Effect of Partial Replacement of Cement by Hydrated Cement on Properties of Cement Paste and Cement Mortar

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Abstract

This work study the effect of partial replacement of cement by hydrated cement on some properties of cement paste and cement mortar such as normal consistency, initial and final setting time, compressive strength, and length change. The results show that pastes containing hydrated cement require more water than reference paste to give normal consistency. The results also show that the replacement by hydrated cement delay the initial and final setting time of cement paste. The delay in setting time increased with increasing the partial replacement by hydrated cement.

Compressive strength test was carried out on (54) cubes of (50) mm side dimensions of mortars containing (5, 10, 15, 20, and 25%) of hydrated cement at (3, 7, and 28) days. They were then compared with reference mortar. The compressive strength results show that the compressive strength decreases with increasing the replacement percentage by hydrated cement at all ages. The decreases in compressive strength reached (23.05 %) when (25%) of cement was replaced by hydrated cement in (28) days.

The results also show that the replacement of cement by hydrated cement increases the length change of mortars compared with reference mortar.

Key Words: Cement, Hydrated cement, Cement storage, Setting time, Compressive strength, Length change.

تأثير التعويض الجزئي للسمنت بسمنت متميئ على خواص عجينة السمنت ومونة السمنت

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الخلاصة

تضمن هذا البحث دراسة تأثير استخدام السمنت المتميئ كنسبة من وزن السمنت على بعض خواص عجينة ومونة السمنت في المرحلتين الطرية وما بعد التصلب مثل القوام القياسي وزمن التجمد الابتدائي والنهائي ومقاومة الانضغاط والتغير في الطول. لقد تبين ان عجينة السمنت الحاوية على السمنت المتميئ تحتاج إلى كمية ماء اكبر مما تتطلبه العجينة القياسية للحصول على القوام القياسي، وهي ايضاً تؤدي الى تأخير زمن التجمد الابتدائي والتصلب النهائي لعجينة السمنت وان مقدار التأخير يزداد بزيادة مقدار تعويض السمنت المتميئ.

تم في هذا البحث ايضاً فحص(٥٤) مكعب مقاس (٥٠) ملم لمقاومة الانضغاط للمونة الحاوية على (٥ ، ١٠، ١٥، ٢٠ و ٢٥%) من السمنت المتميئ ومقارنتها بالمونة القياسية بأعمار (٣ ،٧، و٢٨) يوم وقد

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بينت النتائج ان مقاومة الانضغاط تقل بزيادة نسبة التعويض بالسمنت المتميئ ولجميع الاعمار، حيث بلغ مقدار النقصان بمقاومة الانضغاط بحدود (٢٣.٠٥ %) عند نسبة تعويض مقدارها (٢٥%) بعمر (٢٨) يوم.اما بخصوص فحص التغير بالطول فقد بينت النتائج ان التغير بطول النموذج يزداد بزيادة نسبة التعويض بالسمنت المتميئ ولجميع الاعمار مقارنة بالخلطة المرجعية الخالية من السمنت المتميئ.

1. Introduction

Cement, when protected from moisture and air, can be stored for months without deterioration. Moisture causes prehydration, and carbon dioxide causes carbonation, both of which result in gradual loss of desirable properties of the cement. Cement, when used, should be free-flowing and completely free of lumps. Sometimes cement that has been in the lower bags of large piles for a considerable period assumes a "warehouse pack or set," that is, it appears to be hardened. The presence of lumps that cannot be pulverized readily in the hand, however, is an indication that moisture has been absorbed. Such cement can be used for unimportant work by screening out the lumps (Concrete Manual, 2000).

Damage is indicated by lumpiness, increase in loss of ignition, reduction in specific surface or falling off in strength particularly in early strength (Popovics, 1979).

The cement when stored for long periods of time loses its strength characteristics. The strength of cement when used after one year of its production loses its strength by about (40-50) % on application as compared to that of freshly produced cement (Cement Storage, 2000).

2. Previous Researches

Cement is a very finely ground material. It is highly hygroscopic. It absorbs moisture which may be in the form of free water or moisture from air. The contact of moisture with cement spoils it (Handoo and Puri, 1995).

Old cement is rarely a problem with bulk cement in the modern batching plant except when it is allowed to accumulate on the sides of the silo if the silo is not drained every few months. Old cement containing lumps that can be broken with reasonable pressure between the fingers can be used, but hard lumps surely cause low strength. There have been reports of cement losing strength at rates ranging from one half of 1 percent to 5 percent per month when exposed to moist conditions due to improper storage (Concrete Manual, 2000).

Various studies have been made between cement storage time and strength, whose results show that after storing the cement for 3, 6, 12, 24 months, the strength decreased by 20, 30, 40, 50 %, respectively (Gurcharan, 1986).

(Ahmed, 1991) submitted a paper showing that the effectiveness of hydrated cement can be obtained in fineness of 6250 cm^2/gm (Blain method). The results show a decrease in compressive

strength of concrete when up to 40 % cement is partially replaced by hydrated cement. Further amount does not result in noticeable further reduction.

(Jaber, 2005) investigated the effect of hydrated cement content as a partial replacement of cement on compressive strength, drying shrinkage and swelling of cement mortar. The investigation also extended to evaluate the structural performance of clay brick walls built from hydrated cement mortar as a binding material. His test results show that the compressive strength of mortar decreases gradually with increase of the hydrated cement content in the mix, and for all ages. The results also show that up to 30 % replacement can be made with no significant change in compressive strength compared with control mix. The rate of shrinkage increases with increase of the hydrated cement content in the mix. The percentage of increases in drying shrinkage at the age of 180 days was 13.2 % for 30 % hydrated cement compared with those of the corresponding plain mortar. Also the rate of swelling increases with increase in the hydrated cement content in the mix and the percentage of increases in swelling at the age of 180 days was 9.8 % for 30 % hydrated cement compared with those of the corresponding plain mortar.

3. Materials

3.1. Cement

Ordinary Portland cement type (I) from (Tasluja) Factory has been used in this work. The chemical composition and physical properties of cement are shown in Tables (1) and (2) respectively. Test results indicate that the adopted cement conforms to the Iraqi specification No.5/1984(I.Q.S No. 5:1984).

Table 1.Chemical composition and main compounds of cement *.

Oxide composition	Abbreviation	Content (percent)	Limit of Iraqi Specification No.5/1984
Lime	CaO	62.96	-
Silica	SiO_2	21.10	-
Alumina	Al_2O_3	5.12	-
Iron Oxide	Fe_2O_3	3.15	-
Magnesia	MgO	2.24	≤5.0%
Sulfate	SO_3	2.30	≤2.8%
Loss on Ignition	L. O. I.	2.42	≤4.0%
Insoluble residue	I. R.	1.03	≤1.5%
Lime saturation	L. S. F.	0.91	0.66-1.02
Main Compounds (Bogue's equations)			
Tricalcium Silicate	C_3S	50.43	-
Dicalcium Silicate	C_2S	22.45	-
Tricalcium Aluminate	C_3A	8.24	-
Tetracalcium alumino-Ferrite	C_4AF	9.58	-

Table 2.Physical properties of the cement *.

Physical properties	Test results	Limits of Iraqi Specification No.5/1984
Specific surface area (Blaine method), m^2/kg	290.5	≥ 230
Soundness (Le-Chateler) method, mm	2.0	≤10
Setting time (Vicat's apparatus) Initial setting time, hrs: min. Final setting time, hrs: min.	 2:25 3:15	 ≥ 45 min ≤ 10 hrs
Compressive strength 3days, N/mm^2 7days, N/mm^2	 24.1 35.4	 ≥ 15 ≥ 23

*Chemical and physical tests were made by the National Center for Construction Laboratories and Researches (NCCLR).

3.2. Hydrated Portland Cement

The ordinary Portland cement from the same plant and batch was subjected to the natural weather conditions and continuously moisturized by wet burlap for three months until the cement is lumped, after that, the hydrated cement was crushed and grinded by "Porcelain Ball Mill".

3.3. Sand

Ekadir natural sand was used as a fine aggregate. Table (3) and Figure (1), illustrate the grading of sand used throughout this work. The grading of sand conforms to the requirement of (ASTM C778-06) (ASTM C 778 – 06, Vol.04.02, 2006).

Table 3.Grading of fine aggregate.

Sieve size, mm	Cumulative % passing	Limits of ASTM C778
1.18	100	100
0.60	99	96-100
0.425	72	65-75
0.30	26	20-30
0.15	3	0- 4

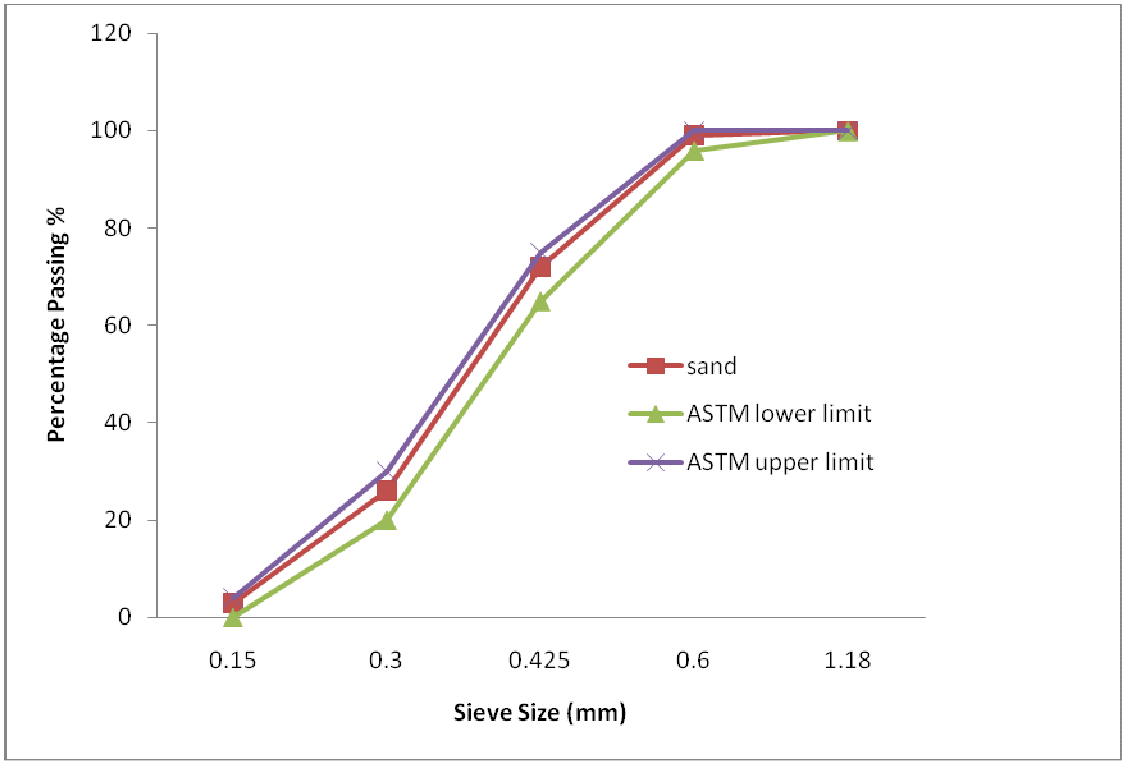

Figure1. Grading of sand.

3.4. Water

Tap water was used as mixing water for all mixes.

4. Experimental Program

The effect of replacement of (5, 10, 15, 20, and 25%) of cement by hydrated cement on normal consistency, setting time, compressive strength, and length change was studied and compared with reference mix.

The mix proportions of the compressive strength and length change tests were (1 cement: 2.75 sand) by weight. The compressive strength test was carried out on (54) cubes of (50) mm size at (3, 7, and 28) days, the average of (3) specimens were test at each age, while The length change test was carried out on (54) specimens of (25*25*285) mm size at (3, 7, and 28) days, the average of (3) specimens were test at each age.

5. Results and Discussions

5.1. Normal Consistency

The amount of water required to prepare hydraulic cement pastes for testing was carried out by Vicat apparatus according to (ASTM C 187 -04) (ASTM C 187-04, Vol.04.02, 2006.).The results in Table (4) shows that the w/c ratio required to give acceptable margin of consistency increase with increase in the hydrated cement content in mortar. This may be due to the addition of fine hydrated cement to mix which increases the water required to get normal consistency.

5.2. Setting Time

The setting time test was carried out by Vicat apparatus according to (ASTM C 191 -04b) (ASTM C 191 – 04b, Vol.04.02, 2005).The results in Table (4) and Figureure (2) shows that the setting time increases with the increase of the amount of replacement by hydrated cement.

Table 4.Initial and final setting time for cement and hydrated cement pastes.

Mixes	w/c	Setting time (h:m)	
		Initial	Final
Ref	0.28	01:35	05:25
5HC	0.285	01:42	05:36
10HC	0.29	01:45	05:42
15HC	0.295	01:50	05:50
20HC	0.3	01:55	05:50
25HC	0.3	01:55	06:05

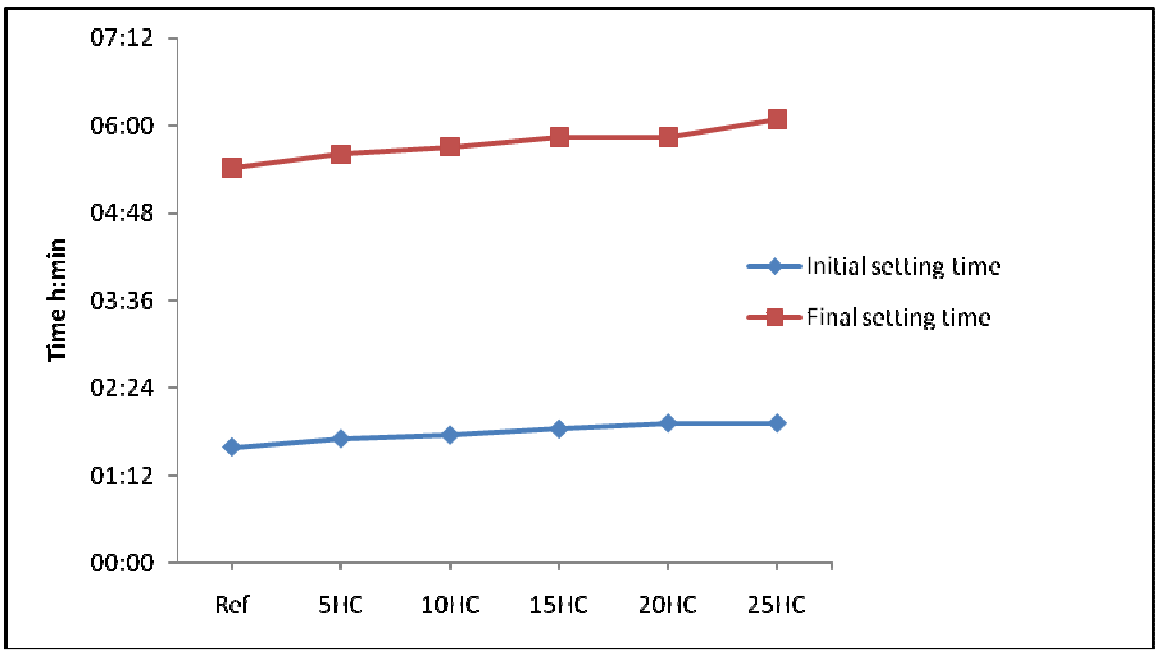

Figure 2. Initial and final setting time for cement and hydrated cement pastes.

5.3. Compressive strength

The effect of replacement of hydrated cement by (5, 10, 15, 20, and 25%) weight of cement on compressive strength of mortars has been studied. (54) Specimens of (50) mm size cube were cast and cured according to (ASTM C 109/C 109M – 05) (ASTM C 109/C 109M – 05 Vol.04.02, 2006.). Tables (5) and (6) and Figures (3) and (4) show that the compressive strength of all specimens increase with the increase of age as a result of the progress of the hydration process, and the compressive strength decreases with the increase in the amount of hydrated cement replaced in mortar which may be due to low activity of hydrated cement compared to reference cement mortar.

The percentage of decrease in compressive strength at (28) day age reaches (23.05%) when replacing (25%) of the cement by hydrated cement.

Table 5.Compressive strength of cement and hydrated cement mortars.

Mixes	Compressive strength ,Mpa		
	3 days	7 days	28 days
Ref	21.3	28.2	38.4
5HC	20.1	26.8	36.1
10HC	18.9	25.3	35
15HC	17.1	24.1	33.2
20HC	15.4	23	32
25HC	13.8	21.7	30.5

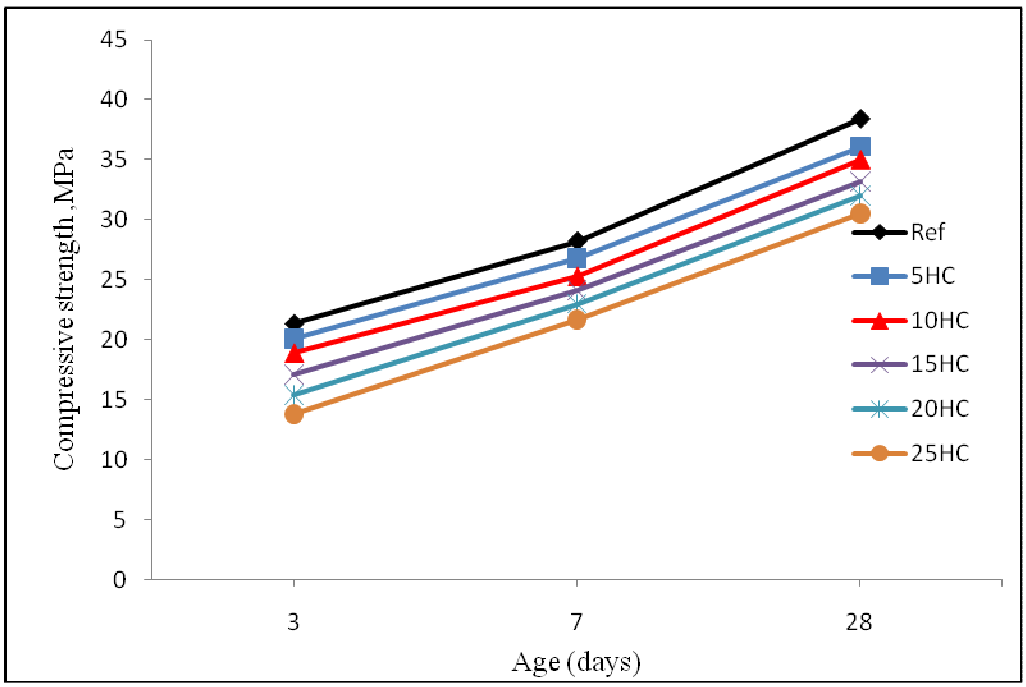

Figure 3. Compressive strength of cement and hydrated cement mortars.

Table 6. Compressive strength of hydrated cement mortars as percentages of reference mortar value.

Mixes	Compressive strength % of reference mix		
	3 days	7 days	28 days
Ref	100.00	100.00	100.00
5HC	94.37	95.04	95.04
10HC	88.73	89.72	89.72
15HC	80.28	85.46	85.46
20HC	72.30	81.56	81.56
25HC	64.79	76.95	76.95

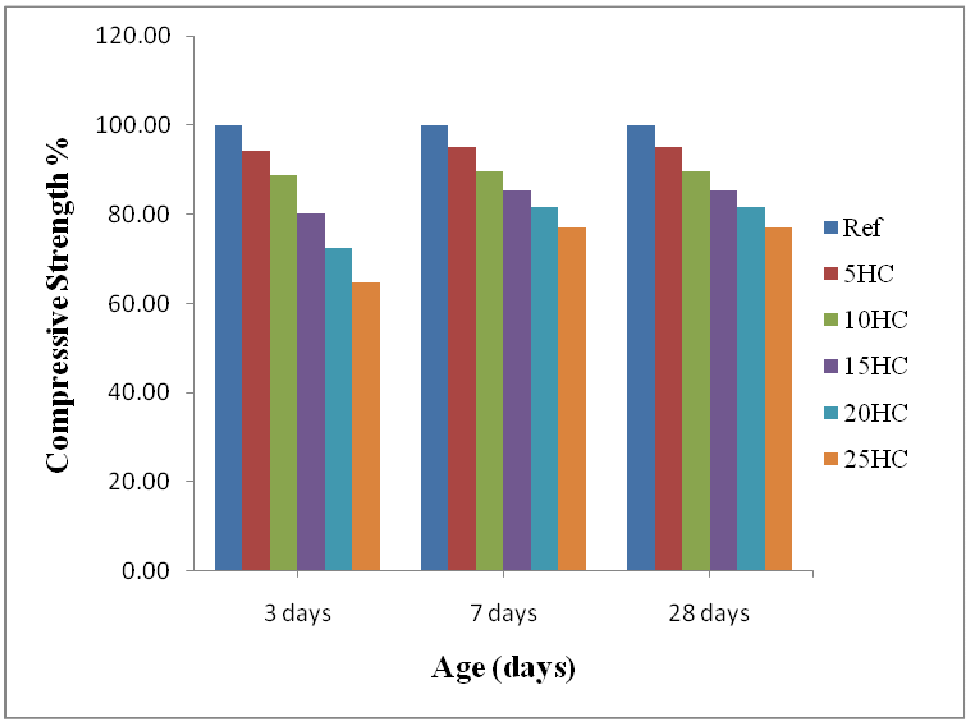

Figure 4. Compressive strength of hydrated cement mortars as a percent of reference mortar.

5.4. Length Change

The length change test was carried out on (25*25*285) mm mortar specimens according to (ASTM C 157/C 157M – 04) (ASTM C 157/C 157M – 04, Vol.04.02, 2006.). The results show that the shrinkage of cement mortars increases with the increasing in the percentage of replacement of hydrated cement. This may be due to the increase in the value of w/c ratio to gives (110 ± 5%) flow, and due to the high fineness of hydrated cement. These negative effects of hydrated cement partially used are shown in Table (7), and Figure (5).

Table 7.Length change of cement and hydrated cement mortars.

Mixes	w/c ratio to gives(110 ± 5%) flow	Length Change * 10^{-6}		
		Age-days		
		3	7	28
Ref	0.49	87	150	302
5HC	0.50	89	155	314
10HC	0.52	92	159	321
15HC	0.53	96	167	327
20HC	0.53	100	173	336
25HC	0.55	105	182	343

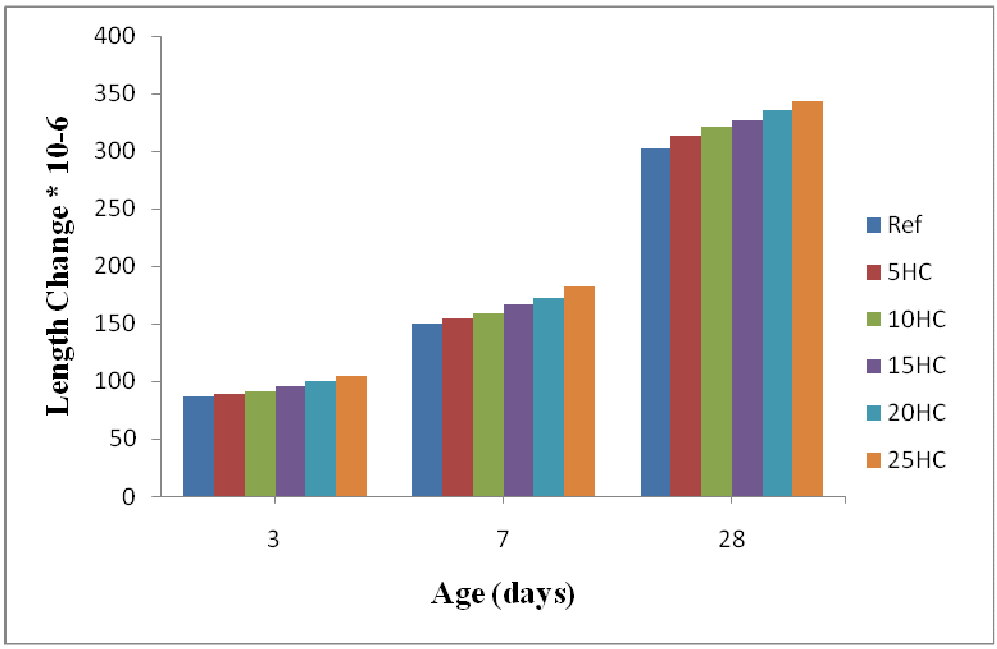

Figure 5. Length change of cement and hydrated cement mortars.

6. Conclusions

Based on this study, it is understood that:

1- The pastes containing hydrated cement require more w/cm ratio values than those fully containing ordinary Portland cement to give standard pastes.

2- The time of setting can be retarded by using the hydrated cement; this can be beneficial in hot weather casting of concrete.

3- Instead of discarding the hydrated cement, it can be used as a partial replacement of cement in sites requiring medium or no high strength concrete or mortar.

4- The replacement of cement by hydrated cement increases the length change of cement mortar.

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Nomenclature

Ref :	Reference mix.
5HC:	Mix containing 5% hydrated cement.
10HC:	Mix containing 10% hydrated cement.
15HC :	Mix containing 15% hydrated cement.
20HC:	Mix containing 20% hydrated cement.
25HC:	Mix containing 25% hydrated cement.