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The heat transfer coefficient of new construction – Brick masonry with fly ash blocks

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ABSTRACT

This paper presents a study of the heat transfer characteristics of new construction - brick masonry with fly ash blocks. Four forms of wall samples were tested to evaluate their heat transfer performance. Based on the mechanism of the thermal conductivity of clay bricks, RCB (recycled concrete bricks) and fly ash blocks, an actual value calculation method for determining the heat transfer coefficient suitable for engineering design was proposed. By analyzing and comparing the experimental values with the theoretical and actual values of the test samples, the proposed method was proved to be reasonably correct; it used RCB instead of ordinary clay bricks and a composite wall with fly ash blocks showed an enhanced insulation effect. New construction of brick masonry with fly ash blocks not only is good for the environment, but also provides good thermal insulation.

1. Introduction

Energy is a crucial factor for the social and economic development of societies. Energy consumption has been rapidly increasing due to population growth, urbanization and industrialization [1]. Many natural resources are being depleted at an unsustainable rate, resulting in higher prices and adverse environmental effects; this has stimulated significant research to advance the utilization of various renewable sources, such as demolition wastes, solar energy and industrial waste heat [2,3]. As urbanization and new rural construction has expanded in China, people's living conditions are also improving. Meanwhile, the improvement of living quality requirements leads to a sharp increase in BEC (building energy consumption). Statistics show that BEC accounts for approximately 40% of total energy consumption [4]. If the energy required for space heating in the colder areas of northern China are considered, the BEC number jumps to nearly 60% of the total [5,6].

Poor thermal performance of the building envelope structure is the main cause of heat dissipation. The heat transfer coefficient (U) has become a common indicator for defining the thermal quality of the building envelope, which is usually influenced by individual material and structural factors [7]. Therefore, problems with materials and heat preservation are particularly acute in northern rural areas in China [8].

The production of clay bricks (Fig. 1a) consumes a large amount of energy and causes a large emission of greenhouse gases; therefore, production of these bricks is limited according to the state plan in China [9]. C&D (Construction and Demolition) materials, generated by various construction and demolition activities are normally referred to as solid wastes, which has imposed significant pressure on the environment [10–12]. RCB (Recycled concrete brick) is a by-product of construction and demolition activities of concrete structures [13]. RCB samples (Fig. 1b) were obtained from a demolished house in Beijing with a maximum particle size of 20 mm and were manufactured by a mechanized molding machine in Beijing (YuanTaiDa Environmental Protection Building Materials Technology Limited Liability Company of China), with the mix proportions showed in Table 1. The cementitious materials used were an ordinary Portland cement (P·O 42.5) complying with GB175-2007. The recycled aggregates were C&D (Construction and Demolition) wastes sourced from a demolished house in Beijing. Then, the C&D wastes underwent a further process of mechanized crushing and sieving to produce fine aggregate and coarse aggregate in the factory mentioned above. The marl, containing some clay, was a kind of precipitate particle obtained from the

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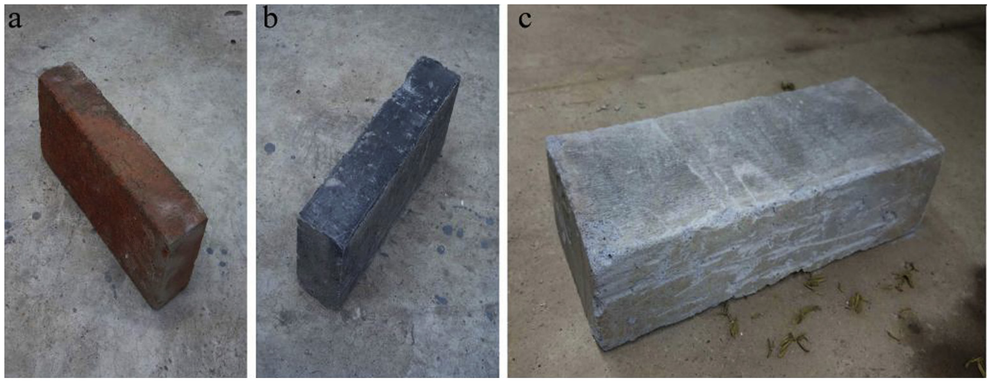

Fig. 1. Clay bricks (a). Recycled concrete bricks (b). Fly ash blocks (c).

Table 1
Mix proportions for recycled concrete bricks. RCB: recycled concrete brick.

Mix notation	Proportion (kg)				
	Cement	Recycled fine Aggregate	Marl	Fly ash	Added water
RCB	143	608	152	240	120

sedimentation tank after the recycled aggregates were rinsed by water. The fly ash was a kind of fine powder, which was collected by the aspiration air separation system during the production process of the recycled aggregate. The mixed materials are molded under a combined vibrating and compacting action. Then, the bricks were removed from the molds and cured in air at room temperature for 28 days. The measured average compressive strength of 28 days for the RCB was 10.30 MPa.

Recycling and reuse of demolition materials has become a topic of global concern in recent decades [14]. Demolition wastes are increasing annually and account for a large proportion of the waste materials present in landfills [15,16]. Therefore, it is necessary to adopt materials and improve techniques to reduce the building heat loss in envelope structures under the premise of their essential functions [17,18]. Fly ash, which is a pozzolanic waste material extracted from flue gases of furnaces fried with coal at electric power plants, has been used in the construction industry [19,20]. The utilization of fly ash blocks (Fig. 1c) in construction as a low-cost filling material has been widely used in the filler walls of multi-story masonry structures and reinforced concrete structures [21]. clay brick and recycled concrete brick were both 240 mm of length × 115 mm of width × 53 mm of thickness. The fly ash block was 600 mm of length × 240 mm of width × 120 mm of thickness.

Awareness of the extent of greenhouse gas emissions has focused more attention on energy efficiency in buildings [22]. Buildings that are labeled “energy-efficient,” “sustainable,” or “green” have taken into account the eco-friendly design of modern building. New construction of brick masonry using fly ash blocks to enhance the heat preservation of a building's envelope structure, was considered in this study (Fig. 2), which mainly focuses on analyzing heat preservation performance.

Air temperature and humidity have been considered the key factors responsible for the heat transfer performance of the building envelope, which is affected by the various thermal conductivity coefficients of building envelope materials.

The heat transfer performance of the building envelope is mainly affected by various thermal conductivity coefficients (λ) of its component materials [23]. Air temperature and humidity have been considered the key factors responsible for λ [24–26]. Some results show that different changes in λ from one material to another were predominantly related to temperature [27]. Some other results indicated that humidity also affected λ to a large degree [28]. Temperature and humidity often coexist in the actual environment, which makes it difficult to separate their effects. However, studies have typically assumed a fixed λ in the heat transfer coefficient calculation [29,30]. Therefore, there has been a growing need to put the dynamic λ in a U value derived calculation. The objectives of this study are: (1) to test the experimental U values of four wall samples, (2) to compare the thermal performance of four construction wall solutions, and (3) to put forward a corrected computational method of the heat transfer coefficient in environmental conditions.

2. Heat transfer coefficient test

Currently, there is no official standard for test methods that directly addresses the dynamic performance of walls: the main reference norms [31] involve the measurement of steady-state characteristics of single materials and multilayer structures under standardized boundary conditions. In this study, an experimental analysis with a climatic chamber was conducted to compare the effect of the heat transfer coefficient of envelope elements characterized by equivalent steady-state performances. In order to reduce the testing uncertainties, the same raw materials, the same masonry worker, and the same test apparatus to ensure the accuracy and reliability of the experimental results.

2.1. Test apparatus

According the standards and studies concerning this type of test [32,33], the experimental study used the steady-state heat transfer measurement apparatus (CD-WTFl515, Shenyang, China). The heat transfer condition of the tested building envelope is simulated based on the standard GB/T 13475 – 2008 and the single directional steady heat transfer principle to measure and analyze the heat transfer coefficient. An environment climate controlled facility consists of two air conditioned chambers in which temperature is controlled by heat resistance wires and refrigeration systems (Fig. 3a and b). One chamber is used to provide the outdoor environmental climate. The metering tank temperature is set to −10 °C