

Characteristics of lightweight concrete with different admixtures

Ahmed Fikry ^{1,*}, Ata El-kareim Shoeib ¹, Anwar Mahmoud ², Mohamed H. Agamy ¹

¹ Faculty of Engineering, Helwan University, Cairo, Egypt

² Housing and Building National Research Center, Cairo, Egypt

* Email: Dranwarm79@gmail.com

ABSTRACT

Lightweight concrete (LWC) is the most needed material to be used in many applications due to its low density, accepted compression strength, and high thermal properties. This paper study the effect of using lightweight concrete in structural elements using three experimental variables such as (admixtures content, cement content and w/c ratio). For twenty-five different mix trial with different admixtures was used. The slump loss, slump flow, compaction factor, compressive strength at the ages of 7, 14, 28, and 56 days and tensile strength at the age of 28 days were obtained. Based on the results the slump ranged from 70 to 140 mm. Moreover, the average slump loss was as same as the average slump loss for the normal concrete (NC). Further, the average compressive strength of the lightweight plain concrete mixtures fluctuated from 70 to 75% of the compressive strength of normal weight concrete and using admixture improved this ratio. By using mineral admixtures, the compressive strength improved to 90 to 95% of the normal concrete compressive strength.

KEYWORDS

Lightweight element; mineral admixture; Compressive strength; Tensile strength.

1. INTRODUCTION

Structural lightweight concrete is expected to produce accepted compressive strength and high durability with low density [1, 2]. The elastic modulus of elasticity of lightweight concrete is lower than that of normal weight concrete. Creep and shrinkage for the lightweight concrete are slightly higher than those of the equivalent normal weight concrete, and this should be taken into account when scheming the structure [3,4]. The lightweight aggregates such as (Lightweight Expanded Clay Aggregate (LECA) – Crushed glass – Perlite – Vermiculite – Crushed brick) , were the main aggregates used to produce a lightweight concrete. Frequently, LECA and vermiculite were used as coarse aggregates to produce lightweight concrete over the last five decades [5,6,7]. Using crushed glass is an innovative technique of producing lightweight concrete according to American Concrete Institute "ACI-130-A Materials for Concrete".[8] Also, the utilization of crushed glass with other quality supplementary cementing materials such as: silica fume, fly ash, and Nano silica (SiO₂) can provide high compressive strength [9,10]. Using these aggregates increased the compressive strength leading to get structural elements with less cross sections. Moreover, it increases the life expectancy for the

lightweight concrete. In addition to, it enhances the workability and segregation resistance at fresh state. Also, it enhances the durability and mechanical characteristics in the hardened state. [11, 12, 13].

2. EXPERIMENTAL PROGRAM

This paper concentrated on the experimental investigation of the fresh and hardened characteristics of lightweight concrete mixes. Twenty-five concrete mixtures were designed. Three parameters were studied: cement content change from 250 to 450 kg/m³, water (w) to cement (c) ratio (w/c) change from 0.3 to 0.5 and admixtures content. Mixtures tested for slump flow, slump loss, compaction factor and the compressive strength at different ages 7, 14, 28, and 56 days.

2.1. Materials

Portland cement type I (CEMI 42.5N) produced by Helwan Cement Company achieving the requirement of E.S.S 4756/1/2013 and E.N 197-1/2011 was used in all mixtures. The coarse lightweight aggregate used in this study was local crushed glass with a maximum nominal size 19 mm. The physical characteristics of the used crushed glass are shown in tables (1) and (2). Shape and size are shown in Fig.1: The physical characteristics, shape and size meeting the requirement of (ACI-130-A Materials for Concrete".) [8]. The coarse aggregate to produce normal concrete was local dolomite. Natural sand from Helwan was used as the fine aggregate. Fly ash complying with chemical and physical requirements of standard specification was used. The used micro silica (silica fume) is a product of SIKA company for chemical materials. The used Nano silica is a product of Nanotech Egypt for Nanomaterials with average particles size around 0.001 micrometers. Sika viscocrete 3425 was used as viscosity enhancing agent (VEA). It contains a polycarboxylic-based copolymer with modified cellulose product to accomplish the dual action effect of high-range water reducer and viscosity-modifying admixture.

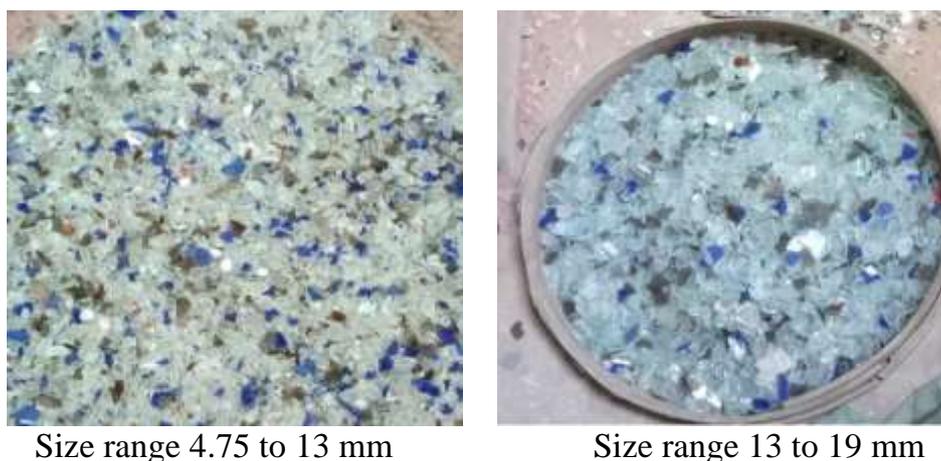


Fig.1: Size and shape of the crushed glass

Table 1: The physical characteristics of crushed glass

Description	24 h water absorption: %	Specific gravity	Unit weight kg/m³
Crushed glass	16.5	1.9	1080

Table 2: crushed glass Sieve analysis

Sieve size (mm)	19	16	9.5	4.75	2.36
%	100	94	73	29	8

2.2. Mix Design

All mixtures unit weight did not exceed 2000 kg /m³, therefore, they were considered lightweight concrete. The mixes were designed according to Standard Practice for selecting characteristics of structural lightweight concrete (ACI 211.2). Table 3 shows the materials quantities for each mix. According to Mix ID: NC, LWC, FA, NS, and SF pointed to normal concrete, lightweight concrete, fly ash, Nano silica and silica fume respectively. Besides, the number signified the ratio of admixtures in the mix design.

Table 3: Concrete Mix Proportions

Group	Mix No.	Mix Code	W/C	Concrete Ingredients (Kg/m ³)								Density Kg/m ³
				Cement	Water	Fine Agg.	Coarse Agg.	Fly Ash	Nano Silica	Silica Fume	VEA	
G A	1	NC0	0.3	450	135	500	1190	0	0	0	2	2277
	2	LWCO					800	0	0	0		1887
	3	LWCFA7.5					800	33	0	0		1920
	4	LWCNS2.5					800	0	11	0		1898
	5	LWCSF7.5					800	0	0	33		1920
G B	6	NC1	0.4	350	140	500	1190	0	0	0	1.5	2231.5
	7	LWC1					800	0	0	0		1814.5
	8	LWCFA10					800	40	0	0		1881.5
	9	LWCNS2					800	0	8	0		1849.5
G C	10	LWCSF10	0.4	350	140	500	800	0	0	40	1	1881.5
	11	NC2					1190	0	0	0		2181
	12	LWC2					800	0	0	0		1791
	13	LWCFA15					800	52	0	0		1843
	14	LWCNS1.5					800	0	5	0		1796
G D	15	LWCSF15	0.45	300	135	500	800	0	0	52	0.5	1843
	16	NC3					1190	0	0	0		2125.5
	17	LWC3					800	0	0	0		1735.5
	18	LWCFA20					800	60	0	0		1795.5
	19	LWCNS1					800	0	3	0		1738.5
G E	20	LWCSF20	0.5	250	125	500	800	0	0	60	0	1795.5
	21	NC4					1190	0	0	0		2065
	22	LWC4					800	0	0	0		1675
	23	LWCFA30					800	60	0	0		1735
	24	LWCNS					800	0	2	0		1677
	25	LWCSF20					800	0	0	60		1735

2.3. Test Specimens

A standard cubic specimens with dimensions (15x15x15 cm) were used for compression test of concrete at ages 7,14,28 and 56 days, as shown in Fig.2.



Fig.2: concrete specimens molds

3. RESULTS & DISSCUSION

The results obtained for the fresh concrete and hardened concrete properties are shown in table 4.

Table 4: Fresh and Hardened Concrete Properties

Group	Mix No.	Mix Code	Slump (mm)	Compaction Factor	Compressive strength kg/cm ²
G A	1	NC0	85	0.98	275
	2	LWC0	73	0.96	220
	3	LWCFA7.5	77	0.95	217
	4	LWCNS2.5	72	0.94	265
	5	LWCSF7.5	75	0.96	220
G B	6	NC1	92	0.96	270
	7	LWC1	83	0.94	215
	8	LWCFA10	88	0.95	224
	9	LWCNS2	89	0.93	260
	10	LWCSF10	90	0.93	230
G C	11	NC2	105	0.95	266
	12	LWC2	97	0.91	211
	13	LWCFA15	100	0.93	231
	14	LWCNS1.5	101	0.91	254
	15	LWCSF15	100	0.91	239
G D	16	NC3	112	0.93	260
	17	LWC3	106	0.89	207
	18	LWCFA20	109	0.90	235
	19	LWCNS1	109	0.9	248
	20	LWCSF20	107	0.9	243
G E	21	NC4	120	0.91	255
	22	LWC4	113	0.86	200
	23	LWCFA30	116	0.88	239
	24	LWCNS0.75	117	0.89	240
	25	LWCSF20	114	0.88	248

3.1. Fresh Properties of lightweight concrete

According to ES: 1658-2/2008 [14] immediately after mixing, the value of slump and slump loss were determined. Compaction factor test was carried out according to (B.S) No 1881-115/1983. The slump flow test was used to evaluate the carried out e deformability and flowability of lightweight concrete in the absence of obstruction as shown in Fig.3: The slump value was recorded every 15 minutes after the end of mixing.



Fig.3: Slump after 30 minutes

3.1.1. Slump

Slump flow and slump loss results for the LWC mixtures due to cement content and w/c ratio as same as the slump flow and slump loss for the normal concrete as shown in Fig.4, Fig.5, Fig.6, Fig.7, Fig.8, respectively. For the lightweight concrete mixtures, the cement content and w/c ratio are the main influences of slump loss optimization as shown in Fig.9.

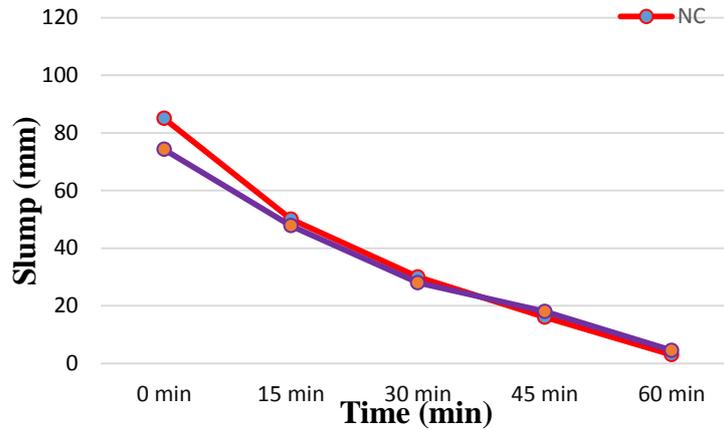


Fig.4: Slump loss- Time relation for mixture having cement content 450 kg/m³

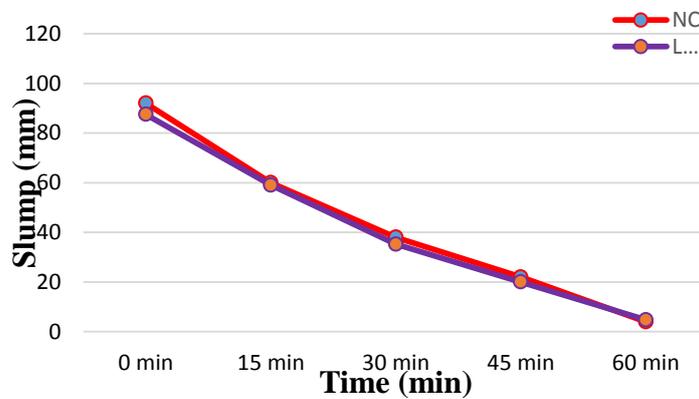


Fig.5: Slump loss- Time relation for mixture having cement content 400 kg/m³

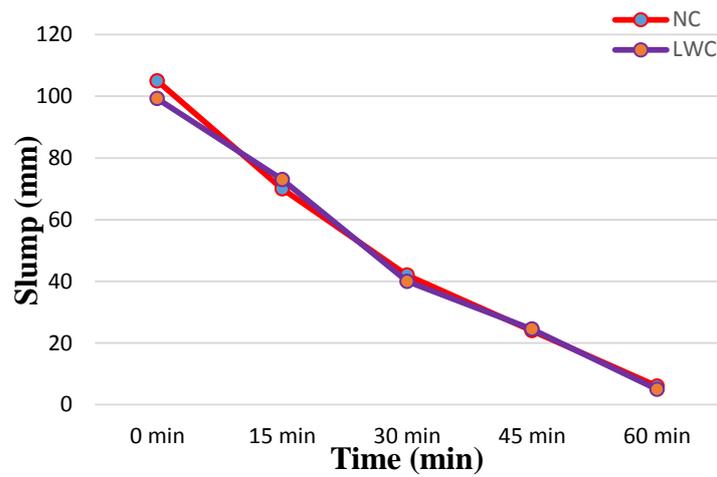


Fig.6: Slump loss- Time relation for mixture having cement content 350 kg/m³

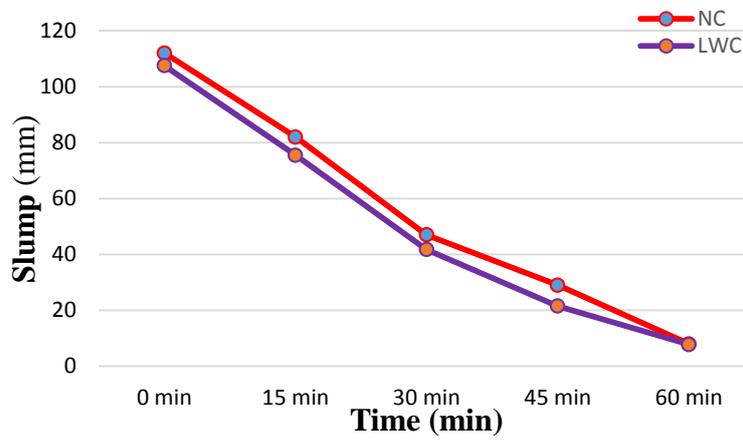


Fig.7: Slump loss- Time relation for mixture having cement content 300 kg/m³

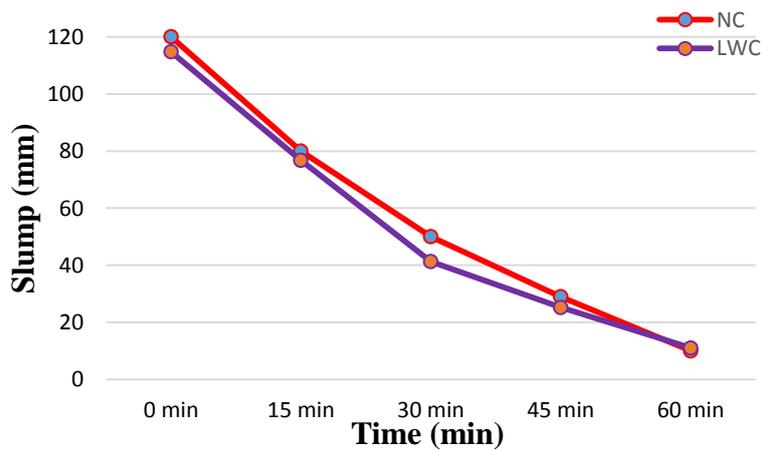


Fig.8: Slump loss- Time relation for mixture having cement content 250 kg/m³

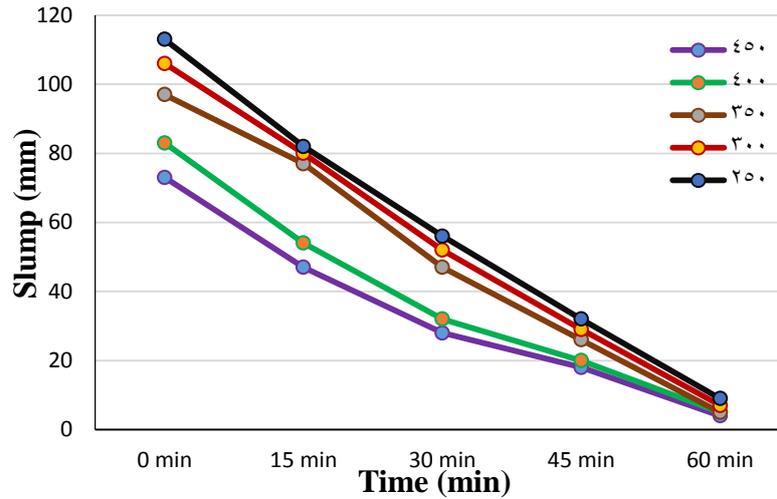


Fig.9: Slump loss- Time relation for LWC mixture having different cement content

3.1.2. Compaction factor

Concrete compaction factor was used to evaluate the workability of fresh concrete. The compaction factor for lightweight concrete reduced by 5% compared with that for the normal concrete as shown in Fig.10. The mineral admixtures increased the compaction factor for the lightweight concrete.

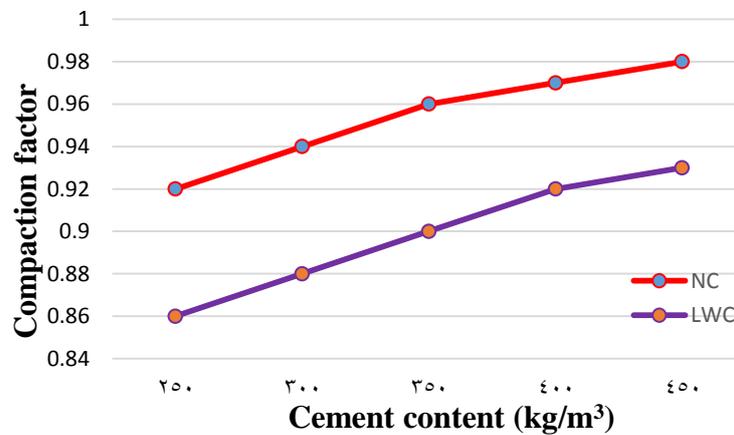


Fig.10: Comparison between compaction factor of NC and that of LWC mixtures

3.2. Hardened Characteristics of lightweight concrete

3.2.1 Compressive Strength

Compressive strength is surely one of the most significant mechanical characteristic of concrete quality. The mode of failure according to the compressive strength test is shown in Fig.11. For Mixtures of cement content is 450 kg/m³ and w/c ratio is 0.3, LWCNS2.5 has attained the objective of this paper that produced a structurally

lightweight concrete. LWCFA, LWCSF are approximately the same manner in the hardened properties. LWC0 is 78% of the compressive strength of NC0 as shown in Fig.12. Decreasing of cement content and increasing of w/c ratio, the compressive strength is reduced for all mixtures as shown in Fig.13, Fig.14, Fig.15, and Fig.16. Generally, the compressive strength for the plain mixture of lightweight concrete is between 79% and 82% of the normal concrete compressive strength. The lightweight concrete with the fly ash of 7.5% and 15% improving the compressive strength with 10.9% and 12.6%, respectively. However, the lightweight concrete with the Nano silica of 2% and 2.5% improved the compressive strength with 19.5% and 23.2%, respectively. Also, the lightweight concrete with the silica fume of 7.5% and 15% improved the compressive strength with 11.1% and 13.3%, respectively. It was observed that the effect of Nano silica on the compressive strength was superior than the using of the others admixtures.

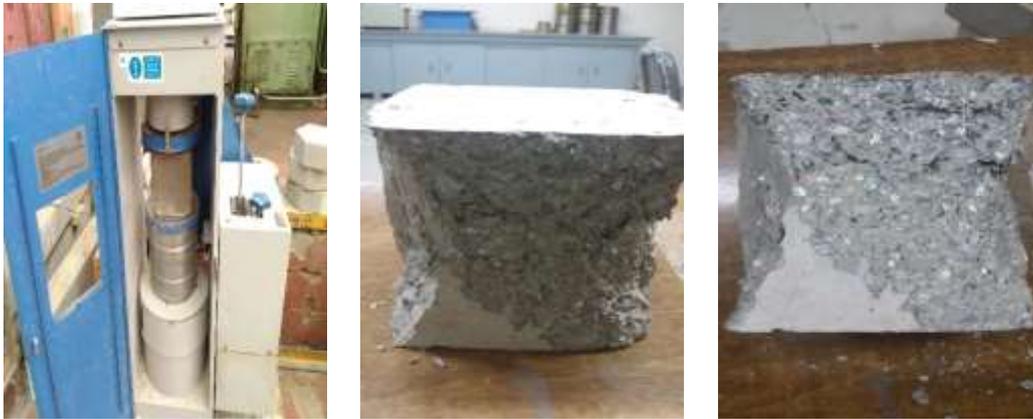


Fig.11: Failure Mode

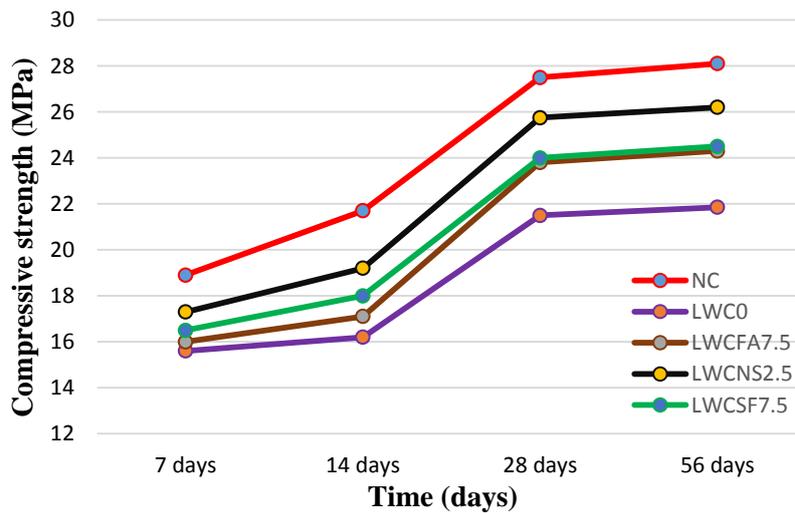


Fig.12: Compressive strength – Time relationship for LWC or NC or both for mixtures having cement content 450 kg/m³

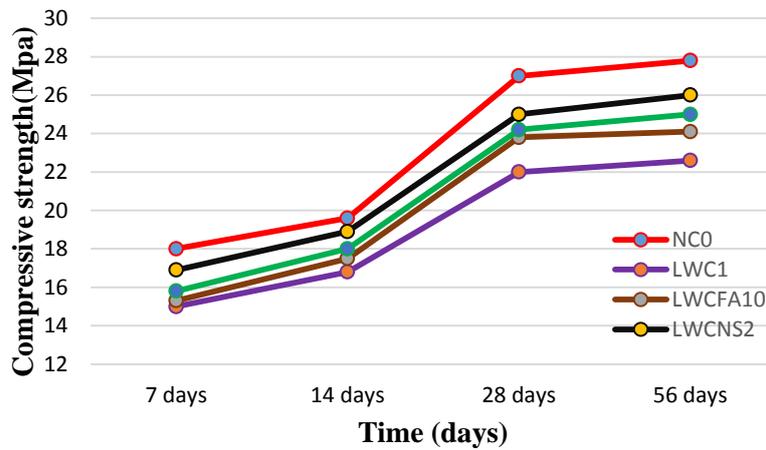


Fig.13: Compressive strength – Time relationship for LWC or NC or both for mixtures having cement content 400 kg/m³

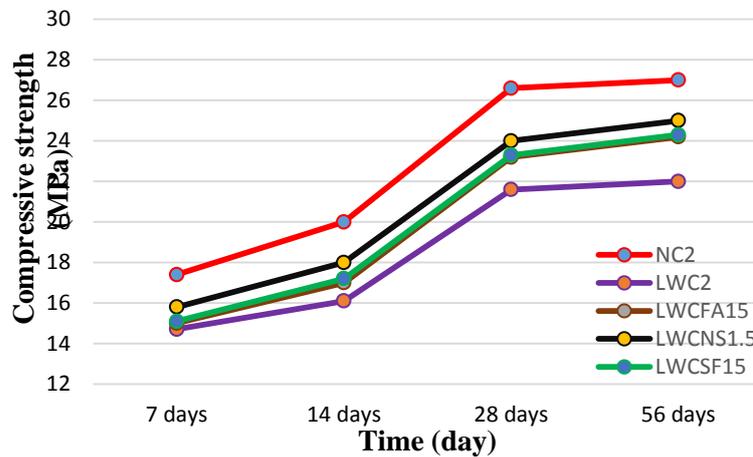


Fig.14: Compressive strength – Time relationship for LWC or NC or both for mixtures having cement content 350 kg/m³

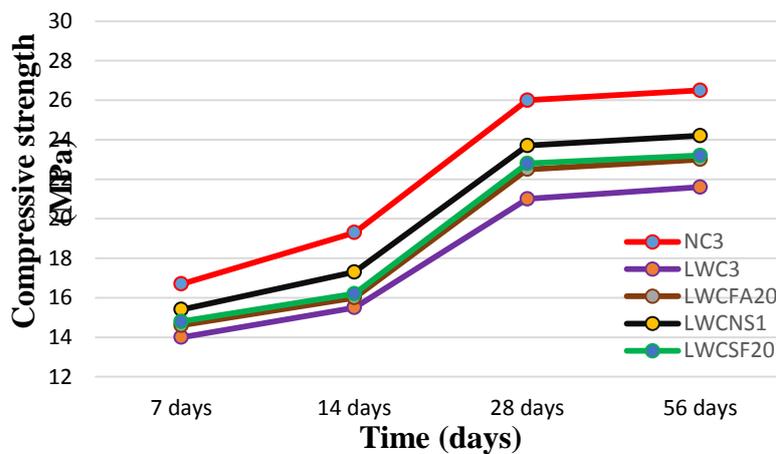


Fig.15: Compressive strength – Time relationship for LWC or NC or both for mixtures having cement content 300 kg/m³

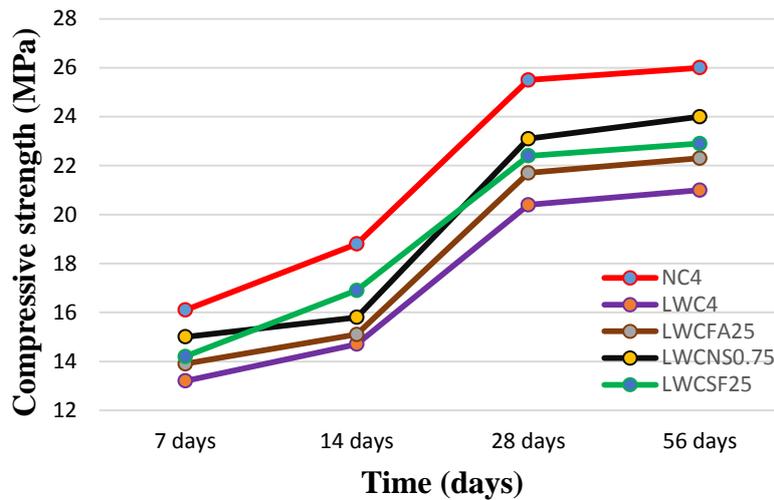


Fig.16: Compressive strength – Time relationship for LWC or NC or both for mixtures having cement content 250 kg/m³

4. CONCLUSION

From the results of the experimental investigation of different LWC and NC concrete mixtures it can be concluded that:

1. Achieving lightweight concrete using crushed glass as coarse aggregate with nano silica by a ratio of 2.5% can be used in structure elements.
2. There are similar behavior in the slump loss for NC and LWC concrete
3. For lightweight concrete cement content and w/c ratio are the most effective factors for enhancing properties in the fresh state, but mineral admixtures are the most effective factors for improving the hardened properties.
4. The compaction factor for the lightweight concrete decreased by 3.75% compared with the compaction factor for the normal concrete.
5. Using Nano silica of 2% and 2.5% can enhance the compressive strength for LWC with 19.5% and 23.2% and can achieve early age strength.
6. Using Fly ash or silica fume did the same behaviour in the hardened state in the compressive strength and the tensile strength.
7. The compressive strength for the plain mixtures of lightweight concrete is between 79% and 82% of the normal concrete compressive strength.

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