning cycle is very less, as well as time taken to complete one burning cycle is at around 24 hours. Also usable percentage of produced RHA is very low. The maximum temperature inside the barrel during the burning was around 450 $^{0}$C. So this method is much better than the open burning process, but efficiency of the process is also not adequate for processing required amount of RHA.

*(a)Filling of Rice husk* *(b) Burning of Rice husk* *(c) Just after complete burning*

*Figure 2- Controlled burning using a barrel*

## 2.1.3 Oven burning

Oven burning is the best method to produce quality RHA by maintaining the constant temperature and controlling the burning duration. But it needs to increase the temperature up to 600 $^{0}$C and maintain over a considerable time. So that it is need more extra energy. So this method is not economical to produce large amount of RHA. It may produce around 200g of RHA during 4 hours burning with its full capacity of 5kg of rice husk[1]. This method wastes considerable amount of energy and production rate of RHA is not enough to produce large amount of RHA. Therefore this method is also not productive under actual conditions with large scale production of RHA.

### 2.1.4 Byproduct from brick-kilns

All methods described above are direct methods of RHA production. But there are places in Sri Lanka utilize rice husk as a fuel in burning process of clay bricks. It may produce huge amount of RHA regularly. The temperature of the brick-kiln is varied from 550 $^{0}$C to 750 $^{0}$C. It is considerably higher than the other methods discussed above. There are no energy losses in this method and RHA is a totally waste product in this process. Therefore utilization of this waste product is more economical and environmentally friendly. In this study it was investigated that the possibility of utilize that waste product as a partial replacement for the cement in OPC concrete.

## 2.2 Investigation of particle size distribution

The RHA directly obtained from the brick kiln was subjected to the sieving according to BS 812-103. 1:1985. Table 1 shows the sieve analysis results. Figure 3 shows the particle size distribution of the RHA.

*Table 1 : Results of Sieve Analysis of RHA*

| ***Sieve Size(mm)*** | ***Percentage passing (%)*** |
|---|---|
| *2.36* | *94.64* |
| *1.7* | *91.8* |
| *1.180* | *88.65* |
| *0.850* | *84.86* |
| *0.600* | *77.92* |
| *0.425* | *71.3* |
| *0.250* | *57.1* |
| *0.075* | *7.89* |
| *Pan* | *0* |

The burning temperature was around 550 $^{0}$C to 750 $^{0}$C inside the brick kiln and it was recorded using digital thermometer. RHA collected from brick kiln also content un-burnt and range of different size of particles. Therefore large particles were separated using wire mesh attached to wooden frame. After that RHA was sieved for 10 minutes using sieve shaker in the laboratory. The particle size of 75 µm passing is shown in Figure 3.

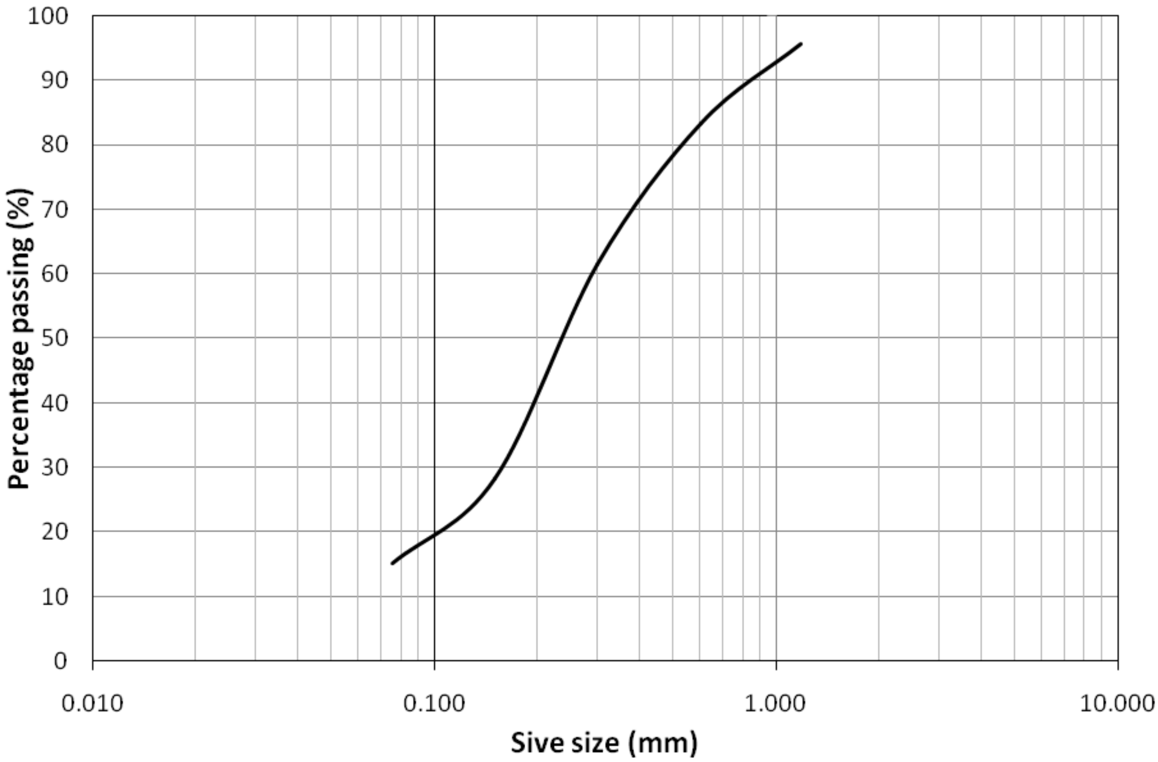


**Figure 3 – Particle Size Distribution for RHA**

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## 2.3 Fine and Coarse aggregates

The fine aggregates that used for the experiment were natural river sand passing from 4.75 mm sieve. The specific gravity of the sand was tested according to BS 812: Part 2: 1995. The specific gravity of fine aggregates was observed as 2.65.

The coarse aggregate that used for the experiment were crushed granite with maximum size of 20 mm. The specific gravity of the coarse aggregate was tested according to BS 812: Part 2: 1995. The specific gravity of coarse aggregates was observed as 2.65.

*Table 2: Water absorption of aggregates*

| ***Type of aggregate*** | ***Water absorption*** |
|---|---|
| *Fine aggregate* | *1.30%* |
| *Coarse aggregates* | *0.31%* |

## 2.4 Compressive Strength

Compressive strength test was carried out in concrete cubes of size 150×150×150 mm. Design compressive strength for all specimens were Grade 25. Specimens with Ordinary Portland Cement concrete (control) and OPC replaced by rice husk ash at 20%, 25% and 30% by weight of cement were prepared. During molding the cubes were mechanically vibrated. After 24 hours the specimens were removed from the moulds and placed for curing at 3, 7, 14, 21, 28, 56 and 91 days. After a specified period of curing, the specimens were tested for compressive strength using AIMIL compression testing machine. The tests were carried out on triplicate specimens and the average compressive strength values were recorded.

## 2.5 Split tensile test

Splitting tensile test was carried out according to the procedure given in BS 1881: Part 117: 1983. Concrete cylinders size of 150 mm diameter and 300 mm height were cast using G25 mix concrete. Specimens were prepaid with OPC (control) and OPC replaced by rice husk ash at 25% (by weight of cement). During molding, the cylinders were mechanically vibrated. After 24 hours the specimens were removed from the moulds and placed in curing tank for 28, 56 and 91 days. After a specified period of curing, the specimens were tested for tensile strength. The tests were carried out on triplicate specimens and the average compressive strength values were recorded

## 2.6 Accelerated corrosion test

For the Acceleration Corrosion Test, three prisms with the size of 100×100×400 mm were prepared according to the procedure given in ASTM B-117 standards. The reinforcement steel cages were connected to anode and cathode with wires. Figure 4 shows the schematic diagram of the ACTM setup. Concrete was prepared for the three prisms and placed in the moulds. Two types of specimens with OPC concrete (control) and OPC replaced with RHA by 25% weight of cement concrete were prepared. During molding, the prisms were mechanically vibrated. After 24 hours specimens were removed from the moulds and placed for curing for 28 days in the tank. Test was carried to investigate the corrosion performance of the sample as shown in Figure 5.

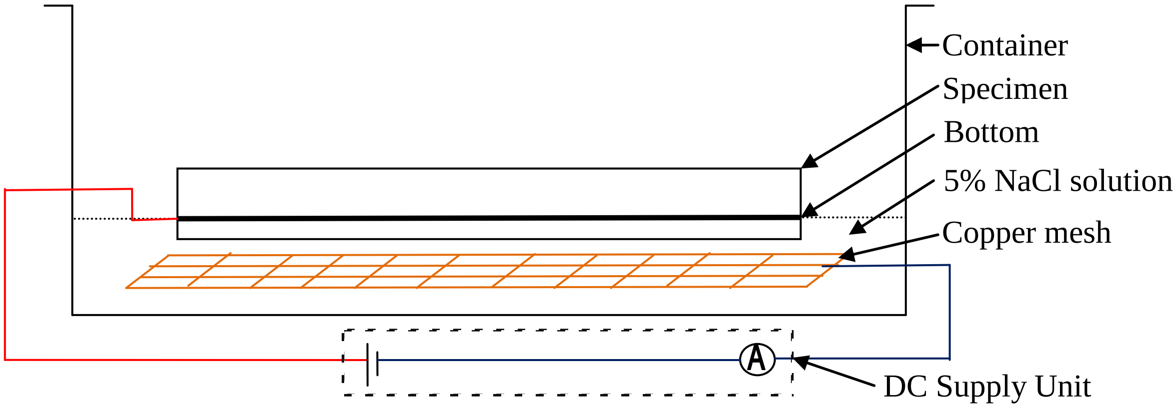
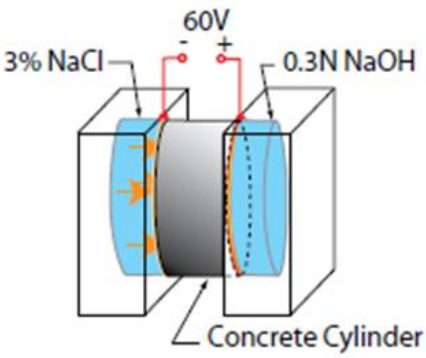


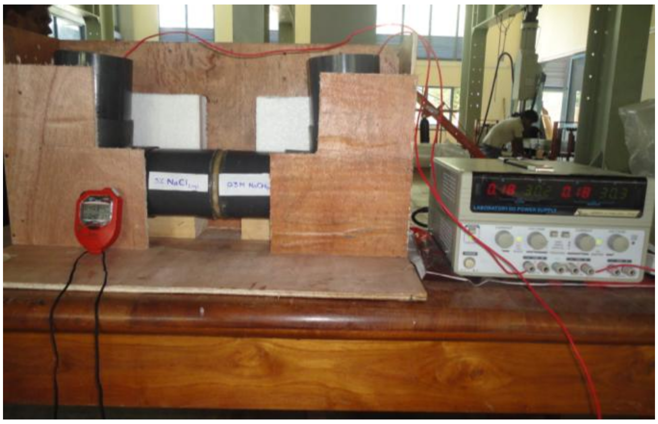

**Figure 4 – Schematic diagram of ACTM Setup**


**Figure 5 – Specimen setup for ACTM**

## 2.7 Rapid chloride ion penetration test (RCPT)

Rapid Chlrode Ion Penetration test was carried out according to the procedure given in ASTM C-1202. Concrete disc of size 100 mm diameters and 50 mm thickness with and without rice husk ash were cast and placed for curing for 28 days. After 28 days of curing the concrete specimens were placed for RCPT by impressing 60 V through the samples as shown in Figure 6(a). Two halves of the specimen is sealed with PVC containers. One side of the container is filled with 3% NaCl solution, the other side is filled with 0.3M NaOH solution. Current is measured at every 30 minutes intervals for 6 hours. From data obtained for current and time, chloride permeability is calculated in terms of Coulombs at the end of 6 hours.



*(a) Schematic view of RCPT* *(b) RCPT setup at the Laboratory*

**Figure 6: Typical setup for the RCPT**

# 3. Results and Discussion

## 3.1 Compressive strength results

Table 3 shows the compressive strength of concrete containing different percentage of RHA mixed samples. Table 3 summarizes strength increment compared to control samples. It was revealed that after 91 days 25% replaced RHA sample shows heights strength increment compared to other mixers.

*Table 3: Results of the Compressive strength of concrete*

| *Number of days cured* | *Specimens (% RHA replaced by weight of cement)* | | | |
|---|---|---|---|---|
| | *(0%) Control* | *20% RHA* | *25% RHA* | *30% RHA* |
| *3* | *13.43* | *12.17* | *12* | *10.83* |
| *7* | *22.61* | *21.12* | *21.47* | *20.13* |
| *14* | *28.05* | *25.39* | *30.61* | *23.07* |
| *21* | *30.35* | *28.76* | *32.25* | *25.22* |
| *28* | *30.79* | *30.94* | *32.86* | *27.89* |

| | | | | |
|---|---|---|---|---|
| *56* | *31.83* | *32.82* | *36.23* | *32.83* |
| *91* | *32.69* | *33.6* | *37.3* | *33.01* |

*Table 4: Compressive strength increments compared to control sample*

| *Number of days cured* | *Specimens (% RHA replaced by weight of cement)* | | | |
|---|---|---|---|---|
| | *(0%) Control* | *20% RHA* | *25% RHA* | *30% RHA* |
| *3* | *0* | *-9.38* | *-10.64* | *-19.35* |
| *7* | *0* | *-6.59* | *-5.04* | *- 10.96* |
| *14* | *0* | *-9.48* | *9.13* | *-17.75* |
| *21* | *0* | *- 5.24* | *6.26* | *-16.9* |
| *28* | *0* | *0.49* | *6.72* | *-9.42* |
| *56* | *0* | *3.11* | *13.82* | *3.14* |
| *91* | *0* | *2.78* | *14.10* | *0.98* |

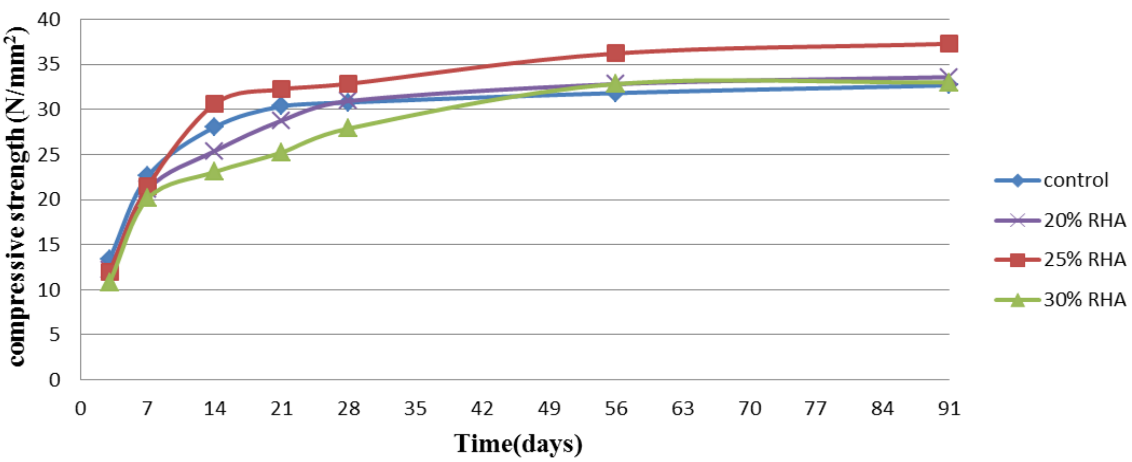


**Figure 7 : Compressive strength of concrete variation with days**

Figure 7 shows compressive strength of concrete variation with days. Experimental investigation revealed that the Compressive strength of concrete containing 20%, 25% and 30% RHA mixes are lower than control sample until those reached to seven days. However with the time increases compressive strength concrete containing higher amount of RHA was decreased. After 14 day, around 9% of strength increment was observed in 25 % RHA mix compared to control sample but 20% and 30% RHA mixes strength decreased by 10% and 15%, respectively. It was observed that the compressive strength concrete of 20% and 25% RHA mixes are higher than control sample at 28 day, however 30% RHA mix is lower than the control sample. After 56 and 91 days compressive strength of concrete containing 20%, 25% and 30% RHA mixes are higher than control sample. After 91 days specimen with 25% RHA mix shows around 15% strength increment compared to the control sample. It was identified that amount of RHA increases, the compressive strength of concrete at 91 days would be decreased. Therefore optimum percentage of RHA can be replaced by 20% to 30% weight of cement to achieve highest compressive strength at 91 days.

## 3.2 Rapid chloride penetration test

*Table 5: Current passing through RHA samples*

| *Time(min)* | *Current(mA)-25% RHA specimens* | | | |
|---|---|---|---|---|
| | *Sample Number* | | | *Average value* |
| | ***1*** | ***2*** | ***3*** | |
| *0* | *72.9* | *52.8* | *64.3* | *63.3* |
| *30* | *74.4* | *57.7* | *67.6* | *66.6* |
| *60* | *73.5* | *58.6* | *67.9* | *66.7* |
| *90* | *73.8* | *60.8* | *65.4* | *66.7* |
| *120* | *74.8* | *63.5* | *71.7* | *70.0* |
| *150* | *82.6* | *63.1* | *74.3* | *73.3* |
| *180* | *82.8* | *63.6* | *73.6* | *73.3* |
| *210* | *83.3* | *64.9* | *81.8* | *76.7* |
| *240* | *84.2* | *66.1* | *79.7* | *76.7* |
| *270* | *84.7* | *67.8* | *87.5* | *80.0* |
| *300* | *85.3* | *68.8* | *85.9* | *80.0* |
| *330* | *86.1* | *69.7* | *84.2* | *80.0* |
| *360* | *87.1* | *70.8* | *92.1* | *83.3* |

$Q = 900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360})$

Q- Charge passing through the sample

$I_x$ -Current passing through the sample at' x' minute

*Table 6: Charge passing through RHA samples*

| *Specimen Number* | *Charge (Q) in coulombs* |
|---|---|
| *1* | *1737.9* |
| *2* | *1379.52* |
| *3* | *1652.04* |
| ***Average Charge pass*** | ***1589.82*** |

*Table 7: Current passing through control samples*

| *Time(min)* | *Current(mA) - 0% RHA specimens* | | |
|---|---|---|---|
| | *Sample Number* | | *Average value* |
| | *1* | *2* | |
| *0* | *260* | *230* | *245* |
| *30* | *300* | *270* | *285* |
| *60* | *320* | *290* | *305* |
| *90* | *340* | *300* | *320* |
| *120* | *350* | *320* | *335* |
| *150* | *370* | *330* | *350* |
| *180* | *380* | *340* | *360* |
| *210* | *380* | *370* | *375* |
| *240* | *390* | *380* | *385* |
| *270* | *400* | *390* | *395* |
| *300* | *400* | *400* | *400* |
| *330* | *400* | *400* | *400* |
| *360* | *400* | *400* | *400* |

$$Q = 900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360})$$

*Table 8: Charge passing through control samples*

| *Specimen Number* | *Charge (Q) in coulombs* |
|---|---|
| *1* | *7848* |
| *2* | *7389* |
| *Average Charge Passing* | *7618.5* |

*Table 9: Rating of chloride permeability (Based on ASTM C1202-97[10] standard)*

| *Charge passing in coulombs* | *Chloride permeability rating* |
|---|---|
| *Greater than 4000* | *High* |
| *2001 to 4000* | *Moderate* |
| *1001 to 2000* | *low* |
| *100 to 1000* | *Very low* |
| *Less than 100* | *Negligible* |

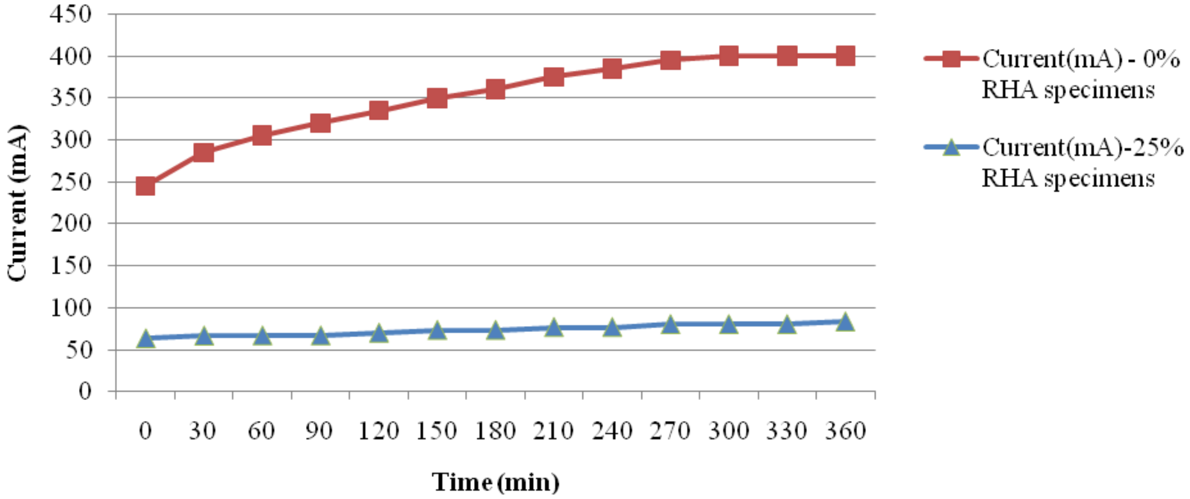



**Figure 9: Current passing through the samples with time**

Tables 5 to 7 shows the current values and charge passing through control and RHA mix concrete samples. Equation 1 was used to calculate diffusion coefficient which is indication of permeability of concrete mixer.

Chloride Diffusivity coefficient can be expressed as;

$$D = \frac{\beta kTLV\frac{dc}{dt}}{ZcECA} \quad (cm^2/s) \qquad \text{Eq (1)}$$

| | |
|---|---|
| D | : Diffusion coefficient, ($cm^2$/s) |
| β | : Corrosion factor for ionic interaction; varies from 1.22 to 1.7 based on the chloride concentration from 0.1M to 0.5M NaCl |
| k | : Boltzman constant, (1.38x10-16 ergs/k/ion) |
| T | : Temperature (K) |
| Z | : Chloride ion valance; Z is 1 for NaCl |
| e | : Charge of Proton; (4.8x10-10 e.s.u) |
| E | : Applied electrical potential (V) |
| L | : Specimen thickness (cm) |
| V | : Volume of chloride collecting tank ($cm^3$) |

C : Initial chloride concentration in chloride source solution, ($mol/cm^3$)

dc/dt : Steady state migration rate of chloride ion, ($mol/cm^3.s$)

*Table 10: Diffusion coefficient of samples*

| ***Sample*** | ***Diffusion coefficient($m^2/s$) x$10^{-9}$*** |
|---|---|
| *25% RHA sample* | *2.5* |
| *control sample* | *3.0* |

Table 10 shows the calculated chloride ion diffusivity values. It was revealed that concrete containing 25% of RHA by weight of cement shows smaller diffusivity value compared to control specimen. This is due to less permeability of the specimen which containing RHA.

### 3.3 Accelerated corrosion Test

The ACTM was carried out until cracks appeared in the samples. However, there was not any crack appeared on samples with in tested period. All samples were broken and weight measurements of the reinforcement bars were recorded. The weight loss of those bars was calculated and summarized in the Table 11. It was recorded that the average percentage of weight loss is smaller in RHA mixed concrete samples compared to that of it in control samples. It was revealed that RHA mix concrete corrosion resistance is much higher compared to that of it in control samples. Therefore concrete containing RHA shows better durability performance compared to OPC concrete samples.

*Table 11 : Results of Accelerated corrosion Test*

| ***Sample*** | ***Length (mm)*** | ***Weight of the steel bar (g)*** | | ***Percentage Loss (%)*** | ***Average Percentage Loss (%)*** |
|---|---|---|---|---|---|
| | | ***Before corrosion*** | ***After corrosion*** | | |
| *RHA Bar 1* | *380* | *337.74* | *312.22* | *7.58* | *6.425* |
| *RHA Bar 2* | *388* | *344.85* | *326.66* | *5.27* | |
| *Control Bar 1* | *380* | *337.74* | *278.23* | *17.62* | *15.84* |
| *Control Bar 2* | *370* | *328.85* | *282.60* | *14.06* | |

## 4.0 Conclusions

It was found that 25% RHA replacement concrete gives higher compressive strength after 91 days. It was about 14% increment than the control sample. Workability of concrete was decreased due to RHA. However, by mixing mineral admixture like fly ash or chemical admixture will improve workability of RHA mixed concrete. Diffusion coefficient of RHA mixed concrete was smaller than the control sample. It indicates that the permeability of RHA mixed concrete is lower than the normal concrete. Percentage of weight loss of reinforcement bars in RHA specimens were less than the control sample. It says that corrosion resistance of RHA mixed concrete is higher than the normal concrete.

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