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Review

Vermiculite as a construction material – A short guide for Civil Engineer

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HIGHLIGHTS

- EV aggregate increased thermal and sound resistance, but reduced mechanical strength.
- EV aggregate increased water absorption and porosity, but increased fire resistance.
- EP powder increased compressive strength and mitigated ASR.
- EV can be used geopolymers and polymers.
- Different additives can be used to improve some properties of EV matrices.

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ABSTRACT

Vermiculite is a mica-like mineral with a shiny flakes which is one member of the phyllosilicate group. It can be expanded up to 30 times its original volume when heated at 650–950 °C. The expanded vermiculite (EV) exhibits prospective properties such as low thermal conductivity, low bulk density, endurance, chemical inertness and relatively high melting point. EV has many applications in the field of civil engineering, chemical industry and agriculture. EV in civil engineering field deals some potential advantages and some disadvantages. In this overview, the author summarizes the previous studies regarding to using EV as a construction material in traditional cementitious materials, geopolymers and other binders. In addition, different additives which employed to modify some properties of EV matrices were summarized.

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1. Introduction

The name "vermiculite" is derived from the Latin – *vermicularis* (wormlike) on account of the curved, elongate and twisted columns produced when the crystals are suddenly exposed to high temperature. Vermiculite is a mica-like mineral with a shiny flakes which is one member of the phyllosilicate group (Fig. 1). Vermiculite is formed under natural conditions such as hydrothermal alternation of biotite or weathering or phlogopite. Vermiculite ore consists mainly of SiO_2 (37–42 wt%), MgO (14–12 wt%), Al_2O_3 (10–13 wt%), Fe_2O_3 (5–17 wt%), H_2O (8–18 wt%) and lesser amount of FeO (1–3 wt%) [1]. The variation in the chemical composition of vermiculite can cause a variation in its physical properties. It is chemically neutral, inert and pH ~7. The overall chemical formula is $(Mg^{2+}, Fe^{2+}, Fe^{3+})_3[(SiAl)_4 O_{10}]OH_2.4H_2O$ [2]. Its specific gravity in the range of 2.2–2.5. Vermiculite showed remarkable ion-exchange characteristics, of which it can be used for preparing materials required for extracting heavy metals salts from water [3,4] and adsorbent of various pollutants in this field [5,6]. The flaky structure of vermiculite enables it to have high lubricating characteristics for wide ranges of temperatures. Thus, it can be used as fireproof material [7] and as lightweight porous filler for heat insulating [8]. Vermiculite can be used as a source material to produce thin inorganic films, foams or coatings [9], as inorganic filler for clay polymer composites [10], for circulation drilling mud and in the annealing of steel [11]. It was estimated that there are approximately 381 and 408 thousand metric tons of vermiculite were produced around the world during 2014 and 2015, respectively [12]. Vermiculite mines are located in many countries around the world (Fig. 2). The main 6 countries which accounted approximately 97.5% of the world production of vermiculite are South Africa, United States, Brazil, Zimbabwe, Bulgaria and India [12].

Vermiculite expands when heated to 650–950 °C. The expansion process is known as exfoliation. When vermiculite heated, it expands, like "popcorn", by approximately 8–30 times its original size and converts into a loose, lightweight fragments which separated by air entrainment. The exfoliated vermiculite exhibits 10–11 times less bulk density than its original volume before heating (80–120 kg/m^3), low thermal conductivity (0.04–0.12 W/m K) and relatively high melting point (1240–1430 °C) [1]. Its sound absorption coefficient in the range of 0.7–0.8 at a frequency of 1 kHz, water absorption reaches 10%, hygroscopicity not more than 3 wt% with ~98% air humidity, exhibits low dust forming and abrasive properties [2]. The chemical composition of vermiculite does not change during thermal expansion, only chemically bonded water is removed [2]. When vermiculite expands >10 times its original size before heating, it can be classified as a good quality, whilst if the expansion <10 times, it can be classified as a low grade [11]. The degree of expansion in vermiculite is governed by many factors such as heating rate, holding time at peak temperature, cooling rate, moisture content, structure of hydromicas, phase composition and technique used for grinding or milling the starting material. The particles are viewed as slender plates, with a porous structure and a greasy or silky luster, separated by a thin air gap (Fig. 3). Their color, shape grain composition and luster are closely related to their originals. In most cases, the particle color of EV usually golden-yellow or brown, occasionally tinted greenish with a nacreous pink luster (Fig. 3). Furthermore, the

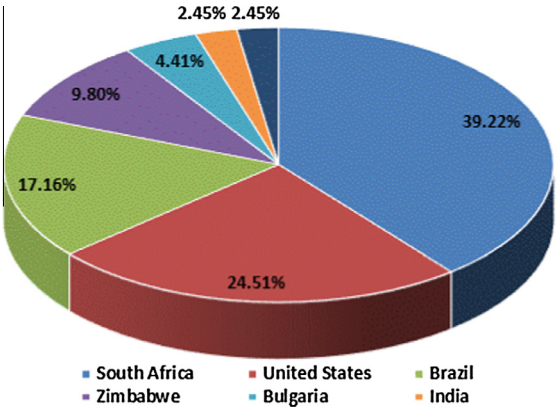

Fig. 2. Percentage of vermiculite production related to total world production in 2015.

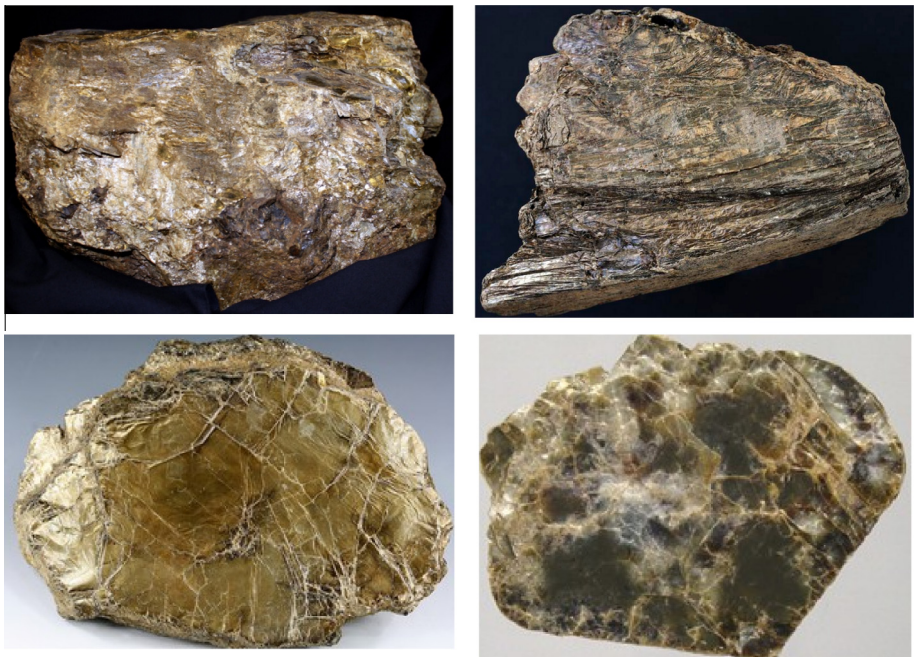

Fig. 1. Vermiculite.