Effect of Time Period between Mixing and Application of Cement Mortar on Compressive Strength

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Abstract

This paper investigates the effects of time period between mixing and application of cement mortar on compressive strength. Two groups with a total of (١٣٥) cubes were cast and tested at ٢٨ days age. In first group (٨١) cubes were made with different water/cement ratios (٠,٥, ٠,٦ and ٠,٧) without adding any additional water to correct the flow of cement mortar while in the second group (٥٤) cubes were made with water/cement ratios (٠,٦ and ٠,٧) with adding some water to correct the flow of cement mortar. Nine different time periods were applied (٠, ٣٠, ٦٠, ٩٠, ١٢٠, ١٥٠, ١٨٠, ٢١٠ and ٢٤٠ minutes). It was found that compressive strength of cement mortar can be reduced to ٥٠٪ of the compressive strength of corresponding original cement mortar after ١٥٠ minutes from mixing water with cement.

الخلاصة

هذا البحث يبحث في تأثير الزمن للفترة ما بين خلط المونة الاسمنتية وبدء استخدامها على مقاومة الانضغاط. تم صب وفحص مجموعتين من النماذج وبما مجموعه (١٣٥) مكعب بعمر (٢٨) يوم. في المجموعة الاولى تم صب (٨١) مكعب بأستخدام نسب ماء الى أسمنت مختلفة وهي (٠,٥ ، ٠,٦ و ٠,٧) وبدون اضافة ماء اضافي الى المونة لتعديل جريان المونة الاسمنتية بينما في المجموعة الثانية من النماذج تم استخدام نسب الماء الى الاسمنت (٠,٦ و ٠,٧) مع اضافة بعض الماء لتعديل جريان المونة الاسمنتية. تم تطبيق تسعة ازمان مختلفة (٠ ، ٣٠ ، ٦٠ ، ٩٠ ، ١٢٠ ، ١٥٠ و ١٨٠ دقيقة). وجد بأن مقاومة الانضغاط لمونة الاسمنت يمكن ان تنخفض الى ٥٠% بالمقارنة مع المونة الاسمنتية المرجعية بعد مرور ١٥٠ دقيقة على زمن الخلط.

١. Introduction

Mortar has been used for centuries as a mean of adhering bricks or concrete blocks to one another. Cement mortar continues to be used in many different types of construction. Professional building projects often employ mortar as the binder between bricks in walls, fences, and walkways. Around the house, cement mortar is often employed to make quick repairs in patio slabs and reset loosened stones or bricks in a walkway or retaining wall.

Cement mortar also makes an excellent medium for creating a smooth surface to walls made from bricks and other forms of masonry. The mortar is applied with the use of a trowel

and then smoothed into position. Often, the application is conducted in more than one coat, making it possible to slowly achieve a covering that adheres properly to the wall surface. The mortar may be tinted in order to add a small amount of color to the façade or paint can be added as a topcoat at a later date.

The purpose of this work is to investigate the effect of time period between the mixing and the application of cement mortar on the compressive strength of cement mortar. Five mixes were made with different water to cement ratio (٠,٥, ٠,٦, ٠,٧), with and without adding additional mixing water when needed in order to correct the consistency of cement mortar. Tests were carried out to study the following properties of the cement mortar: flow of cement mortar; compressive strength of cement mortar.

٢. Materials Used

٢.١ Cement

Saudi ordinary Portland cement manufactured by Riyadh Cement Company was used. The cement satisfies ASTM C١٥٠-٠٢a[١] specification for ordinary Portland cement (Type I).

٢.٢ Fine aggregate

Fine aggregate from Al-Akhaider region was used. It is a yellowish-brown colored sand with sub-angular to sub-rounded shaped particles. The grading of this sand satisfies ASTM C٣٣-٠٣[٢] specification as illustrated in Table ٢.١.

Table ١: Grading of fine aggregate

Sieve size	Percent passing	Limit required by ASTM standard C٣٣-٨٦.
٤,٧٥mm	٩٥	٩٥-١٠٠
٢,٣٦mm	٨٥	٨٠-١٠٠
١,١٨mm	٧٠	٥٠-٨٥
٦٠٠µm	٢٥	٢٥-٦٠
٣٠٠µm	٣٠	١٠-٣٠
١٥٠µm	٥	٢-١٠

٢.٣ Water

Ordinary tap water was used throughout this work for mixing and curing of cement mortar.

٣. Experimental Work

٣.١ Mortar composition and mixing

Mixing mortar materials, casting and curing mortar test specimens were carried out in accordance with (ASTM C٣٠٥) using a ٥٠mm cube specimens[٣].

٣,١,١ Mortar Composition:

The proportions of materials for the standard mortar shall be one part of cement to ٢,٧٥ parts of graded sand by weight. Different water-cement ratio of ٠,٥, ٠,٦, and ٠,٧ were used.

٣,١,٢ Specimen Mold Preparation:

A thin coating of mold release was applied to the interior surfaces of the molds and base plates. Then surfaces were wiped with a cloth to remove any excess.

٣,١,٣ Mortar Mixing Procedure:

Dry paddle and dry bowl were placed in the mixing position of the mixer. Then the materials were introduced into the bowl in the following manner:

١) All the mixing water was placed in the bowl.
٢) Then the cement was added to the water; then the mixer was started at slow speed (١٤٠ rpm) for ٣٠ s.
٣) Then sand was slowly added over a ٣٠ s period, while continued mixing at slow speed.
٤) Then the mixer was stopped, changed to medium speed (٢٨٥ rpm), and then started for an additional ٣٠ s.
٥) Then the mixer was stopped and let the mortar stand for ١,٥ minutes. During the first ١٥ s, any mortar that may have collected on the side of the bowl should quickly scrape down into the batch; then for remainder of the interval, the mortar should be covered with the lid.
٦) Finally the mortar should be mixed for ١ minute at medium speed (٢٨٥ rpm).

٣.٢ Determining flow of mortar and casting the mold

٣,٢,١ Determining the flow of mortar:

Determining the flow of mortar was carried out in accordance with (ASTM C٢٣٠[٤] and ASTM C١٤٣٧[٥]) as follows:

a) The table was wiped clean and dried and the flow mold was placed at center.
b) A layer of mortar about ١ inch thickness was placed in the mold and tamped ٢٠ times.
c) Then the mold was filled with second layer and tamped ٢٠ times.
d) Then the mortar flush was cut with top of mold with a trowel, held perpendicular to the mold, using a sawing motion.
e) Then the table was wiped around mold and cleaned of all mortar and dried; then the mold was removed.
f) Then the table was dropped through ½ inch height ٢٥ times in ١٥ seconds.
g) Then a ruler was used to measure the diameters along the ٤ scribed lines on the table. The sum of the four readings is the flow (the percent increase in the original diameter) and this flow value was recorded.
h) Following flow test, all mortar was returned to the mixing bowl. Then scraped down the sides and remixed for ١٥ seconds at medium speed (٢٨٥ rpm).

٣,٢,٢ Molding Test Specimens:

١. A layer of mortar was placed about ١ in. (٢٥ mm) (approximately one half of the depth of the mold) in all of the cube compartments.

٢. The mortar was tamped in each cube compartment ٣٢ times in about ١٠ s in four (٤) rounds, each round to be at right angles to the other and consisting of eight adjoining strokes over the surface of the specimen (see Figure ٣.١).

٣. Then the compartments were filled with the remaining mortar and tamped as specified for the first layer. During tamping of the second layer, we bring in the mortar forced out onto the tops of the molds after each round of tamping using gloved finger and the tamper. On completion of the tamping, the tops of all cubes should extend slightly above the top of the mold.

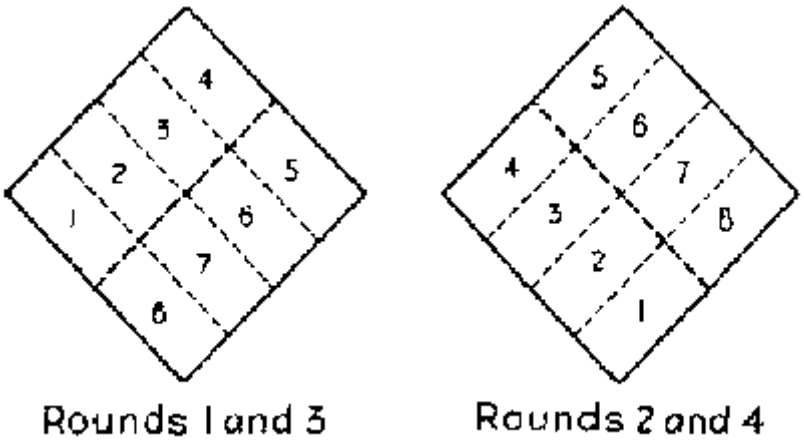

Figure ٣.١. Order of Tamping in Molding of Test Specimens.

٤. Then trowel mortar of each cube both laterally and longitudinally. Cut off mortar to a plane surface with the top of the mold by drawing the straight edge of the trowel, held perpendicular to the mold, with a sawing motion over the length of the mold.

٥. Specimens were placed in a room for ٢٤ hours. Keep specimens in their molds for this initial curing period. After ٢٤ hours, specimens were removed from the molds and immersed in a water curing tank.

٣.٣ Compressive Strength Determination

Compressive strength test was conducted according to ASTM C١٠٩M-٠٢[٦]. An Auto testing machine of ١٠٠٠ kN capacity was used for testing cubes with a loading rate of ١,٣٥ kN/sec. Three cubes were tested for each mixing time at the age of ٢٨ days, and an average value of the compressive strength was obtained.

١) Specified test specimen was removed from the curing tank. Then wiped to a surface dry condition and remove any loose sand grains or incrustations for test surfaces.

٢) The load was applied to specimen faces that were in contact with the true plane surfaces of the mold. The straightness of these faces was checked with a straight edge. Opposing surfaces were selected which have the straightest profiles.

٣) Specimen was placed below the center of the upper bearing block of the testing machine. This spherically seated block was ascertained that is free to tilt. The specimens were tested at a loading rate such that the peak load will be reached in a period of ٢٠ s to ٨٠ s. No adjustments were made in the controls of the testing machine while specimen is yielding prior to failure.

٤) The total maximum load was recorded as indicated by the testing machine. Then the compressive strength of the specimen was calculated in Newton per square millimeters ($N/mm^{٢}$) or (MPa).

٥) Then the average of all like specimens was calculated.

٤. Results and discussion

٤.١ Flow of Cement Mortar

According to the results of flow tests tabulated in Table ٤,١, It is seen that there was zero flow of cement mortar with water/cement ratio of ٠,٥, while Table ٤,٢ shows that the flow of cement mortar with water/cement ratio of ٠,٦ was ٤٠٪ at the time of mixing and drops to ٥٪ after ١٢٠ minutes from the time of mixing after that it records zero flow this was due to the loss of mixing water either in absorption of sand or in evaporating. In Table ٤,٣, the flow of cement mortar with water/cement ratio of ٠,٧ was ٧٤٪ at the time of mixing and drops to ٤٠٪ after ٢٤٠ minutes from the time of mixing this means that there was enough excess water to keep the flow of mortar in high range even after ٤ hours from the beginning of mixing the cement with water.

In Table ٤,٤ when the water/cement ratio was ٠,٦, It is seen that after ٣٠ minutes there will be decreasing in the flow of cement and we need to add some water (٥٠ ml.) to correct the flow of the cement mortar in order to study the effect of adding the water on the compressive strength of cement mortar the lose in water is mainly due to the absorption of sand. Another decrease in flow happened after ١٥٠ minutes but this time the main cause is the evaporation and in order to correct the flow we add only (٢٠ ml.).

In Table ٤,٥ when the water/cement ratio was ٠,٧, It is seen that after ٣٠ minutes there will be decreasing in the flow of cement and we add only (١٠ ml.) in order to correct the flow of the cement mortar and this is (٨٠٪) less compared to the amount of water we added when the water/cement was ٠,٦, the lose in water is mainly due to the absorption of sand. Another

decrease in flow happened after ١٥٠ minutes but this time the main cause is the evaporation and in order to correct the flow we add only (٥ ml.).

٤,٢ Compressive Strength of Cement Mortar

٤,٢,١ Compressive strength of cement mortar without adding water

The results of the compression tests for the cement mortar are summarized in Tables ٤,١, ٤,٢ and ٤,٣ and in Figures ٤,١, ٤,٢ and ٤,٣. In general, for water/cement ratio equal to ٠,٥ it can be expected to have a compressive strength of cement mortar that molded after ٩٠ minutes after mixing within the limit of ٢٪ to ٦٪ less compared with those for corresponding original cement mortar (molded immediately after mixing). After ١٢٠ to ١٥٠ minutes of mixing time the compressive strength of cement mortar are ٤٪ t٠ ٩٪ higher than the compressive strength of the corresponding original mortar this was mainly because of water reduction due to the absorption of sand, but after ١٥٠ minutes the compressive strength of cement mortar were always lower than the compressive strength of the compressive strength corresponding original mortar the drop in compressive strength can reduced to percentage of ٣٨٪ when the mortar was molded after ٢٤٠ minutes.

For water/cement ratio equal to ٠,٦ the compressive strength of the cement mortar was always lower than the compressive strength of the corresponding original mortar. It can be expected to have a compressive strength of cement mortar that molded after ٦٠ minutes after mixing within the limit of ٣٣٪ to ٣٥٪ less compared with those for corresponding original cement mortar (molded immediately after mixing). After ٩٠ to ١٢٠ minutes of mixing time the compressive strength of cement mortar are ٢١٪ to ٢٤٪ less than the compressive strength of the corresponding original mortar this was mainly because of water reduction due to the absorption of sand, but after ١٥٠ minutes the compressive strength of cement mortar were extremely lower than the compressive strength of the compressive strength corresponding original mortar the drop in compressive strength can as lower as ٤٢٪ to ٤٨٪..

For water/cement ratio equal to ٠,٧ the compressive strength of the cement mortar was always lower than the compressive strength of the corresponding original mortar. It can be expected to have a compressive strength of cement mortar that molded after ٦٠ minutes after mixing within the limit of ١١٪ to ٢٧٪ less compared with those for corresponding original cement mortar (molded immediately after mixing). After ٩٠ to ١٥٠ minutes of mixing time the compressive strength of cement mortar are ١٣٪ to ٢٢٪ less than the compressive strength of the corresponding original mortar this was mainly because of water reduction due to the

absorption of sand, but after ١٨٠ minutes the compressive strength of cement mortar were extremely lower than the compressive strength of the compressive strength corresponding original mortar the drop in compressive strength can as lower as ٣٦٪ to ٤٩٪.

٤,٢,١ Compressive strength of cement mortar with adding water

The results of the compression tests for the cement mortar with adding water to correct the flow of cement mortar are summarized in Tables ٤,٤ and ٤,٥ and in Figures ٤,٤ and ٤,٥. In general the compressive strength of the cement mortar was always lower than the corresponding compressive strength of original cement mortar. For water/cement ratio equal to ٠,٦ the compressive strength of the cement mortar was always lower than the compressive strength of the corresponding original mortar. It can be expected to have a compressive strength of cement mortar that molded after ٦٠ minutes after mixing within the limit of ٢٠٪ to ٢٣٪ less compared with those for corresponding original cement mortar (molded immediately after mixing). After ٩٠ to ١٢٠ minutes of mixing time the compressive strength of cement mortar are ٢٣٪ to ٣١٪ less than the compressive strength of the corresponding original mortar this was mainly because of water reduction due to the absorption of sand, but after ١٥٠ minutes the compressive strength of cement mortar were lower than the compressive strength of the compressive strength corresponding original mortar the drop in compressive strength can as lower as ٢١٪ to ٢٦٪.

For water/cement ratio equal to ٠,٧ the compressive strength of the cement mortar was always lower than the compressive strength of the corresponding original mortar. It can be expected to have a compressive strength of cement mortar that molded after ٦٠ minutes after mixing within the limit of ٧٪ to ١٥٪ less compared with those for corresponding original cement mortar (molded immediately after mixing). After ٩٠ to ١٢٠ minutes of mixing time the compressive strength of cement mortar are only ٤٪ less than the compressive strength of the corresponding original mortar this was mainly because of water reduction due to the absorption of sand, but after ١٥٠ minutes the compressive strength of cement mortar were lower than the compressive strength of the compressive strength corresponding original mortar the drop in compressive strength can as lower as ١٢٪ to ١٧٪.

Table ٤,١: Flow and Compressive strength of cement mortar of water/cement ratio = ٠,٥

Mix designation	Time before molding (minutes)	Flow (%)	Compressive strength (MPa)	The ratio to the corresponding original mortar (%)

C٥	٠	٠ %	٢١,٣٧	١٠٠ %
C٥	٣٠	٠ %	٢٠,٣٢	٩٥ %
C٥	٦٠	٠ %	٢١,٠٥	٩٨,٥ %
C٥	٩٠	٠ %	٢٠,٠٨	٩٣,٩٦ %
C٥	١٢٠	٠ %	٢٣,٢٣	١٠٨.٧ %
C٥	١٥٠	٠ %	٢٢,٤٨	١٠٥,٢ %
C٥	١٨٠	٠ %	١٩,٨٥	٩٢,٨٩ %
C٥	٢١٠	٠ %	١٧,٠٦	٧٩,٨٣ %
C٥	٢٤٠	٠ %	١٣,٤٤	٦٢,٨٩ %

Table ٤,٢: Flow and Compressive strength of cement mortar of water/cement ratio = ٠,٦

Mix designation	Time before molding (minutes)	Flow (%)	Compressive strength (MPa)	The ratio to the corresponding original mortar (%)
C٦	٠	٤٠٪	١٧,٤٥	١٠٠ %
C٦	٣٠	٣٤ %	١١,٣٨	٦٥,٢١ %
C٦	٦٠	٣١ %	١١,٧١	٦٧,١١ %
C٦	٩٠	٦٪	١٤,٠٧	٨٠,٦٣ %
C٦	١٢٠	٥ %	١٣,٢٨	٧٦,١٠ %
C٦	١٥٠	٠ %	٩,٢٣	٥٢,٩٠ %
C٦	١٨٠	٠ %	٩,٦١	٥٥,٠٧ %
C٦	٢١٠	٠ %	١٠,٠٣	٥٧,٤٨ %
C٦	٢٤٠	٠ %	٩,٧١	٥٥,٦٤ %

Table ٤,٣: Flow and Compressive strength of cement mortar of water/cement ratio = ٠,٧

Mix designation	Time before molding (minutes)	Flow (%)	Compressive strength (MPa)	The ratio to the corresponding original mortar (%)
C٧	٠	٧٤ %	١٥,٣٦	١٠٠ %
C٧	٣٠	٦٤ %	١٣,٧٠	٨٩,٢٠ %
C٧	٦٠	٦١ %	١١,٢١	٧٣ %
C٧	٩٠	٦٠ %	١٣,٤٤	٨٧,٥٠ %
C٧	١٢٠	٦٠ %	١١,٩٤	٧٧,٧٣ %
C٧	١٥٠	٦٠ %	١٢,٠٢	٧٨,٢٥ %
C٧	١٨٠	٦٠ %	٧,٧٨	٥٠,٦٥ %
C٧	٢١٠	٥٥ %	١٠,١٢	٦٥,٨٨ %
C٧	٢٤٠	٤٠ %	٨,٣١	٥٤,١٠ %

Table ٤,٤: Flow and Compressive strength of cement mortar of water/cement ratio = ٠,٦ with adding water for correcting the flow.

Mix designation	Time before molding (minutes)	Flow (%)	Water Added (ml)	Compressive strength (MPa)	The ratio to the corresponding original mortar (%)
$C٦_w$	٠	٣٦ %	٠	١٣,٩٥	١٠٠ %
$C٦_w$	٣٠	٥٣ %	٥٠	١٠,٧٨	٧٧,٢٨ %
$C٦_w$	٦٠	٥٠ %	٠	١١,٠٩	٧٩,٥٠ %
$C٦_w$	٩٠	٤٩ %	٠	١٠,٧٠	٧٦,٧٠ %
$C٦_w$	١٢٠	٣٨ %	٠	٩,٦٨	٦٩,٣٩ %
$C٦_w$	١٥٠	٤٣ %	٢٠	١٠,٢٨	٧٣,٦٩ %
$C٦_w$	١٨٠	٣٦ %	٠	١٠,٩٢	٧٨,٢٨ %
$C٦_w$	٢١٠	٤٤ %	١٠	١١,٠٥	٧٩,٢١ %

$C٦_w$	٢٤٠	٤٢ %	٣٠	١٠,٧٨	٧٧,٢٨ %

Table ٤,٥: Flow and Compressive strength of cement mortar of water/cement ratio = ٠,٧ with adding water for correcting the flow.

Mix designation	Time before molding (minutes)	Flow (%)	Water Added (ml)	Compressive strength (MPa)	The ratio to the corresponding original mortar (%)
$C٧_w$	٠	١١١ %	٠	١١,٠٧	١٠٠ %
$C٧_w$	٣٠	١١٤ %	١٠	١٠,٣٢	٩٣,٢٢ %
$C٧_w$	٦٠	١٠٧ %	٥	٩,٣٤	٨٤,٣٧ %
$C٧_w$	٩٠	١١٦ %	٥	١٠,٦٢	٩٥,٩٣ %
$C٧_w$	١٢٠	١١١ %	٠	١٠,٥٩	٩٥,٦٦ %
$C٧_w$	١٥٠	١٠٢ %	٥	٩,١٧	٨٢,٨٣ %
$C٧_w$	١٨٠	١١١ %	٤٠	٩,٥٦	٨٦,٣٦ %
$C٧_w$	٢١٠	١١٣ %	١٠	٩,٢٠	٨٣,١٠ %
$C٧_w$	٢٤٠	١٠٣ %	٠	٩,٦٧	٨٧,٣٥ %

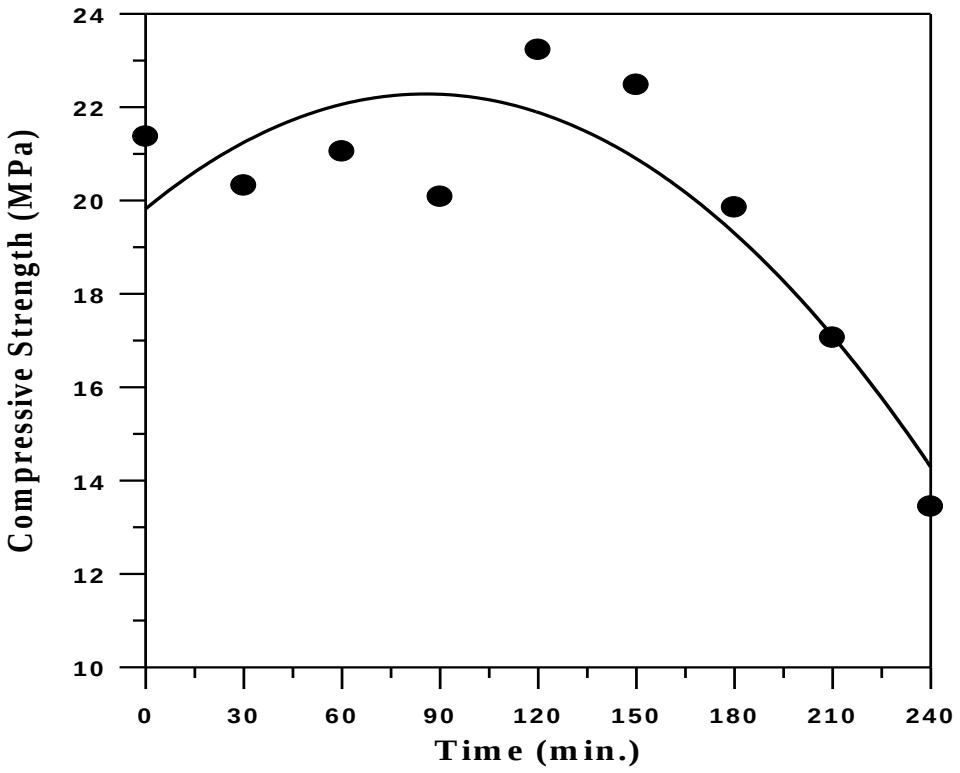

Figure ٤,١: Relationship between compressive strength and Time before molding for water/cement ratio = ٠,٥

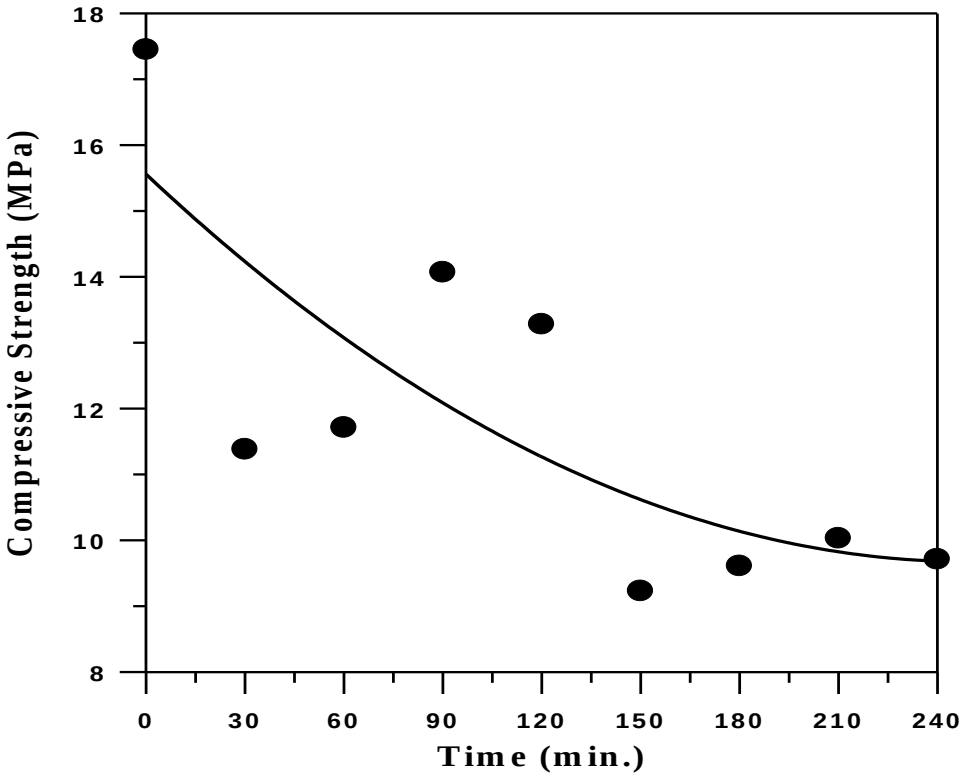

Figure ٤,٢: Relationship between compressive strength and Time before molding for water/cement ratio = ٠,٦

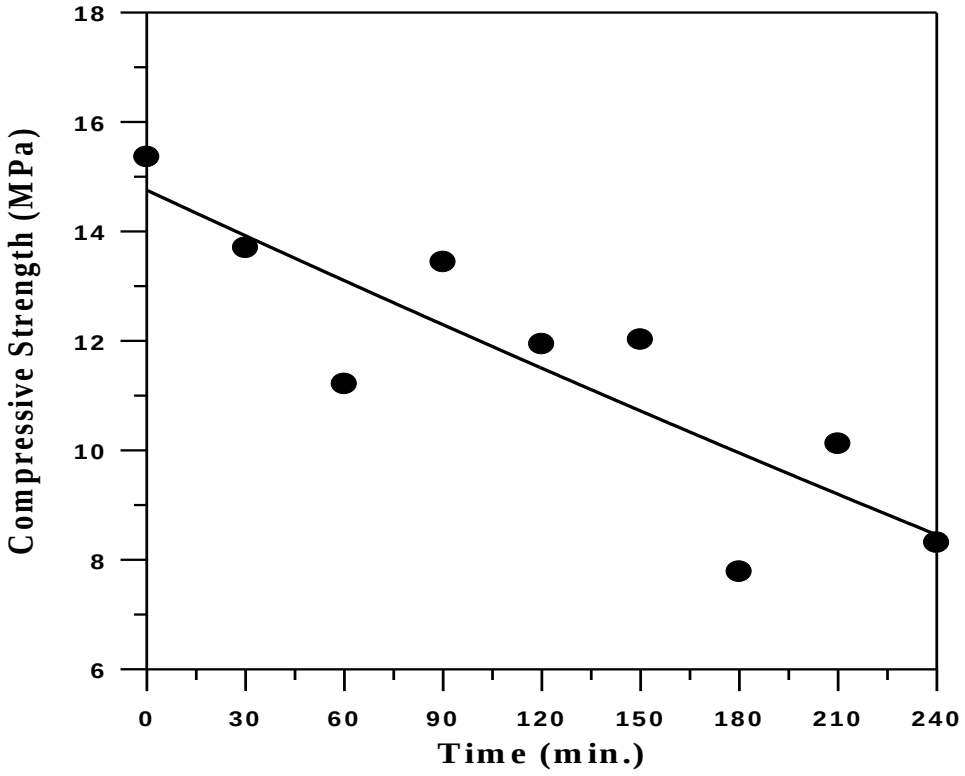

Figure ٤,٣: Relationship between compressive strength and Time before molding for water/cement ratio = ٠,٧

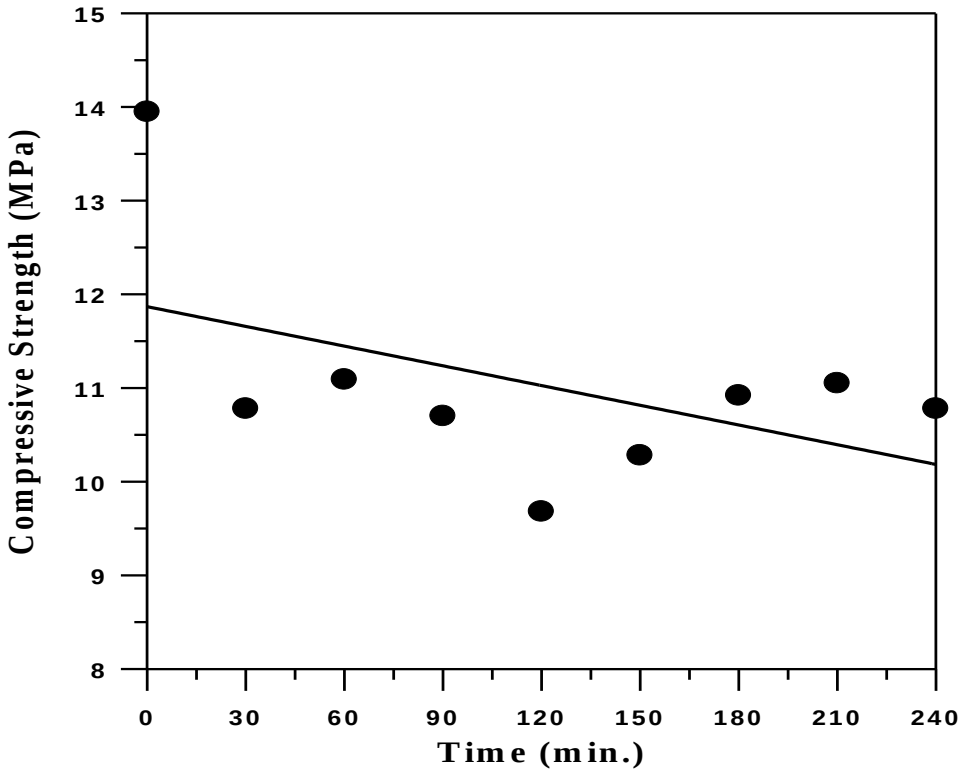

Figure ٤,٤: Relationship between compressive strength and Time before molding for water/cement ratio = ٠.٦ with adding water.

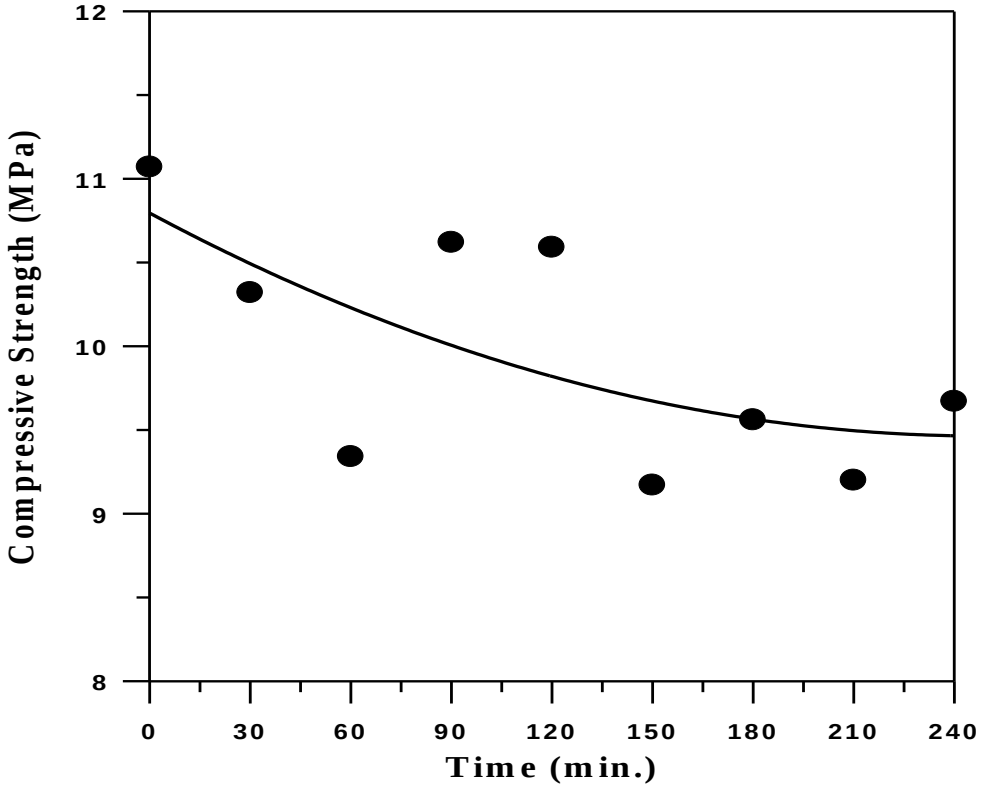

Figure ٤,٥: Relationship between compressive strength and Time before molding for water/cement ratio = ٠,٧ with adding water.

٥. Conclusions

Based on the results of experimental work done in this study, the following conclusions were deduced:

١- The flow of cement mortar will drop significantly with time and additional water was needed to correct the flow of cement mortar compared to reference cement mortar.

٢- The ideal water to cement ratio for cement mortar was ٠,٥, in which only ١٠٪ reduction in compressive strength was obtained after ١٥٠ minutes of mixing cement with water and the compressive strength will decreases as low as ٣٨٪ lower than the compressive strength of original mortar after ٢٤٠ minutes as the worse case.

٣- The reduction in compressive strength of cement mortar may be as low as ٥٠٪ compared to the original cement mortar after ١٥٠ minutes of mixing cement with water.

٤- It was found that the best time for using cement mortar is no more than ١٥٠ minutes from adding water to the cement.

References

[١] American Society for Testing and Materials, "Standard Specification for Portland Cement", Annual Book of ASTM Standards, Vol. ٠٤,٠١, ٢٠٠٣, C١٥٠-٠٢a.

[٢] American Society for Testing and Materials, "Standard Specification for Concrete Aggregates", Annual Book of ASTM Standards, Vol. ٠٤,٠٢, ٢٠٠٣, C٣٣-٠٣.

[٣] American Society for Testing and Materials, "Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency ", Annual Book of ASTM Standards, Vol. ٠٤,٠١, ٢٠٠٣, C ٣٠٥ – ٩٩.

[٤] American Society for Testing and Materials, "Standard Specification for Flow table for use in tests of hydraulic cement ", Annual Book of ASTM Standards, Vol. ٠٤,٠١, ٢٠٠٣, C ٢٣٠/C ٢٣٠M – ٩٨.

[٥] American Society for Testing and Materials, "Standard Test Method for Flow of Hydraulic Cement Mortar", Annual Book of ASTM Standards, Vol. ٠٤,٠١, ٢٠٠٣, C ١٤٣٧ – ٠١.

[٦] American Society for Testing and Materials, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using ٢-in. or [٥٠-mm] Cube Specimens", Annual Book of ASTM Standards, Vol. ٠٤,٠١, ٢٠٠٣, C ١٠٩/C ١٠٩M – ٠٣.