# Studying The Effects Of The Pozzolanic Materials And The High Range Water Reducing Admixtures On The Water Absorption Of The High Performance Concrete (HPC)

**Adnan Abod M.**
Technical Institute Al-Musseib

## Abstract

This research aims to study the water absorption of the hardened high performance concrete (HPC) containing high reactivity metakaolin (HRM) or the rice husk ash (RHA) as a partial replacement 8% by weight of cement . They were added to improve the properties of concrete as a pozzolana.The study also investigates the role of the water reducing superplasticisers in reducing the water absorption .The results of water absorption are expressed in terms of quantity of water absorbed per unit surface area as a function of the elapsed time , also the compressive strength were detected at 7, 28 and 90 days for the purpose of comparison with the changes in water absorption.

The mixes were composed of Ordinary Portland Cement, natural sand, gravel (maximum size 10mm) , the pozzolanic material was mixed as a partial replacement by weight of cement, and the high range water reducing admixture (HRWRA) which was added at the optimum dosage of each mix.

The results show that the high reactivity metakaolin or the rice husk ash effectively decrease the water absorption. Also, when the water reducing admixtures improve the properties of the mixtures, the porosity of the hardened concrete is reduced , consequently the water absorption is reduced significantly.

## الخلاصة

يهدف هذا البحث لدراسة خاصية امتصاص الماء للخرسانة عالية الاداء والتي تحتوي على الميتاكاؤلين عالي الفعالية او رماد قشور الرز كأستبدال جزئي بنسبة 8% من وزن السمنت حيث ان هذه المواد تضاف عادة لتحسين مختلف الخصائص للخرسانة كذلك يهدف هذا البحث لمعرفة دور المضافات المقللة للماء في تقليل الامتصاص للماء . . ان نتائج فحص امتصاص الماء تم التعبير عنها بدلالة كمية الماء الممتص في وحدة واحدة من سطح النموذج وكذلك تم اختبار مقاومة الأنضغاط في عمر 7و 28 و90 يوم لغرض المقارنة مع التغيرات في امتصاص الماء للخلطات. ولغرض دراسة تأثير المواد البوزلانية والمضافات المقللة للماء على خاصية امتصاص الماء تم اختبار أربعة مجموعات من النماذج تختلف في طبيعة مكوناتها .إن الخلطات الخرسانية في هذا البحث تتكون من السمنت البورتلاندي الاعتيادي والرمل والحصى ذات المقاس الاقصى (10mm) بالاضافة الى الميتاكاؤلين عالي الفعالية او رماد قشور الرز و التي يتم خلطهما كمادة بوزلانية مضافة كاستبدال جزئي من وزن السمنت بالأضافة إلى المضافات( المقللة للماء بدرجة متفوقة) بنسبة مثالية لكل خلطة . أظهرت النتائج أن المواد البوزلانية لها تأثير فعال في تقليل الامتصاص . كذلك فان المضافات المقللة للماء التي تعمل على تقليل المسامية تلعب دورا واضحا في تقليل امتصاص الخرسانة للماء .

## Introduction

The term High Performance Concrete (HPC), refers to cement mixtures with a water binder ratio as low as 0.3-0.4, so that 28-day compressive strength as high as 70-100MPa or even 1-day compressive strength as high as 45-55MPa can be obtained. Due to these mechanical properties, the structural design of the modern reinforced concrete constructions, as well as the executing techniques, can be significant changed. (***Collepardi*** , 2001)

***Aitcin*** (1997) stated that the concrete that was known as high strength concrete in the late 1970s is now referred to as high performance concrete because it has been found to be much more than simply stronger. **(*Neil et al***, 2001)discussed some significant differences between conventional and high performance concrete such as size and composition of constituents **,** water to cementitious material ratio (w/cm) ,the use of steel fibers , the amount of mixing energy employed, and the curing procedures .

The water absorption was tested by ***Roux et al*** (1996).They considered that the very low water absorption is a characteristic of a concrete without capillary porosity . Anyhow, the reduction in water absorption can be attributed to the fact that the capillary voids are either eliminated or reduced considerably in size, and dense crystals of $Ca(OH)_2$ are replaced with additional C–S–H . They also stated that an excessive absorption of water by concrete can cause a certain number of structural disorders , notably the scaling of the material through exposure to freezing /thawing and the corrosion of reinforcement from the penetration of chloride ions tidal areas .

The benefits of using the microsilica are filling the voids between the next larger class particles (cement) ,enhancement of rheological characteristics by lubrication effect resulting from the perfect sphericity of the basic particles , and production of secondary hydrates by pozzolanic reaction with the lime resulting from primary hydration. **(*Richard and Cheyrez*** , 1995).

The previous studies in water absorption of concrete were achieved by introducing different types of pozzolana and different HRWRA . This study show the effects of introducing another types of local pozzolana - such as HRM and RHA – and a new HRWRA called TufFlow . Besides , the studying of the water absorption can be regarded as a good indicator of the durability of concrete .

## 1- Materials

### 1-1 Cement :

Ordinary Portland cement (Type I) was used in this work. Test results indicate that the adopted cement conformed to the **Iraqi specification No.5 / 1984.**

### 1-2 Fine Aggregate:

The fine aggregate used was from Al-Ekhaider region and tested to determine the grading and other physical properties. Results indicate that the fine aggregate grading and sulfate content were within the requirements of the **B.S. specification No.882/1992**. The physical properties of this fine sand comply with Limits of **Iraqi specification No.45/1984**[8].

### 1-3 Coarse Aggregate:

Crushed aggregate of 10 mm maxim size was used. It was obtained from AL-Nebai quarry. Its grading confirms to the **Iraqi specification No.45/1984.**

### 1-4 High Range Water Reducing Admixture (HRWRA):

A high performance concrete super-plasticizer based on sulphonated naphthalene with suitable additives for longer retention, without effecting the setting time. This HRWRA is known commercially as **TufFlow SP603 . Table (1)** below show the technical properties :

**Table (1) Typical properties of TufFlow SP603.**

| | |
|---|---|
| **Appearance** | dark brown liquid |
| **Relative density** | 1.22 gm/cm$^3$ at 25 $^oC$ |
| **Chloride content** | >0.01% |
| **Air Entrainment** | 1-2% according to dosage rate used. |
| **Freezing point** | 00C. Mix prior to use |
| **Flash point** | None |

**1-5 High Reactivity Metacaoline (HRM)**:

Kaolin is a fine , white clay mineral that has been traditionally used in the manufacture of porcelain. It can be calcined at specific temperature and under controlled conditions to form high reactivity metakaolin(HRM) that exhibits pozzolanic properties. ***Al-Hadithi*** (2003)concluded that, in view of strength, the optimum calcination temperature for the kaolin is 700 $^oC$ and the most suitable percentage of HRM as a partial replacement of cement was **(8%)** .**Table (2)** and **table (3)** show the physical and chemical properties respectively of HRM used in this research .

**1-6 Rice Husk Ash (RHA)**

The RHA used in this work conforms to the chemical and physical requirements of **ASTM 618 class N pozzolan**[10] as shown in **table (2) and table (3).**The amorphous silica in RHA can be converted into very fine particles by grinding resulting in a highly active pozzolana. The grinding of ash was carried out in a mill for a period of 20 hours for each 0.5kg of the ash**. (*Yousif* , 1997).**

**Table (2) Chemical analysis of HRM and RHA.**

| Oxide composition | Oxide content % | | Limit of ASTM C 618-89 |
|---|---|---|---|
| | HRM | RHA | |
| $SiO_2$ | 56.66 | 87.53 | 70(min) |
| $Al_2O_3$ | 36.56 | 0.11 | |
| $Fe_2O_3$ | 1.62 | 0.29 | |
| $SO_3$ | - | 0.10 | 4(max) |
| $Na_2O$ | 0.03 | 1.45 | 1.5(max) |
| L.O.I | 1.3 | 2.39 | 10(max) |

**Table (3) Physical Properties of HRM and RHA.**

| Physical Properties | | | Limit of ASTM C 618-89 |
|---|---|---|---|
| | HRM | RHA | |
| **Strength activity Index** | 145 | 139 | 75(min) |
| **Flow table test** | 95 | 110 | 115(max) |
| **Specific gravity** | 2.63 | 2.14 | -- |

## 2- Concrete Mixes

Many specimens of concrete mixes are used to investigate the water absorption of the (HPC). The high reactivity metakaolin or the rice husk ash are used as partial replacement to cement (8% by weight of cement) . The mixtures have a convenient consistency measured by the slump test. Their slump varies from 71 to 79mm. The details of the mixes used in this research are as indicated in **table (4).** For the purpose of investigating the effects of the pozzolanic materials and the high range water reducing admixtures on the water absorption, four groups of specimens were casted and cured as the following :-

**The first group** :The reference mixtures ,they were composed to detect the water absorption of the ordinary mixtures without pozzolanic materials or high range water reducing admixtures.

**The second group**: This mixtures were casted to investigate the effects of the high range water reducing admixtures **(**HRWRA) on the water absorption.

**The third group**: The aim of this mixtures were to investigate the effects of the high reactivity metakaolin (HRM) on the water absorption. They referred to as **HRM-HPC**.

**The fourth group**: This mixtures were composed to investigate the effects of the rice husk ash (RHA) on the water absorption . They referred to as **HRM-HPC**.

The optimum dosage of HRWRA , the w/c ratio( to give Slump 100±5mm),water reduction, and the slump(mm) are determined and discussed in the next items.

**Table(4) The mix proportions ((kg/m$^3$)**

| **Mixtures** | **The components** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Cement** | **HRM** | **RHA** | **HRWR % by wt. of cement** | **Water** | **W/C or W/B to attain slump 100±5 mm** | **Sand** | **Gravel** |
| **Reference** | 460 | -- | -- | -- | 207 | 0.450 | 692 | 1037 |
| **Ref. + HRWRA** | 460 | -- | -- | 0.70 | 142.6 | 0.310 | 692 | 1037 |
| **HRM-HPC** | 368 | 92 | -- | 0.78 | 147.2 | 0.320 | 692 | 1037 |
| **RHA-HPC** | 368 | -- | 92 | 0.75 | 138 | 0.300 | 692 | 1037 |

## 3- Concrete Testing

### 3-1 The water absorption

According to **B.S.1881:part 122**,the water absorption was carried out on 100 mm cube specimens. The specimens were dried at a temperature of (105±5 $^{o}$C) for 72±2 hours. Then, they were wrapped securely with a nylon sheet and left in the laboratory to cool for 24±0.5 hours. After that , they were weighed and then immersed in the water .

The specimens were weighed at specific time intervals. The surface of the specimens was wiped with a slightly absorbent cloth prior to weighing. Results are expressed in terms of quantity of water absorbed per unit surface area as a function of the square root of elapsed time. ***Fagerlund* (1982)** had determined that after a time t, an inflection point occurs on the curve that depicts the beginning of the stationary state. This inflection point is derived by extrapolating the points located at the beginning and the end of the test. It has thus been possible to calculate the values of two parameters; the resistance to water penetration and the coefficient of capillary absorption.

In this study ,the specimens were weighed at 3 hours, 9 hours, 1day, 2 days , 3 days , 6 days , 9 days , 12 days and 15 days respectively within the test period .

**3-2 The compressive strength** :The compressive strength test was determined according to **B.S. 1881; part 116**[(14)] on 100 mm cubes, the loading rate of 15N/mm$^2$ was depended. The average of three cubes was adopted at each test.

**3-3 The Slump test** : The consistency of all the mixes were tested by the slump test, in accordance with **ASTM C 143–89a.**[(15)] . The Slump test is a suitable test to determine the workability for all types of concrete mixes.

## 4-Results and Discussion

### 4-1 Water reduction of the HRWRA

Results indicate that the optimum dosage of the HRWRA required to attain maximum water reduction of 32.61 is 0.7% by weight of cement for the reference mixes as indicated in **table (5) and Fig(1)** . The water reduction of the mixes incorporating HRWRA, can be calculated as follow :-

$$\%W.R = \left[ \frac{[w/c]ref.mix - \left[ w/c \quad or \quad w/cm \right] testmix}{[w/c]ref.mix} \right] \times 100$$

The water-cement ratio was reduced while maintaining the consistency of the reference mix, slump 100±5mm. The effectiveness of the HRWRA on water requirement of the mixes is shown in **Table( 5 ) .**

By following the same procedure , the properties of the mixes can be determined as in **Table(6)**

**Table (5) Testing the water reduction of the reference mixes .**

| **HRWRA % by wt. Of cement** | **0** | **0.3** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** |
|---|---|---|---|---|---|---|---|
| **w/c ratio to give Slump 100±5mm** | 0.410 | 0.335 | 0.322 | 0.316 | 0.310 | 0.287 | 0.289 |
| **Water Reduction(%)** | --- | 24.89 | 26.67 | 29.14 | 32.61 | 31.99 | 31.11 |

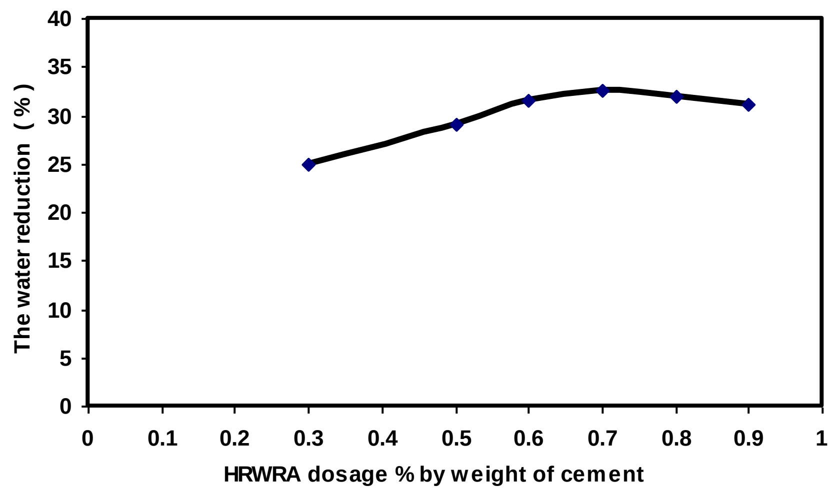



**Fig.(1) The water reduction of the reference mixes containing different HRWRA .**

**Table (6) Determination the properties of the mixes.**

| **Index** | **The mixes** | | |
|---|---|---|---|
| | **Ref. + HRWRA** | **HRM-HPC** | **RHA-HPC** |
| **Optimum dosage of HRWRA % by wt. Of cement** | 0.70 | 0.78 | 0.75 |
| **w/c ratio to give Slump 100±5mm** | 0.31 | 0.32 | 0.30 |
| **Water reduction(%)** | 32.61 | 30.98 | 29.71 |
| **Slump(mm)** | 98 | 97 | 110 |

### 4-2 Strength Activity Index of HRM and RHA (S.A.I)

The mortars used to determine the (S.A.I) consist of (1) part of cement or cementious materials and (2.75) parts of sand by weight. The cement mortar of the test mix incorporate 20% of HRM or RHA as addition by weight of cement as recommended by **ASTM C311–02**.The test mix also includes high range water reducing agent at optimum dosage (0.7% by wt. of cement). **Table (7)** shows the Strength Activity Index and w/c or w/cm ratios for tested mortars . The Strength Activity Index (S.A.I) with Portland cement was determined as follows in accordance with **ASTM C311–02:-**

**S.A.I =(A/B)×100**

where A : average compressive strength of test mix cube.

B : average compressive strength of reference mix cube

**Table (7) Strength activity Index of HRM and RHA (S.A.I).**

| Index | HRWRA % | HRM % | RHA % | w/c or w/cm ratio to give flow (110±5) | Compressive Strength (MPa) | S.A.I % |
|---|---|---|---|---|---|---|
| **M** | _ | _ | _ | 0.50 | 32.55 | |
| **M-HRM-HRWRA** | 0.7 | 20* | _ | 0.40 | 47.80 | 146.8 |
| **M-RHA-HRWRA** | 0.7 | _ | 20* | 0.44 | 40.26 | 123.6 |

***As specified by the ASTM C 311 – 02[16]**

M: reference mix.

M – HRM – HRWRA :test mix (with high reactivity metakaolin and high range water reducing admixture **TufFlow SP603**)

M – RHA – HRWRA :test mix (with rise husk ash and high range water reducing admixture **TufFlow SP603**)

### 4-3 The Water Absorption

The water Absorption is indicated in **Table (8)**. The results represent the water absorption of the four groups of the concretes. For the reference mixes , the results varies from 0.50 to 0.63 kg/m$^2$ . These mixes were composed without the water reducing admixtures or any pozzolanic materials.

**Table (8) Water absorption of the mixes .**

| **The mixtures** | **Water absorption (kg/m$^2$)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **3 hr** | **9 hr** | **1 days** | **2 days** | **3 days** | **6 days** | **9 days** | **12 days** | **15 days** |
| **Reference** | 0.50 | 0.53 | 0.57 | 0.59 | 0.60 | 0.61 | 0.62 | 0.63 | 0.63 |
| **Ref. + HRWRA** | 0.31 | 0.35 | 0.38 | 0.41 | 0. 42 | 0.44 | 0.45 | 0.45 | 0.45 |
| **HRM-HPC** | 0.27 | 0.29 | 0.31 | 0.33 | 0.35 | 0.38 | 0.39 | 0.40 | 0.40 |
| **RHA-HPC** | 0.29 | 0.31 | 0.34 | 0.36 | 0.37 | 0.40 | 0.41 | 0.42 | 0.42 |

According to the results , the water Absorption of the(Ref.+ HRWRA) mixes varies from 0.31to 0.45 kg/m$^2$ , the reduction in water absorption due to the addition of the HRWRA is approximately is **28.57%** . **Fig. 2** displays the relationship between the water absorption and the elapsed time for the( Ref. + HRWRA) mixes compared to the Reference mixes.

By introducing the HRWRA , the high performance concrete can achieve remarkable low w/c ratio , the porosity consequently reduced, resulting in low water absorption.**O'Neil et al.**[3] stated that the low w/c ratio not only produces the highest range of strengths, but also ensures that all the water in the mixtures will be combined in producing calcium silicate hydrate (C-S-H) and will form voids . **O'Neil and Dowd** [17] also stated that the low and non-interconnected porosity diminishes mass transfer making penetration of liquids , gas or radioactive elements nearly non-existent .

The advanced mechanical properties can be obtained by decreasing the water/ cementitious ratio (W/C) , as a result the porosity of the paste will be decreased and the durability will be improved **.(Sadrekarimi).**[18]

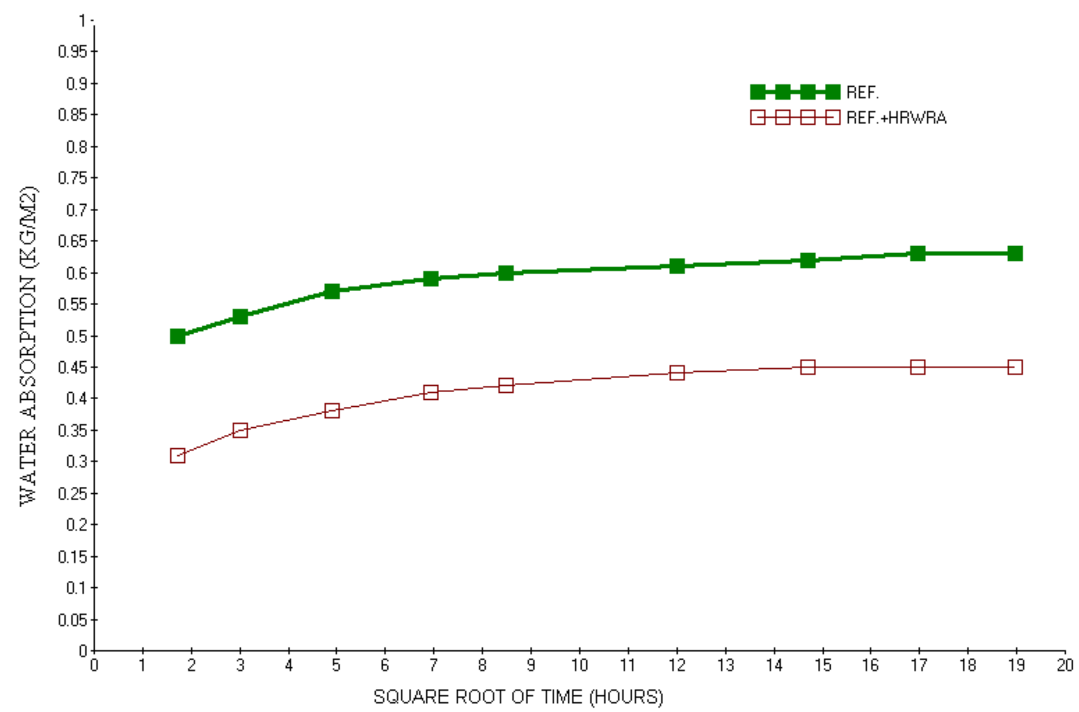
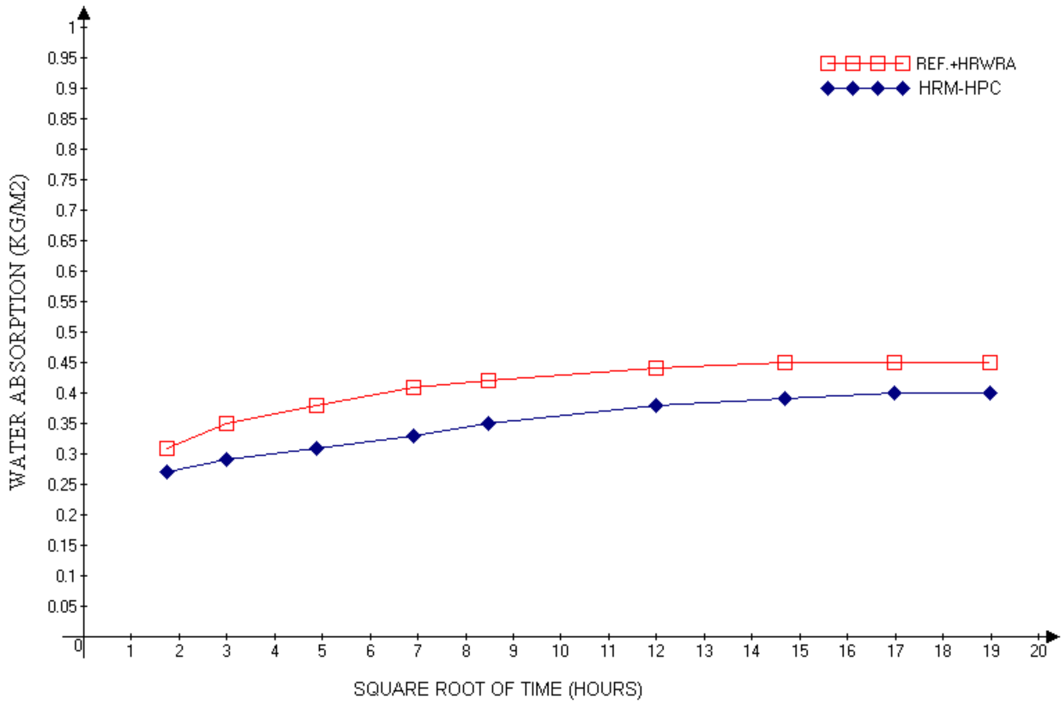



Fig.(2) The water absorption of the Ref. mixes compared to Ref.+HRWRA mixes.

In general ,the water absorption of the HPC can be decreased significantly by introducing the microsilica such as HRM . It is clear that the addition of HRM increases the interlocking of the components producing very dense microstructure and reducing the capillary pores, then the microstructure is considerably enhanced. **Fig.**3 displays the relationship between the water absorption and the elapsed time for the (HRM-HPC) mixes compared to the ( Ref. + HRWRA) mixes. The water absorption of the (HRM-HPC) mixes varies from 0.27 to 0.40 kg/m$^2$ , the reduction in water absorption due to the addition of HRM is approximately **11.11%** compared to the ( Ref. + HRWRA) mixes and the reduction is **36.50%** compared to the Ref. mixes.




Fig(3).The water absorption of the HRM-HPC compared to Ref.+HRWRA mixes

By observing the results in **Fig. 4**. it is obvious that the water absorption of the RHA-HPC mixes varies from 0.29 to 0.42 kg/m$^2$ at the test period. The decrease in the water absorption of these concretes is higher than the others except HRM-HPC. The reduction in water absorption of the RHA-HPC mixes due to the addition of RHA is **6.66%** compared to the (Ref. + HRWRA) mixes but the reduction is **33.33%** compared to the Ref. mixes.

The resistance to water absorption of the RHA-HPC mixes is higher than the Reference and Ref. + HRWRA mixes. This behavior can be ascribed to the fact that additional activated pozzolanic materials became available to react with the liberated calcium hydroxides leading to produce more quantities of hydrates to strengthen the microstructure.

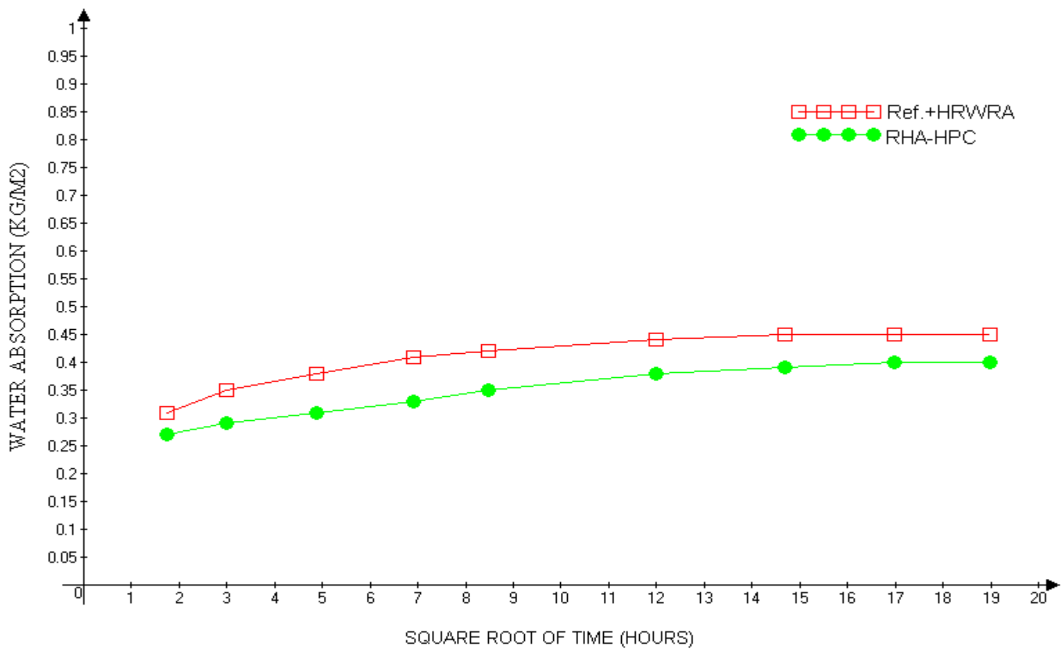
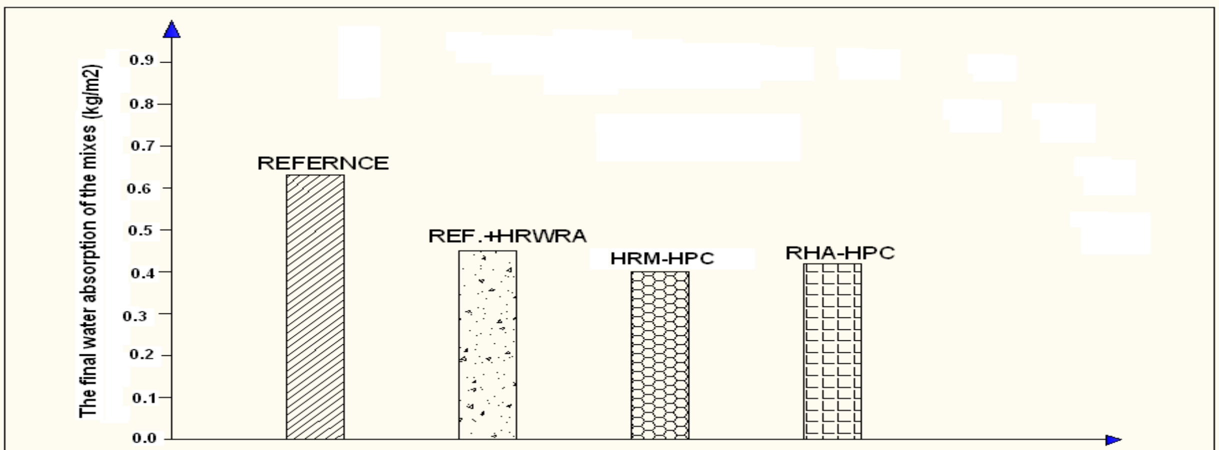



Fig (4). The water absorption of the RHA-HPC compared to Ref.+HRWRA mixes.

For all mixes , the results show that the water absorption increased rapidly at the first stage of the test, then the rate of absorption decreased gradually. Beyond 15 days the water absorption became unchanged . The histogram in **Fig. 5** show the variations in the final water absorption , it is clear that the reduction in water absorption due to the addition of the HRWRA or the microsilica is higher than the reference mixes . The results also indicate that the improvement due to the addition of the HRM is higher than that due to the RHA. Since the pozzolanic activity of the HRM is higher than the RHA , it can be concluded that the water absorption is significantly reduced in HRM-HPC.




Fig(5). The final water absorption of the mixes.

## 5-3 The Compressive strength

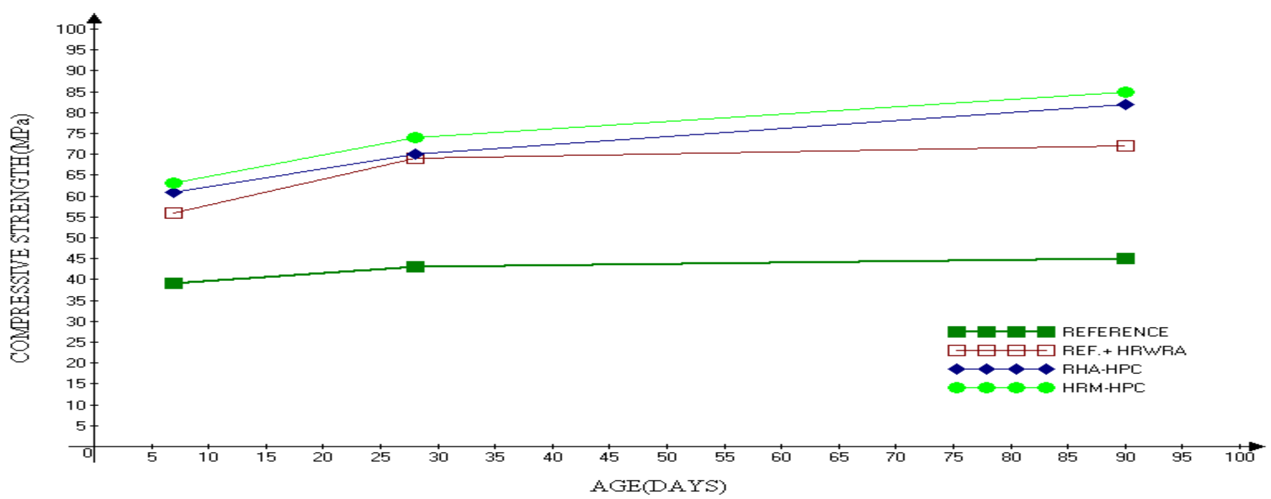
The results demonstrate considerable increase in compressive strength of all mixes compared to the Ref. mixes which. The results indicate that the concretes incorporating HRWA, HRM and RHA exhibit superior performance as indicated in **Fig. 6 and Table 9** .

The increase in compressive strength at the age 28 days are **60%** , **7.2%** , and **5.4%** for the effects of HRWA, HRM and RHA respectively . It is clear that the effects have the same manner for both the compressive strength and the water absorption . It means that the increase in compressive strength results in significant reduction in the water absorption .

Chemically, active silica helps to produce larger volumes of calcium silicate hydrates (C–S–H), high amounts of (C–S–H) increase the strength of the binder and improve the bond between cement and aggregate.

**Table( 9 ) The compressive strength of the mixes (MPa)**

| The mixtures | 7 days | 28 days | 90 days |
|---|---|---|---|
| **Reference** | 39 | 43 | 45 |
| **Ref. + HRWRA** | 56 | 69 | 72 |
| **HRM-HPC** | 63 | 74 | 85 |
| **RHA-HPC** | 61 | 70 | 82 |




Fig(6) The compressive strength of mixes

## Conclusions

Depending on the results of this research , the following conclusions can be drawn:

1. The final water absorption of the HPC in this study varied from 0.4 to 0.63 $kg/m^2$ for all mixes. It is very low compared with the conventional concrete.
2. The addition of the HRWA improved the properties of the HPC in view of reduction the water absorption . The percentage decrease in water absorption is 28.57% compared to the Ref. mixes
3. The HRM decreased the water absorption of the HPC. The percentage decrease in water absorption is 11.11% compared to the Ref. + HRWRA mixes and the reduction is 36.50% compared to the Ref. mixes.
4. Incorporating the RHA in HPC affected the water absorption significantly .The reduction in water absorption is 6.66% compared to the Ref. + HRWRA mixes but the reduction is 33.33% compared to the Ref. mixes.
5. The effect of the RHA is not high as the effect of the HRM , but it is significantly better than the other concretes , that is ascribed to the fact that HRM is more effective than RHA.
6. The increment in compressive strength results in significant reduction in the water absorption .
7. The increment in compressive strength due the effect of HRWRA at the age 28 days is 26% , and 55% , 33% due the effects of HRM and RHA compared to the Ref. + HRWRA respectively
8. The water absorption and compressive strength followed the same manner in increasing or decreasing due to the effects of the pozzolanic materials and HRWA .

## Recommendations

1. The pozzolana such as silica fume or fly ash can be studied widely to determine their effects on the water absorption of the HPC which tested in this research .
2. There is a need to test the ability of some effective method of curing such as steam curing to improve the resistance to water absorption of the HPC .
3. It is interesting to study the water absorption of the other types of the Portland cement such as the sulfate resistance Portland cement or the rapid hardening Portland cement .
4. A study can be achieved to discover the effects of the fibers in the water absorption of the concrete .

## References

M. Collepardi, **"Innovative concretes for civil engineering structures: SCC, HPC and RPC"**, Symposium on Sustainable Development and Concrete Technology, S. Francisco(USA),PP.431-450,Suppl.Vol.,2001.

Aitcin,P. C. **" The art and science of high performance concrete."** In P. K. Mehta, Ed. Proceedings of Mario Collepardi Symposium on Advances in Concrete Science and Technology,8 October 1997,Rome ,107-126.

O'Neil, E.F., Neeley, B.D. and Cargile, J.D. **"Tensile properties of very high strength concrete for penetration – resistant structures [online]** ." US army Engineers Research and Development Centre, 2001, pp.1

Roux, N. Andrade, C. and Sanjuan, M.A. **"Experimental Study of Durability of Reactive Powder Concretes"**. "Journal of Materials in Civil Engineering, 8 (1), 1996, pp. 1 - 6.

Richard, P. and Cheyrezy, M.H. **"Composition of reactive powder concrete.** " Cement and Concrete Research, 25 (7), 1995, pp. 1501 – 1511.

Iraqi specification . No.5/1984 . **" Portland cement "**.

B.S.882:1992 sited by: Neville , A.M. , **" Properties of concrete** . " Fourth Edition , Longman . Group Limited , Essex , England , 1995, P. 844 .

Iraqi specification. No.45/1984. **"Aggregates from natural sources for concrete and construction** "

Al–Hadithi , R. Y., **" Durability of high performance concrete incorporating high reactivity metakaoline and rice husk ash "** , M.Sc Thesis , University of Technology, September,2003, p. 35 .

ASTM C618, **" Standard specification for chemical admixtures for concrete** .", Annual Book of ASTM Standards American Society for Testing and Materials, Vol. 04.02, 1989, pp. 291 – 293.

Yousif, H. A., **"Corrosion of reinforcement in concrete containing high range water reducing agent and rice husk ash** " Ph. D. Thesis, University of Technology, January 1997, PP. 1-195.

B.S. 1881, part 122, **"Method of determination of water absorption**." British Standards Institution,1989, 2pp

Fagerlund, G. **" On the capillary of concrete** , " Nordic concrete Res., Vol . 1, 1982,pp. 1 – 20 .

B.S. 1881, part 116, **"Method of determination of compressive strength of concrete cubes**." British Standards Institution,1989, 3 pp.

ASTM 143-89a , **"Standard test method for slump of hydraulic cement concrete** ", Annual Book. of ASTM Standard American Society for Testing and Materials , Vol.04.02 , 1989 , pp.85–86 .

ASTM 311-02 , **"Standard test method for sampling and testing fly ash or natural**

**pozzolans for use in Portland cement concrete** ", Annual Book. of ASTM Standard American Society for Testing and Materials , Vol.04.02 , 2002 , pp.182 – 186 .

17- O'Neil, E.F., Neeley and Dowd,W. M. **"Reactive powder concrete : A new material for the construction industry** ." In : S.K. Ghosh, Ed. Third National Concrete and Masonry Engineering Conference, 15-17 June 1995, San Francisco,CA.,43-50.

Sadrekarimi, A. **"Development of a light weight reactive powder concrete"**. "Advanced Concrete Technology, 2 (3), 2004 ,pp. 409 – 417.