CONSTRUCTION AND BUILDING MATERIALS FROM LIGNOCELLULOSIC MATERIALS

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INTRODUCTION

Construction and building materials including a wide variety of materials intended for construction purposes. The materials consist of wood and timber, fired bricks and clay blocks, steel, concrete, cement composites and many more. Lignocellulosic materials are plant dry matters that composed of carbohydrate polymers, namely cellulose and hemicellulose, and an aromatic polymer, which is lignin. These three components play their own role in providing the strength properties to the materials. In concrete terms, hemicellulose is the boding agent or crosslinking material between cellulose and lignin. Cellulose acts as reinforcement that contributes to tension forces and lignin for compression forces (Homan and Jorissen, 2004).

Construction and building materials can be generally categorized as structural and non-structural materials. Major structural materials comprise concrete, wood and steel. On the other hand, glass, plastics, insulator and adhesives are the examples of non-structural materials (Sev and Ezel, 2014). Materials derived from lignocellulosic biomass can be applied in the manufacturing of construction and building materials. Nanomaterials are able to enhance the properties of construction and building materials by acting as a reinforcement to the concrete and steel (Sev and Ezel, 2014). When it comes to the application in the construction and building materials, nanotechnology offers several advantages such as sturdier and stronger but relatively lighter structural composites, cementitious materials with superior properties, thermal and sound insulators with lower thermal transfer rate and better sound absorption capability (Lee *et al.*, 2010). According to Zhu *et al.* (2004), nanomaterials has been applied in the construction sectors aiming to increase the strength and durability of construction materials and components while reducing pollution at the same time.

CONCRETE AND CEMENT COMPOSITE

performance of concrete and cement composite. There are currently a huge number of studies reported the application of lignocellulosic biomass as reinforcement materials in cement and concrete composites. These lignocellulosic biomasses including oil palm shell, coconut shell, palm fibers, date palm fibers, hemp fibers and shives, flax shives, kenaf bast fibers, bamboo and eucalyptus kraft pulps (Vo and Navard, 2016). As a reinforcement materials, better flexural strength and modulus of elasticity of cement mortar composites was recorded when nanofibrillated cellulose were added (Claramunt *et al.*, 2015). Similarly, nanocellulose fiber gel prepared from bleached softwood pulp has reduced the hydration rate of the limestone cement paste as well as improved flexural strength and energy absorption property (Onuaguluchi *et al.*, 2014).

Cement composite reinforced with nanofibrillated cellulose derived from bamboo pulp displayed better mechanical properties even after weathering (Da Costa Correia *et al.*, 2018). Apart from the materials that synthesized from lignocellulosic sources, bacterial nano-cellulose and marine biomass have also been used widely as the reinforcement of concrete and cement. The benefits of marine biomasses over land plants is that they have higher rapid growth rate and are low in natural physicochemical barriers. Therefore, no severe chemical treatment is required to remove their inherently recalcitrant structure in order to enhance the cellulose accessibility (Chen *et al.*, 2016). For a more sustainable development of construction and building materials, application of recycled cellulosic fibers and lignocellulosic aggregates in the production of cement-based mortars shown positive aspect that could be potentially contributed to the environment benefits (Stevulova *et al.*, 2016).

WOOD

As one of the renewable resources for construction and building materials, application of wood is always constraint by its poor dimensional stability and biological durability nature. However, coating derived from lignocellulosic materials could help in mitigate the problems faced by wood. Nanocomposite coating could be used to protect the wood from the elements apart from improved its mechanical properties and abrasion resistance (Kaboorani *et al.*, 2017). Nanocellulose-filled coatings could improve the thermal properties, dimensional stability, stiffness, hydrophobicity and surface hardness of maple wood (Cataldi et al., 2017). Waterborne polyurethane coating exhibited high compatibility with TEMPO-oxidized cellulose nanofibers which in turn enhanced the properties of the waterboard wood coating (Cheng *et al.* 2016).

POLYMER COMPOSITES

The growing public's awareness around the world have lessened the dependency on petroleum-based polymers. Demand for greener and renewable polymers are in the rise. Nevertheless, renewable polymers have inferior thermo-mechanical properties compared to that of the conventional petroleum-based polymers. Modification is therefore needed to enhance its performance. Nanofillers could be act as a reinforcement to enhance the properties of the composite. Clay minerals, carbon nanotubes and silica nanoparticles are among the nanofillers that often used in enhancing the physical, mechanical and thermal properties of polymers (González-Irún et al., 2007). Table 1 summarised the nanomaterials derived from various lignocellulosic sources and its uses in the construction and building materials.

Table 1. Nanomaterials derived from various lignocellulosic biomass sources and its uses in the construction and building materials

Biomass source	Nanomaterial	Application	Reference
Green algae (*Cladophora* sp)	cellulose nanofiber	Reinforcement in concrete.	Cengiz et al. (2017)
Softwood pulp	nanocellulose fiber gel	Reinforcement in cement composites	Onuaguluchi et al. (2014)
Bacteria (*Gluconacetobacter xylinus*)	bacterial nanocellulose powder, gel and coated onto bagasse fibers	Reinforcement in fiber-cement composites	Mohammadkazemi et al. (2015)
Bacterial cellulose extracted from *nata-de-coco*	bacterial nanocellulose	Reinforcement in soy polyol-based polyurethanes nanocomposites	Ozgur Seydibeyoglu et al. (2013)
Balsa tree (*Ochromapyramidale Cav*)	nanofibrillar cellulose	balsa wood fibers - castor bean cake – glycerol matrix composites	Nishidate Kumode et al. (2017)
Rachis of date palm tree (*Phoenix dactylifera* L.)	Nanofibrillar cellulose	hybrid composites aerogels made with combinations of cellulose microfibers, cellulose nanofibers and nanozeolites	Bendahou et al. (2015)
Bamboo pulp	Nanofibrillated cellulose and cellulosic pulp	Reinforcement of the extruded cement-based materials	da Costa Correia et al. (2018)
Raw jute fibers	Nanocellulose fiber	Reinforcement in natural rubber nanocomposite	Thomas et al. (2015)
Waste jute fibers	Nanocellulose suspension	Coating for woven jute fabric to produce green epoxy composites	Jabbar et al. (2017)
By-products from pulp and paper industries	Lignin nanoparticles - Lignosulfonate	Substitution of phenol in the synthesis of phenol-formaldehyde (PF) wood adhesive	Akhtar et al. (2011) Domínguez et al. (2013)
Sugarcane bagasse	Lignin acetate	Water resistance surface coating	Park et al. (2008)

CHALLENGES AND LIMITATIONS

The production cost for nanomaterials is very high and consume a lot of energy. Therefore, in developing countries that are facing financial constraints, they are still stick to traditional building industry that incurs lesser production cost to them. Apart from that, lack of exposure to the nanotechnology is also a major reason that inhibited the growth of application of nanomaterials in construction and building sector (Yousef Mohamed, 2015). Lacking of specific standard in some countries has made application of nanomaterials least favoured. In addition, low confidence from users towards its biological impacts is another one of the biggest barriers for the development and promotion of lignocellulosic nanomaterials. All stages in a life-cycle of producing nanomaterials pose potential human exposure with inhalation and skin exposure being the main two exposure routes to human (Camarero-Espinosa et al., 2016). However, there is currently lack of understanding and information to the biological impacts of these lignocellulosic nanomaterials upon exposure. Such information is vital for the future determination of biocompatibility and hazard assessment of the lignocellulosic nanomaterials. Although some preliminary studies on the toxicity of unmodified nanocellulose revealed low-to-minimal adverse health effects from oral or dermal, the health risks associated with nanomaterials are remain uncertain. Contradict results has been reported particularly on the health effects on the respiratory system and cytotoxicity (Moon et al., 2016). Absence of the information inevitably restricted the application of these lignocellulosic nanomaterials. In order to convince the user in using nanomaterials, the biological impacts and it's on the human health must be studied thoroughly. A comprehensive report or reference regarding to this topic must be readied for the viewing of public. Apart from that, exposure of the researchers to the needs of the marketplace and product value chain is also a vital future topic.

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