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Research Article

Advance in Environmental Waste Management & Recycling

Utilization of Construction and Demolition Waste, Fly Ash Waste in Autoclaved Aerated Concrete

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Abstract
China's industries are rapidly growing, and with that generation of waste is also increasing. Associated environmental concerns over construction and demolition waste, industrial waste such as fly ash generated by thermal power plants need to be utilized in some form. Autoclave aerated concrete is a lightweight material that can be used as an alternative building material; it is widely composed of raw materials such as cement, quicklime, sand, gypsum, and an aerating agent like aluminum powder. In this study, 40% waste will be utilized, Construction waste (5%,10%,15%....40%) and Fly ash (35%,30%,25….0%)respectively, keeping the aerating agent constant at 0.06% that is aluminum powder. The compressive strength of the material will be checked after autoclaving at 200^0 temperature and 1Mpa Pressure for 6 hours. The study aims to design an autoclave aerated concrete material and to recycle the waste generated by various industries mainly from the construction sector.

Keywords: Autoclavedaerated concrete, Light weight concrete, Eco-friendly, Construction and demolition waste, Flyash,Aluminum

Background, Introduction and Research Objectives
Construction and demolition waste (C&D) have become a significant concern,not only for China but also for many countries throughout the world, because of rapidindustrialization and economic growth, Cities are experiencing tremendous expansion, especially those from the developing world, primarily due to the increasing urbanization and in its development plans [1,2]. Typically, construction and demolition waste usually consist of construction concrete, construction site debris, wood, metals, plastics, carton, glass, asphalt, rocks, and soils [3]. Several studies have shown that construction and demolition waste problems impacts the society, the economy and the environment negatively, so finding controlling measures are necessary to deal with such waste [4-8]. The estimates from 2015 to 2035 suggest that the world would have about 1.5 billion new urban residents with a rise of 90 percent increase, especially in growing economies in Asia, which will cause new infrastructure and housing challenges [9]. It is all happening because ofan increase in populations, boom in construction sectors, rapid development from rural to urban areas, and rising community living standards, which have speeded up construction and demolition waste generation considerably [10].

China is one of the largest producers of construction and demolition waste, and it is because China is still stated as a developing country [11]. The volume of waste generated in any region of a nation can be based on many factors, town or regional planning, population, legislation, and the state of the construction industry [12]. According to previous study, in 2011 China produced from 600 to 800 million tons of construction and demolition waste (C&D), 75% of which was C&D waste and 25% was pavement asphalt waste [13]. Astonishingly, this number corresponds to the total generation of C&D waste across the whole of the European Union(E.U.) and five times more than in the United States (USA) [13,14]. Construction and demolition waste inevitably end up in landfill sites after segregation and recycling in many developed countries; however, it's not the case with China [10].

China pays little to no attention towards the serious problem hence according to another data the generation of excess waste from the construction industries is still growing [2,4]. It was calculated that in 2015-2016 the annual amount generationof C&D waste in China is approximately 1.4 to 2.4 billion tons, an unprecedented increase in waste in human history [11,15]. Due to the improper management of land fill sites for C&D waste, even less than 5% is recycled and only 10% capacity of landfill sites are properly managed [16]. The majority of the waste goes to open dumping sites, farmlands, gravel pits, river banks, far awayresidential lands. Each of these unauthorized dumping sites lacks sufficient leachate collection systems and stability and safety considerations. Hence waste management has not been improved [17-19]. It is considered thatthe practice of C&D wastemanagement should abidebe obey with the "3R" rule providing thewaste reduce, recycle and reuse [20]. The developed countries such as Germany, Japan, Singapore, United States, South Korea try to follow this rule [20]. Awareness and urgent steps are needed to reduce C&D waste or to use it in one or another form through waste control and balancing of itssource [21].

Autoclaved aerated concrete (AAC) is a lightweight porous building material that is a factory-made product available in the form of precast units for partition walls, roof insulations, trench fills and floors or sometimes used as a low load-bearing wall structure [22-24].The AAC use is similar to concrete blocks. AAC material does not consist of any coarse aggregates, it is lighter and can easily be transported as compared to concrete precast units, AAC can similarly be used as to make other masonry units [25,26]. Moreover, AAC has other beneficial properties such as fire resistance, thermal, and sound insulation value. Generally, the main raw materials used for manufacturing commercialized AAC is cement, quick lime, quartz sand, water and an expansion agent such as aluminum.The raw materials are mixed, set for a brief amount of time for the reaction to take place and then autoclaved subsequently at high temperature and pressure to impart strength and increase stock life. Finally, the lightweight porous product is obtained. The industrialized manufacturing process is shown in Figure1.

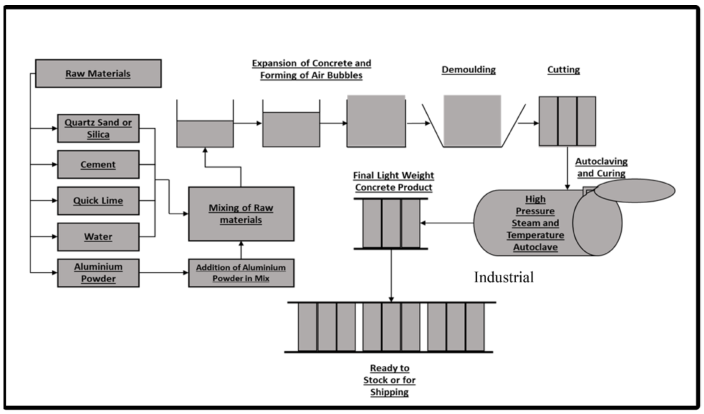

Figure 1: Manufacturing Process of Autoclaved Aerated Concrete

The AAC makingfrom various industrial wastes has been suggested in many studies to reduce the production costand to increase the variety of raw materials, such as glass waste, air-cooled slag, fly ash, municipal solid waste incinerated bottom ash, copper tailing and blast furnace, efflorescence sand, coal bottom ash, power industry waste, iron tailings,etc [24,27-34].

Production of AAC using waste utilization is the best technical route.Studies have reported that the production of good quality AAC is achievable [35-38]. Due to the ever-booming construction industries, especially in China, waste of construction and demolition isa widely available. The aim of thisstudy was to investigate the feasibility of AAC productionusing waste of construction and fly ash as a substitute for siliceous material, e.g. quartz sand.

Reducing the consumption of valuable siliceous raw material, sand, through the processing and disposal of waste, allows to save energy and improve the ecological state of the environment.

Materials and Methods

Preparation of Raw Materials

Raw materials such as cement quicklime, gypsum, aluminum powder and fly ash were provided by The National Dredging Company Shanghai China. Fly ash, a byproduct of thermal power plants, was used as an alternative for quartz sand in the production of AAC [39,40].

The production of AAC blocks from fly ash is economically advantageous, since this raw material is a reusable waste of the thermal industry [41,42].

Construction and demolition waste debris was obtained from a construction site near the Environmental Department Donghua University Shanghai China.

First, materials such as wood, plastic, and steel were removed. Then concrete waste, construction debris, demolished waste were coarsely crushed using a mechanical crusher, and then they were finely crushed using an industrial grinder. Finally, fine fractions of 1 mm and less were selected using aset of sieves.

Experimental Procedure

The composition of mixed samplesis shown in Table 1. Percentages of cement, gypsum, lime and aluminum powder were constant, whilepercentages of fly ash, construction and demolition (C&D) wastewere variable.

Table 1: The composition of mixed samples

Sample Identification	Portland Cement	C&D Waste	Fly Ash	Quick Lime	Gypsum	Aluminum Powder	W/R
AC-1	28%	5%	35%	30%	2%	0.06%	0.65
AC-2	28%	10%	30%	30%	2%	0.06%	0.65
AC-3	28%	15%	25%	30%	2%	0.06%	0.65
AC-4	28%	20%	20%	30%	2%	0.06%	0.65
AC-5	28%	25%	15%	30%	2%	0.06%	0.65
AC-6	28%	30%	10%	30%	2%	0.06%	0.65
AC-7	28%	35%	5%	30%	2%	0.06%	0.65
AC-8	28%	40%	0%	30%	2%	0.06%	0.65

Note: W/R is ratio of water to final material

The starting raw materials (except Al) were weighed with an accuracy of ± 2 g, while aluminum powder was weighed with an accuracy (± 0.02 g). The dry compositions were thoroughly mixed. Then, a warm water (52 ± 2°C) was slowly added to the mixture and stirred for 4 minutes to obtain a uniform paste. After that, the aluminum powder was added to the paste and mixed for 1 minute. The final mixtures were poured into preheated molds with size of 60x60x60 mm.

The samples were processed at a pressure of 1 MPa and temperature of 200°C for 6 hours. The process diagram is shown in Figure 2.

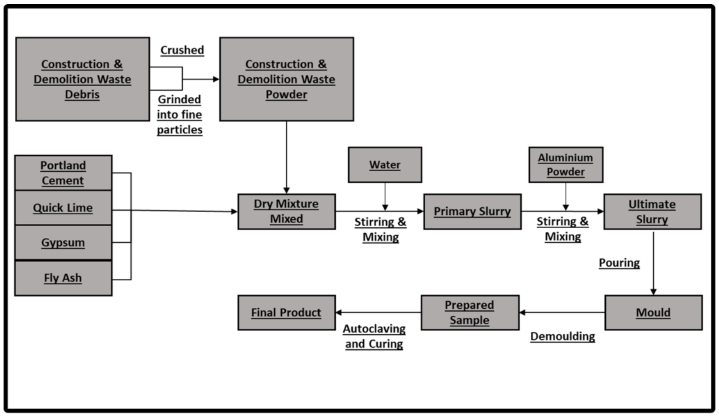

Figure 2: Flow Diagram of Experimental Process

Density Control and Analysis

During the chemical reaction, the expansion agent – aluminum, reacts with calcium hydroxide (product of interaction between water and Portland cement). As a result, tricalcium hydrate and hydrogen gas are formed. Large volume of generated hydrogen cause pore formation and expansion of concrete (Figure 3A). The reaction equation is depicted as follows [43,44]:

$$2Al + 3Ca(OH)2 + 6H2O \rightarrow 3CaO.Al2O3.6H2O + 3H2 \quad eq\ (1)$$

The density of porous material was controlled by the Chinese standards of GB11968-2006. The Figure 3B shows the controlled sample having density in the rangebetween 600 to 800 kg/m3. Figure 3C shows the final lightweight porous concrete. The compression strength was tested after drying of the final material according to GB/T 11969-2008. Water absorption test was carried out according to GB/T 11970-1997.

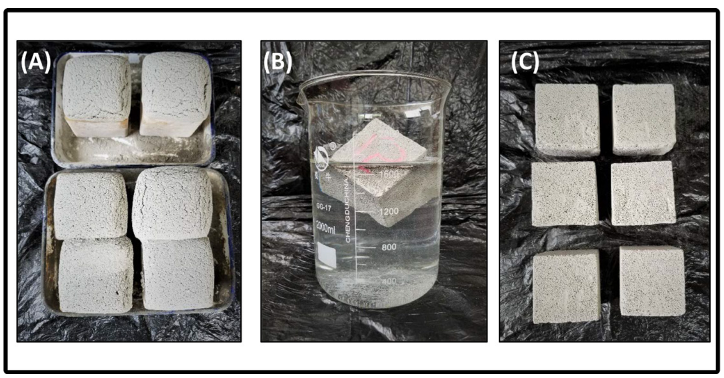

Figure 3: Expanded Concrete (A), Controlled Sample (B), Final Porous Concrete (C)

Results and Discussion

Mechanical Properties

The results of the compression strength are given in Table 2. The first two samples AC-1 and AC-2 gave approximately similar results. Sample AC-4 containing 20% C&D waste and 20% fly ash showedthe highest strength of 2.2 MPa. On the other hand, sample AC-8 containing 40% C&D waste and zero additive of fly ash gave the lowest strength (1.43 MPa) and lowest density (655.49 Kg/m3) (Table 2, Figure 4).

Table 2: Characteristics of the tested samples

Sample Identification	Cross-sectional area (mm^2)	Density (Kg/m^3)	Compression strength (MPa)
AC-1	3600	753.83	1.83
AC-2	3600	746.54	1.80
AC-3	3600	739.26	2.00
AC-4	3600	728.33	2.22
AC-5	3600	721.04	1.74
AC-6	3600	710.12	1.47
AC-7	3600	680.99	1.53
AC-8	3600	655.49	1.43

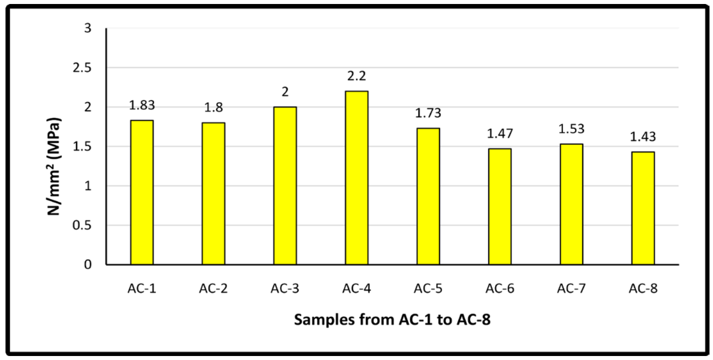

Figure 4: Compression Strength of samples

Water Absorption

The value of water absorption (WA) of the samples is given in Figure 5. The samples AC-7 and AC-8 had relatively high WA value, 23.0-25.6%. This is due the fact that these samples were too porous as compared to other samples.

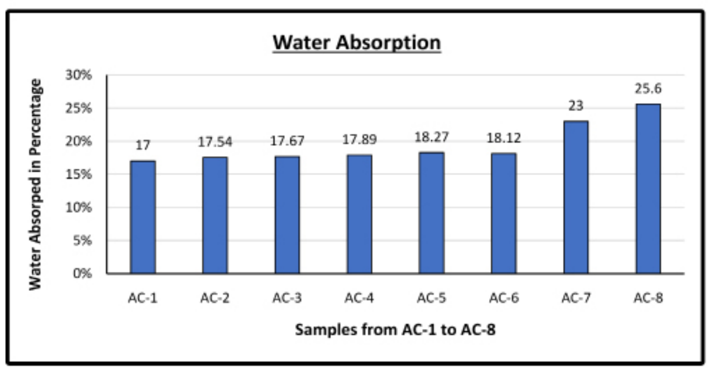

Figure 5: Water Absorption of Samples

Conclusions

In this study, the feasibility of utilizing construction and demolition waste, fly ash waste for the production of lightweight autoclaved aerated concrete has been illustrated. Based on the work, the following conclusions may be undertaken. Sample AC-4, containing 20% fly ash and 20% C&D waste, showed the highest compressive strength along with satisfactory density and low water absorption. An increase in the content of C&D waste and a corresponding decrease in the content of fly ash leads to a deterioration of all studied features of AAC, especially for sample AC-8 with zero content of fly ash.

Based on the obtained results, the AC-4 concrete with the highest compressive strength can be used for simple applications such as partitions, roofing, floor filling, and possibly for masonry.

However, even this material does not meet the strength standard required for load-bearing structures. Finally, it can be concluded that the use of construction waste along with waste of other industries in concrete production can be a positive step forward in saving resources and improving the environment.

Conflicts of interest
There are no conflicts to declare.

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