HBRC Journal (2015) 11, 311–320

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

Mechanical properties of self-curing concrete (SCUC)

Magda I. Mousa [a,*], Mohamed G. Mahdy [a], Ahmed H. Abdel-Reheem [a], Akram Z. Yehia [b]

[a] Structural Engineering Department, Faculty of Eng., El-Mansoura University, El-Mansoura, Egypt
[b] Ministry of Water Resources and Irrigation, El-Mansoura, Egypt

Received 18 February 2014; revised 6 June 2014; accepted 11 June 2014

KEYWORDS

Self-curing concrete;
Leca;
Polyethylene-glycol;
Silica fume;
Mechanical properties;
Dry-air Curing

Abstract The mechanical properties of concrete containing self-curing agents are investigated in this paper. In this study, two materials were selected as self-curing agents with different amounts, and the addition of silica fume was studied. The self-curing agents were, pre-soaked lightweight aggregate (Leca); 0.0%, 10%, 15%, and 20% of volume of sand; or polyethylene-glycol (Ch.); 1%, 2%, and 3% by weight of cement. To carry out this study the cement content of 300, 400, 500 kg/m^3, water/cement ratio of 0.5, 0.4, 0.3 and 0.0%, 15% silica fume of weight of cement as an additive were used in concrete mixes. The mechanical properties were evaluated while the concrete specimens were subjected to air curing regime (in the laboratory environment with 25 °C, 65% R.H.) during the experiment. The results show that, the use of self-curing agents in concrete effectively improved the mechanical properties. The concrete used polyethylene-glycol as self-curing agent, attained higher values of mechanical properties than concrete with saturated Leca. In all cases, either 2% Ch. or 15% Leca was the optimum ratio compared with the other ratios. Higher cement content and/or lower water/cement ratio lead(s) to more efficient performance of self-curing agents in concrete. Incorporation of silica fume into self-curing concrete mixture enhanced all mechanical properties, not only due to its pozzolanic reaction, but also due to its ability to retain water inside concrete.

Introduction

In order to achieve the designated self-curing concrete properties, water evaporation at the surface should be avoided in addition to supplying water from the exterior. If enough water is at the disposal of the cement paste for hydration to proceed, the concrete will achieve excellent properties. The traditional ways of curing often fail in practice. Even when meticulously

* Corresponding author. Tel.: +20 1002223458.
E-mail address: dr.magdashehata@yahoo.com (M.I. Mousa).
Peer review under responsibility of Housing and Building National Research Center.

Production and hosting by Elsevier

1687-4048 © 2014 Production and hosting by Elsevier B.V. on behalf of Housing and Building National Research Center.
http://dx.doi.org/10.1016/j.hbrcj.2014.06.004

performed only water evaporation can be reduced, but the water supply on the surface of vertical structural elements is still a technical problem. The time allocated for curing is a stagnation of building time increasing costs and efforts. The efficiency of modern technology such as climb and slip forming is perturbed and the risk of damage caused by the improper curing is still not eliminated. In the case of high strength concrete (HSC) used commonly for vertical structural elements the problem is more difficult. Due to a very low water cement ratio in combination with high cement content and the addition of silica fume the concrete shows high compressive strength at early age, which makes an early form stripping possible. The high self-desiccation was the reason for using this concrete for self-desiccation slabs [1]. The very dense structure of high-performance concrete might lead to the assumption that water evaporation is low and therefore water from the surrounding can penetrate only very slowly and not in a sufficient amount to reach the interior of the member. So, the effect of curing can therefore be neglected. Saving the curing time would positively influence the construction costs. On the other hand when exposed to air, water evaporation was observed resulting in a considerable reduction of the compressive strength and micro cracks appear [2,3]. Many researches [4] showed failure of the traditional curing methods for HSC. Wet curing for a longer time even submersing in water did not always positively influence the mechanical properties. Hence, the opinions in the literature about curing high strength concrete are contradictory. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. Currently, there are two major methods available for internal curing. The first method uses saturated lightweight aggregate in order to supply an internal source of water [5,6] and the second one uses polyethylene-glycol which reduces water evaporation from the surface of concrete and also helps in water retention [7,8].

Research significance

The principal aim of this paper is to evaluate the effects of different types and percentage of self-curing agents on the mechanical properties of concrete (such as compressive, tensile, flexural strength and modulus of elasticity). The self-curing agents employed in this paper were pre-soaked in water lightweight aggregate (leca) and chemical agent of polyethylene-glycol (Ch.) with different ratios. Different cement contents (300, 400, 500 kg/m^3), different water–cement ratios (0.5, 0.4, 0.3) and silica fume ratios (0.0%, 15%) were used in concrete and cured in dry air (25 °C) during the experiment. The results should help explain the effect of self-curing agents on the mechanical properties of concrete. Also, the results provide more knowledge about the determination of self-curing agent ratios and the best type to optimize the mechanical properties of concrete.

Experimental programme

Material and mix proportion

To carry out this study, an ordinary Portland cement (Chemical Composition and Physical Properties shown in Table 1) and silica fume, which are widely available in Egypt, siliceous sand as a fine aggregate (with fineness modulus of 2.79) and gravel as a coarse aggregate of nominal maximum size (20 mm) from Suez quarry were used. The silica fume used contains silica (SiO_2) of 95% and was in powder form (Table 1). The superplasticizer used was of sulfated naphthalene formaldehyde condensate type. The superplasticizer dosage was adjusted to produce concretes with the same slump of 120 ± 10 mm and do not show visual signs of segregation during the normal casting of concrete in the moulds. Leca which is a brand name for an expanded clay clinker burned in a rotary kiln at approximately 1200 °C was used as self-curing agent (Leca type). Leca was oven-dried at 105 °C for 24 h, air cooled and then submerged in water for 24 h before mixing while polyethylene-glycol of characteristics as produced by the manufacturer and indicated in Table 2 was used as self-curing agent of chemical type (Ch. type). Twelve concrete mixes were used in this study. The main variables considered in this programme include, the type and ratio of self-curing agent, cement content, water/cementitious ratio. Mixes with the same w/c ratio, cement and coarse aggregate content were used as references. The proportions of concrete batches are tabulated in Table 3.

Table 1 Chemical composition and physical properties of Portland cement and silica fume.

Chemical composition (%)	Portland cement	Silica fume
Loss on ignition	1.36	1.0
SiO_2	19.49	95
AL_2O_3	7.36	0.4
Fe_2O_3	2.68	0.6
CaO	62.51	0.2
MgO	3.7	0.4
SO_3	2.4	0.3
Specific weight (g/cm^3)	3.12	2.2
Specific surface (cm^2/g)	3000	150,000
Setting time (min)		
Initial	130	–
Final	235	–
Compressive strength (kg/cm^2)		
3 days	170	–
7 days	260	–
Mineralogical components (%)		
C_3S	37.17	–
C_2S	33.65	–
C_3A	11.73	–
C_4AF	8.15	–

Experimental procedures

Mixing of concrete components was done using a horizontal mixer. All the dry constituents were mixed for 2 min to ensure

Table 2 Characteristics of polyethylene-glycol.

Type	Molecular weight	Maximum solubility at 20 °C (mass fraction%)	Functional group	
			Hydroxyl	Ether
Synthetic	200	100	Yes	Yes

Table 3 Composition of concretes (kg/m^3).

Mix No.	Cement	Silica Fume	Water	Superplasticizer	Self-curing agent		Gravel (20 mm)	Sand
					Ch.	Leca		
M1	400	–	120	8	–	–	1252	674
M2	400	–	120	8	–	26	1252	607
M3	400	–	120	8	–	39	1252	573
M4	400	–	120	8	–	52	1252	539
M5	400	–	116	8	4	–	1252	674
M6	400	–	112	8	8	–	1252	674
M7	400	–	108	8	12	–	1252	674
M8	400	–	192	2.4	8	–	1128	608
M9	400	–	152	4	8	–	1189	640
M10	300	–	84	12	6	–	1360	732
M11	500	–	140	5	10	–	1142	616
M12	400	60	129	4.6	9.2	–	1174	632

uniformity of the mix. Half of the mixing water was added gradually during mixing and followed by the remaining water with SP. However in the case of SCUC, self-curing agent such as polyethylene-glycol or saturated light weight aggregate (leca) was added gradually during mixing. Mixing of all ingredients continued for a period of 2 min. The content of SP was adjusted for each mix to achieve the required workability without segregation. After mixing, two sizes of specimens were cast using $100 \times 100 \times 100$ mm cubic moulds and $100 \times 100 \times 500$ mm prismatic moulds. After the moulds had been filled of concrete and compacted, the surface of concrete was levelled, and they were kept in laboratory conditions for 24 h while the surfaces of moulds were covered by plastic sheets. And then, demoulded specimens were kept in dry air (25 °C) during the experiment in a laboratory. Compressive and indirect tensile strengths were carried out on cubic specimens while flexural strength and modulus of elasticity were performed on beam specimens ($100 \times 100 \times 500$ mm) which loaded at the middle third with two equal concentrated loads in flexural test, while with one concentrated load at mid-span in the modulus of elasticity test. Compressive strengths were measured at 3, 7, 28 and 56 days while tensile, flexural strength and modulus of elasticity were measured at 3, 7 and 28 days.

Results and discussions

Compressive strength

Figs. 1–5 show, the compressive strength of all the concretes studied either self-curing or conventional concretes (reference concrete), which increase gradually with time in different rates under air curing. Compressive strength systematically increases as self-curing agent (leca type) used in the concrete as shown in Fig. 1, which may be attributed to the continuation of the hydration process as a result of providing the cement paste by store water in the saturated Leca particles, resulting in, lower voids and pores, and greater bond force between the cement paste and aggregate as stated by other researchers [9–12]. At 28 days concrete with 10%, 15% and 20% leca give higher compressive strength by about 10%, 17.5% and 15%, respectively compared with conventional concrete to be an indicator that 15% leca is the optimum ratio in this study (Table 4).

It is well known that, the concept of polyethylene-glycol (ch. type) is to reduce water evaporation from concrete, and hence increase the water retention capacity of concrete compared with conventional concrete which leads to improved compressive strength [13–17]. The results in Fig. 2 illustrate a significant increase in the compressive strength of concretes

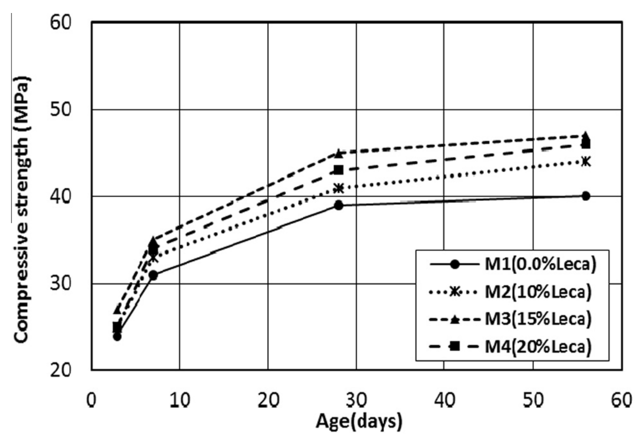

Fig. 1 Effect of saturated Leca % on compressive strength of self-curing concrete (SCUC).

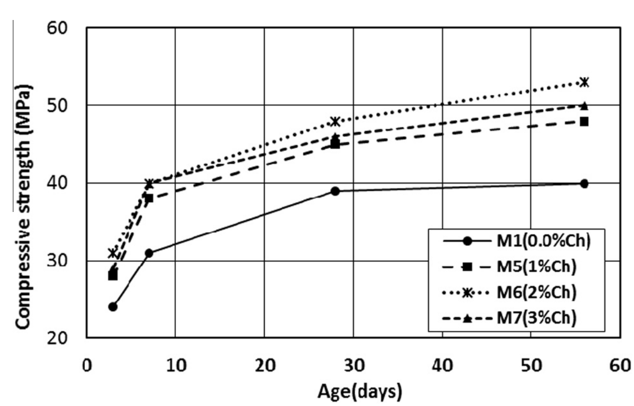

Fig. 2 Effect of polyethylene-glycol (Ch.) % on compressive strength of self-curing concrete (SCUC).

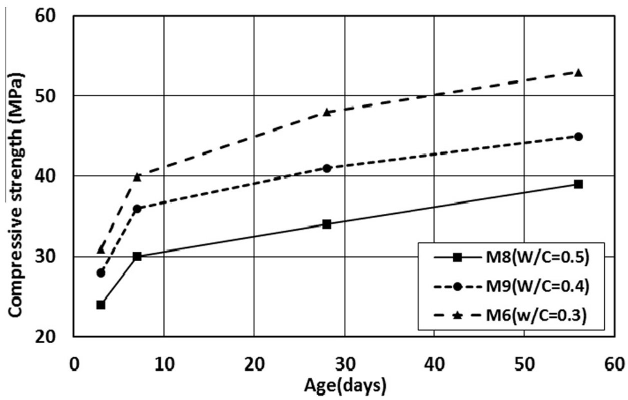

Fig. 3 Effect of water cement ratio on compressive strength of SCUC (concrete with 2% Ch.).

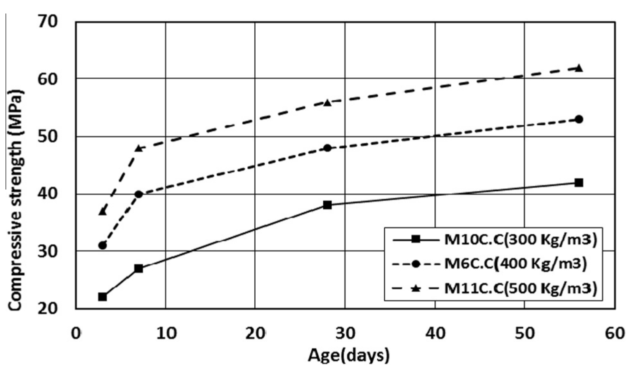

Fig. 4 Effect of cement content (C.C) on compressive strength of SCUC (concrete with 2% Ch.).

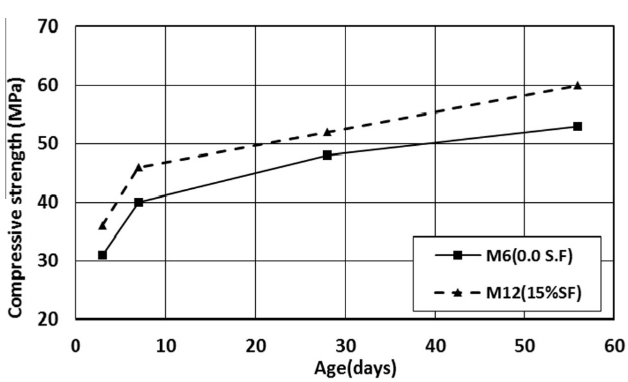

Fig. 5 Effect of Silica fume ratio on compressive strength of SCUC (concrete with 2%Ch.).

containing ch. (SCUC) with time relative to conventional concrete during the experiment. After 28 days, concrete with 1%, 2% and 3% ch. exhibited strength increase by about 20%, 32.5% and 25%, respectively, compared with conventional concrete, which indicates that 2% ch. is the optimum ratio [18].

For the concrete series having 2% ch. (SCUC) with different water–cement ratios, it was obvious that reducing the water–cement ratio significantly increases the compressive strength and improves the performance of ch., which may be attributed to the reduction in the greater number of random voids that form as a result of free water evaporation particularly at high w/c ratios. Reducing the water–cement ratio in concrete from 0.5 to 0.4 and to 0.3 caused higher strength by about 15.4% and 35.9%, respectively, after 28 days as shown in Fig. 3.

Increasing the cement content in concrete enhanced the compressive strength and the effect of ch. as shown in (Fig. 4). After 28 days cement-contents (c.c) of 400, and 500 kg/m^3 with 2% ch. resulted in strength increase by about 26.2% and 47.6%, respectively, relative to a cement content of 300 kg/m^3.

From Fig. 5, the incorporation of silica fume (15%) into concrete mixtures with 2% ch. caused additional improvement in strength (13.2%). This improvement in strength is not only due to the ability of concrete to retain water which causes continuation of the cement hydration, but also due to the conversion of calcium hydroxide which tends to form on the surface of aggregate particles, into calcium silicate hydrate (C–S–H) causing strengthening to the aggregate matrix transition zone which becomes less porous and more compact [19–21].

Indirect tensile strength

The use of saturated leca with different ratios in concrete mixes provide internal curing for the concrete by allowing a continuous hydration, which leads to improvement of the tensile strength of the concrete as shown in Fig. 6. The tensile strength of concretes with saturated leca (SCUC) or without leca (conventional concrete) increased with time, and at 28 days 15% leca gave the highest increase in tensile strength (by about 7.4%) compared to conventional concrete.

Test results of concretes containing polyethylene-glycol with different ratios and conventional concrete are shown in Fig. 7. Results showed higher strength of concretes with ch. relative to conventional concrete. After 28 days, the strength of concretes with 1%, 2% and 3% ch. increased by about 7.4%, 14.8% and 10%, respectively, compared to reference concrete (0.0% ch.).

For the results of the concrete series having 2% ch., reducing the water–cement ratio from 0.5 to 0.4 and 0.3 causes increases in tensile strength by about 6.5% and 5.8%, respectively, after 28 days as shown in Fig. 8.

A higher cement content in self-curing concrete (with 2% ch.) improves the tensile strength at all ages. It is obvious from the test results that, cement contents of 400 and 500 kg/m^3 with 2% ch. caused a higher strength by about 10.7% and 27%, respectively, relative to a cement content of 300 kg/m^3 after 28 days as shown in Fig. 9.

As shown in Fig. 10, the incorporation of silica fume (15%) into concrete mixtures with 2% ch. causes higher strength of concrete at early age (3 days) relative to concrete without silica fume. Beyond that, the rate of increase in strength is approximately constant and the silica fume concrete exhibits a higher strength by about 6.5% relative to concrete without silica fume after 28 days.

Relation between indirect tensile and compressive strength

Based on the test results, the following experimental relationship for predicting the tensile strength based on the compressive strength value can be expressed as in Eqs. (1) for the

Table 4 Effect of self-curing agents on different mechanical properties of concrete at 28 days.

Self-curing agents (SCUA) and SF		The variation percent			
Type	Percent (%)	Comp. strength (%)	Tensile strength (%)	Flexural strength (%)	Modulus of elasticity (%)
Leca	10	+10.0	+3.7	+1.6	+1.4
	15	+17.5	+7.4	+7.2	+4.1
	20	+15.0	+5.6	+3.4	+2.1
Ch.	1	+20.0	+7.4	+2.0	+3.1
	2	+23.5	+14.8	+6.8	+5.0
	3	+25.0	+10.0	+3.6	+3.5
Ch. + SF	2 Ch. + 15 SF	+50.0	+22.2	+13.6	+7.1

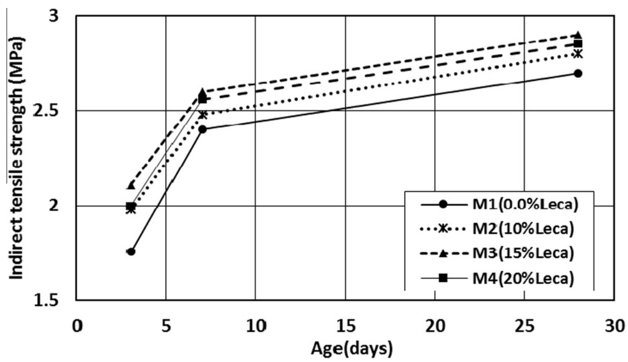

Fig. 6 Effect of saturated Leca% on indirect tensile strength of self-curing concrete (SCUC).

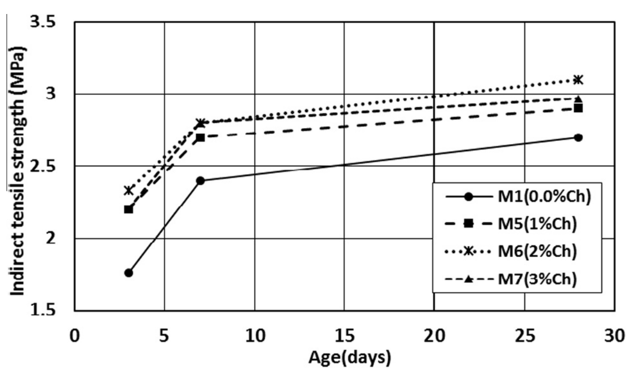

Fig. 7 Effect of polyethylene-glycol (Ch.) % on indirect tensile strength of self-curing concrete (SCUC).

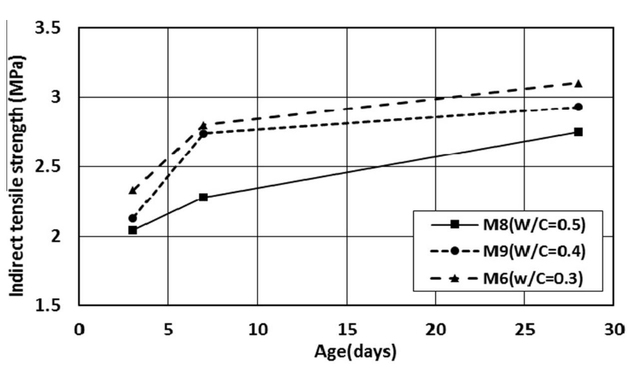

Fig. 8 Effect of water-cement ratio on indirect tensile strength of SCUC (Concrete with 2% Ch.).

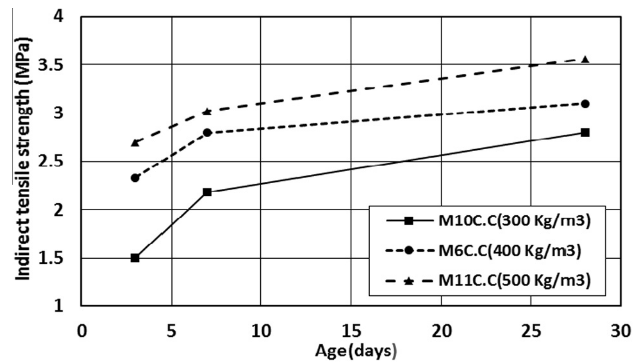

Fig. 9 Effect of Cement Content (C.C) on indirect tensile strength of SCUC (Concrete with 2% Ch.).

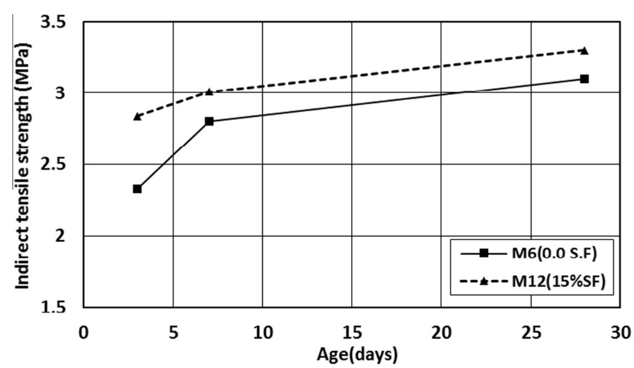

Fig. 10 Effect of silica fume ratio on indirect tensile strength of SCUC (Concrete with 2% Ch.).

case of SCUC (ch. type) and (2) for the case of SCUC (Leca type).

$$F_t = 0.26(f_{cu})^{0.64} \quad (1)$$

$$F_t = 0.24(f_{cu})^{0.66} \quad (2)$$

where f_t is the indirect tensile strength in (MPa) and f_{cu} is the compressive strength for the cube in (MPa). The degree of confidence is 0.9589 in the case of SCUC (ch. type) and 0.9783 in the case of SCUC (Leca type) as shown in Figs. 11 and 12, respectively.

Flexural strength

Fig. 13 shows that, concrete without leca (conventional concrete) exhibited a higher flexural strength at early ages compared with concretes containing leca. Beyond that, the strength of self-cured concretes increases gradually and becomes higher than their reference at 28 days. The concrete containing 10%, 15% and 20% leca gave a higher 28 days strength by about 1.6%, 7.2 and 3.4%, respectively, relative to conventional concrete (0.0% leca).

It can be seen from the results that, the rate of flexural strength gain in the case of conventional concrete (0.0% ch.) is lower than that of self-cured concretes as shown in Fig. 14. At 28 days, self-cured concrete of 3% ch. showed the highest increase in strength by about 6.8%, relative to conventional concrete (Table 4).

For the concrete series with different water–cement ratios with 2% ch., obviously reducing the water–cement ratio significantly increases flexural strength and improves the effect of ch. Reducing the water–cement ratio in concrete from 0.5 to 0.4 and to 0.3 caused a higher strength by about 5.1% and 9.9%, respectively, after 28 days as shown in Fig. 15.

Increasing the cement content in concrete from 300 kg/m^3 to 400 kg/m^3 significantly increased the flexural strength while the cement content of 500 kg/m^3 did not significantly change the results as shown in Fig. 16. In general a cement content of 400 and 500 kg/m^3 with 2% ch. caused a higher strength by about 32.2% and 36.4%, respectively, relative to a cement content of 300 kg/m^3 after 28 days.

From Fig. 17 it is obvious that, the incorporation of silica fume (15%) into concrete mixture with 2% ch. improved the flexural strength. The rate of increase in strength is approximately similar to the reference concrete, and silica fume concrete exhibits a higher strength by about 6.4% compared to concrete without silica fume after 28 days.

Relation between flexural and compressive strength

Based on the test results, the following experimental relationship for predicting the flexural strength based on compressive strength value can be expressed as in Eqs. (3) for the case of SCUC (ch. type) and (4) for the case of SCUC (Leca type).

$$F_r = 0.48(f_{cu})^{0.62} \quad (3)$$

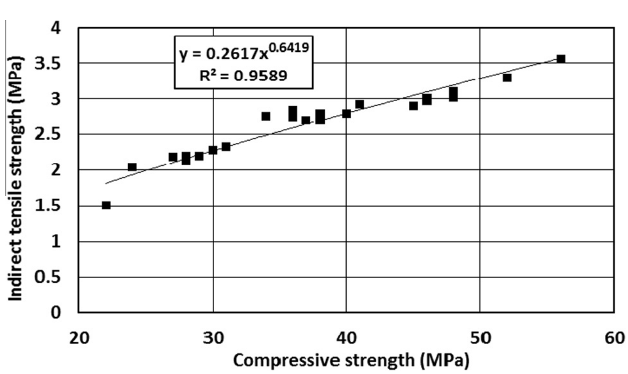

Fig. 11 Compressive strength versus indirect tensile strength of Self-curing concrete (Concrete with Ch.).

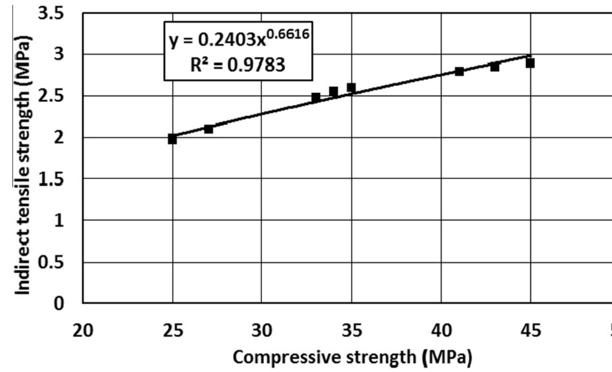

Fig. 12 Compressive strength versus indirect tensile strength of self-curing concrete (Concrete with Leca).

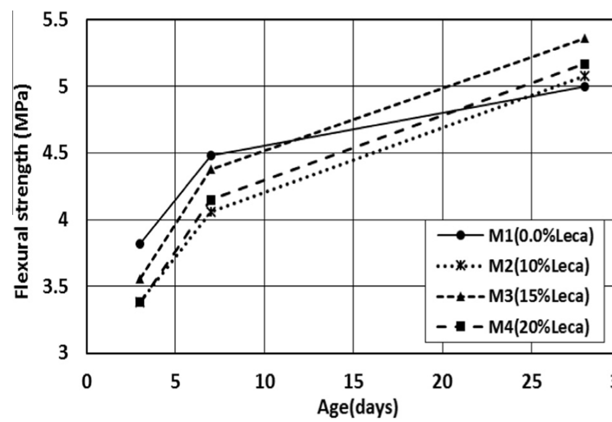

Fig. 13 Effect of saturated Leca % on flexural strength of self-curing concrete (SCUC).

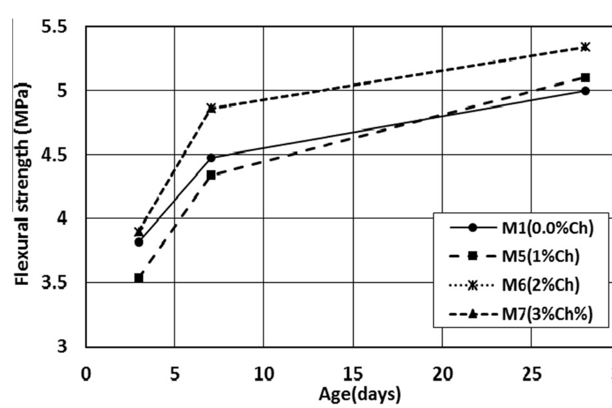

Fig. 14 Effect of polyethylene-glycol (Ch.) % on flexural strength of self-curing concrete (SCUC).

$$F_r = 0.99(f_{cu})^{0.8} \quad (4)$$

where f_r is the flexural strength in (MPa) and f_{cu} is the compressive strength for the cube in (MPa). The degree of confidence is 0.9452 in the case of SCUC (ch. type) and 0.9908 in the case of SCUC (Leca type) as shown in Figs. 18 and 19, respectively.

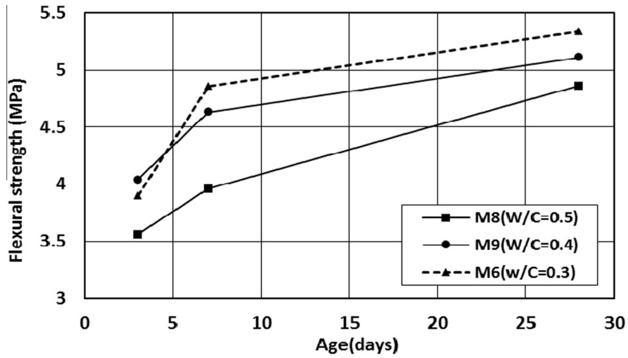

Fig. 15 Effect of water-cement ratio on flexural strength of SCUC (concrete with 2% Ch.).

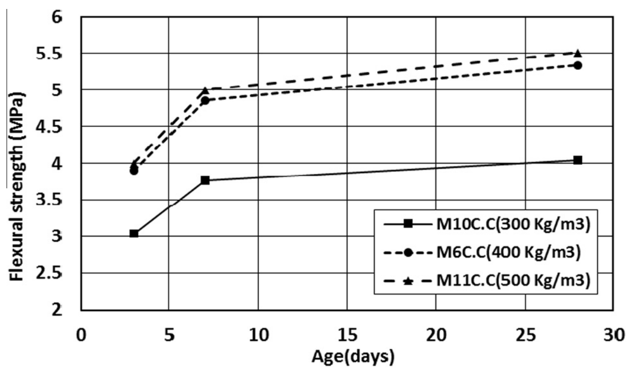

Fig. 16 Effect of cement content (C.C) on flexural strength of SCUC (concrete with 2% Ch.).

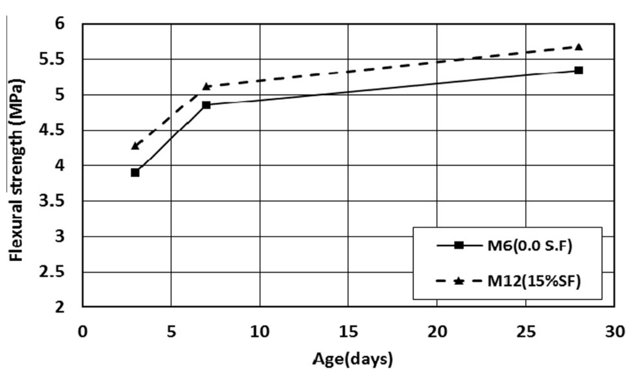

Fig. 17 Effect of silica fume (S.F) on flexural strength of SCUC (concrete with 2% Ch.).

Modulus of elasticity

The modulus of elasticity of all concrete mixes (self-curing and conventional concretes) increase gradually with time under air curing (Fig. 20). The use of saturated leca as self-curing agent (leca type) in concrete causes continuation of the hydration process of cement paste, and thereby less porosity concrete is produced. At 28 days concrete with 15% leca shows a higher modulus of elasticity followed by 20%, 10% and 0.0% (conventional concrete). In general 10%, 15% and 20% leca exhibited little increase in the modulus of elasticity by about 1.4%

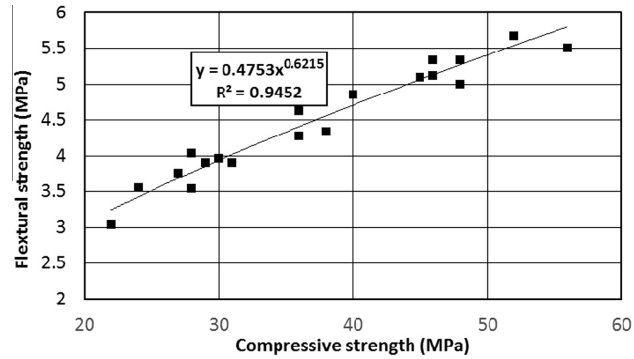

Fig. 18 Compressive strength versus flexural strength of self-curing concrete (concretes with Ch.).

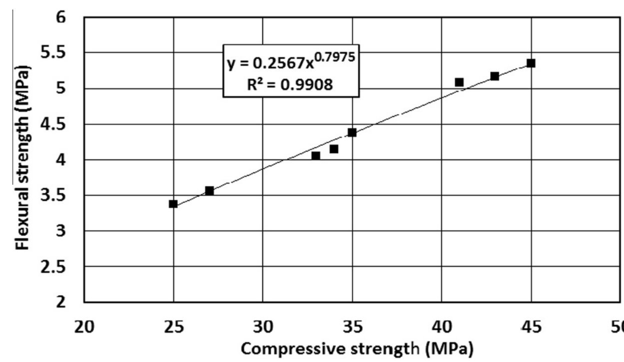

Fig. 19 Flexural strength versus compressive strength of self-curing concrete (concrete with Leca).

4.1% and 2.1%, respectively, compared with their reference concrete (0.0% leca).

The effect of ch. agent addition on the modulus of elasticity can be seen in Fig. 21. The test results show a higher modulus of elasticity of concretes containing ch. relative to conventional concrete during the experiment. Increasing ch. ratio from 2% to 3% was not effective where the modulus of elasticity reduced at all ages. After 28 days, concrete with 1%, 2% and 3% ch. caused an increase in the modulus of elasticity by about 3.1%, 5% and 3.5%, respectively, compared with conventional concrete.

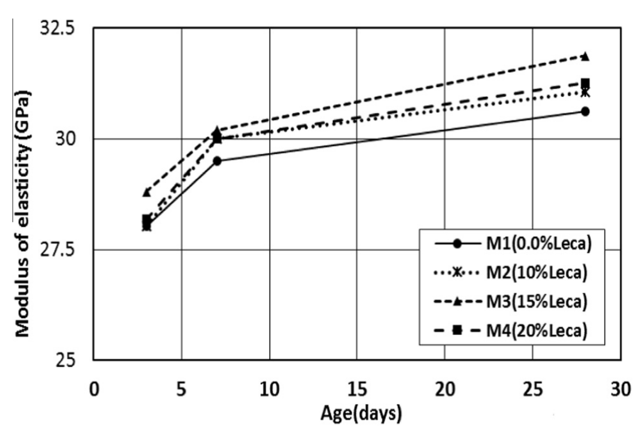

Fig. 20 Effect of saturated Leca % on modulus of elasticity of self-curing concrete (SCUC).

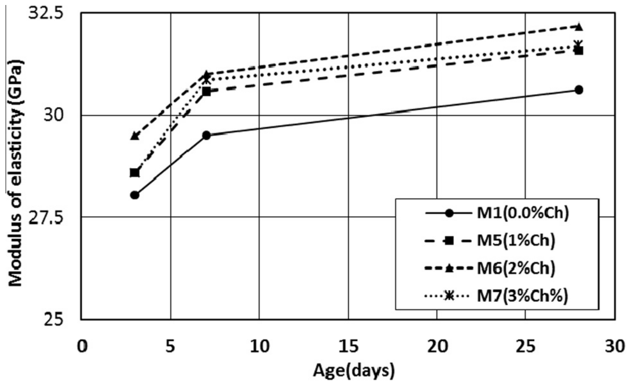

Fig. 21 Effect of polyethylene-glycol(Ch) % on modulus of elasticity of self-curing concrete (SCUC).

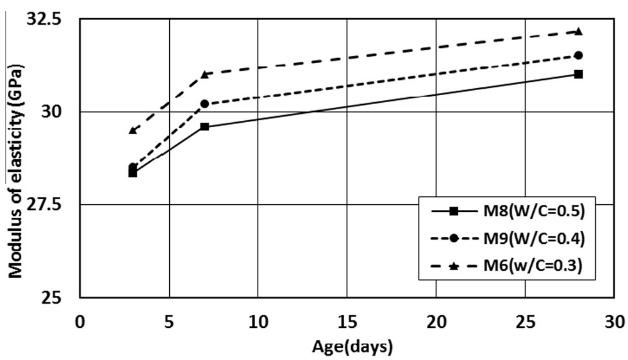

Fig. 22 Effect of water–cement ratio on modulus of elasticity of SCUC (concrete with 2% Ch.).

From the test results shown in Fig. 22 it is noticed that, reducing the water–cement ratio significantly increases the modulus of elasticity at all ages and improves the effect of ch. in self curing concrete. Reducing the water–cement ratio from 0.5 to 0.4 and 0.3 increased the modulus of elasticity by about 1.7% and 3.8%, respectively, after 28 days.

The modulus of elasticity of concretes containing cement contents of 300 kg/m^3, 400 kg/m^3 and 500 kg/m^3 significantly increased with time and had the same behaviour as shown in Fig. 23. The higher cement content always gives a higher modulus of elasticity as a result of less voids and pore decrease, and

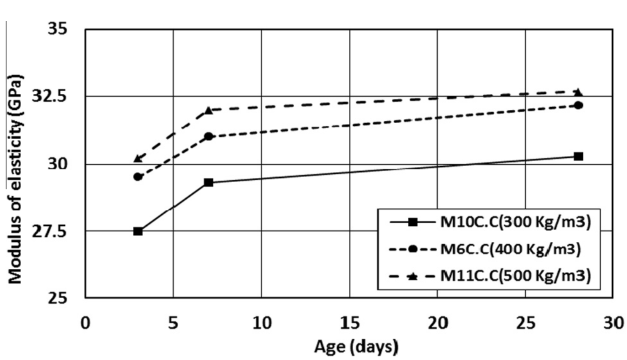

Fig. 23 Effect of cement content (C.C) on modulus of elasticity of SCUC [concrete with 2% Ch.).

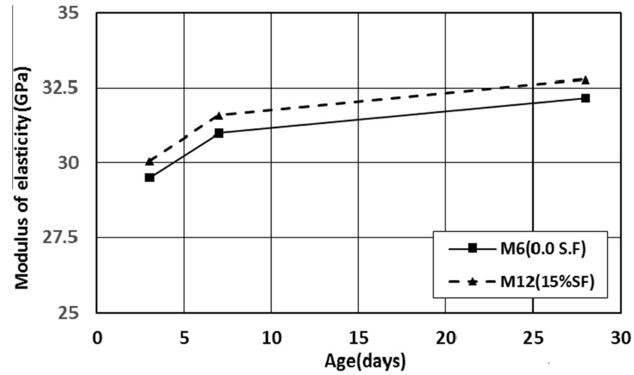

Fig. 24 Effect of silica fume (S.F) on modulus of elasticity of SCUC (concrete with 2% Ch.).

the greater bond force between cement past and the aggregate. In general, cement contents of 400 and 500 kg/m^3 with 2% ch. caused a higher strength by about 6.3% and 7.9%, respectively, relative to a cement content of 300 kg/m^3 after 28 days.

Fig. 24 shows that, the incorporation of silica fume (15%) into concrete mixtures with 2% ch. improved slightly the modulus of elasticity of concrete during the experiment. The rate of increase in the modulus of elasticity is approximately equal in the two types of concrete (with and without silica fume) and at age of 28 days silica fume concrete gives a higher value of modulus of elasticity (by about 1.9%) relative to concrete without silica fume. This may be attributed to the ability of silica fume

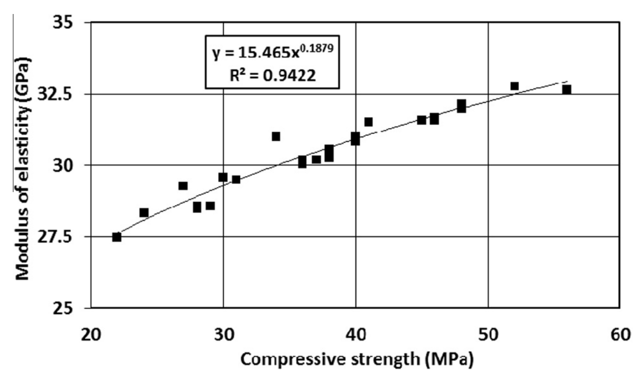

Fig. 25 Compressive strength versus modulus of elasticity of self-curing concrete (concrete with Ch.).

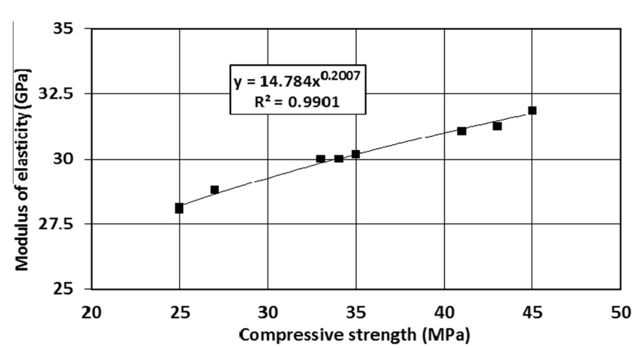

Fig. 26 Compressive strength versus modulus of elasticity of self-curing concrete (concrete with Leca).

to retain water for the continuation of the cement hydration and create a great bond force between the cement paste and aggregate.

Relation between modulus of elasticity and compressive strength

Based on the test results, the following experimental relationship for predicting the modulus of elasticity based on the compressive strength value can be expressed as in Eqs. (5) for the case of SCUC (ch.t) and Eq. (6) for the case of SCUC (Leca.t).

$$E = 15.47(f_{cu})^{0.19} \quad (5)$$

$$E = 14.78(f_{cu})^{0.2} \quad (6)$$

where E is the modulus of elasticity in (GPa), and f_{cu} is the compressive strength for the cube in (MPa). The degree of confidence is 0.9422 in the case of SCUC (ch. type) and 0.9901 in the case of SCUC (Leca type) as shown in Figs. 25 and 26, respectively.

Conclusions

From the results obtained in this study the following conclusions can be noted:

1. The use of self-curing agents (polyethylene-glycol or saturated leca) in concrete mixes improves the mechanical properties of concretes under air curing regime which may be attributed to a better water retention and causes continuation of the hydration process of cement past resulting in less voids and pores, and greater bond force between the cement paste and aggregate.
2. The improvement in the mechanical properties of self-curing concrete (SCUC) was superior while using self-curing agent of chemical type (polyethylene-glycol) compared to aggregate type (saturated leca) as shown in Table 4. The values of 2% polyethylene-glycol and 15% saturated leca represent the optimum doses as self-curing agents in concrete, among the values examined (1–3% ch.) or (10–20% leca), respectively.
3. In self-curing concrete, increasing the cement content and/or reducing w/c ratio markedly enhance(s) the mechanical properties of concrete. On the other hand the lowest allowable cement content and the highest allowable w/c ratio that should be used in self-curing concrete are about 300 kg/m^3 and 0.5, respectively, otherwise the self-curing effect thereafter may vanish.
4. The incorporation of silica fume (SF) in SCUC (concrete with 2% ch.) causes additional improvement in the mechanical properties of concrete (Table 4). This improvement is not only due to pozzolanic reaction but also due to its ability to retain water (better water retention) which causes continuation of the cement hydration and great bond force between cement paste and aggregate compared with reference concrete (without SF and SCUA).
5. The test results of this investigation illustrate that, the indirect tensile strength was in the range of 6.4% to 8.5% f_{cu} for all self-curing concrete and is perfectly correlated with compressive strength by the proposed Eqs. (1) for the case of ch. and (2) for the case of leca.
6. The test results of flexural strength represented 10–14.5% of compressive strength of all self-curing concrete type. Good correlation was observed between Flexural and compressive strength through the proposed Eqs.; (3) for the case of ch. and (4) for the case of leca.
7. The results of this study revealed that, the statical modulus of elasticity (E) was strongly correlated with compressive strength (f_{cu}) for all self-curing concrete types at different ages. The predicted values of E (in terms of f_{cu}) using the proposed Eqs. (5) for the case of ch. and (6) for the case of leca revealed a close agreement with the measured values.

References

[1] Persson BSM. Self-desiccating high-strength concrete slabs. In: Proceedings Utilization of High Strength Concrete, Symposium in Lillehammer, Norway, June 20–23, 1993; 882–889.

[2] Hammer TA. The Maturation of Mechanical Properties of High Strength Concrete Exposed to Different Moisture Conditions. In: Proceedings Third international Symposium on Utilization of high-Strength Concrete, Lillehammer, Norway, June 20–24, 1993; 1084–1091.

[3] Weber S, Reinhardt HW. Various curing method applied to high-performance concrete with natural and blended aggregates. In: Proceedings of Fourth International Symposium on the Utilization of high Strength/High Performance concrete, Paris, May 29–3, 1996; 3: 1295–1303.

[4] S. Weber, H.W. Reinhardt, A new generation of high performance concrete: concrete with autogenous curing, Adv. Cement Based Mater. 6 (1997) 59–68.

[5] J. Castro, L. Keiser, M. Golias, J. Weiss, Absorption and desorption properties of lightweight aggregate for application to internally cured concrete mixtures, Cem. Concr. Compos. 33 (2011) 1001–1008.

[6] S. Zhutovsky, K. Kovler, Effect of internal curing on durability-related properties of high performance concrete, Cem. Concr. Res. 42 (2012) 20–26.

[7] M.V. Jagannadha Kumar, M. Srikanth, K. Jagannadha Rao, Strength characteristics of self-curing concrete, IJRET 1 (2012) 51–57.

[8] Troli R, Borsoi A, Cllepardi S, Fazio G, Collepardi M, Monosi S. Self-compaction/Curing/Compressing Concrete. 6th International Congress, Global Construction, Ultimate Concrete Opportunities, Dundee. U.K.-5-7 July; 2005.

[9] Cusson D, Hoogeveen TJ, Mitchell LD. Internally-cured high-performance concrete under restrained shrinkage and creep, 7th International Symposium on utilization of High-Strength/High Performance Concrete, Nates, France, 12–14, 2005, p. 579–584.

[10] D.P. Bentz, P. Lura, J.W. Roberts, Mixture proportioning for internal curing, Concr. Int. 27 (2005) 35–40.

[11] D.P. Bentz, O.M. Jensen, Mitigation strategies for autogenous shrinkage cracking, Cem. Concr. Compos. 26 (2004) 677–685.

[12] O.M. Jensen, P.F. Hansen, Water-entrained cement-based materials I. Principle and theoretical background, Cem. Concr. Res. 31 (2001) 647–654.

[13] B. Mather, Self-curing concrete, why not?, Concr Int. 23 (2001) 46–47.

[14] D.P. Bentz, P. Lura, J.W. Roberts, Mixture proportioning for internal curing, Concr. Int. 27 (2005) 35–40.

[15] j. Wang, R.K. Dhir, M. Levitt, Membrane curing of concrete, Cem. Concr. Res. 24 (1994) 1463–1474.

[16] R.K. Dhir, P.C. Hewlett, j.S. Lota, T.D. Dyre, An investigation into the feasibility of formulating self-curing concrete, Mater. Struct. 27 (1994) 606–615.

[17] A.S. El-Dieb, Self-curing concrete: water retention, hydration and moisture transport, Constr. Build. Mater. 21 (2007) 1282–1287.
[18] Yehia AZ. Application of Self-Curing Concrete in Egypt. Ph.D thesis, Structural Engineering Department, Mansoura University, Egypt, 2010.
[19] M.J. Ole, L. Pietro, Techniques and materials for internal water curing of concrete, Mater. Struct. 39 (2006) 817–825.
[20] M.D. Cohen, B. Mather, Sulphate attack on concrete–research needs, ACI Mater. J. 88 (1991) 62–69.
[21] R.F. Feldman, C.Y. Huang, Properties of Portland cement-silica fume pasts 1, porosity of surface properties, Cem. Concr. Res. 15 (1985) 765–774.