Journal of Building Engineering 4 (2015) 247–254

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Use of synthetic fibers in self-compacting lightweight aggregate concretes

V. Corinaldesi *, G. Moriconi

Università Politecnica delle Marche, Ancona, Italy

A R T I C L E I N F O

Article history:
Received 3 December 2014
Received in revised form
17 July 2015
Accepted 28 October 2015

Keywords:
Expanded clay
Fiber reinforced concrete
Lightweight aggregate concrete
Self-compacting concrete
Recycled aggregate concrete

A B S T R A C T

In this work, fiber reinforced SCLWAC (self-compacting lightweight aggregate concrete) mixtures were studied, in which synthetic fibers were used. Eight different SCLWACs were prepared, in which, as aggregates, different combinations of fine and coarse expanded clay were tried, also partially replaced by either quartz sand or aggregate coming from concrete recycling. SCLWACs were characterized at the fresh state by means of slump flow, V-funnel and L-box tests, and after hardening by means of compression, splitting tension and bending tests, and drying shrinkage measurements. Strength class of LC 45/50 was obtained by using synthetic macrofibres when the oven dry density of SCLWAC was about 1600 kg/m^3, while if the oven dry density of SCLWAC was lower than 1250 kg/m^3 a strength class of LC 25/28 was reached as well. Tensile and flexural strength values were consistent with concrete strength class, while the elastic modulus was quite low with respect to normal weight self-compacting concrete (SCC). The post-cracking behavior of SCLWAC was strongly improved by the addition of synthetic macrofibers, which provided strain-hardening effect similar to that achievable by means of steel fibers, even if characterized by a sensibly lower weight. In conclusion, SCLWACs showed excellent combination of mechanical and functional properties.

1. Introduction

A great deal of experimental work has been reported and there are several examples of the use of self-compacting normal weight aggregate concrete. Recently, several studies have been published on the production and characterization of self-compacting lightweight aggregate concrete (SCLWAC) [1–6]. Some examples of SCLWAC application are related to bridge decks, repair work and strengthening of structural panels. The weight of concrete structures is quite large compared to the bearing loads, indeed. With the rapid development of very tall buildings, large-size and long-span concrete structures, structural lightweight concrete (LWAC) with different types of LWA has been widely investigated and successfully developed and used in recent years [7–13].

In fact, the application of structural lightweight concrete in the construction industry has many advantages, such as: high strength/weight ratio, savings in dead load for structural design and foundation, reduced risk of earthquake structural damage, superior heat and sound insulation characteristics, low coefficient of thermal expansion. Nevertheless, some limits in its engineering properties have prevented its widely use in the construction industry, as load bearing structural members. In particular, the brittleness of lightweight concrete is higher than normal weight concrete (NWC) for the same mix proportion and compressive strength [14]. Furthermore, generally, the mechanical properties of LWAC are lower than NWC, and if in general an increase in the concrete strength causes further brittleness of the concrete in compression and tension, this effect is especially evident in the case of LWAC [15]. One way to resolve the brittleness of LWAC can be the use of fibers. The literature on fiber reinforced LWAC shows that most of the research focused on the use of steel fibers, as single or combined with non-metallic fibers [16–20].

Eight SCLWAC mixtures were prepared by using either fly ash of silica fume as mineral addition, and different combinations of aggregates with different specific weights, ranging from 890 (fine expanded clay) to 2650 kg/m^3 (sand), in order to obtain several density classes of concrete.

In three mixtures, polypropylene microfibers were also added in order to prevent early concrete cracking, and preserve concrete durability. Moreover, in further three mixtures macrofibers were added in order to achieve an improvement of their post-cracking behavior. Macrofibers are covered externally by a polypropylene reeded sheath, while their core is made of a glass fiber.

All the SCLWACs were characterized both at the fresh and hardened state, in order to evaluate the influence on concrete

* Corresponding author. Fax: +39 071 2204401.
E-mail address: v.corinaldesi@univpm.it (V. Corinaldesi).

http://dx.doi.org/10.1016/j.jobe.2015.10.006
2352-7102/

performance of the various ingredients introduced in the mixture.

2. Research significance

The objective of this research is to design a special concrete with excellent combination of performances, such as high strength and low weight, which are difficult to combine within the same concrete mixture (as enhanced by the state-of-the-art), as well as excellent fresh concrete workability and good post-cracking behavior. For example, Mazaheripour et al. [21] showed that SCLWACs could be obtained by using expanded clay, silica fume and polypropylene fibers (the same ingredients used in this work) with 28-day compressive strength in the range 24–26 MPa and density in the range 1800–2000 kg/m^3.

The main scope of this work was to obtained higher performance than those reported in [21] with mixtures characterized by lower unit weight. In particular, the goal was to achieve the highest concrete strength class as possible by means of SCLWACs with a dry oven density in the range 1200–1600 kg/m^3.

Moreover, an attempt was also made in order to reduce the cost (as well as to improve sustainability evaluable by means of life cycle assessment) of the mixture by using recycled aggregates from concrete demolition, partially replacing expanded clay. In fact, the expanded clay production requires rotary kilns and temperatures of about 1200 °C, while recycled aggregate production just requires crushing of demolished material with low consumption of energy and raw materials saving [22].

The field of application of this special concrete can be, first of all, that of reinforced concrete structures for seismic areas, where lightness, elasticity, easiness of concrete placing, and post-cracking ductility are essential requirements for reducing costs, risks and damages.

3. Preparation of concrete specimens

3.1. Materials

Portland cement type CEM I 52.5R, according to EN-197/1, was used. The Blaine fineness of cement is 0.45 m^2/g, while its relative specific gravity is 3.15.

A low-calcium fly ash (ASTM C 618 Class F) produced by a thermal generating station was used as mineral addition besides to cement. The Blaine fineness of fly ash was 0.48 m^2/g and its relative specific gravity was 2.25.

A silica fume obtained as a by-product of silicon wafer sawing during the production process of solar panels was used, as an alternative to fly ash. The BET fineness of silica fume was about 16 m^2/g and its relative specific gravity was 2.21.

As aggregate fraction, the heavier used was quartz sand (0–6 mm). Its relative specific gravity was 2.65 and its water absorption was equal to 1.5%.

In addition, light expanded clay aggregates (either finer, 0–4 mm, or coarser, 0–15 mm in size) were used to decrease the overall weight of SCC. These aggregates are constructed from clay: they are produced in rotary kilns at temperatures of about 1200 °C. The resulting produced aggregates are very lightweight, resulting of its internal spongy and porous structure. The relative specific gravity depends on their grain size of either 0.89 or 1.15 for the fine and coarse fraction, respectively, and they show high water absorption (15%) with respect to conventional aggregate.

Partially replacing light expanded clay aggregates, a further lighter than natural aggregate was used: recycled concrete aggregate (0–15 mm). It comes from a recycling plant in which rubble from concrete structure demolition is suitably treated.

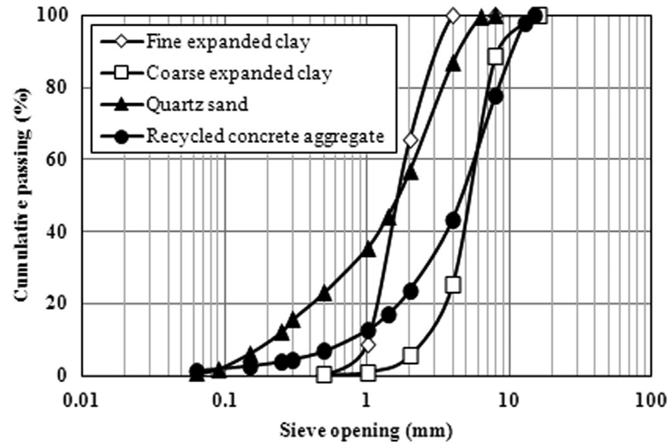

Fig. 1. Grain size distribution of the aggregate fractions.

Previous studies showed the feasibility of the use of recycled aggregates coming from the same plant for structural concrete production [23–25]. Its composition is 100% recycled concrete; the original concrete strength class was unknown and likely different for waste concrete coming from different sources. The main physical properties of the recycled aggregate fraction were relative specific gravity of 2.30 and water absorption of 8%.

The grain size distribution curves of all the aggregate fractions are shown in Fig. 1.

As water reducing admixture, a 30% aqueous solution of carboxylic acrylic ester polymer was added to the mixtures.

Finally, polypropylene microfibers (19 mm long, aspect ratio equal to 63) were added to some mixtures. Alternatively, synthetic reeded macrofibers were used, they were externally made by a polypropylene sheath with a corrugated surface, while their core is made of a glass fiber. Their length is 50 mm and their aspect ratio is equal to 110.

3.2. Concrete mixture proportions

Eight different SCLWAC mixtures were prepared with the same kind of cement (CEM I 52.5R), employed at a quite high dosage of 560 kg/m^3. As mineral addition either fly ash (20% by weight of cement) or silica fume (12.5% by weight of cement), were adopted. Concerning the water reducing admixture, a dosage of either 1.4% or 1.6% by weight of cement was used, in the presence of fly ash and silica fume, respectively; the different dosage is due to the huge specific surface area of silica fume. Usually, the water to cement ratio adopted was equal to 0.42, but in the presence of polypropylene microfibers, due to their high specific surface area, the water content necessary to achieve the same workability level was higher, consequently the water to cement ratio increased up to 0.44. The SCLWACs mixture proportions are reported in Table 1.

As aggregate, different combinations of quartz sand (0–6 mm), fine expanded clay (0–4 mm), coarse expanded clay (0–15 mm), as well as recycled aggregate (0–15 mm) were tried. The recycled-aggregate fraction was added to the mixture after water-soaking, in a condition very close to that defined as saturated surface-dried, as suggested in previous works [26]. The same procedure was followed for the expanded clay fractions.

In order to meet the self-compactability requirement, firstly the two expanded clay fractions were suitably combined at 38% and 62% for the fine and coarse fractions, respectively.

Then, expanded clay was partially replaced by recycled aggregate at the 28% by volume of the total aggregate (the dosage obviously has been corrected keeping into account the different volumic mass of the two kinds of aggregate).