An Environmental Concrete with Algerian Concrete

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Abstract

Materials called very fine aggregate or filler may affect the performance of concrete in an either positive or a negative way. Discussions on aggregate containing very fine material are vitally important. The goal of the study was to determine how the content of filler might affect properties of concrete. The effect of applying different amounts of filler on concrete was then determined. An experimental approach developed a building product consisting mainly of limestone dust, which is considered as waste or by product material of aggregates industry. The majority of abandoned limestone powder wastes (LPW) is accumulated from the countries all over the world and causes certain serious environmental problems and health hazards. This paper presents a parametric experimental study which investigates the potential use of LPW combination for producing a low-cost and lightweight composite as a building material. The results of investigations on the suitability of using limestone dust as aggregate in lightweight aggregate concrete (LWAC) production are reported. In this way, different amounts of limestone dust were used. Some of the physical and mechanical properties of concrete mixes having high level of LPW are investigated. The obtained compressive strength, flexural strength and unit weight satisfy the relevant international standards.

Keywords

Waste, Environmental, Limestone dust, Concrete

1. Introduction

Lightweight aggregate concrete (LWC), popular through the ages, was reported to have a comparable or some times better durability even in severe exposure conditions (Galetakis, 2004). Researches had been conducted worldwide on a large number of natural or artificial lightweight aggregates (Ganesh Babu, 2004). The mix design of lightweight concrete is complicated because it depends on the type of lightweight aggregate (LWA). The use of a local product depends on its specific properties and the requirements for a particular job. One of the methods of producing lightweight concrete is to use light aggregate instead wholly or partially of normal concrete aggregates.

The most important uses limestone dust are: in agricultural as liming material, in plastics and paper industry as filler, in iron and steel industry as flux, for flue gas desulphurization and for wastes neutralization. Since limestone dust is of varying quality it has to be further processed such as drying or screening or blended to meet the specific market requirements. There is an increasing interest to turn limestone dust into a building product (Khandaker, 2004). Nevertheless, there are limited numbers of studies about the possible utilization strategies of limestone in civil engineering industry (Turgut, 2007). Using limestone as lightweight aggregate in its natural form allows economical, lighter and environmental-friendly new composite material.

In earlier studies, the effects of this material on fresh concrete properties and the influence on hardened concrete properties have been already pointed out the mechanical properties of concrete made from substitution of 30% of coarse aggregates by limestone (Kitouni, 2013). In addition, the mechanical properties of concrete made from substitution of 50% and 100% of coarse aggregates by limestone were studied (Kitouni, 2015). In this work, the mechanical properties of concrete made from substitution of 70% of coarse aggregates by limestone are investigated. Concrete test samples were standard cylindrical samples with 160 mm diameter and 320 mm length and were cast to examine the compression resistance and elastic properties. Furthermore, 7x7x28 cm prismatic test samples were used to examine the flexural tensile strength. For each test, three samples were prepared and cured for 28 days, 90 and 180 days at ambient temperature until the time of testing.

2. Experimental Details

Algerian Grade 42.5 ordinary silicate cement of with qualified stability was purchased from El Hamma carrier (Constantine, Algeria), the tap-water, the natural sand in middle fineness was purchased from E.N.G carrier (Constantine, Algeria), and the fine limestone was used and was purchased from E.N.G carrier (Constantine, Algeria). The properties of fine limestone are summarized in Table 1. The normal weight aggregate used was grading of 3-8 mm with specific gravity of 2.7 g/cm^3 and was purchased from E.N.G carrier (Constantine, Algeria). The superplasticizer used is SP40. The mixture was prepared by replacing 30% and 70% weight of normal aggregate by limestone (Table 2).

Table 1. Uniaxial tension test results

Specific gravity (g/cm^3)	Whiteness (%)	Moisture (%)
2.7	92	0.1

Table 2. Mix proportions by weight (cement: sand: limestone)

Cement	Sand	Limestone
1	1.976	2.074

Figure1.
(a) Cylinder 16x32 cm before and after test (b) Elastic modulus test before and after test (c) Beams before and after test

3. Results

All of the results are mainly listed in Table 3.

The compressive strengths data for 28, 90 and 180 days of age LWC are plotted in Figure 2. Each value is averaged from the results of three values.

The 28-day compressive strength in surface dry condition was 18.87 MPa for 70% replacement.

For a given w/c, the compressive strength of lightweight concrete is controlled by the feature of lightweight aggregates (LWA), as indicated in ACI 213 codes as the strength ceiling of LWC. The compressive strength of LWC can be divided into two phases. The mortar phase containing cement, water and sand mainly supports the strength of LWC, and the LWA phase mainly reduces the density of LWC (Hwang, 2005).

Samples show a slight drop in strength between 28 and 180 days (Figure 1). The most significant aspect of the compressive strength data is the slight loss of compressive strength after 28 days. This regression which has been reported by others is usually attributed to microscopic shrinkage cracks which occur with the air drying after the steam cure.

The elastic modulus of concrete can be determined by static modulus of elasticity tests or by the secant modulus of the stress–strain curves resulting from compressive tests. In this study, the second method was used and the measured E value was compared with static modulus of elasticity estimated by empirical formulae.

Table 3. Compressive strength, flexural strength & static modulus of elasticity results

	Compressive Strength (f_c) (MPa)	Flexural strength (MPa)	Modulus of elasticity (GPa)	Static modulus of elasticity (GPa)	Dynamic modulus of elasticity (GPa)
28 days	18.87	6.23	21.87	17.81	22.24
90 days	17.51	5.98	19.95	17.49	21.89
180 days	12.85	5.61	17.08	16.24	20.51

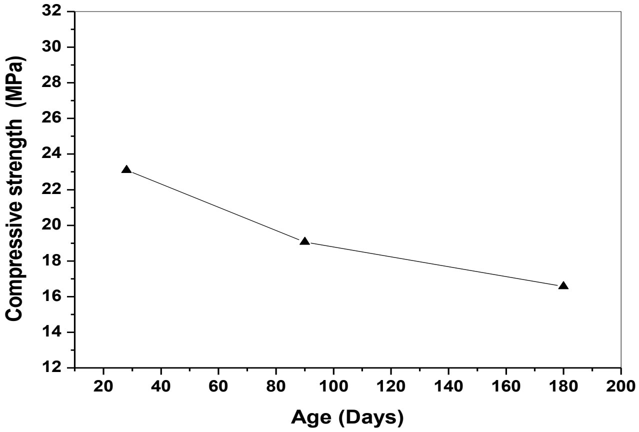

Figure 2. Evolution of the compressive strength of the hardened concrete with age for specimen with 30%, 50% and 70% limestone dust content.

The E value of the concrete at 28 days is about 21.87 GPa for 70% replacement (Figure 3).

In the main, the development of E is influenced by type of coarse aggregate, type of cement, w/c ratio of the mix and curing age. The E of lightweight aggregate concrete is usually between 40% and 80% of ordinary concrete of the same strength (Khandaker, 2004).

The E of concrete is a function of compressive strength. Various building codes have provided empirical equations relating E and compressive strength. The E value of concrete also depends on the stiffness of coarse aggregate, interfacial zone between the aggregates and paste and the elastic properties of constituent materials (Khandaker, 2004).

The statistical analysis carried out to obtain the power relationship between the modulus of elasticity and compressive strength yielded the following equations for the lightweight concretes (Balendran, 1995):

Static modulus: $E_s=8{,}8\ f_c^{0{,}24}$ (1)

Dynamic modulus: $E_d=12{,}0\ f_c^{0{,}21}$ (2)

Where:
E = Modulus of elasticity [kN/mm^2]
f_c = Compressive strength [N/mm^2].

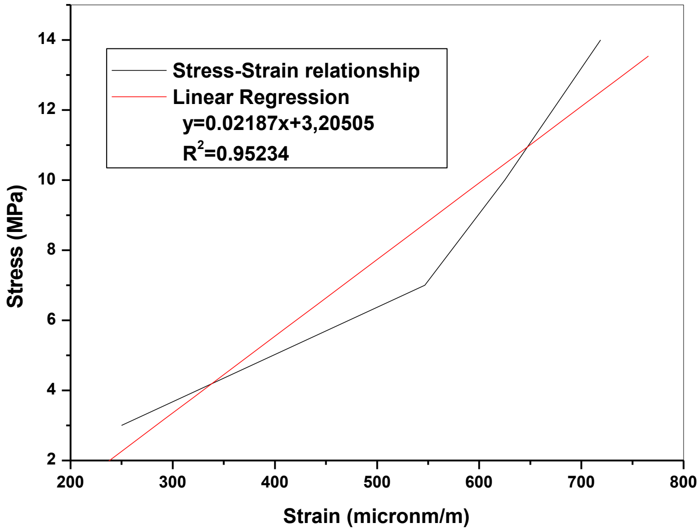

Figure 3. Elastic modulus at 28 days

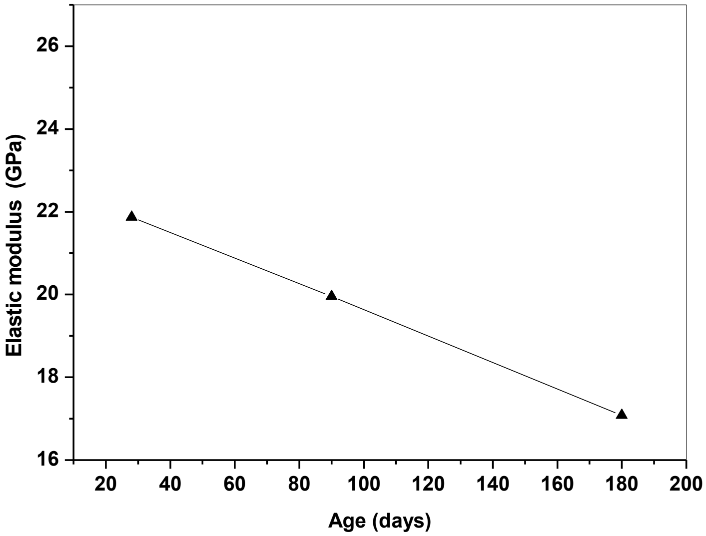

Figure 4. Elastic modulus at different ages

The values of E_s and E_d are listed in Table 3. The calculated 28-day value of E using expression (1) is 17.81 GPa for 70% replacement. In expression (1), f_c is the cube compressive strength. The above value of 17.81 GPa was obtained using cylinder strength value of 18.87 MPA. If the cylinder strength were converted into equivalent cube strength, the estimated value of E would be even greater than 17.81 GPa. More often than not, the empirical formulae are reported to overestimate the E value of lightweight concretes However, for the concrete reported here the calculated E values are less than the observed value.

In a situation where the static modulus of elasticity of a particular mix of concrete may not be readily available for design purposes, it will be quicker and convenient to determine the dynamic modulus, and the static modulus of lightweight concrete can then be determined from the following recommended equation:

$E_s = 0.87\ E_d - 0.78 \pm 3\text{kN/mm}^2$

This equation should give satisfactory results for most of the structural lightweight aggregate concretes.

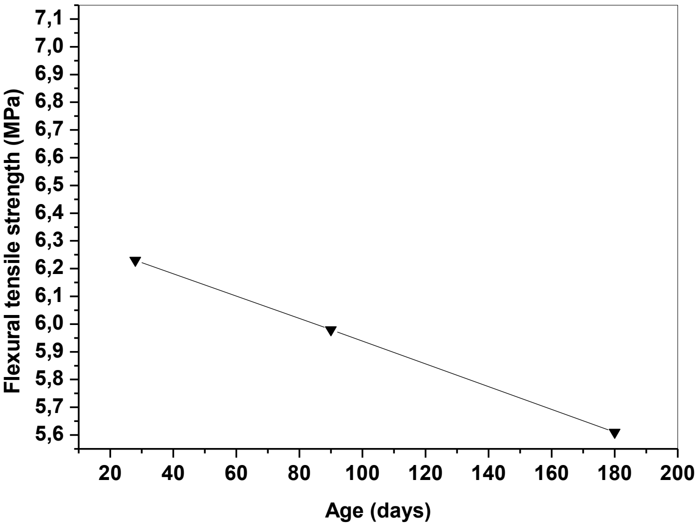

Figure 6. Flexural test results at different ages

The effect of age on the moduli of elasticity is shown in Figure 5. As with the compressive strength there is retrogression at later ages. It is noted that the later curing did not significantly decrease the E value as it did in case of the compressive strength (Table3).

Compared to the compressive behavior of concrete, its tensile behavior has received a little attention in the past, partly because it is a common practice to ignore tensile resistance in reinforced concrete design. Interest in tensile properties has grown substantially in recent years partially due to introduction of fracture mechanics into the field of concrete structures. In addition, the flexural tensile of concrete is important to resist cracking from shrinkage and temperature changes.

The flexural tensile of concrete specimens were measured up to 28, 90 and 180 days of curing (Figure 6). The variation of tensile strength shows trend, similar to that of compressive strength. It is concluded that the concrete strength depends on the strength, stiffness and density of coarse aggregates. For building materials to be used in structural applications, the minimum flexural tensile strength requires is 0.65 MPa (Turgut, 2007).

The flexural tensile strength value was 6.23 MPa for samples with 70% replacement (Figure 6). Generally, the compressive strength is over 15 MPa and the flexural tensile strength is over 3 MPa. The increase in the flexural tensile strength has the advantage that the corrosion resistance of such concrete will be improved. The flexural tensile strength of concrete is one of the parameters that control the rate of reinforcement corrosion. Therefore, increased flexural tensile strength of concrete indicates the potential for an increase in the useful service life of the concrete structures (Mouli, 2008).

4. Conclusions

This paper demonstrates how the use technology can transform the cause of social and environmental disaster into a natural resource and, hence, can be used in the post disaster rehabilitation construction projects. It is confirmed that limestone can be used as a resource in concrete production and can be used in low cost construction especially in seismic zones.

This experimental work showed that limestone can be used for the production of concrete with acceptable mechanical properties. However the complete investigation of limestone concrete, should include further tests concerning mainly with their durability. To investigate the utilization of limestone dust for the production of high strength building products, like concrete paving blocks, new specimens with higher cement content must be prepared and tested. Also the use of other types of cements, like cements with high Blaine value, may be investigated.

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Acknowledgements

This study was conducted under the guidance of Professor Hacene Houari in the Laboratoire Matériaux ET Durabilité des Constructions (LMDC), Department of Civil Engineering University of Constantine, Constantine, Algeria.

Biographies

Kitouni Saida received Ph.D. degree in physics from the University of Constantine, Algeria in 2013. She is currently a fulltime lecturer in Department of Process Engineering Constantine 3 University Constantine, Algeria. Her current research interests are lightweight concretes. Participate in some international conferences in Algeria and others countries in the world.