# EFFECT OF CURING METHOD AND INSOLUBLE RESIDUE IN CEMENT ON THE COMPRESSIVE STRENGTH OF PORTLAND CEMENT MORTAR

**Asst. lecturer Mohamed Jassam Mohamed**
**University of Babylon, College of Engineering**

**ABSTRACT**
In this experimental work, four different curing methods were applied namely including water, air, water heated-air and water heated –water. The results showed that the highest compressive strengths are attributed to the air cured under room temperature after 20hrs curing in heated water at each age. To verify the effect of insoluble residue on the compressive strength of Portland cement, fine particles sand passing from sieve no. 200 and washing in hydrochloric acid were used as an insoluble residue. The Portland cement was replaced by insoluble residue which varied between (0 - 7.0) % by weight. The results showed that the higher percentage of insoluble residue to 8.13% in cement mortar gives the lower the compressive strength by 12% of the control mortar compressive strength at 1 day .Although of this reduction of strength, it was found that the compressive strength was still higher than the limits given by ASTM ,BS and Iraqi standards.

**KEYWORDS: Curing Method, Insoluble Residue, Portland Cement, Mortar, Compressive Strength.**

**الخلاصة:**

في هذا البحث العملي تم تطبيق أربعة طرق للإنضاج وهي الغمر بالماء،تركها بالهواء بدرجة حرارة الغرفة،الغمر بالماء الساخن ومن ثم تركها في الهواء بدرجة حرارة الغرفة والنوع الأخير من الإنضاج هو الغمر بالماء الساخن ومن ثم الغمر بالماء بدرجة حرارة الغرفة. لقد أظهرت النتائج إن الطريقة الأفضل للإنضاج هي ترك النماذج بالهواء بدرجة حرارة الغرفة بعد الغمر بالماء الحار لمدة 20 ساعة.أما الشق الثاني من البحث هو التحقق من تأثير المواد الغير الذائبة في السمنت على مقاومة الانضغاط للمونة حيث تم استخدام حبيبات الرمل الناعمة المارة من منخل رقم 200 والمغسولة في حامض الهيدروكلوريك كمواد مضافة غير ذائبة وبنسب تراوحت بين(0−7)% من وزن السمنت. إن النتائج بينت إن النسبة العالية من المواد الغير الذائبة والتي تصل إلى 8.13 % في مونة السمنت تعطي أقل مقاومة حوالي 12% من مقاومة النموذج القياسي عند اليوم الاول . بالرغم من هذا النقصان في المقاومة فقد وجد إن قيم المقاومة للنماذج بقيت أعلى من الحدود التي حددتها المواصفات الأمريكية والبريطانية .

## 1. INTRODUCTION:

Curing is used to provide an appropriate environmental condition within a concrete structure, i.e. relative humidity and temperature to ensure the progress of hydration reactions causing the filling and segmentation of capillary voids by hydrated compounds. In a specific condition, curing duration to achieve an adequate hydration of Portland cement mortars and concretes depends mainly on the chemical and mineralogical compositions. **ACI 308[2001]** recommended practice suggests 7 days of moist curing for most structural concretes. However, the period of curing should be extended to 14 days when the cement contains supplementary cementitious materials, such as slag and fly ash, owing to the slow hydration reactions between supplementary cementitious materials and the calcium hydroxide. The process of this reaction requires the presence of water to produce the cementing compounds to contribute for filling the capillary voids.

Curing methods can be used once the concrete surface will not be damaged by the application of curing materials or water. The need for continuous curing is greatest during the first few days after placement of the concrete in hot weather. During hot weather, provided that favorable moisture conditions are continuously maintained, concrete can attain a high degree of maturity in a short time. Water-curing, if used, should be continuous to avoid volume changes due to alternate wetting and drying [**ACI 308,2001]**.

The rate and degree of hydration, and the resulting strength of concrete and other properties, depend on the curing process that follows placing and consolidation of the plastic concrete. Hydration of cement continues for years at a decreasing rate as long as the mixture contains water and the temperature conditions are favorable. Once the water is lost, hydration ceases. Curing of mortar and concrete is very essential for their strengths gain durability [**Al-Gahtani, 2010**].

ACI 305[2002] requires that the temperature of the moist concrete be kept above 10 $^{\circ}$C. Although concrete continuously maintained at a curing temperature of 10$^{\circ}$C in the field will be protected against freezing, such concrete will develop compressive strength at about half the rate of a companion cylinder cured in the lab at 23$^{\circ}$C (73 F).

Insoluble residue is a measurement of adulteration of cement, largely coming from impurities in gypsum and can be found by treating the cement with hydrochloric Acid and sodium hydroxide [**Neville, 1995**]. ASTM C 150 [2005] limits the insoluble residue in Portland cement type I not higher than 0.75%. BS 12 [1996] and I.Q.S No.5 [1984] set the limit for insoluble residue at 1.5% for cement not containing a minor additional constituent, and release the limit to 5.0% for cement including a minor additional constituent, such as granulated blast furnace slag, natural pozzolana, fly ash or filler.

It is found that in modern cement, there is a higher content of C3S and a greater fineness than that of 40 years ago. As a consequence, cement mortar has, nowadays, a 28 days compressive strength perhaps 25 MPa higher than in 1925 [**Neville, 1995**]. It seems that a higher insoluble residue in Portland cement can be increased to a higher value without any negative effect on its strength. This premise was confirmed by Poupongphan [1992]. They found that with 0.5% of finely crushed brick as an insoluble residue in Portland cement type I, the compressive strength of cement mortar was reduced by 1.6%, and by increasing the insoluble residue up to 1.5%, this mixture resulted in a lowering of the cement mortar strength of less than 4% compared to the control cement mortar strength at 28 days. Normal consistency and setting times are not changed by the addition of insoluble residue in cement. However, this premise still needs more data for support and confirmation that slightly increased rates of insoluble residue are not a major factor affecting its strength.

## 2. EXPERIMENTAL PROGRAM

### 2.1The Mix and Testing For Curing Effect:

The mix proportion was W/C = 0.5, 1:3 cement and standard silica sand respectively. At first, cement and standard silica sand were mixed manually. After that, mix was put into the mixture, followed the mixing water was added to the mix and mixing was continued for two minutes, then the mortar was de-molded in 7.5cm cube specimens. After twenty-four hours casting, the six specimens were exposed to the each curing conditions as shown in the **Table 1.**

### 2.2 Insoluble Residue:

In this experiment, fine particles sand passing from sieve no. 200 and dissolving in hydrochloric acid were used as an insoluble residue. Portland cement type I was replaced with the insoluble residue by 0%, 1.0%, 1.5%, 3.0%, 5.0% and 7% by weight of cement, plus the existing insoluble residue in cement as shown in **Table 2**. The mixed cement was also used to prepare mortar in According to ASTM C 109 [2005] and demoulded into 7.5 cm cube specimens. After 24 hr, the molds were cured in water. The compressive strengths of mixed cement mortar were tested at the age of 1, 3, 7, 14, 28, and 60 days. At each date of testing, the data are the average of three specimens.

## 3. RESULTS AND DISCUSSION

### 3.1 Curing Method:

**Figure 1** shows that strength at 3, 7, 14, 28 and 60 days for OM–WH–AC mix are more than the others, but the strengths of all are same at 90 days unless OM–AC mix is less by 21.5%. At 90 days the strength of OM–AC mix is minimized and there is strength loss about 10% compared to 60 days. Therefore curing in the air is not practically recommended. It can be seen that for OM–WC (control mix) the strengths are continuously increased at all ages and there is not any strength loss. The two mixes OM–WH–AC and OM–WH–WC which are in water heated for duration of 20 h with 60 °C after specimen de-molding. It is observed that for OM–WH–AC mix, strength at 3 and 7 days are more about 21% and 20% than those for control mix at the same ages, while for OM–WH–WC mix are more 8% and 4% than those for control mix. It is noted that for both mixes there are some strength loss at later ages. Strength loss contents are 4.3% at 90 days and 3.2% at 60 days for OM–WH–AC and OM–WH–WC, respectively. Comparing between the strengths for both mixes shows that it is better that the specimens are cured in air under room temperature after heating in the bath water. It has a significant effect in pre-cast concrete industry with advantages from economy. Moreover, the strength improvements of OM–WH–AC mix at 28 days and above are more than those of OM–WH–WC mix and control mix at the same ages.

### 3.2. Effect of Insoluble Residue on Compressive Strength of Portland cement

After the insoluble material was replaced in cement at the proposed percentage the cement and insoluble residues were mixed together to make the sample uniform. The proposed and the tested results of the insoluble residue material in the mix are shown in **Table 2**. It can be seen from **Figure 2** and **Figure 3** that the higher the percentage of insoluble residue in cement to give the lower the compressive strength cements mortar. The compressive strengths of control sample vary from 8.1 MPa at 1 day to 40 MPa at 60 days. The sample IR0.5 (0.5% added) with 1.63% of insoluble residue has the compressive strengths of 7.9 MPa at 1 day and increases to 39.5MPa at 60 days. These strengths are lower than the control strength 2.4% at 1 day and 1.25% at 60 days, respectively. The compressive strengths of cement mortar with 2.13% of insoluble residue, sample IR1.0 (1.0% added), are, respectively, 7.7 MPa at 1 day and 39 MPa at 60 days. They are lower than the control strength by 4.9% at 1 day and by 2.5% at 60 days. It is noted that the reduction in strength due to insoluble residue is rather high at the early ages and tends to reduce when the age of cement mortar increases. At the highest amount of insoluble residue in the mix, 8.13%, in sample IR7.0(7.0% added), it is found that the compressive strength is still higher than the given limit by ASTM C 150 [2005]. For ASTM C 150 [2005], the cement mortar strength with 0.75% of insoluble residue has to be not lower than 12.4 MPa at 3 days and 19.3 MPa at 7 days for Portland cement type I. Sample IR7.0 gives compressive strength of mortar at 3 and 7 days equal to 17.2 and 25.9 MPa, respectively. This means that the insoluble residue to 8.13% in cement is not seriously harmful to its strength. It reduces the strength of cement mortar, but it is not the main factor affecting the strength of cement mortar. The value of the insoluble residue limited by ASTM C 150 [2005], 0.75% and I.Q.S No.5 [1984], 1.5%, seems to be rather low and can be slightly increased without lowering the standard of cement.

### 3.3 Effect Of Insoluble Residue On Setting Time Of Portland Cement:

The initial and final setting times of the control sample (only cement paste) were 108 and 195 min, respectively. With the replacement of cement by insoluble residue up to 7.0%, the setting times were changed little; they varied from 102 to 111 min for the initial setting time and from 195 to 210 min for the final setting time as shown in **Table 3**. This may be because the particles size and particles shape of the insoluble residue were similar to that of the Portland cement. This means that there is no effect of insoluble residue on setting time of cement paste by replacing insoluble residue up to 7.0%.

## 4. CONCLUSION:

1. The curing under in air under room temperature after heating in the bath water has an increasing strength values at 3 and 7 days are more about 21% and 20% than those for control mix at the same ages.
2. It can be seen that for control mix, the strengths are continuously increased at all ages and there is not any strength loss otherwise others.
3. The higher percentage of insoluble residue to 8.13% in cement mortar gives the lower the compressive strength but is not seriously harmful to its strength.
4. It is noted that the reduction of strength due to insoluble residue is rather high at the early ages and tends to reduce when the age of cement mortar increases.
5. The value of the insoluble residue limited by ASTM C 150[2005], 0.75% and I.Q.S No.5 [1984], 1.5%, seems to be rather low and can be slightly increased.
6. The setting times of cement was not significantly affected by finely sand as insoluble residue material in cement by replacing insoluble residue up to 7.0%.

## REFERENCES:

ACI Committee 308, recommended practice for curing concrete, MCP, American Concrete Institute, Farmington Hills, USA; 2001.

A.S. Al-Gahtani, Effect of curing methods on the properties of plain and blended cement concretes. Construction Build Materials Journal, 2010, pp. 308–314.

ACI Committee 305, recommended practice for Hot Weather Concreting, MCP, American Concrete Institute, Farmington Hills, USA; 2002.

A.M. Neville, Properties of Concrete, 3rd edition., Pitman Book, London, 1995, p. 10.

ASTM C150, Standard specification for Portland cement, ASTM C 150- 95, in: Annual Book of ASTM, Vol. 04.01, 2005.

BS 12, Specification for Portland cement, 15th edition., British Standards Institution, London, 1996.

P. Poupongphan, S. Boonsiri and V. Karunyavanich," Effect of insoluble material on properties of hydraulic cement" King Mongkut's Institute of Technology Thonburi, 1992.

ASTM C 109, Standard test method for compressive strength of hydraulic cement mortars , ASTM C109- 95, in: Annual Book of ASTM, Vol. 04.01, 2005.

I.Q.S No.5, Iraqi Specification Standard for Portland cement, Baghdad, 1984.

**Table 1** Mix proportion and curing conditions of ordinary Portland cement mortars.

| Symbol | Curing method | Curing condition |
|---|---|---|
| OM–WC (control) | Water | After 24hr,immerged in the water under room temperature to the testing age. |
| OM–AC | Air | After 24hr,left in the air under room temperature to the testing age. |
| OM–WH–AC | Air | After 24hr, immerged in the heated water at 60 °C for duration of 20 hr, then left in the air under room temperature to the testing age. |
| OM–WH–WC | Water | After 24hr, immerged in the heated water at 60 °C for duration of 20 hr, then immerged in the water under room temperature to the testing age. |

**Table 2** Compressive strength of cement mortars that containing insoluble residue after adding insoluble materials.

| Sample number | Added insoluble material (%) | Total insoluble residue (%) | Average Compressive strength (MPa) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 day | 3 days | 7 days | 14 days | 28 days | 60 days |
| Control | 0.0 | 1.13 | 8.1 | 19.0 | 27.8 | 30.8 | 35.9 | 40.0 |
| IR0.5 | 0.5 | 1.63 | 7.9 | 18.6 | 27.6 | 30.5 | 35.4 | 39.5 |
| IR1.0 | 1.0 | 2.13 | 7.7 | 18.4 | 27.2 | 30.1 | 35.2 | 39.0 |
| IR1.5 | 1.5 | 2.63 | 7.6 | 18.1 | 27.1 | 29.9 | 34.8 | 38.9 |
| IR2.0 | 2.0 | 3.13 | 7.5 | 17.9 | 26.7 | 29.5 | 34.3 | 38.4 |
| IR3.0 | 3.0 | 4.13 | 7.4 | 17.6 | 26.2 | 29.4 | 34.1 | 38.3 |
| IR5.0 | 5.0 | 6.13 | 7.2 | 17.2 | 26.0 | 29.1 | 33.7 | 38.1 |
| IR7.0 | 7.0 | 8.13 | 7.1 | 17.2 | 25.9 | 28.6 | 33.5 | 37.8 |

I.R: Insoluble Residue

**Table 3** Setting times of cement paste that containing insoluble residue after added insoluble materials.

| Sample | Added insoluble material (%) | Total insoluble residue (%) | Setting times (min) | |
|---|---|---|---|---|
| | | | Initial | Final |
| Control | 0.0 | 1.13 | 108 | 195 |
| IR0.5 | 0.5 | 1.63 | 108 | 210 |
| IR1.0 | 1.0 | 2.13 | 109 | 195 |
| IR1.5 | 1.5 | 2.63 | 111 | 210 |
| IR2.0 | 2.0 | 3.13 | 109 | 210 |
| IR3.0 | 3.0 | 4.13 | 109 | 195 |
| IR5.0 | 5.0 | 6.13 | 105 | 210 |
| IR7.0 | 7.0 | 8.13 | 102 | 195 |

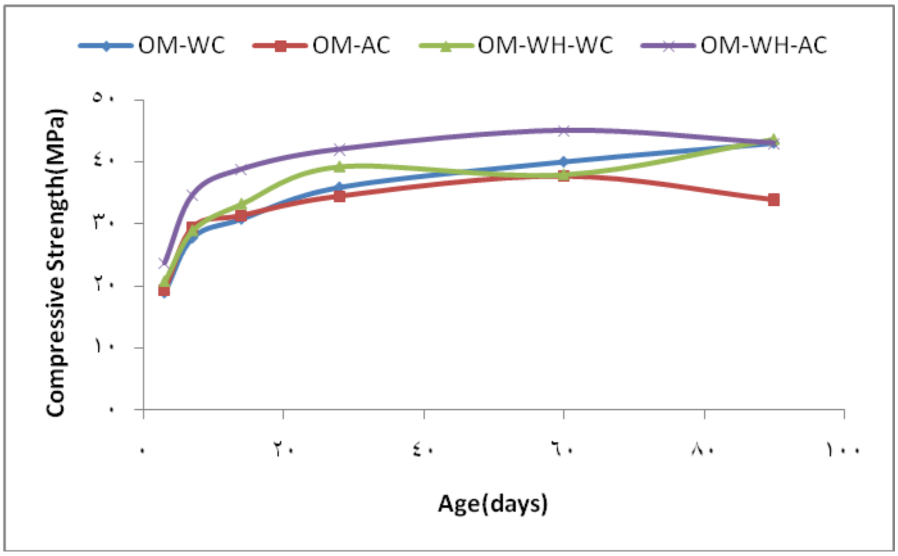


**Figure 1** The relationship between the compressive strength of cement mortar and percentage of insoluble residue.

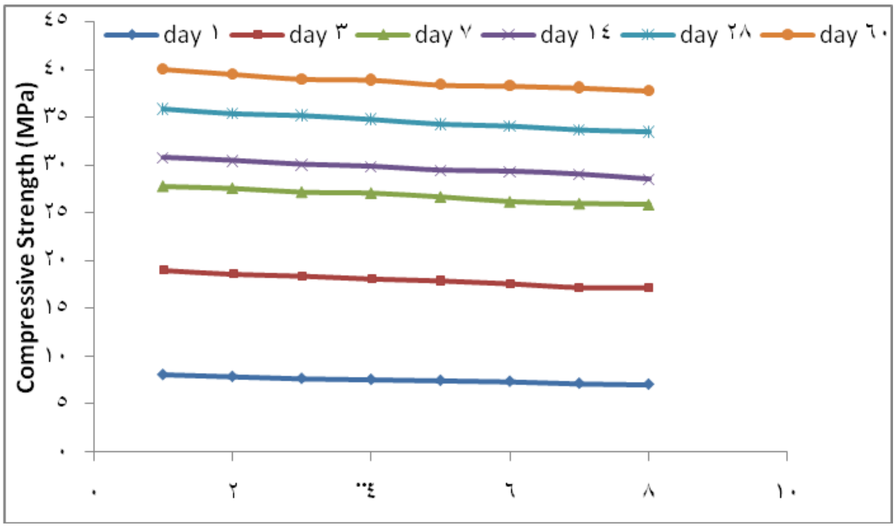


**Figure 2** The relationship between the compressive strength of cement mortar and percentage of insoluble residue.

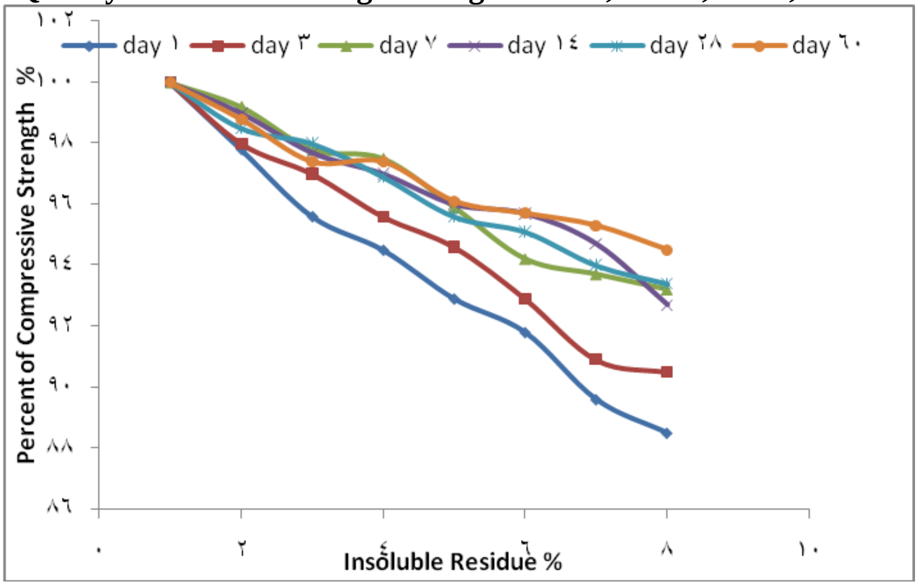


**Figure 3** The relationship between the percentage of compressive strength of cement mortar and percentage of insoluble residue.