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EFFECT OF CERAMIC POWDER (CP) ON COMPRESSIVE STRENGTH AND DRYING SHRINKAGE CRACKS OF CEMENT MORTAR

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ABSTRACT

This investigation is conducted to study the effect of addition of ceramic powder (CP) on drying shrinkage cracks and compressive strength of cement mortar. Steel molds having a trapezoidal section, and the end restrained at square shape used to study restrained drying shrinkage of cement mortar. Specimens of compressive strength, density, were cast. The admixture (CP) was used as addition with three levels of (2%, 4% and 8%) by weight of dry cement. All specimens were cured for (14 days). Average of six results was taken for any test of compressive strength and density. The experimental results showed that the adding of this admixture cause a delay in a formation of cracks predicted from a drying shrinkage, increase compressive strength at levels of (4%) of admixture and cause the decreasing in the density of cement mortar Specimens. The increment in compressive strength at level (4%) was (6.11%), but at level of (8%) it was decreased by (3.9%). The admixture has the visible effect in delay of the information of shrinkage cracks and decrease of its numbers.

KEYWORDS: Ceramic powder, Compressive strength, drying shrinkage cracks, cement mortar and Density.

تأثير مسحوق السيراميك على مقاومة الانضغاط وتشققات انكماش الجفاف لمونة السمنت

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الخلاصة

هذه الدراسة تهدف الى دراسة تأثير اضافة) مسحوق السيراميك (على تشققات انكماش الجفاف ومقاومة الانضغاط لمونة السمنت، في هذه الدراسة تم استخدام قوالب حديدية بمقطع على شكل شبه منحرف بطول 2.5 متر ومن نهايتيه قالب بشكل مربع لغرض تقييد النموذج لضمان حدوث) تشققات انكماش الجفاف (لمونه السمنت وأيضاً تم صب نماذج لغرض تعيين مقاومة الانضغاط والكثافة .استخدمت ثلاث نسب مئوية من (مسحوق السيراميك)وهي 2%) و 4% و (8% من الوزن الجاف للسمنت تم انضاج النماذج جميعاً بفترة إنضاج (14 يوم .)تم اخذ معدل ستة نتائج لكل فحص من مقاومة الانضغاط والكثافة .أوضحت النتائج العملية أن إضافة هذا المضاف يؤخر حدوث التشققات الناتجة من) انكماش الجفاف) وتزيد من مقاومة الانضغاط عند النسبة (4%) وتقلل الكثافة عند كل النسب للمضاف (CP) وان مقدار الزيادة في مقاومة الانضغاط عند النسبة (4%) هي,(6.11 %) ولكنها تقلل من مقاومة الانضغاط عند النسبة (8%) بمقدار (3.9%) ولها تأثير قليل في تأخير حدوث) تشققات الانكماش)وتقلل من عددها .

1. INTRODUCTION

In order to recycle different materials wastes many attempts have been made recently to use the construction waste material such as sustainable concrete components or some raw materials in the concrete or cement mortar mixture. Also to reducing or preventing, environmental harms arising from the chemical reaction (as a side effect) such as Alkali Silica Reaction (ASR), which resulting from the lead and Boron Silicate. Debris of ceramic construction work is available so this investigation is an attempt to study of using it with cement mortar mixture to known the effects on shrinkage cracks for cement mortar, whereas concrete or cement mortar cracks in drying conditions. High fineness of (CP) considers as a pozzalanic materials.

Pincha and Arnon, 2010, investigated the effect of using Portland cement and fly ash and fine aggregate from the ceramic waste on the workability and compressive strength. They found that the compressive strength increases with increasing ceramic waste content up to (100%) in the fly ash concrete and the workability remained sufficient while reduced for the Portland cement concrete closed to zero slumps. In addition, they found that the compressive strength for the ceramic waste concrete was increased and the optimum content of the ceramic waste at (50%), then decreasing with the increasing of ceramic waste content. Therefore, they confirmed the advantages of using ceramic waste in concrete containing as fine aggregate.

Maria and Andrea, 2012, verified that ceramic waste as aggregate and supplementary cementing material had a combined action to contrast alkali silica reaction (ASR). The combined action of the investigated wastes has become clear due to the expansion tests carried out in accelerated conditions together with mechanical and microstructure characterizations of mortar. They shows that the porcelain stoneware polishing residue mixed with the cement can be effectively exploited as valid alternative to pozzolan cement.

Hanifi, 2007, used the crushed ceramic (CC) and basaltic pumice (CBP) as fine aggregates in concrete mortars and studies its effect on the mortar properties. He observed that minimum abrasion rate was obtained from M3 (60% crushed ceramic concrete) specimens while the maximum abrasion rate obtained from specimen control (M0). The results show that decreasing the crushed ceramic causing increasing in the abrasion resistance. In addition, the compressive strength and crashed ceramic and basaltic pumice content strongly impressed on the abrasion resistance of concrete. So the crushed ceramic and basaltic pumice could be easily used to increase the compressive strength for the concrete and to decrease the abrasion for it and the crushed ceramic addition percentage decreased as the chloride penetration depth increased.

Hiroshi et al., studied the Chloride ion penetration into mortar containing ceramic waste aggregate. Results state that the CWA mortars are more effective in the resistance of chloride ion penetration than a typical mortar made of river sand. They verified that the effective chloride diffusion coefficient in the river sand mortar is higher than that in the CWA mortars when either the amount of the CWA is increased or the particle size of the CWA is decreased.

Durgun et al., 2012, studied the influence of the incorporating blast furnace slag and ground basaltic pumice as fine aggregates. It was observed that the ultimate load of specimens depends on the type and percentage of admixtures. The maximum ultimate load was obtained in concrete specimens containing 5% blast furnace slag and 5% ground basaltic pumice, which was 20% larger than that of the reference concrete specimens. Furthermore, concrete specimens with 10% ground basaltic pumice were found to have the highest sulfate resistance.

Senthamarai and et al., 2010, investigated the durability properties for the concrete made from ceramic industry wastes. They compared the results with the conventional concrete and they found not much change in the basic trend of permeation characteristics of this recycled aggregate concrete. Only the permeation characteristic values were higher for the recycled aggregate concrete than those for the conventional concrete and decreased when the cement water ratio decreased for both concrete mixtures.

P., Sandor, 1982, state that usually admixtures are classified according to their major purpose of use and they are used to improve the concrete or mortar properties and make them more suitable for hand working and economy or such other purpose as saving energy. In many cases, very high strength, resistance to freezing and thawing, delay and acceleration.

Cengiz, 2004, used the Afsin – Elbistan FA as a shrinkage reducing agent that its reduced drying shrinkage of the mortar by 40%. Romild D. et al., 2005, study the influence of using vegetable fibers as reinforced for the cement mortar on its free restrained and dry shrinkage. They adjust an equation using the recommendation of ACl mode B3 based on the obtained results on drying shrinkage and compared widely with the obtained experimental data. A. Naceria and et al., 2009, shows that the variation of the physic and chemical properties of the cement tested was mainly affected by the quantity of pozzalanic admixture (waste brick) in cement manufactured.

2. EXPERIMENTAL WORKS

2.1. Materials

2.1.1. Cement

Ordinary Portland cement (Type 1) from Al-kouffa cement factory used for cement mortar mixes. This cement conformed to the Iraqi specification (IOS NO 5-1984). The physical and chemical properties are given in Tables 1 and 2.

Table 1. Physical properties of the OPC used.

Physical properties	**Test Result**	**I.O.S.NO5: 1984**
Fineness, blain test (m^2/kg)	330	≥ 230
Sitting time, Vicat's method		
Initial hrs:min	1: 22	≥ 00:45
Final hrs:min	2: 33	10: 00
Compressive strength of 70 mm Cube (MPa)		
3day	19.8	≥ 15
7day	29	≥ 23
Soundness %, (Auto clave) method	0.45	≤ 0.8

Table 2. Chemical properties of OPC used.

Oxide	**(%)**	**I.O.S. NO5: 1984**
CaO	61.93	-
SIO_2	23.0	-
Al_3O_3	5.1	-
Fe_2O_3	3.66	-
MgO	3.87	$\leq$5%
SO_3	2.44	$\leq$2.8%
L.S.F	0.93	0.66 – 1.02
L.O.I	1.76	$\leq$4%
I.R	0.91	$\leq$1.5 %
Compounds Composition	**(%)**	**I.O.S. NO5: 1984**
C_3S	37.0	-
C_2S	30.8	-
C_3A	9.09	-
C_4AF	10.51	-

2.1.2. Fine Aggregate

Natural sand form Al- Akhaidur was used. It is grading and other characteristics conformed to the Iraqi specification (IOS NO45- 1984) as shown in Table 3.

Table 3. Properties of the sand used.

Sieve size (mm)	Percent passing (%)	(I.O.S. NO45 : 1984)
9.5	100	100
4.75	100	90-100
2.36	88	85-100
1.18	85	75-100
0.6	68	60-74
0.3	14	12-40
0.15	6	1-10
Impurities content	2.1	$\leq$ 3
Sulphate content SO_3	0.09	$\leq$ 0.05
Fineness modules	2.39	-

2.1.3. Admixture (Ceramic Powder)

The admixture (CP) was brought form ceramic used for walls from one of the buildings in Hilla city. This dust was predicted from the crushing and softening by Los Angeles device and it is brown in color and sieve analysis are shown in Table 4. Ratios of the materials constituents the ceramics are shown in Table 5 and

Table 4. Grading of Ceramics Powder.

Sieve size (mm)	Percent passing (%)	I.O.S. NO45 : 1984
9.50	100	100
4.75	100	90-100
2.36	100	85-100
1.18	88	75-100
0.60	67	60-79
0.30	32	12-40
0.15	8	0-10

Table 5. The percentage limits of constituents materials for ceramics.

Substance	Ratio, (%)
Kaolin	25-35
Hydrated Aluminum Silicate	10-20
Quartz Sand (Silica)	15-35
Feldspar or Nepheline Syenite	4-15
Secondary substance that helps melting	0-3
Colors and Coating materials	5

2.2. Molds

The molds used in this study are as follows:

- Channel shape steel molds having a Trapezoidal section, (2500) mm in length, dimension of section (80, 50, 60) mm (top base, bottom base, height) respectively, as shown in Plate 1. This frame used to study shrinkage cracking of end (restrained cement mortar specimens).
- (50 * 50 * 50) mm cube steel molds of cement mortar specimens for compressive strength test. For the Trapezoidal section steel mold, a layer of polyethylene sheets was put over the mold base after cleaned and carefully oiled to minimize base friction with shrinkage specimens of cement mortar.

2.2.4. Mix design

The cement mortar mix designed according to (ASTM C270-14a). The quantities of the materials for cement mortar are as follows:

Mix proportions	1 : 3 (cement : sand)
W/C ratio	0.10 (by weight of (cement + sand))

Cement (kg/m^3)	***Sand (kg/m^3)***	***Water (kg/m^3)***
560	1680	224

Plate 1. Channel shape steel molds.

2.3. Curing

Wet hassian sheet and polyethylene sheets were used to cover the surface of shrinkage specimens after casting to prevent plastic shrinkage cracking due to rapid evaporation from the upper surface of specimens. The chosen period of curing time is (14 days). Compressive strength specimens put in water at (22°C) for (14 days) after covered with polyethylene sheets.

2.4. Testing

2.4.5. Drying shrinkage Test

This test was done according to (ASTM C1581M-09a). Cement mortar specimens were tested for restrained shrinkage cracking. The end of the mold offers an end- restraint to the web, which would be formed as result of the stresses induced from concrete shrinkage. Reading was taken at the occurrence of crack, till when no movement could be recorded. A crack dial microscope took in the reading for the crack width each (7 days). Results average for two specimens for each mix was taken.

2.4.6. Compressive strength Test

This test was done according to (ASTM C109/C109M-13). The specimen’s surfaces should be dried from the excess water after taken out from water tank and kept in the laboratory for two minutes to obtain saturated dry surface specimens before testing. Average for six results was taken for each mix except for drying shrinkage specimens, that it was two for each mix.

3. RESULTS AND DISCUSSION

3.1. Shrinkage Cracks test

From Table 6 and Figs. 1, 2, 3 and 4 it can be seen that the effect of admixture on drying shrinkage cracking was different depending on the admixture content. The measurement of crack width for all specimens was achieved by portable dialed microscope, which shown in Plate 2 every (7 days) at early ages and the different periods at later ages. The first crack time for each specimen was recorded to evaluate the improvement in cement mortar shrinkage cracking. A clear influence in cracking time was caused for admixture at level (8%) compared with control specimens.

Ceramic powder (CP) is classifying as a very soft material, thus achieved a wide surface area, and it is can cover the gel granules with high efficiency and cause reduction in the surrounding water. This will contribute to reduce the water out of the inner layers of the capillary pores and thus delays the growth of cracks resulting from mortar shrinkage.

Plate 2. Portable Dialed Microscope.

AL- Khalaf, 1983, state that, cracking time increase when admixture are used but in other side these admixtures have a property they have a high surfactant effect, forming air voids in concrete during the mixing process, and thus the concrete strength is reduced.

Al-Nassar, 2002, generally, the crack width development is slower with age progress when admixtures were added compared with control mix. This can be considered, as an advantage reflection of using some admixture, as reducing crack width is very important from durability point of view because it is effect for structural action of the member.

Table 6. Crack development and crack width for cement mortar specimens made with and without of admixture (CP) at drying period (150 days)

Control Specimens (CP)	**Drying period (days)**	7	14	21	28	45	58	70	83	105	150
	Crack width (mm)	0.23	0.49	0.50	0.59	0.63	0.649	0.656	0.659	0.659	0.659
Specimens with admixture contains (2%)(CP)	**Drying period (days)**	12	19	24	31	45	58	70	83	110	150
	Crack width (mm)	0.27	0.44	0.56	0.63	0.65	0.659	0.66	0.667	0.667	0.667
Specimens with admixture contains (4%)(CP)	**Drying period (days)**	30	37	44	56	62	70	86	110	150	
	Crack width (mm)	0.20	0.31	0.42	0.51	0.54	0.55	0.56	0.56	0.56	
Specimens with admixture contains (8%)(CP)	**Drying period (days)**	60	68	75	90	110	150				
	Crack width (mm)	0.24	0.35	0.38	0.397	0.397	0.397				

From the Table 6 and Figs. 1, 2, 3 and 4, it can be seen that the specimens with admixture are delay of occurrence of crack and decreased of its width, especially at level of (8%) for the admixture content.

Al-Rawi, 1985, the position of crack occurred within the middle third of cement mortar specimen rather than at the side thirds. This means that the higher restrained shrinkage strain is at the middle of the specimen rather than at the sides. This behavior is attribute to the growth of a strain gradient at the end, which increases the restraint loss and reduces the possibility of cracking, while at interior, higher strain would be developed due to the buildup of friction forces and the absence of strain gradient, so cracks would be expected to initiate at the interior regions of member.

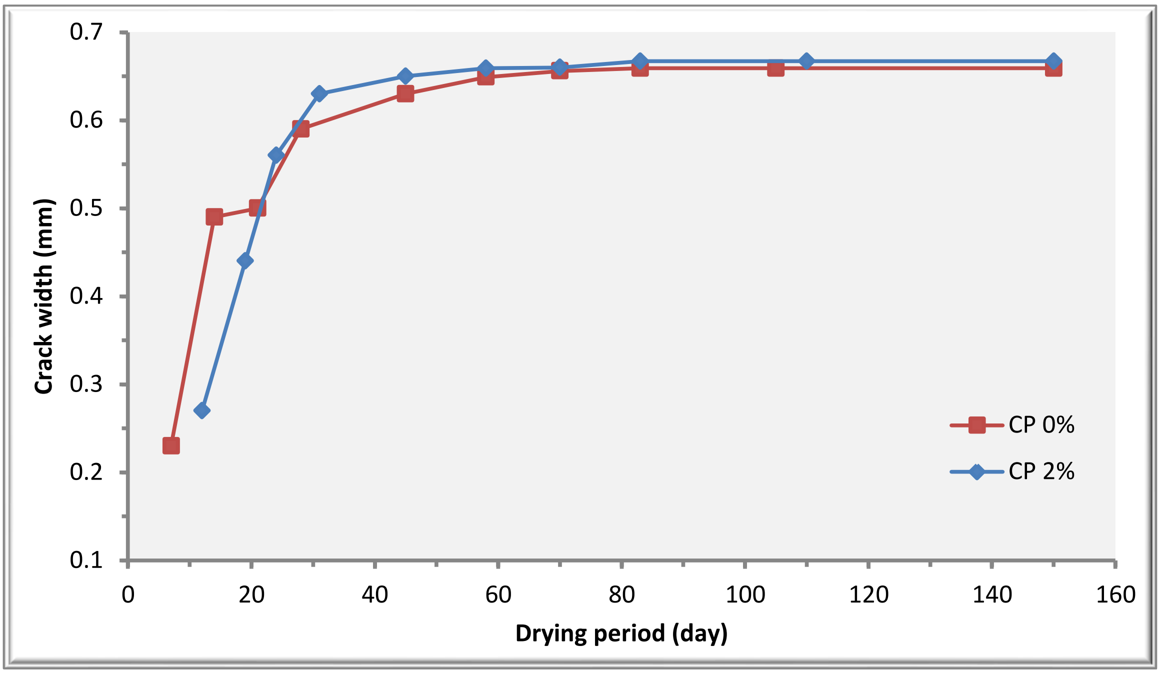

Fig. 1. Crack width development for specimen with admixture (CP) at level (2%)

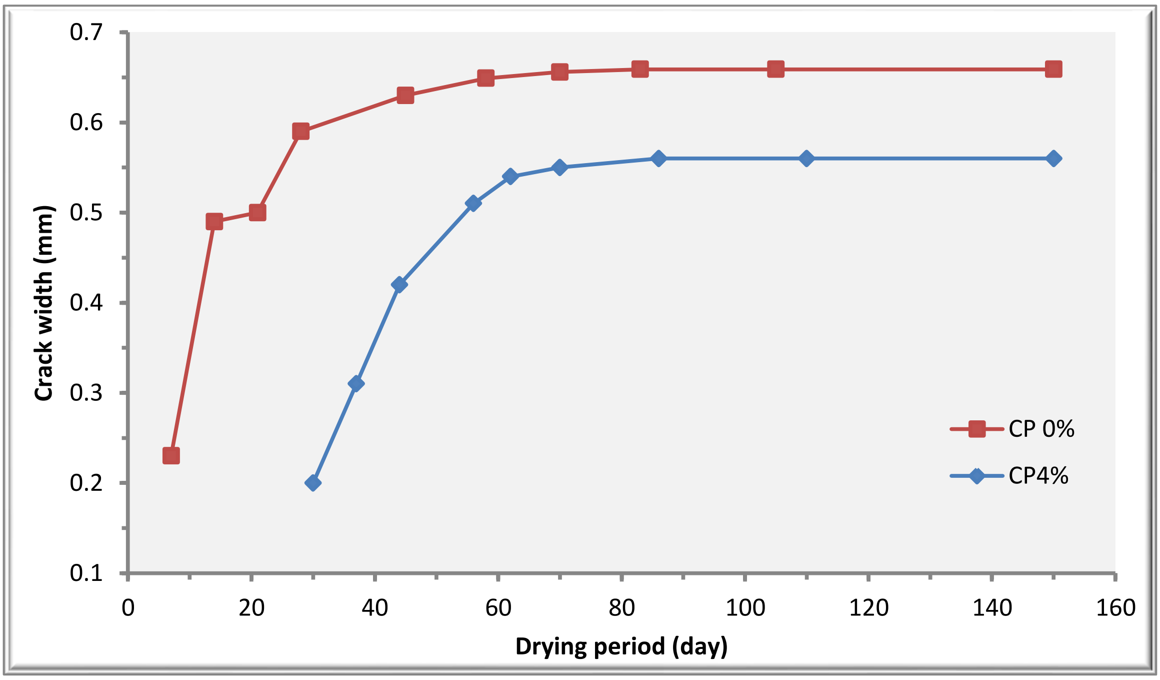

Fig. 2. Crack width development for specimens with admixture (CP) at level (4%)

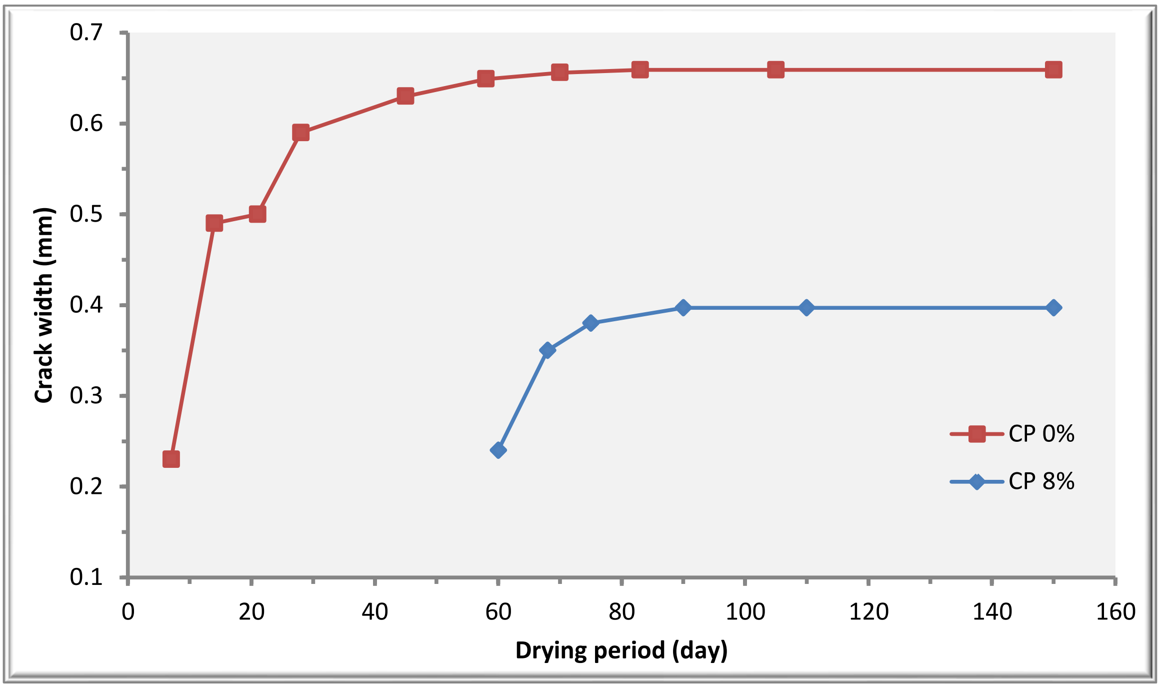

Fig. 3. Crack width development for specimens with admixture (CP) at level (8%)

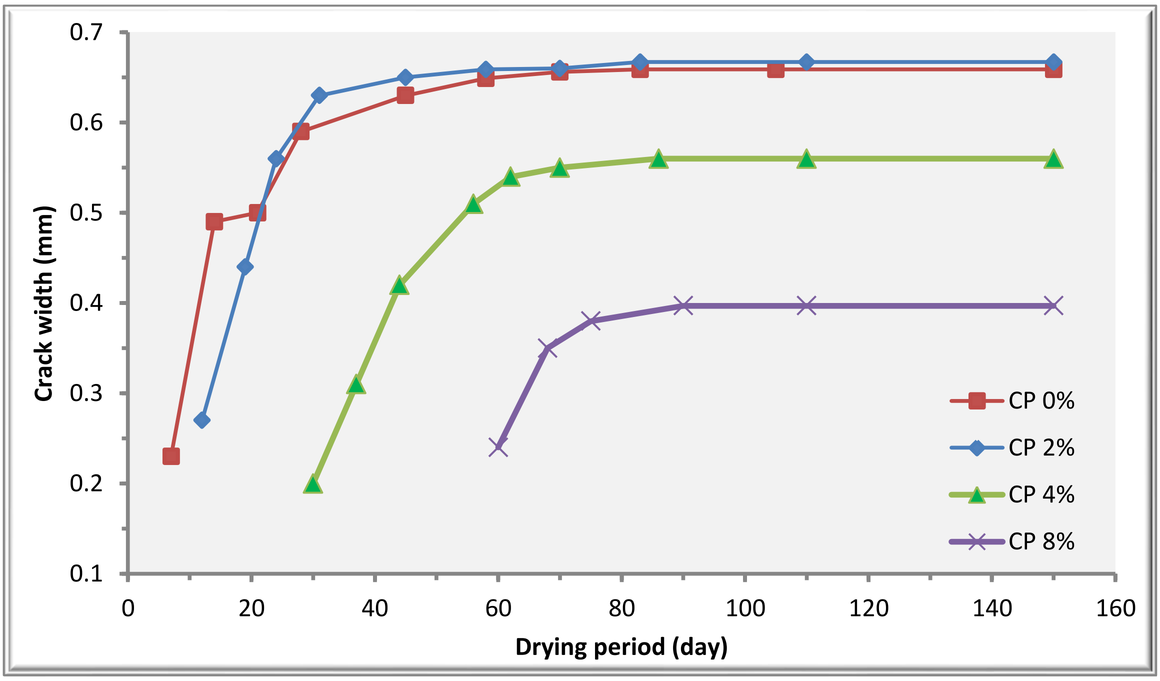

Fig. 4. Crack width development for specimens with and without admixture contents (CP)

3.2. Compressive Strength Test

The results of the compressive strength tests of specimens with and without admixtures are given in Table 7 and Fig. 5. Results illustrate that the increase of admixture (CP) addition increases the compressive strength up to level (8%). There was a reduction of about (3.91%). AL-Khalaf, 1983, The reduction of water powder ratio (W/P) can be attributed of the increasing of compressive strength, that due to absorption of these fine particle to water content, and the effect of their fineness and large surface area, cement mortar density. Especially at early age, and that can be attributed to the accelerated hydration cement paste. The cause of the reduction in compressive strength at level (8%) was due to the high fineness, high absorption of water and the large amount of this admixture, which leads to lack in hydration action and presence of air voids in cement mortar structure. Table 8 and Fig. 6 showed that, reduction in the density of specimens especially at level (8%).

Table 7. Compressive strength test results for the cement mortar specimens made with and without (CP).

Mixes symbol	Admixture content (by weight of cement) %	Compressive strength at age (14 days) MPa	Change in compressive strength for specimens contains (CP) compared with control specimen %
*M0	0	24.55	-
**CPM2	2	24.57	-
***CPM4	4	26.05	+ 6.11
****CPM8	8	23.59	-3.91

* cement mortar mix without (CP).
** cement mortar mix with (CP) at level 2%.
*** cement mortar mix with (CP) at level 4%.
**** cement mortar mix with (CP) at level 8%.

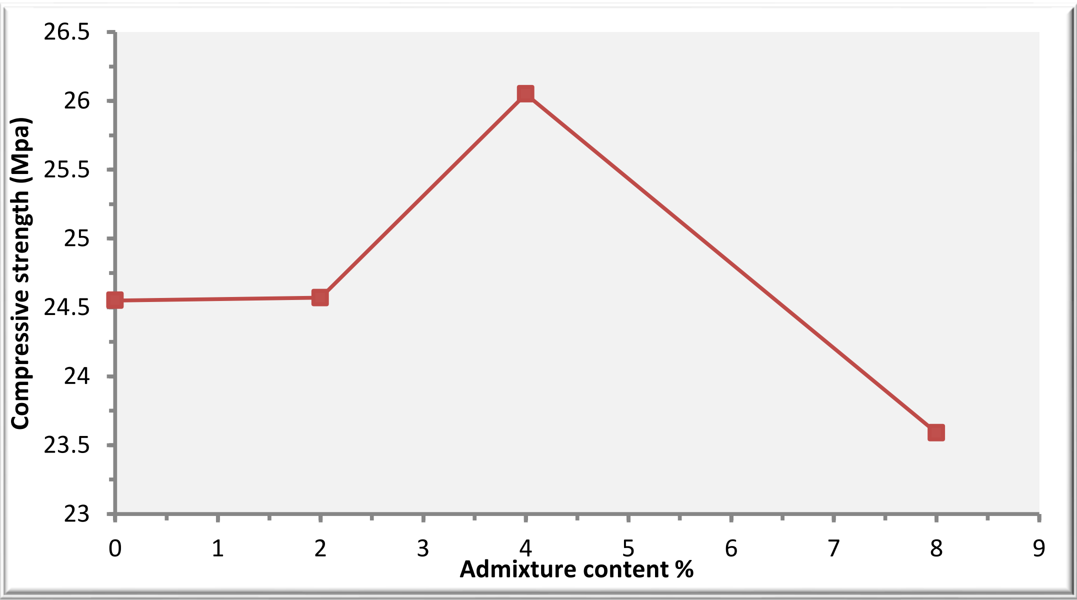

Fig. 5. Effect of admixture contents (CP) on compressive strength of cement mortar specimens

Table 8. Density test results for the cement mortar specimens made with and without (CP)

Mixes symbol	Admixture content (by weight of cement) %	Density g/cm^3	change in density for specimens contains (CP) compared with control specimen %
*M0	0	2.250	-
**CPM2	2	2.238	- 0.53
***CPM4	4	2.236	- 0.622
****CPM8	8	2.221	- 1.288

* cement mortar mix without (CP).
** cement mortar mix with (CP) at level 2%.
*** cement mortar mix with (CP) at level 4%.
**** cement mortar mix with (CP) at level 8%.

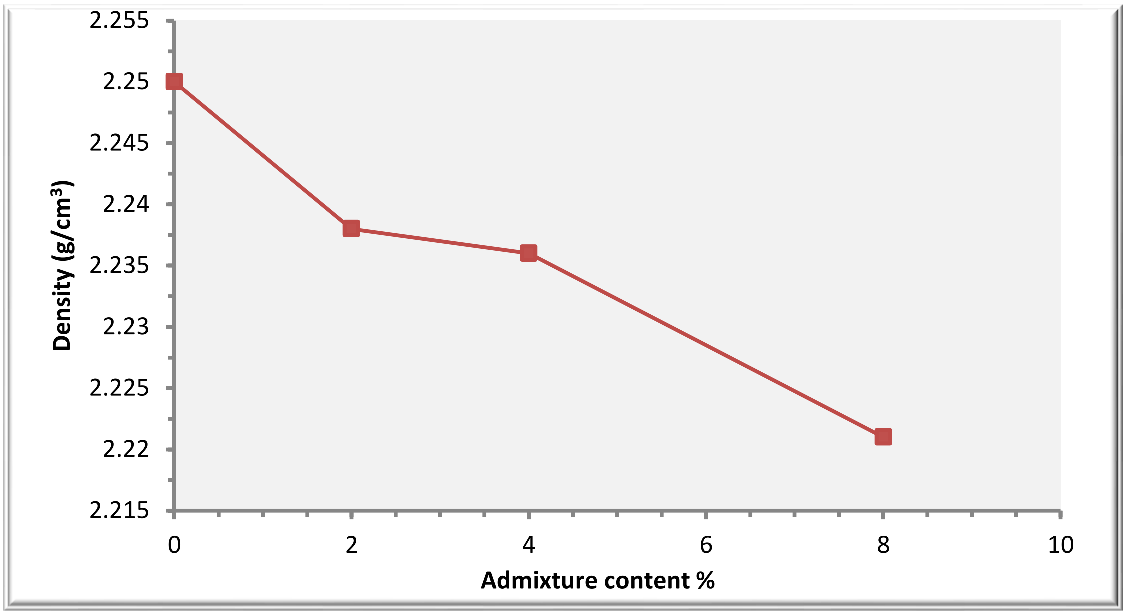

Fig. 6. Effect of admixture contents (CP) on density of cement mortar specimens

4. CONCLUSIONS

- The drying shrinkage cracking development of cement mortar is attached by amount of (CP).
- For all cement mortar specimens containing different contents of (CP), first crack width is lower than of the control specimens.
- The cracking time increases with the increase of the (CP) content, especially at highest admixture content. The increasing is 17% for level 2% (CP) and 757% at level 8% (CP).
- The development of crack width for specimens with (CP) is lower than that of control specimen. The drawdown is 39.7% at level 8%.
- Adding of (CP) content increasing the compressive strength, but high contents of (CP) decreased it. The increasing is 6% at level 2% (CP) and decreasing to 3.9% at level 8% (CP).

- The addition of (CP) for cement mortar specimen is delaying the occurrence of cracking for 53 days at level 8% (CP) comparing with control mix.
- No obvious effect on cement mortar specimen's density when the (CP) admixture was added at any ratio.

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