Sustainable Solutions in Structural Engineering and Construction
*Edited by* Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A.

ISBN: 978-0-9960437-0-0

# PRODUCING LIGHTWEIGHT CONCRETE AGGREGATE FROM IRAQI ATTAPULGITE

JAWAD F. QAIS, ABDULRAZZAQ A. WALEED, and JASIM H. MAHDI

*Building and Construction Engineering Department, University of Technology, Baghdad, Iraq*

This research aimed to produce a type of lightweight concrete aggregate by using available local materials. The lightweight aggregates were produced using methods of sintered strand produced from Iraqi Attapulgite. Clay particle size, firing temperature, and firing soaking time were selected to determine the effectiveness of these parameters on the relative density of produced aggregate. It was found that decreasing particle size has a negative effect, and the optimum firing temperature is 1100°C for 30 minutes. The unit weight density for LWA obtained is about 808 kg/m$^3$, and the relative density is 1.445.

*Keywords*: Lightweight aggregate, Clay, Relative density, Firing temperature.

## 1 INTRODUCTION

Structural lightweight concrete (LWC) has many applications in various types of structures (ACI 2003, Chen and Liu 2005). The density of LWC typically ranges between 1440 and 1840 kg/m$^3$ (Neville 2011, Kivrak, et. al. 2006).

### 1.1 Lightweight Aggregate

Lightweight aggregate (LWA) is a type of aggregate used in the production of lightweight concrete products such as concrete block, structural concrete, and pavement, having low bulk specific gravity (ACI 2003). Most lightweight aggregates (LWAs) are of natural origin, mostly volcanic (pumice, tuff, etc.), and are ready to use, while the remaining types have been developed for factory production from natural raw materials (expanded clay, shale, etc.) by heat treatment. Internal porosity of lightweight aggregate is high, which leads to a low apparent specific gravity (Chi et. al. 2003). High porosity may result in lower strength and low heat conductivity (Campione and Mendola 2004).

### 1.2 Lightweight Concrete (LWC)

LWC is produced by the following methods: (a) using lightweight aggregate, (b) introducing large voids within the concrete, (c) using coarse aggregate only in the mix (Newman and Choo 2003, Kivrak et. al. 2006).

## 2 RESEARCH SIGNIFICANCE

Artificial LWA are being produced due to the scarcity of natural sources, manufactured from a widely available material: clay (Arioz et. al. 2008). The main goal of this research is to investigate and produce a new LWC aggregate according to ASTM (2005) from Attapulgite (Palygorskite) clay (Bradley 1940, Liu, et al. 2013, Velde 2010). The formula of the ideal unit cell is $Mg_5Si_8O_{20}(OH)_2(OH_2)_{4.d}4H_2O$, which is available in Iraq in large amounts in the Tar AL-Najaf Injana region, Al-Najaf governorate. Its formation is from the late Miocene–Pliocene as bluish-green and gray clay stone 0.5 m thick.

## 3 EXPERIMENTAL WORK

### 3.1 Attapulgite

Table 1 shows the chemical analysis of Attapulgite used.

Table 1. Chemical analysis of Attapulgite after grinding.

| Chemical Compound | Oxide content (%) |
|---|---|
| $SiO_2$ | 51.2 |
| $Al_2O_3$ | 8.26 |
| $Fe_2O_3$ | 7.90 |
| $TiO_2$ | 0.29 |
| CaO | 1.12 |
| MgO | 16.4 |
| $SO_3$ | 0.65 |
| $Na_2O$ | 0.41 |
| $K_2O$ | 0.38 |
| L.O.I | 13.54 |

Refer to the X-Ray diffraction analysis of Attapulgite, where the presence of Quartz ($SiO_2$), Palygoriskite, Illite, and Calcite ($CaCO_3$) is in a high percentage, with a low percentage of Hematite ($Fe_2O_3$) and Feldspar ($K_2O.Al_2O_3.6SiO_2$). The higher peak of Quartz in the intensity level, and its presence in a high sharpness, is because the Quartz has a high crystalline surface. This causes a high reflection in the X-Ray. The Palygoriskite peak has a lower sharpness in intensity level because the surface of clay layer is not crystalline, causing irregular reflection in the X-Ray (Boynton 1980, Lea 1976).

### 3.2 Production Techniques

Local naturally-occurring LWA of Attapulgite rock in large lumps was used as coarse aggregate. The lumps were manually crushed into smaller sizes by means of a hammer to give a finished product of about 19 mm maximum aggregate size. The aggregate was then screened on a standard sieve series complying with ASTM (2005) as shown in Table 2. The individual size fraction for each batch was recombined in proper proportions to produce the desired grading. The prepared raw material was placed in

loose layers, approximately 100–150 mm thick, on a sinter strand and carried, under drying and ignition hoods fired by gas, in such a manner that baking, initiated at the surface, continued through the full depth of the bed. The gases formed caused expansion; however, in some cases, the cellular structure resulted from the baking of the fuel grains and loss of moisture, and from fusion of the fine particles of the raw material (FIP Manual 1983, European Union 1998, Liu, et al. 2013) as shown in Figure 1. The raw material was reduced to the desired size before firing in a kiln to incipient fusion (temperature of 1000ºC to 1100ºC), where expansion of the material takes place due to the generation of gases which become entrapped in a viscous pyroplastic mass. This porous structure was retained on cooling so that the apparent specific gravity of the expanded material is much lower than before heating. The temperature can be controlled by using Sager cone. Because a cone measures the heat work rather than the temperature, it is a more accurate indicator of completion of firing than an electric pyrometer (Hamer 2004).

Figure 1. Attapulgite is reduced to the desired size before firing by sager cone.

Table 2. Grading of coarse lightweight aggregate.

| Sieve size (mm) | % Passing | % Passing ASTM C330-05 |
|---|---|---|
| 25 | 100 | 100 |
| 19 | 95 | 90-100 |
| 12.5 | - | - |
| 9.5 | 30 | 10-50 |
| 4.75 | 0 | 0-15 |

### 3.3 Determination of the Suitable Firing Temperature for Attapulgite

A laboratory kiln of a maximum temperature 1400˚C was used to reach the suitable firing temperature, having a rate of 5˚C/min, and when the kiln temperature reached the required degree, the samples were treated for 30, 60, and 90 minutes. Then, the cooling phase of the model started gradually overnight by opening the kiln door very slightly to allow heat exchange with the laboratory temperature. The Attapulgite samples were baked under temperatures ranging between 1000˚C-1200˚C. When heat was first

applied, the absorbed water was removed and, as the temperature increased, the interlayer and hydrated water removed too from 100˚C to 1000ºC, as shown in Figures 2 to 6. This represents a steep increase in relative density and a corresponding decline in absorption percentage with the temperature increase.

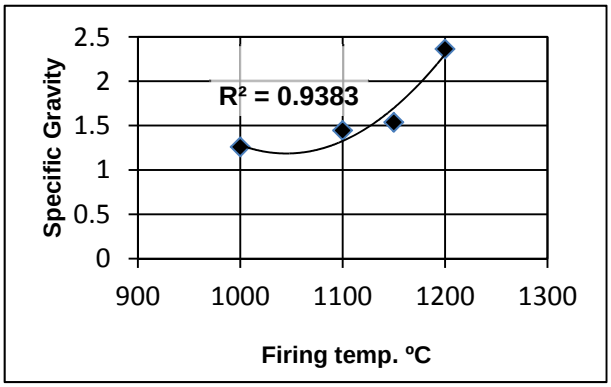


Figure 2. Firing temperature and specific gravity.

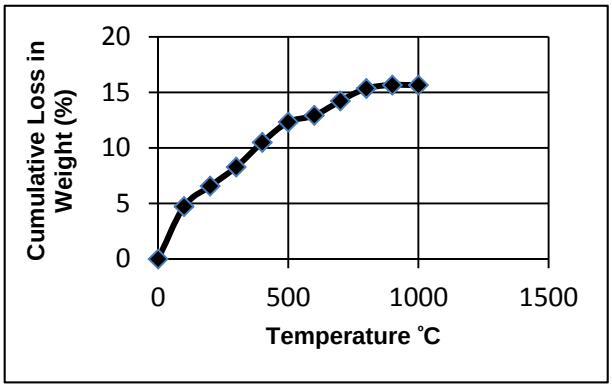


Figure 3. Loss in weight with temperature.

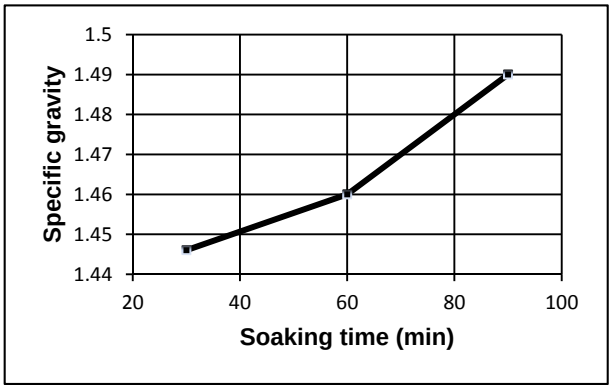


Figure 4. Effect of soaking time temperature on specific gravity at 1100ºC.

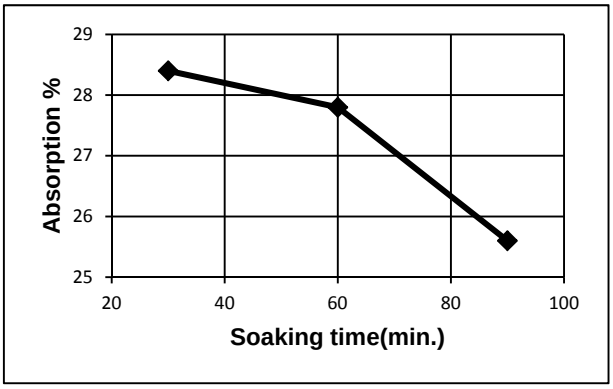


Figure 5. Effect of soaking time temperature on absorption at 1100ºC.

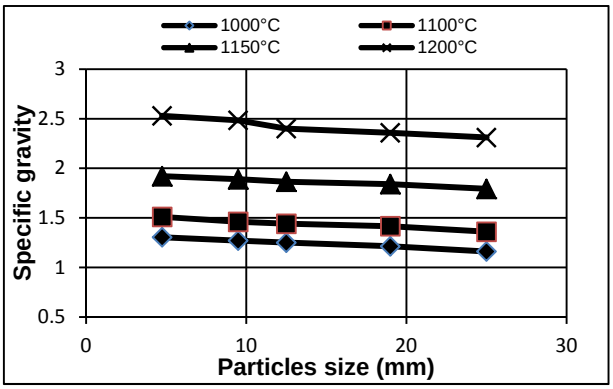


Figure 6. Effect of firing temperature on the specific gravity of different particle sizes.

### 3.4 Effect of Temperature

Temperature's effect on production was evidenced separately, as shown in Figure 4. It was found that decreasing clay particle size has a negative effect on relative oven dry density.

## 4 CONCLUSION

LWA can be produced by using methods of sintered strand produced from Iraqi Attapulgite. It was found that decreasing the particle size has a negative effect, and the optimum firing temperature is 1100°C for 30 minutes. The unit weight density for LWA obtained is about 808 kg/m$^3$, and the relative density is 1.445.

## References

ACI Committee 213R-03, Guide for Structural Lightweight-Aggregate Concrete, *ACI Committee 213*. American Concrete Institute, USA, 2003.

Arioz, O., Kilinc, K., Karasu, B., Kaya, G., Arslan, G., Tuncan, M., Tuncan, A., Korkut, M., and Kivrak, S., A Preliminary Research on The Properties of Lightweight Expanded Clay Aggregate. *Journal of the Australian Ceramic Society* 44(1), 23-30, 2008.

ASTM C330-05, *Standard Specification for Lightweight Aggregates for Structural Concrete*, USA, 2005.

Boynton, R. S., *Chemistry and Technology of Lime and Limestone*, Wiley Interscience, 2nd. Ed., 1980.

Bradley, W. F., The Structural scheme of Attapulgite, *Am. Mineral*, 25(6), 405–10, 1940.

Campione, G., and Mendola L. L., Behavior in Compression of Lightweight Fiber Reinforced Concrete Confined With Transverse Steel Reinforcement, *Cement and Concrete Composites*, 26(6), 645–656, August 2004.

Chen, B., and Liu J., Contribution of Hybrid Fibers on The Properties of The High-Strength Lightweight Concrete Having Good Workability. *Cement and Concrete Research*, 35(5), May 2005.

Chi, J. M., Huang, R., Yang, C. C., and Chang J. J., Effect of Aggregate Properties on The Strength and Stiffness of Lightweight Concrete, *Cement and Concrete Composites*, 25(2), 197–205, February 2003.

European Union – Brite EuRam III, LWAC Material Properties State-of-The-Art. *EuroLightCon, Economic Design and Construction with Light Weight Aggregate Concrete*. Document BE96-3942/R2, 16, December 1998.

*FIP Manual of Lightweight Aggregate Concrete*, 2nd. Ed., Thomson Science and Professional, London, 1983.

Hamer, F., *The Potter's Dictionary of Materials and Techniques*, University of Pennsylvania Press, 5th. Ed., 2004.

Kivrak, S., Tuncan, M., Onur, M.I., Arslan, G., and Arioz, O., *An Economic Perspective of Advantages of Using Lightweight Concrete in Construction*. 31th. Conference on Our World in Concrete & Structures, 6-17 August 2006, Singapore. CI-Premier PTE LTD, Orchard Piaza, Singapore.

Lea, F. M., *Chemistry of Cement and Concrete*, 3rd. Ed., Chemical Publishing Co., Inc., London, 1976.

Liu, H., Chen, T., Chang, D., Chen D., Qing, C., Xie, J., and Frost, R. L., The Difference of Thermal Stability Between Fe-Substituted Palygorskite and Al-Rich Palygorskite, *Journal of Thermal Analysis and Calorimetry*, 111(1), January 2013.

Neville, A. M., *Properties of Concrete*, Pearson Education Limited, 5th. Ed., Wiley, UK, 2011.

Newman, J., and Choo, B. S., *Advanced Concrete Technology: Processes*, Elsevier 2003.

Velde, B., *Origin and Mineralogy of Clays: Clays and the Environment*, Springer, 2010.