Structural Lightweight Concrete in Hong Kong: Now, New, Next

Tommy Y. Lo
Department of Building & Construction
City University of Hong Kong

ABSTRACT

Lightweight aggregate concrete offers considerable weight advantages over other form of concrete and can be used in structural application. This paper reports the use of lightweight concrete in Hong Kong and the results of a pilot study using synthetic expanded clay aggregate for prefabrication of a façade. The test result is positive showing that lightweight concrete can be an alternative to the heavy weighted concrete for prefabrication production; enhance green construction, reduce dead load and speed of construction.

INTRODUCTION

Structural lightweight aggregate concrete has been used worldwide for ship construction, bridge, floating oil-production platform and for buildings construction [1,2]. In Hong Kong, it is limited to non-structural application such as fill and drywall. This paper reviews the development of lightweight concrete in Hong Kong and presents the work on structural lightweight aggregate concrete using a locally available lightweight aggregate. The use of synthetic lightweight aggregate provides an alternative to the natural heavy weighted concrete; enhance prefabrication industry and green construction.

STANDARDS AND PRINCIPLE

Definitions of lightweight aggregate concrete varies between international standards and code of practices:

**CEB/FIP (Europe):** An air-dry density ranging from 1600 to 2000kg/m³ and a 28-day cube compressive strength from 20 to 70MPa.

**ACI 213-87 (USA):** Structural LWAC is concrete which (a) has a minimum compressive cylindrical strength at 28 days of 17.2MPa, (b) has a corresponding air-dry unit weight not range of 1440 to 1850 kg/m³ and (c) consists of all LWA or a combination of LWA and normal weight aggregates.

**UNI 7548.1 (Italy):** LWAC is made with lightweight aggregate i.e. made by replacing some or all of the ordinary aggregates with lighter aggregates. Lightweight aggregate concrete is characterized by the fact that its density is not greater than 1850 kg/m³.

**BS3797-90 (Britain):** Concrete of air-dry density not exceeding 2000kg/m³.

**JGJ 51-90 (China):** Concrete of oven-dry density not exceeding 1950kg/m³.
As illustrated in Figure 1, lightweight concrete can be achieved by three different methods: by the use of lightweight aggregates, by ‘aerating’ with gas bubbles or by eliminating the fine aggregate from the mix to produce ‘no-fines’ concrete.

**Figure 1: Principle of lightweight concrete**

**LIGHTWEIGHT AGGREGATE**

The lightweight aggregate can be industry by-products, such as Furnace bottom ash, furnace clinker; natural lightweight aggregate such as pumice, wood particle; artificial lightweight aggregate such as foamed slag, expand shale aggregate, expand clay aggregate, sintered pulverized-fuel ash aggregate, perlite and vermiculite. The aggregate used in this paper is expanded clay aggregates comply with BS3797.

Most of the lightweight aggregates are porous and the water absorption rate is higher than normal weight aggregate. Figures 2 shows absorption rate of a 14mm lightweight aggregate. Traditionally, design of lightweight concrete mix was done by volumetric method and the aggregates has to be pre-wetted [3].
STRUCTURAL LIGHTWEIGHT CONCRETE

Current specification do not stipulated the requirement of lightweight aggregate concrete. Indeed, lightweight aggregate concrete offers considerable weight advantages over other form of concrete for both structural and non-structural application (see figure 3). The lower E-value of lightweight concrete absorbs energy from impact and cyclic loading, reducing the formation of micro cracking at the cement/aggregate interface.
Strength of lightweight concrete closely associated with the density and strength of lightweight aggregate. Figure 4 below shows the relationship between concrete strength, aggregate strength with aggregate density. Figure 5 highlighted the strength development curve of a typical lightweight concrete at water to cement ratio of 0.42 using 420kg/m$^3$ cement.

![Figure 4: Relationship between concrete strength aggregate strength with aggregate density](image)

![Figure 5: Strength development (w/c = 0.42, cement = 420 kg/m$^3$)](image)

Figure 4: Relationship between concrete strength aggregate strength with aggregate density

Figure 5: Strength development (w/c = 0.42, cement = 420 kg/m$^3$)
PILOT TEST ON PREFABRICATION

Pilot test on fabrication of a structural lightweight façade wall panel was conducted in 2002. The concrete is designed to strength 25MPa with slump 50mm. The construction sequence follows the workflow of the existing façade construction. Process of concrete batching, casting and quality control measures was recorded and monitored. The finishes of the lightweight façade were good as shown in Figure 6.

Figure 6

Finished Lightweight Façade

The test results show that the workflow for lightweight façade construction is similar to normal weight façade casting. No additional training is required to the labour. Figure 7 compared the exposed surfaces of both normal weight and lightweight concrete showing that the placing and compaction of lightweight concrete is good.

Figure 7: Exposed surfaces of lightweight and normal weight concrete
CONCLUSION

The using of structural lightweight concrete in prefabrication of a façade module has been presented. The test results show that the workflow for lightweight façade construction is similar to normal weight façade casting. The quality of concrete is good and comparable to normal weight concrete. Lightweight concrete can be an alternative to the heavy weighted concrete for prefabrication production, enhance green construction, reduce dead load and speed of construction.

ACKNOWLEDGEMENT

The work described in this paper was supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China [Project No. CityU 1037/01E] and China State Construction Engineering (H.K.) Ltd.

REFERENCES

1. An Introduction to Lightweight Concrete. Cement and Concrete Association. 1980