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Technical note

Incorporation of expanded vermiculite lightweight aggregate in cement mortar

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ABSTRACT

This investigation presents an evaluation of the properties of cement mortars containing expanded vermiculite as partial sand replacement. When the expanded vermiculite was included at 30% and 60% replacement levels, the flow diameter was higher compared to the plain mortar without expanded vermiculite. The porous lightweight nature of the expanded vermiculite also contributed to the reduction in the unit weight and compressive strength of mortars, as well as increased water absorption. Although weight loss of the expanded vermiculite mortars subjected to elevated temperature was increased, the expanded vermiculite had positive effect in providing heat resistance and thermal stability to the mortars, observed by the reduction of compressive strength loss of mortars upon exposure to elevated temperatures.

1. Introduction

Nowadays, there is increasing interest in the development of construction materials to resist high temperature, in particular for application in building structures. The resistance towards elevated temperature of building materials is of significant importance, particularly during the course of a fire event. For instance, in concrete or cement-based materials, fire could cause damage or in worse case, failure of building structures due to risk of spalling and significant loss of materials strength.

Accordingly, plastering mortars with improved resistance towards elevated temperature could provide a solution for the aforementioned concern. One of the methods is through the introduction of thermally stable and porous aggregate in the mortar. This is because conventionally used siliceous aggregate may cause distress at temperature of about 570 °C and de-carbonation at temperature above 700 °C, resulting in significant loss of strength [1]. In the past, concrete with various porous lightweight aggregate materials such as pumice [2], scoria [3], expanded clay [4], palm oil clinker [5], oil palm shell [6] and plastic aggregate [7] were researched with the aim of investigating the performance when subjected to elevated temperatures.

In recent times, non-structural lightweight aggregates such as vermiculite, perlite and expanded polystyrene aggregates which are very low in density were incorporated as partial sand replacement in cement-based mortars. The prime advantage of these materials is the good insulation properties owing to their highly porous nature. The improved thermal insulation performance of cement-based materials incorporating these aggregates were evidenced in literatures [8,9]. Based on this, because of the porous structure of these materials, there is also potential in utilizing these materials in plastering mortars for enhanced resistance towards elevated temperature. While the use of expanded perlite is more widespread [10], research on the utilization of vermiculite in cement-based materials is fairly limited and only recently garnering increased attention. Vermiculite is hydrated magnesium-aluminium-iron silicate, formed by the alteration of mica and appear in the forms of flakes. When exfoliated by heating to temperature of 900 °C or higher, water is released and the flakes expand into very lightweight porous material. The resulting expanded vermiculite is considered to be heat resistant and exhibits good sound and thermal insulation properties.

Thus, this research aims on exploring the possibility of incorporating expanded vermiculite as partial sand replacement in cement-based plastering mortar, and focuses on the performance when subjected to elevated temperatures. Additionally, the effects of incorporating expanded vermiculite were investigated with

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regards to other properties of mortar relevant to plastering uses, such as consistency, compressive strength and water absorption.

2. Materials and methods

2.1. Materials

Type I Ordinary Portland cement with specific gravity of 3.15 was used for all mixes in the study. River sand with maximum size of 2.36 mm was selected as the fine aggregate used in the mortars. The specific gravity of river sand was found to be 2.62. Expanded vermiculite (Fig. 1) with specific gravity of 1.17 (maximum size of 2.36 mm) was used as partial river sand replacement. The expanded vermiculite was used in saturated surface dry condition for the prepared mortars. The particle size distributions of the river sand and expanded vermiculite are shown in Fig. 2. Mixing water was obtained from pipe water in the laboratory.

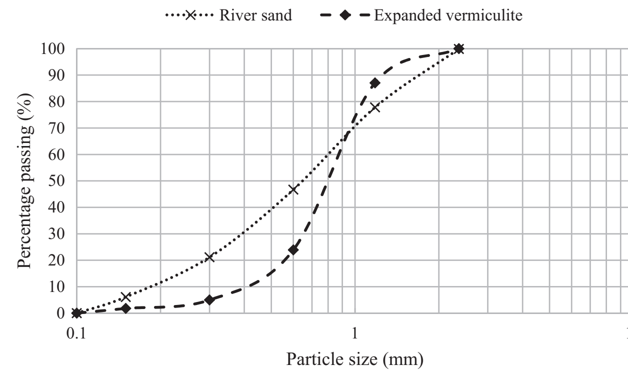

Fig. 2. Particle size distribution of river sand and expanded vermiculite.

2.2. Mix proportions

A total of four mixes were prepared in this investigation as shown in Table 1. Mixes C0 and C1 were control mortars without expanded vermiculite as sand replacement with targeted 28-day compressive strength of 30 MPa and 15 MPa, respectively. On the other hand, mixes V30 and V60 were mortars prepared with expanded vermiculite at 30% and 60% of partial sand replacement (by volume), respectively.

Table 1
Mix proportions.

Mix	Water/cement ratio	Sand/cement ratio	Vermiculite/cement ratio
C0	0.52	2.57	–
C1	0.71	4.21	–
V30	0.52	1.80	0.19
V60	0.52	1.03	0.67

2.3. Mixing

Mixing of mortar was done using a table top mixer in the laboratory. The cement and fine aggregates (river sand and expanded vermiculite) were first allowed to mix homogenously for about 30 s. The water was then added without stopping the mix and the process lasted for 3 min to ensure thorough mixing. The fresh mortars were subjected to flow table test before poured into mortar moulds and compacted on a vibration table.

2.4. Test methods

Flow table test was carried out on the fresh mortars in accordance with ASTM C1437-15 in order to determine the consistency of the mortars. The test was performed by filling, tamping of fresh mortars in the mould and dropping the mortar for 25 times within 15 s upon removal of the mould. The diameter of the flow spread of the fresh mortar was recorded subsequently (Fig. 3).

Cubic mortars measuring 50 mm^3 were de-moulded 24 h after casting and the hardened mortars were cured in laboratory condition until the age of testing. Compressive strength tests were carried out on the cubic mortars during the 7th and 28th days age, and the tests were performed according to BS EN 12390-3: 2009. Additionally, the residual compressive strength of the 28-day aged cubic mortars were evaluated upon exposure to elevated temperatures of 600 °C and 800 °C. The mortars were kept in a muffle furnace at the selected temperature for 1 h, and then allowed to cool internally for a further hour before the furnace was opened (Fig. 4). The heating curves of the muffle furnace up to 600 °C and 800 °C are shown in Fig. 5. After the mortars were removed from the furnace, the mortars were allowed to cool in air in the laboratory for a further 2 h before the residual compressive strength of mortars were determined.

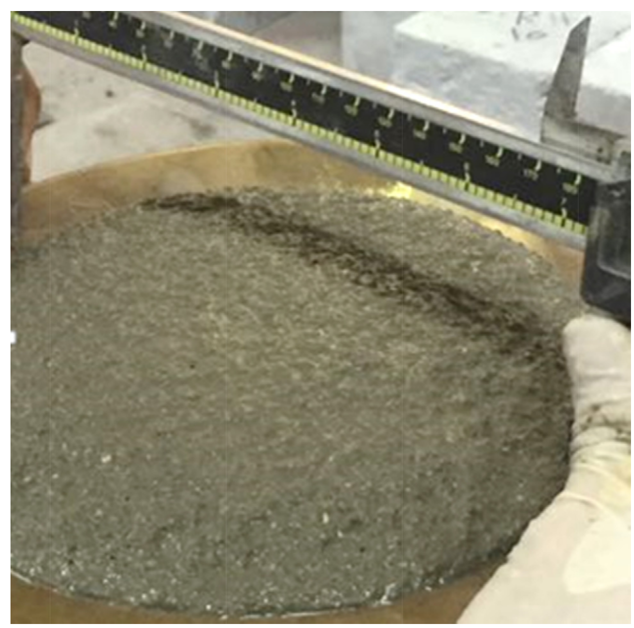

Fig. 3. Measurement of flow spread diameter.

Besides that, the cubic mortars at 28-day age were subjected to water absorption test. In order to remove moisture, the mortars were first dried in oven at 105 °C for 24 h. Subsequently, the dry weight of the mortars were taken and immersed in water. The saturated weights of the mortars after immersion for 30 min and 72 h were taken to determine the initial and final water absorption values, respectively. The water absorption of mortar was also similarly tested and calculated previously by Mo et al. [11].

Fig. 1. Expanded vermiculite.

3. Results and discussion

3.1. Consistency

The consistency of the fresh mortars presented in Fig. 6 were determined based on the flow diameter recorded from flow table