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The Effect of zeolite on the properties of the LightWeight Concrete

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Abstract— Natural zeolite (clinoptilolite) is a porous silico-aluminate mineral. In this research clancied zeolite was used as an aggregate and bubble-generating factor in production of light weight concrete (LWC). The experimental program consists of four concrete mixes were prepared by using cement 42.5, water, fine and/or coarse zeolite and superplasticizer. Zeolite samples were classified into (coarse zeolite-Zc) with particles greater than or equal to 5 mm and (fine Zeolite-Zf) with particles less than 5 mm .the used percentage of fine and coarse zeolite are (25%, 75%), (50%, 50%), (75%, 25%), (100%, 0%) respectively. This paper aims to study the pozzolanic effect of locally available zeolite in Egypt. And using clainced Zeolite (fine and course) as an aggregate and bubble generating agent, whereas previous research studied fine zeolite only as bubble generating agent and aggregate. And it was found in this research that the Zeolite has a Bozolanic effect that appears in case of long curing times. Usage of coarse zeolite improves the physical and mechanical properties. The optimum replacement amount of natural zeolite were determined to be 50% for ZF and 50% for ZC and at this rate, structural light weight concrete can be produced with compressive strength, unit weight and flexural strength 28 MPa, 1830 kg/m3, 4.7 MPa respectively. Zeolite has a Bozolanic effect that appears in case of long curing times.

Index Terms— Natural zeolite, clinoptilolite, Light Weight Concrete, Compressive strength, flexural strength, Foaming agent.

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1 INTRODUCTION

In the previous years, researches succeed in producing light weight concrete with purpose of reduce the dead load of structural elements, thus reducing the costs of whole structure through allowing the designer to reduce the dimensions of structural elements and the amount of steel reinforcing, in addition to improving the purposes of acoustics and thermal insulation [1]. Light weight concrete can be produced by one or more of the following methods such as producing finless concrete that consists of cement, water and coarse aggregate. Another method is by using lightweight aggregate, or by adding foam materials for the mixture or inserting gas or air bubbles into concrete mixture like aluminum powder or zinc [2, 3]. Structural lightweight concrete is an important and versatile material in modern construction. It has many and diverse enforcement including precast elements or prestressed, multistory building, oil platforms, bridges and. Many contractors and architects realize the inherent and economic advantages obtainable from this material, as illustrated the numerous impressive LWC structures found nowadays around the world [4]. Structural lightweight aggregate concrete is defined as concrete which: (a) is made with lightweight aggregates compliant to ASTM C 330, (b) has a compressive strength at 28 days more than 17.25 MPa (2,500 psi) when examined in agreement with procedures specified in ASTM C 330, and (c) has an air dry density less than 1,840 kg/m3 (115 pcf) as determined by ASTM C 567 [5]. In latest years, the use of pozzolanic materials for the preparation of LWC, e.g., slags, natural zeolite, fly ash, and silica fume has acquired attention due to rigid environmental instructions to recycle discarded material. Zeolites are crystalline alumina silicates with uniform pores, channels and cavities. They possess special properties such as ion exchange, molecular sieves, a large surface area and catalytic activity, which makes them a preferable material for enormous industrial applications [6]. More than 50 natural zeolite and 150 minerals are known and are used in various industries [7]. Some of the researchers studied the utilization of synthetic zeolite in concrete such as G. Girskas, G. Skripkiunas [8] studied the effect of synthetic zeolite on hardened cement paste microstructure and freeze-thaw durability of concrete. Vitoldas, et al. [9] studied the properties of synthetic zeolites when used as supplementary material in hardened cement paste and G. Girskas et al [10] studied the Durability of concrete containing synthetic zeolite from aluminum fluoride production waste as a supplementary cementitious material. Natural Zeolite can be used as internal curing agent in normal strength concrete for permeability improvement and shrinkage reduction[11] also Zeolite can be used in restoration Renders with lightweight aggregate and boiler slag[12]. In the cement industry, asubstantial amount of researchers studied the utilization of zeolite in concrete applications as a pozzolanic material [13-18], for this purpose, this paper studied the pozzolanic effect of locally avaliable zeolite in Egypt. The using of natural zeolite showed modifications in transition zone and quality of pastes through production of secondary C–S–H by The microstructure analysis [19]. natural zeolite is an excellent supplementary cementitious and blending material [7,18,20-22] this is due to The large quantity of reactive SiO_2 and Al_2O_3 in zeolite chemically combines with the calcium hydroxide produced by the hydration of cement to form additional C–S–H gel and aluminates [7,23-27]. Eva et al. [22] studied the properties of concrete containing natural

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zeolite and showed that 20% zeolite content in the blended binder is the most suitable. In China, it is widely used as a cement blending material. It is reported that in 2005 the total quantity of zeolite consumed for this purpose is as much as 30 million tons per year in China [24-28]. J.J. Chen et al. [29] used superfine zeolite to replace part of the cement to reduce the cement consumption and carbon footprint of concrete production because of being a pozzolanic material. It was found that the addition of superfine zeolite as cement replacement up to 20% slightly decreased the early strength, but slightly increased the long-term strength. Yudhishthir et al [30] studied the utilization of Zeolite as A Cementious Material in Concrete and concluded that the generous effects on the durability might be attributed to the pozzolanic reactions Developed in the concrete mixtures incorporated zeolite as supplementary cementitious materials. Dzigita, D. Nagrockiene, G. Girskas [31] studied the properties of concrete modified with natural zeolite addition, and found that Modification of concrete with natural zeolite additives improves the durability of concrete that may be successfully used in various structures. The compressive strength tests showed that in specimens containing 10% of zeolite additive the compressive strength increases up to 13.3% and up to 15.0% after 28 days of curing. K. Samimi et al. [32] studied Influence of pumice and zeolite on compressive strength, transport properties and resistance to chloride penetration of high strength self-compacting concretes and showed that zeolite is higher pozzolan activity compared to pumice. Mahdi et al [15] studied the comparison between a natural pozzolan, zeolite, to metakaolin and silica fume in terms of their effect on the durability characteristics of concrete. the utilization of pozzolanic material as a supplementary cementitious material has a direct relationship with sustainable development because Consuming energy in cement industry is very high and CO2 emissions generated during the production of Portland cement has serious environmental threatens[14]. M. Valipour et al [27] presented that replacement of cement with zeolite reduce global warming potintial. Therfore zeolite can be making highly environmentally friendly concrete. Cenk et al studied the usage of clancied zeolite in production of aerated concrete as a bubble generating agent and as an aggregate [33]. Zeolite surface can be stimulate to have a high energy after calcination at temperatures greater than 400 C. When afterwards submerge in water, the surface produces a big quantity of air and heat because of adsorption [33, 34] this heat increases the air temperature in the pores, or is absorbed on the surface of zeolite particles. Expansion of air volume increases concrete expansion and volume during mixing and pre-storing periods. Isu et al. [35] studied the effect of quartz particle size and found that the crystallinity of tobermorite was increased with increase of quartz particle size. most of researches studied usage of fine zeolite in aerated concrete but The usage of coarse and fine zeolite as an aggregate and bubble generating agent in the production of light weight concrete is still limted .The aim of this study is to test the use of coarse zeolite and fine zeolite in LWC production as a bubble-generating agent and an aggregate and studing pozzolanic of Zeolite locally avalliable in egypt.

2 Experimental Study

2.1 Material and method

The zeolite-light-weight concrete (ZLWC) mixture was produced by using ordinary Portland cement (CEM I 42.5R), zeolite and water. The zeolite, sample used in the LWC mixture was supplied by A and O for trading company, Egypt. The samples were classified into two different particle sizes, fine zeolite with particle size less than 5mm and coarse zeolite with particle size (5 mm to 10 mm) using in LWC mixtures. The main oxide compositions of zeolite were determined by using X-ray fluorescence (XRF) analysis and the other components used in concrete preparation are presented in Table1. Representative LWC compositions were set by dividing the content of zeolite into the following percentages by weight (25% fine to 75% coarse, 50% fine to 50% coarse, 75% fine to 25% coarse and 100% fine to 0% coarse), respectively. The mixture components of the test specimens are abstracted in Table1. Compressive strength, flexural strength tests were performed on 100 mm cubic, 100* 100*500 mm prismatic specimens, respectively. Mixtures were molded in steel molds. Zeolite samples were first heated for 2 h at 550 ºC in a furnace to supply foaming and volume swelling of concrete when mixing and activate the zeolite surface according to previous study performed by Fu et al., 1996 as an optimal condition [34]. The activated zeolite were cooled then used for the preparation of four different types of concrete mixtures.

TABLE 1
MIXING POROPORATIONS FOR 1M³ OF LWC SPECIMENS

Specimen type	Cement (kg)	Water (kg)	Calcined ZF (kg)	Calcined ZC (kg)
Mix I	400	320	311	934
Mix II	400	360	622	622
Mix III	400	440	934	311
Mix IV	400	520	1245	—

3 Evaluation of test results

3.1. Chemical and mineralogical analyses

The chemical analyses obtained from XRF results that identify the major oxide compositions of the major ingredients of ZLWC specimens are presented in Table 2. As shown in Table 2, natural zeolite can be classified as K-rich clinoptilolite. The mineralogical analysis results of zeolite with the XRD technique are presented in Fig. 1. As shows in Fig. 1, zeolite consists of clinoptilolite, quartz and feldspar phases. The glassy phase in zeolite indicate to the pozzolanic property of this material

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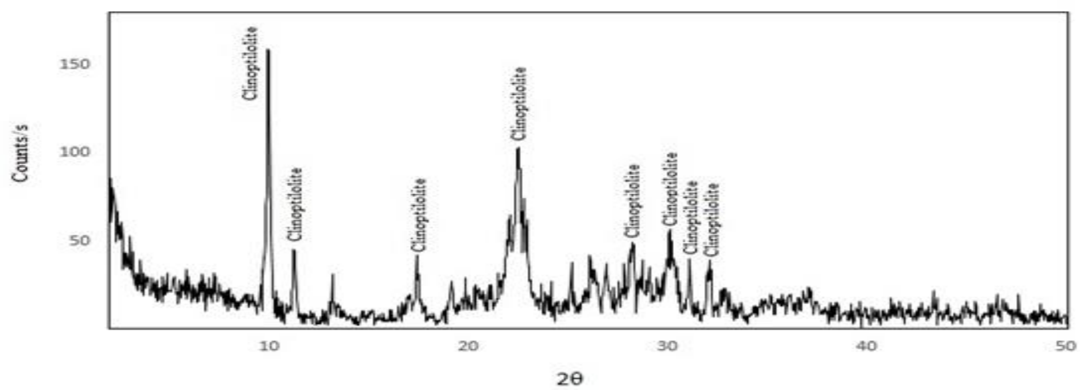

Fig.1.XRD analyses of zeolite used for ZLWC production.

TABLE 2
PROPERTIES OF NATURAL ZEOLITE

Chemical composition	Zeolite (%)
SiO_2	67.11
Al_2O_3	13.01
K_2O	3.17
CaO	2.87
Na_2O	1.30
MgO	0.51
Fe_2O_3	3.14
Na_2O	1.30
TiO_2	0.29
MnO	0.11
P_2O_5	0.02
LOI	8.22

3.2 Unit weight

The unit weight variation of ZLWC specimens, is graphically represented in Fig. 2. It indicates that the increase in the amount of fine zeolite reasons the reductionism of the unit weight for all mixture compositions. The ability of zeolite to generate bubbles within concrete mixtures.

3.3. Ultrasound pulse velocity (UPV)

The ultrasonic method is a common technique employed for analyzing the porous structure of concrete to detect the internal defects (cracks, voids, delaminations, etc.) [36,37]. The measured UPV values opposite zeolite replacement ratios are presented in Fig. 3. Cleary, the velocity is less in specimens cured at 7 days than cured at 28 days. This behavior may be due to incomplete hydration reaction within 7 days curing time. Increasing the curing time leads to more solid form of the concrete. The previously research performed by Alexanderson [38] showed that the shrinkage and porosity decreased with an increasing amount of 1.1 nm tobermorite in calcium silicate hydrates. certainly, the occurrence of the 1.1 nm tobermorite is the most important feature of AAC production. The phase evolution during the production of AAC was reported in an earlier study performed by Mitsuda et al. [39]. It was suggested that alite and belite in cement were mainly transformed to the C–S–H phases and $Ca(OH)_2$ during the molding process, the initial products occurred due to hydrothermal reactions between the different components in the green body. At this stage, hydrothermally formed C–S–H rapidly reacts with dissolved silica. Thereafter, the crystalline tobermorite phase happens with in progress the curing time, it was also spotted that the particle size of incoming zeolite has an effect on the variation of UPV values of ZLWC. Isu et al. [35] discussed the effect of quartz particle size on the chemical and mechanical properties. It was reported that the use of coarser quartz bring about the production of higher crystalline 1.1 nm tobermorite in the state of Ca-reached calcium silicate hydrates, mostly for a longer curing time. The measured lower UPV values for the ZAC for coarser zeolite usage show a good agreement with the findings.

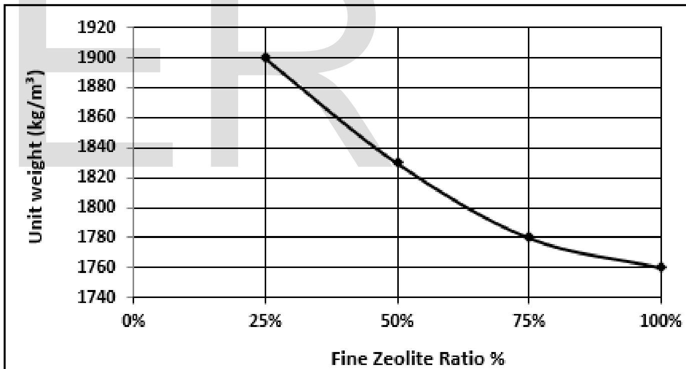

Fig. 2. Unit weights ZLWC specimens.

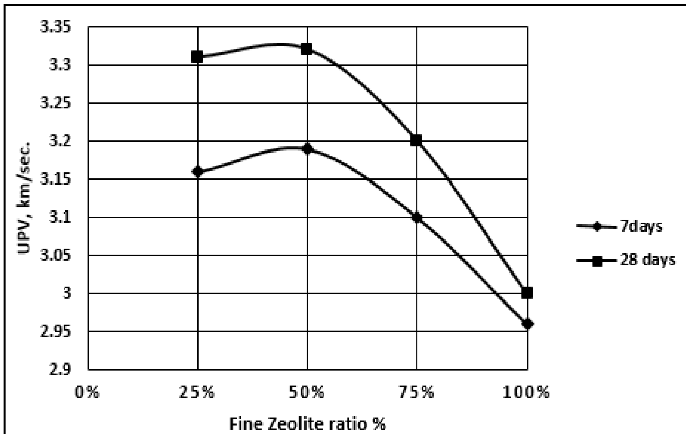

Fig. 3.Ultrasound pulse velocity (UPV) of ZLWC

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3.4. Mechanical properties

The compressive and flexural strength test results of ZLWC specimens versus zeolite replacement ratios are graphically presented in Figs.4 and 5, respectively.

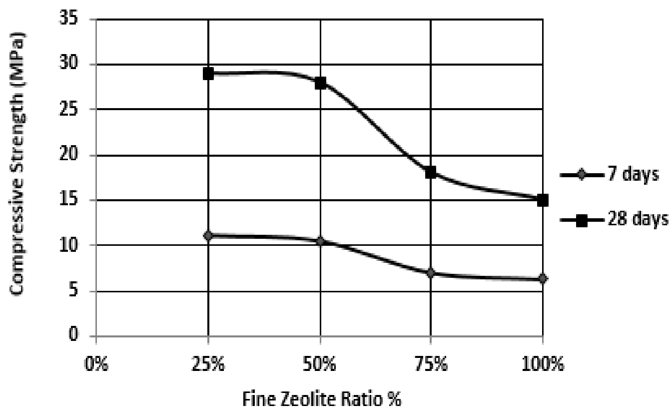

Fig.4. Compressive strength of ZLWC specimens

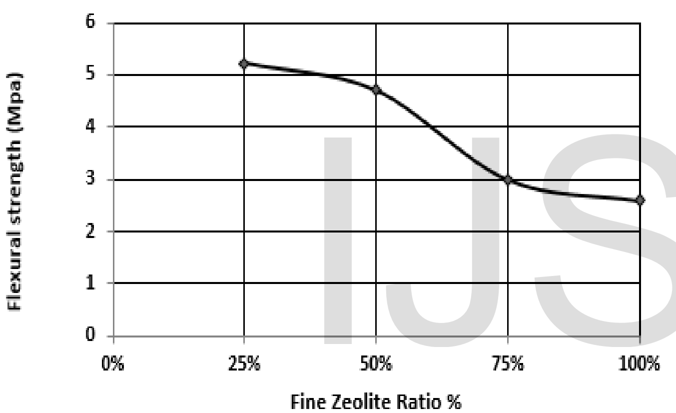

Fig.5. Flexural strength of ZLWC specimens.

These indicate that usage of coarse zeolite with fine zeolite of the substitution material and curing time are efficacious on the strength development of concrete as discussed above. Relatively higher strength values were measured for the concretes cured for a longer time, this is due to the pozzolan effect of zeolite. In cement chemistry, it is usually accepted that the principle products of the hydration of Portland cement are amorphous calcium–silica–hydrate (C–S–H) (60–70%), portlandite $Ca(OH)_2$ 20–25% and other secondary phases, such as calcium carbonate [40]. Zeolite has a pozzolanic influence. Subsequently, through the hydration of cement, it readily reacts with Ca $(OH)_2$ (CH) and transform into the components that have cementitious features. As a result, the strength of hardened concrete is improved [41]. This phenomenon plainly clarifies the increase of strength, especially the specimens containing 75% coarse zeolite where compressive strength increased by 190% with increase of the curing time from 7 day to 28 days. The lower strength values determined at 7days are thought to be an incomplete reaction between zeolite and portlandite, due to the retardant effect of pozzolanic materials. The final properties of the zeolite-Light-Weight concrete (ZLWC) specimens are shown in Table 3.

TABLE 3
PROPERTIES OF LWC PRODUCED WITH CALCINED ZEOLITE.

Mix type	Property			
	Unit weight (kg/m3)	Flexural strength (MPa)	Compressive strength (MPa)	
			7days	28days
Mix I	1.900	5.22	10	29
Mix II	1830	4.7	10.4	28
Mix III	1780	3	6.99	18
Mix IV	1760	2.6	6.3	15

4. Conclusions

This article explains the Practical application of using natural zeolite in lightweight concrete production as an aggregate and a foaming agent. The next derivation can be drawn from this study:

1. It was found that usage of calcined zeolite decreases the unit weight of concrete. Relatively lower specific gravities (2.1) pore structures of zeolite could be attributed to unit weight reductions.
2. Use of fine zeolite compared with a coarse sample increases the water requirement of the mixture. And therefore affects the strength negatively.
3. The ZLWC produced with coarse zeolite (ZC) shows better physical and mechanical properties than specimens contain fine zeolite only.
4. Long curing time strongly affects the final properties of the Light Weight concrete. It was found that LWC specimens cured for 28 days have more tobermorite crystalline phases compared with those cured for 7 days, which correspondingly provided higher compressive strength to these concrete spiecmens.
5. The optimum replacement amount of natural zeolite were determined to be 50% for ZF and 50% for ZC.
6. Zeolite has high Bozolanic effect that appears in case of long curing times.

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