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Effectiveness of temperature on the lightweight concrete made from cured crushed glass by Nano Silica

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الملخص العربي

فى هذة الدراسة تم إستخدام كسر الزجاج كركام خشن رئيسي بديل عن الزلط حيث وذلك للحصول علي خرسانه خفيفة الوزن. حيث تم دراسة سلوك الخرسانة تحت تأثير درجات الحرارة المرتفعة من خلال برنامج عملى يتكون من مرحلتين. المرحلة الأولى عبارة عن صب ستة خلطات مختلفة عبارة عن خلطتين من الخرسانة العاديه كخلطة كنترول وأربعة خلطات من الخرسانه الخفيفه الوزن بنسب مختلفه لمحتوي الأسمنت والاضافات حيث تم عمل إختبار الهبوط والفقد في الهبوط ومعامل الدمك لتحديد خواص الخرسانة الطازجة وكذلك تم تحديد خواص الخرسانة المتصلدة مثل مقاومة الضغط عند أعمار (7 ، 28) يوم وكذلك بعد التعرض للحريق لمدة ساعتين و 3 ساعات لدرجات حرارة 300 و ايضا 500 درجة مئوية وكذلك استخدام طريقتين للتبريد الماء ثم اجراء الاختبار فيما بعد والمقارنه بين النتائج وذلك لدراسة مدي تأثير درجات الحرارة علي الخرسانه الخفيفه الوزن ومدي تحملها كمادة انشائية. المرحلة الثانية تتضمن دراسة سلوك الكمرات الخرسانيه قبل وبعد التعرض لنفس درجات الحريق ونفس عدد الساعات التي تم تعريضها للمكعبات الخرسانية وكذلك اتباع طرق التبريد الموضحة.

ABSTRACT

The use of lightweight concrete makes of which in the forefront of materials used in various construction works due to its low density and high thermal insulation. Many attempts have been done to develop a practical and dependable code for lightweight concrete design worldwide to get a satisfactory, practical standard for lightweight concrete mix design. Standards methods for designing the mix of lightweight concrete are few such as ACI 211.2. However, Standard methods did not expose to all the types of lightweight aggregates and its properties. This study is scoped to provide references for the effectiveness of temperature using crushed glass as a coarse aggregate for lightweight concrete. More than, 6 mixes were prepared according to ACI and tested for Slump loss, compaction factor, and compressive strength before and after the temperature exposes.

Lightweight concrete made from crushed glass which is cured by nano silica were scored compressive strength more than the normal weight concrete.

Keywords: lightweight concrete; crushed glass; Nano silica; slump; compressive strength.

1. Introduction

Lightweight concrete is defined as the concrete which its density is lower than 2000 kg/m3, Modern construction has become more in need of multi-use materials and many properties, structural lightweight concrete is one of these materials, Used in many diverse applications such as residential buildings, frames, space frames, structural bridges, harbor berths and pre-stressed or pre-manufactured elements of various types. Using crushed glass is an innovative method of producing lightweight concrete according to American Concrete Institute "ACI-130-A Materials for Concrete". Also, the utilization of crushed glass with other quality supplementary cementing materials such as: fly ash, silica fume and Nano silica (SiO_2) can provide high compressive resistance. High-Performance Light-Weight Concrete (fc = 55–70 MPa, rc = 1900 kg/m3) is increasingly considered as a viable alternative to ordinary and high-performance concrete whenever the size and the slenderness require the reduction of the structural self-weight, and – at the same time – the durability has to be guaranteed under the most severe environmental conditions. The effects of high temperature on the mechanical properties of concrete have been investigated since the middle of the 20 century. The fire resistance capacity of concrete is complicated because not only is it a composite material with components having different thermal characteristics, it also has properties that depend on moisture and porosity. One of the main purposes of this study is to investigate the effect of experimental parameters on compressive strength and crack characteristics of structural lightweight concrete after exposed to high temperature.

2. Experimental study

2.1 Materials

2.1.1 Cementitious materials

ASTM Type I (CEM I 42.5N) Portland cement with specific gravity of 3.15 and Blaine fineness of 3519 cm2/g meeting the requirement of E.N 197-1/2011 was used.

2.1.2 Aggregates

Crushed glass was used to produce the lightweight concrete as a coarse aggregate with a specific gravity of 1.9, grain size was between 4.75 to 19 mm and water absorption by mass of 16.5%. Crushed glass was tested to ASR by immersing in 1N NaOH solution at 80° C according to mix proportion BS 812-123, the result was negative. Dolomite was used to produce the normal concrete. Natural siliceous sand with specific gravity 2.6, volumetric weight of 1.7 t/m3 and fineness modulus of 2.6, was used as a fine aggregate. The properties are presented in table and sieve analysis presented in table 2.

Table (1): The Physical Properties of crushed glass

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

Table (2): Sieve analysis of crushed glass

Sieve size (mm)	19	13	9.5	4.75	2.36
%	100	94	73	29	8

2.1.3 Admixtures

In this study, Sika Viscocrete 3425 was used as a viscosity enhancing agent (VEA) as a chemical admixture to reduce the ratio of water in mix proportions. Nano silica was used in the mix proportions as a pozzolanic admixtures to improve the compressive strength for concrete.

2.2 Mix Proportions

The mix proportions of each mix were calculated by assuming that all its ingredients have to produce a cubic meter of concrete. In mixtures containing. In mixtures containing Nano Silica 2.5% of Portland cement by weight were replaced with Nano silica. The superplasticizer (VEA) was used to improve the workability. Table 4 shows the materials quantities for each mix and The density of the used materials of the mixes design. According to Mix ID: NC, LWC, and NS pointed to normal concrete, lightweight concrete, and Nano silica respectively. Besides, the number represented the ratio of admixtures in the mix design.

Table (3): Mix design (Proportions)

Mix ID	**w/c**	**Cement**	**Fine agg.**	**Coarse agg.**	**Fly Ash**	**Nano SiO_2**	**Silica Fume**	**VEA**	**Density**
		kg/m^3							
NC0	**0.3**	**450**	**500**	**1190**	**0**	**0**	**0**	**1.5**	**2276.5**
LWC0	**0.3**	**450**	**500**	**800**	**0**	**0**	**0**	**1.5**	**1886.5**
LWCNS2.5	**0.3**	**450**	**500**	**800**	**0**	**11.25**	**0**	**1.5**	**1897.75**

2.3 Tested Specimens and parameters

The experimental specimens were 90 cubes to determine the hardened state of concrete. The cubic specimens (150 × 150 × 150 mm) were prepared to determine the compressive strength, shown in Fig.(1).

Fig. (1): Preparing and Casting of samples

To study the above-mentioned issues three mixes of normal and lightweight concrete were made and tested. The lightweight aggregates used were in compliance with the standard ASTM C330 and determination of the lightweight aggregate concrete mixing ratio was based on standard ACI 211.2. Measuring, mixing, transporting, and placing operations for lightweight concretes are similar to the procedures for normal weight concrete. However, there are certain differences, especially in proportioning and batching procedures that should be considered to produce a fin- finished product of the highest quality. In this study, more than 90 concrete samples have been tested. Slump flow, slump loss and compaction factor are the tests to determine the fresh properties. Compressive strength is the test to determine the hardened properties. The tests were made in HRBC, Egypt.

3. Test Results and Analysis

3.1 characteristics of concrete for fresh state

- *Slump Loss Test*

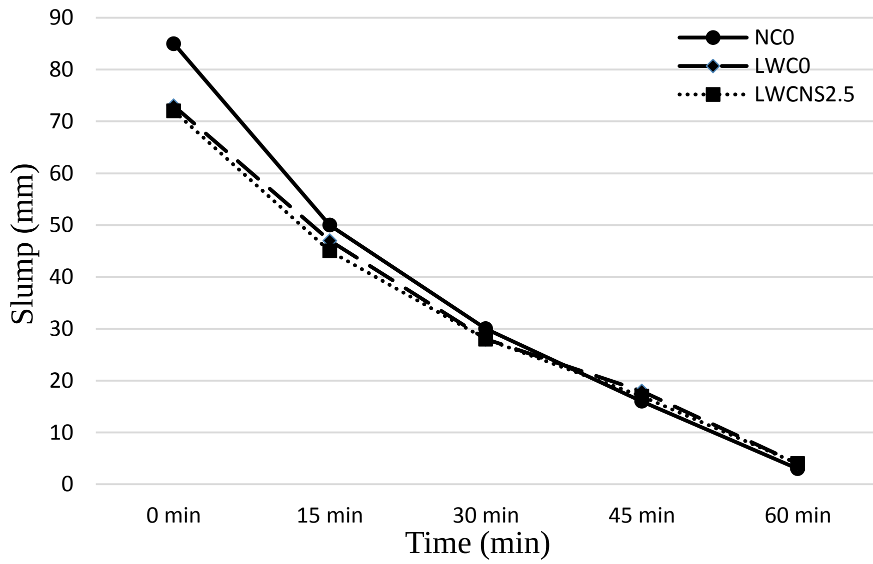

Fig. (2): Slump loss

- NC0 is the highest value of slump, but LWCNS2.5 is the lowest value of Slump loss due to its pozzolanic properties or the nano silica.

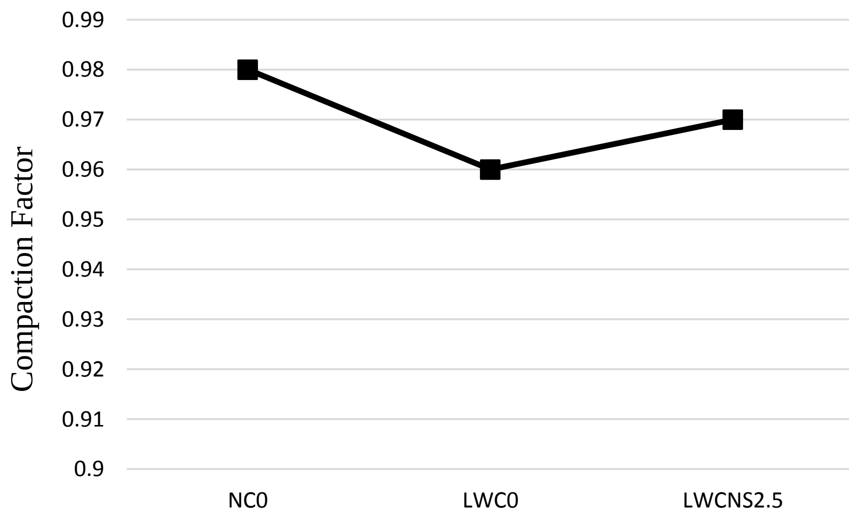

Fig. (3): Compaction factor for Group

- NC0 is the highest value of Compaction factor, but LWC0 is the lowest value of Compaction factor due to its lightweight.

3.2 characteristics of concrete for hardened state

- *Compressive strength test*

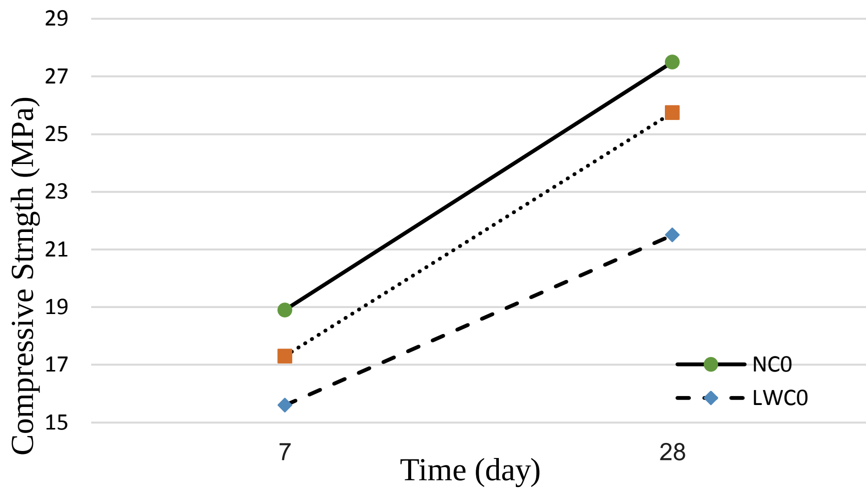

Fig. (4): Compressive Strength Before expose to temperature

- LWCNS2.5 is observed has the same behavior of normal weight concrete in the hardened state that scored 26 MPa, where NC0 is scored 27.5 MPa, Fig. (5). present the failure mode.

Fig. (5): the failure mode.

- *Compressive strength test after temperature exposed*

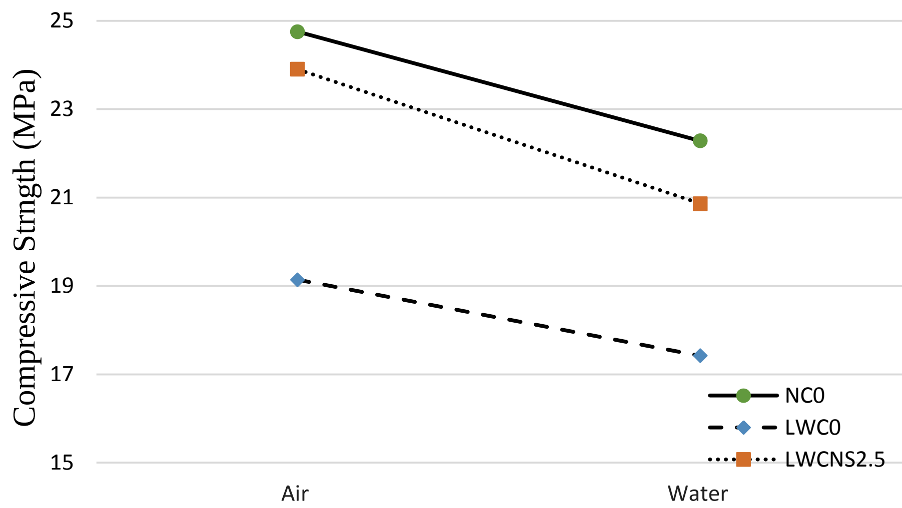

Fig. (6): Compressive Strength after temperature of 300 °C for 2hr

- LWCNS2.5 was scored a nearly values of normal weight concrete, Nano silica enhancing the properties of concrete in the critical states such as temperature.

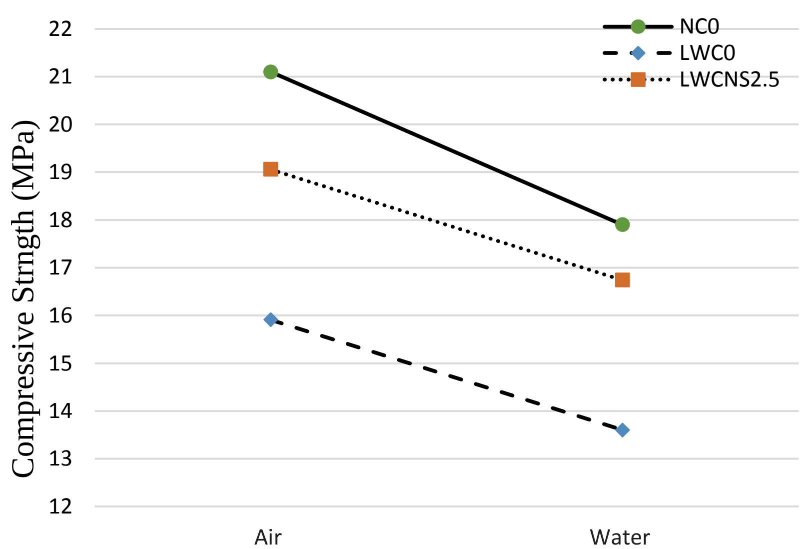

Fig. (7): Compressive Strength after temperature of 500 °C for 2hr

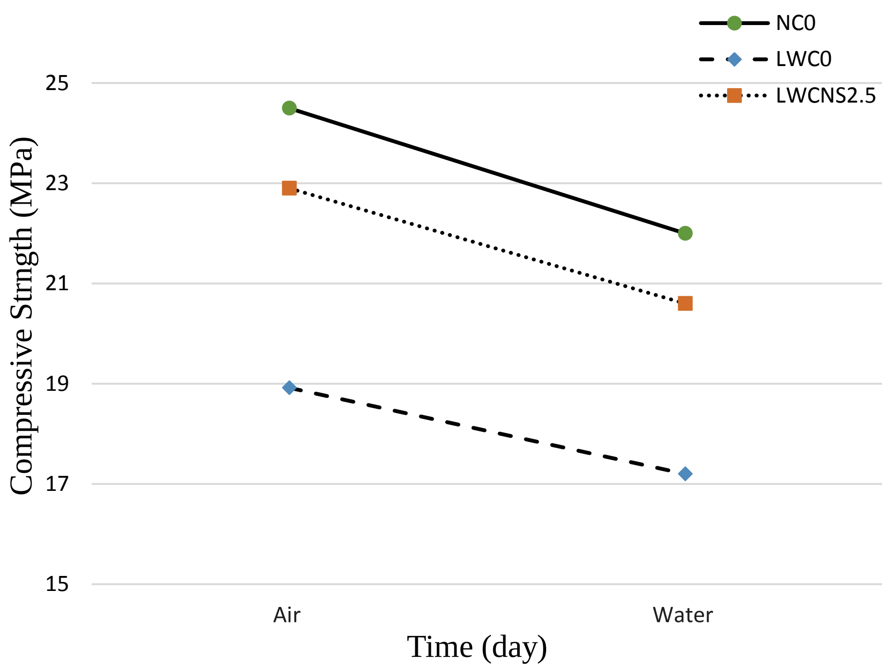

Fig. (8): Compressive Strength after temperature of 300 °C for 3hr

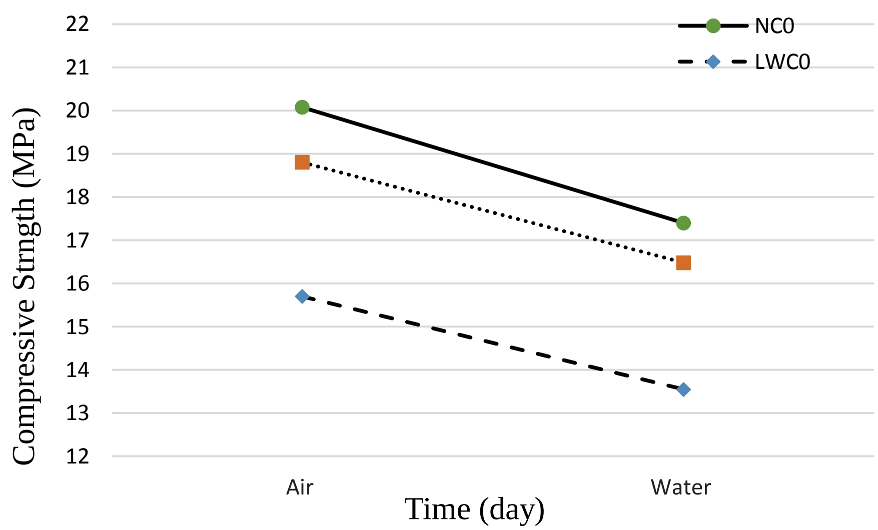

Fig. (9): Compressive Strength after temperature of 500 °C for 3hr

- For the previous curves, it is noticed that in case of temperature the compressive strength is decreased, but LWCNS2.5 has the same behavior of normal weight concrete in the hardened state.

4. Conclusion

1. Lightweight concrete using crushed glass as the main coarse aggregate with Nano silica by a ratio of 2.5% with a density of 1850 kg/m3 can behave structurally almost the same manner as the normal weight concrete that density of 2250 kg/m3 by using the dolomite as the coarse aggregate.
2. Early age strength could be improved by adding Nano silica particles.
3. Nano silica is improving the compressive strength for the lightweight concrete by 18.6%.
4. High temperatures can be divided into distinct ranges in terms of effect on concrete strength in the range of 300-500. Until 500C, an increase in strength was observed in LWCNS2.5 and a slight decrease observed, air-cooled concrete maintained 80% of original strength, while an average loss of 30% strength was observed in water-cooled specimens.

5. References

1. ACI 213R–14, Guide for Structural Lightweight Aggregate Concrete, Reported by ACI Committee 213, (2014).
2. ACI (American Concrete Institute) "ACI 211.2 Standard Practice for Selecting Proportions of Structural Lightweight Concrete", ACI, Detroit, (2009).
3. ACI 209.2R-08. Guide for modeling and calculating shrinkage and creep in hardened concrete. American Concrete Institute, (2008).
4. Magdy Youssef and Ata El-kareim Shoeib, "Behavior of Structural Lightweight Polystyrene Foam Concrete Flat Slabs When Exposed to Fire" The Open Construction and Building Technology Journal, Volume 12, pp 362-374 (2018).
5. Harun Tanyildizi. "Variance analysis of crack characteristics of structural lightweight concrete containing silica fume exposed to high temperature" Construction and Building Materials 49, 1154-1159, (2013).
6. M.A.Hadianfard, S.Jafari. "Prediction of the lightweight aggregate concrete compressive strength using ultrasonic pulse velocity test through gene expression programming", Int. J. Sci. Technol. Civ. Eng. Trans.(2015)
7. Du, Hongjian, Du, Suhuan, & Liu, Xuemei. "Durability performances of concrete with nano-silica". Construction and Building Materials, 73, pp. 705-712 (2014).
8. Miguel C.S.Nepomuceno. "Mix design of structural lightweight self-compacting concrete incorporating coarse lightweight expanded clay aggregates" Construction and Building Materials, 166, pp. 373-385 (2018).
9. Helmut Weigler. " Structural lightweight aggregate concrete with reduced density—lightweight aggregate foamed concrete" International Journal of Cement Composites and Lightweight Concrete, 2, pp. 101-104 (2000).
10. Shahid Iqbal. "Effect of Fibers on Bond Performance of Lightweight Reinforced Concrete" Periodica Polytechnica Civil Engineering 1, pp 20-34 (2015).
11. Victor vaganov. " Performance of Lightweight Concrete based on Granulated Foamglass" Procedia Engineering 3, pp 650-664 (2015).

12. Nurnbergerova T. "Effect of temperature on structural quality of the cement paste and high-strength concrete with silica fume". Nuclear Engineering and Design 2005; 235:2019–2032.
13. Lau A, Anson M. “Effect of high temperatures on high performance steel fibre reinforced concrete”. Cement and Concrete Research 2006; 36:1698–1707.
14. Shuaib H. Ahmad. "Flexural Behavior of Reinforced High-Strength Lightweight Concrete Beams" Structural Journal, 88, pp 69-77 (1991).
15. Seung Bum Park, , Bong Chun Lee and Jeong Hwan Kim, "Studies on mechanical properties of concrete containing waste glass aggregate" Cement and Concrete Research 34, pp 2181–2189, (2004).
16. Weihua Jin, Christian Meyer, and Stephen Baxter. "Glascrete" Concrete with Glass Aggregate that post-consumer represents a major component of solid waste " ACI Materials Journal, 97-M27, Technical Paper (2000).
17. Egyptian Standard Specifications “Standard Test Method for Concrete”, no 1658/2008.
18. Egyptian Standard Specifications, “Concrete Aggregates from Natural Sources”, No1109/2002.
19. Egyptian Standard Specifications, “Portland Cement”, No. 4756-1 / 2013