Construction and Building Materials 159 (2018) 54–63

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Upcycling wood waste into fibre-reinforced magnesium phosphate cement particleboards

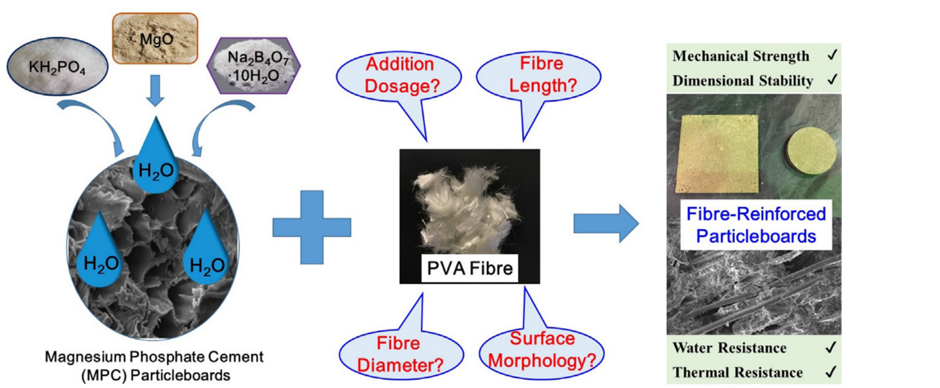
Lei Wang, Iris K.M. Yu, Daniel C.W. Tsang *, Kequan Yu, Shuang Li, Chi Sun Poon **, Jiang-Guo Dai

Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China

HIGHLIGHTS

- PVA fibre reinforced flexural strength and fracture energy of MPC particleboards.
- Surface characteristics of fibre determined reinforcement mechanisms and efficiency.
- Hydrophobic fibre provided higher reinforcing efficiency for MPC particleboards.
- Fibre-reinforced MPC particleboards presented promising thermal and water resistance.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 August 2017
Received in revised form 24 October 2017
Accepted 25 October 2017

Keywords:
Construction waste
Fibre reinforcement
Microstructure
MPC
Waste recycling
Wood particleboard
Cement-bonded composite
Rapid-shaping production

ABSTRACT

Upcycling contaminated wood waste by magnesia-phosphate cement (MPC) into rapid-shaping cement-bonded particleboards is a promising technology. MPC binder exhibited superior compatibility with wood waste. However, there is a need to address the limitations of high brittleness, low strain capacity, and low water resistance of MPC products. High content of recycled wood in the MPC particleboards (20 wt%) should be accomplished without compromising their mechanical strength and durability. In this study, the addition of 2% (v/v) polyvinyl alcohol (PVA) fibre significantly reinforced flexural strength and fracture energy of particleboards, as high as 56.5% and 891.9%, respectively. The characteristics of PVA fibre determined the efficiency of reinforcement. At the same dosage, addition of shorter fibre (3 mm in length) presented higher strength, whereas incorporation of longer fibre (12 mm) improved fracture energy. Thinner fibre (35 μm in diameter) showed a larger increase in both flexural strength and fracture energy. Surface morphology of PVA fibre played an important role in determining the reinforcement mechanisms and reinforcing efficiency. Under stress, hydrophobic fibres (oil-treated) were pulled out from MPC matrix, whereas hydrophilic fibres (untreated) were ruptured. The former showed higher reinforcing efficiency for MPC particleboards. The fibre-reinforced particleboards maintained sufficient mechanical strength and dimensional stability after 24-h water immersion or 1-h heating at 100 °C, which fulfilled the standard requirements. This study demonstrated that PVA fibre addition is an effective method to reinforce mechanical properties as well as thermal and water resistance of MPC particleboards.

* Corresponding author.
** Co-corresponding author.
E-mail addresses: dan.tsang@polyu.edu.hk (D.C.W. Tsang), chi-sun.poon@polyu.edu.hk (C. Sun Poon).

https://doi.org/10.1016/j.conbuildmat.2017.10.107
0950-0618/

1. Introduction

Magnesium phosphate cement (MPC) is a new inorganic cementitious material composed of dead-burned magnesia, phosphate, and retardant. Acid-base reaction between magnesia and phosphate (usually KH_2PO_4) generates crystalline magnesium potassium phosphate hexahydrate ($MgKPO_4{\cdot}6H_2O$), which primarily builds the strength of MPC [1]. It exhibits superior properties such as fast setting and hardening, high early strength, low drying shrinkage, resistance to corrosion, and good compatibility with contaminants [2,3]. These advantages have made MPC popular in different fields, including fast repair and reinforcement of structure, solidification/stabilization of hazardous substances, and biomedical application [4].

Significant wood waste generation due to urbanization imposes burdens on sustainable development. For example, hundreds of tonnes of wood waste are produced daily from construction industry (e.g., timber formwork) and shipping industry (e.g., wooden pallet) in Hong Kong, resulting in massive waste of resources and occupation of limited landfill space [5]. Transforming the construction wood waste into cement-bonded particleboards has emerged as an innovative upcycling option [6], and MPC binder was first demonstrated in our recent study for rapid-shaping particleboard production [7]. The MPC particleboards presented remarkable advantages over conventional ordinary Portland cement (OPC)-based particleboards. Because of the fast-setting property, the prime advantage of MPC particleboard lied in the favourably short compression time (5 min) required for maintaining consistent dimensions in comparison to the OPC particleboard (8–24 h) [6,8]. The use of MPC showed better compatibility with wood particles, because its fast hydration (final setting time of 4.5–5.8 min) took precedence of the binder cations from exchanging with the soluble wood extractives [9], which was more pronounced in OPC system disturbing its early strength development [10,11]. The relatively low pH (5–8) in MPC binder [12] also relieved the degradation and mineralization of wood particles [13].

However, MPC products have some drawbacks such as high brittleness and low strain capacity, which presents limitations to their applications [14]. The MPC paste is susceptible to cracking and the microcracks can readily spread over the surface as a result of low fracture toughness [9]. Our recent study indicated that the flexural strength of MPC particleboards was lower than OPC particleboard [7], highlighting the room for strength improvement. In addition, as the MPC hydration products are unstable in water, the mechanical strength of MPC particleboards may be compromised in a humid environment. For indoor applications, fire performance of the particleboards is also a matter of concern, i.e., exposure to elevated temperature causes physical and chemical changes, leading to deterioration of the mechanical properties [15].

Fibre addition is a simple and effective approach to reinforce the strength and dimensional stability of construction materials [11]. Commonly used fibres include steel, glass, carbon, basalt, polypropylene, and nylon fibre. In particular, polyvinyl alcohol (PVA) fibre as a hydrophilic synthetic polymer presents excellent strength, elastic modulus, corrosion resistance, and durability [16,17]. It shows excellent adhesion properties for cementitious materials [18] and homogeneous dispersion in cement matrix, forming good interfacial bonding [19,20]. The current study thereby considered PVA fibre as a potential modifier to enhance the mechanical strength and dimensional stability of the MPC particleboard. Although the PVA fibre has been well documented used in OPC-based products (e.g., fibre-cement roofing, industrial floors, roadbed overlays, and engineered cementitious composites) [15,21,22], the fibre-induced reinforcement remained uncertain in the MPC particleboard system in view of distinctive MPC hydration chemistry. The significance of fibre characteristics, such as diameter, length, and surface morphology, in determining the efficiency of improvement [19,23,24] would vary from the OPC to the MPC particleboard system. Thus, the efficacy of PVA fibre addition should be further investigated for the production of high-performance MPC particleboard.

This study aimed to: (i) evaluate the influence of content and particle sizes of wood waste on the mechanical performance of MPC particleboards; (ii) investigate the reinforcing efficiency of PVA fibre with varying diameter, length, surface morphology, and loading rate; (iii) elucidate the mechanism of different PVA fibres in strength reinforcement and fracture energy enhancement; and (iv) assess the thermal and water resistance of PVA-reinforced MPC particleboards.

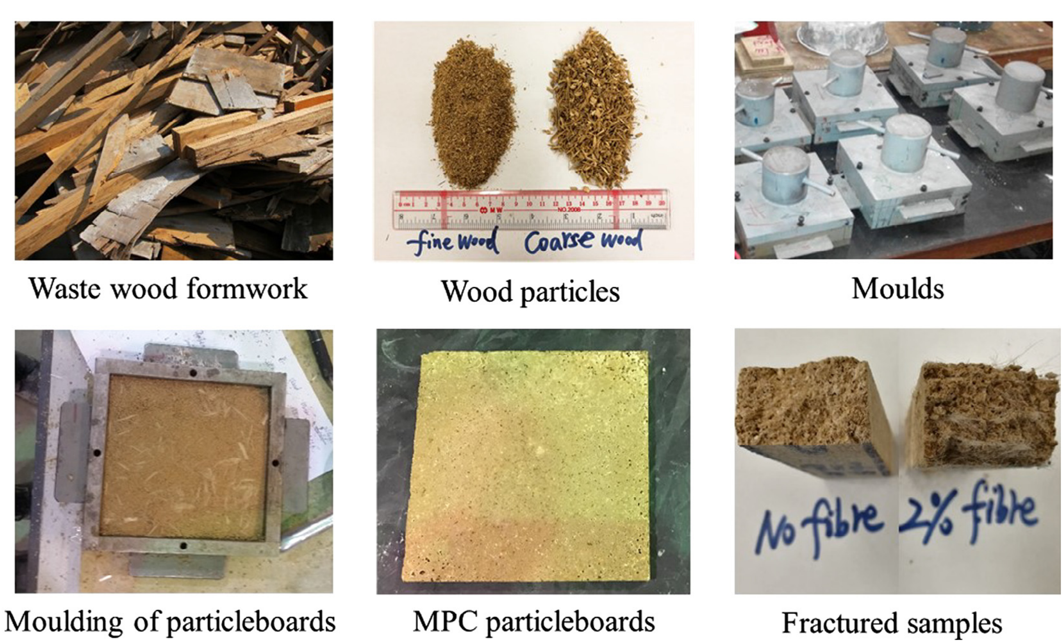


Fig. 1. Photos of MPC particleboards manufacturing process from waste wood formwork to particleboards.