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# Impact of leaf fibre modification methods on compatibility between leaf fibres and cement-based materials

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## HIGHLIGHTS

- Five methods were used to modify poplar leaf fibres.
- Impact of leaf fibre modification methods on compatibility between leaf fibres and cement-based materials was analysed.
- SEM and XRD were used to analyse the chemical structure of before-and-after modification fibres.
- Get the optimum fibre modification methods to improve compatibility between leaf fibres and cement-based materials.

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## ABSTRACT

To make effective use of plant leaves as an environment-friendly heat-insulating building material, our research group has tested five poplar leaf modification methods to improve compatibility between leaf fibres and cement-based materials. The work involved testing water absorption of before and after modification of leaf fibres, the setting time and hydration heat of the fibre–cement paste, and analysed the mechanisms and effect of fibre modification methods on compatibility between fibres and cement-based materials. The results show that processing of fibres with surface coating and dipping methods improved compatibility between fibres and cement-based materials to some extent and in different aspects. Overall, the following three methods gave superior performance: pure acrylic polymer emulsion spraying, sodium silicate solution spraying and water dipping.



## 1. Introduction

Development and use of environment-friendly thermal insulating building materials is important from the consideration of energy saving [1–5]. Use of plant fibres as a thermal insulating building material is gaining increasing attention [6–8]. Because of its low cost, abundance and environment friendliness, many regions of the world have shown strong interest in the research and development of plant fibre cement-based composite materials, and the achievements to date are remarkable [9–12]. Up till now, attention has not been given to using leaf fibres for preparing fibre cement-based composites. In many parts of the world, leaves are still used for fertilizer, feed, fuel, and medicine etc., but no consideration has been given for using leaves as an insulating building material. According to the statistics, Beijing's autumn is the peak period of defoliation, fallen leaves amount to about 3,000 tons every day, of which utilisation is less than 50%. This is a huge waste of this important sustainable natural resource, which can be utilised to make value-added products, such as fibre–cement based composites.

Merta et al. [13] used fibres from hemp, elephant grass and wheat straw to increase the fracture toughness of concrete. They found that when mixed with hemp fibres, concrete fracture energy could be increased by 70%, while increases in the fracture energy with straw and elephant grass amounted to 2 and 5%, respectively. Tang et al. [14] evaluated the residual compression and shear strengths of coconut fibre-reinforcing concrete interlocking blocks, and discovered the mortar free interlocking blocks made from coconut fibres could be used in building important components of seismic building structures. In the early 1990s, Sarigaphuti et al. [15] Sarigaphuti et al. used fibres from pine and poplar trees as a concrete reinforcing material. Filho et al. [16] prepared plant fibre–reinforced cement mortar composites from short sisal and coconut fibres, and studied the effect of fibres on the free and restricted plastic shrinkage, early drying shrinkage cracks,

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and long-term drying shrinkage of the cement mortar. Pacheco-Torgal et al. [17] investigated the characteristics of plant fibre–reinforced cement-based materials, methods for improving fibre properties, compatibility of fibres and cement matrix, and how fibres affect the performance of cement.

Although the research and application of plant fibre cement-based composites have made gratifying achievements both at home and abroad [18–21], they are still faced with many problems and shortcomings, in such aspects as: first, lack of compatibility between plant fibres and cement, and second, little attention has been given to utilisation of leaf fibres in existing applications of cement-based materials.

The hydration characteristics of plant fibres and cement mixture, namely compatibility. The problem of plant fibres and cement compatibility has always been a difficult problem in the process of research and utilisation plant fibres at home and abroad. The poor compatibility [22–24] of plant fibres and cement is mainly due to following factors: first, anti-coagulant effect of dissolved substances (called extracts) of plant fibres on cement hydration; second, presence of a large number of hydroxyl groups in the cell walls of plant fibres with high water absorption, resulting in an adverse effect on the physical and mechanical properties of fibre cement-based materials; third, alkaline attack in cement hydrates can significantly reduce the strength and durability of plant fibres.

In order to reduce water absorption and anticoagulation of plant fibres on cement, and to improve corrosion resistance, strength of fibre bonding in cement-based materials, and compatibility of fibres with cement-based materials, several methods have been used to improve cement hydration conditions, to extract anticoagulating components of fibres, and to modify fibre surfaces [25–27]. However, fibre pretreatment methods used are few and limited in their scope. For example, silane or sodium silicate treatment and the modification technology are too cumbersome, involving alkali and/or enzyme treatments. Therefore, further studies directed to developing processes and technologies to extend the application of plant fibres, and particularly leaf fibres, are warranted.

We are undertaking comprehensive studies on developing most effective leaf fibre modification processes [28], and characterising the composites made from leaf fibres for their quality and performance. Through testing the mechanical performance of before and after modification of leaf fibres and of the leaf fibre cement-based composite materials (referred to as LFCCM), we have analysed the effectiveness and mechanism of several fibre modification methods, as well as their influence on the compatibility between leaf fibres and cement-based composite materials. We are using sophisticated and most appropriate analytical methods, e.g. FTIR and XRD and SEM, to fully characterise before and after modification of leaf fibres and fibre cement-based materials and to understand the influence of modification methods on fibre–cement compatibility. We consider that the detailed fundamental information obtained will prove invaluable in developing technologies suitable for producing targeted and high performance leaf fibre cement-based materials and products.

## 2. Test

### 2.1. Raw materials

Cement: 42. 5R "Diamond" Brand ordinary Portland cement produced by Yanjiao New Building Materials Co., Ltd., Sanhe City, Hebei Province. The chemical composition of cement and mineral admixtures is shown in Table 1.

Flyash: II flyash from Shijingshan Power Plant. The chemical composition of the flyash is shown in Table 1.

Leaf fibres: Poplar leaves were collected from Beijing downtown areas in November. The collected leaves were dried, crushed, screened and then processed into fibres (granules) (Fig. 1). The appearance of poplar leaf fibres is shown in Fig. 2. The bulk density and appearance of grain size of leaves is shown in Table 2, and chemical composition of poplar leaf fibres in Table 3.

Sodium silicate solution ($Na_2O{\cdot}nSiO_2$): Made in Beijing Yongfei Adhesive Factory. Modulus 3.1, Baume 40°, density 1.38 g/cm$^3$, total solids content 36.20%.

Pure acrylic polymer emulsion: PRIMAL MAC-261P acrylic polymer emulsion by Rohm and Haas, USA.

Organosilicon waterproof emulsion: IE-6683 Water Repellent Emulsion by Dow Corning, USA.

Sodium hydroxide (NaOH): Beijing Chemical Plant, AR, the content of main ingredients ⩾96.0%.

Water: Drinking water complied with national standards, pH = 6.91 at 25 °C.

**Table 1**
Chemical composition of cement and mineral admixtures (%).

| Type of materials | CaO | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MgO | $SO_3$ | $Na_2O$ | Ignition loss |
|---|---|---|---|---|---|---|---|---|---|
| Cement | 62.38 | 25.52 | 6.15 | 3.27 | 0.57 | 1.54 | 1.65 | 0.21 | 2.87 |
| Fly ash | 1.93 | 54.88 | 32.12 | 4.28 | – | 1.45 | 1.46 | – | 3.82 |

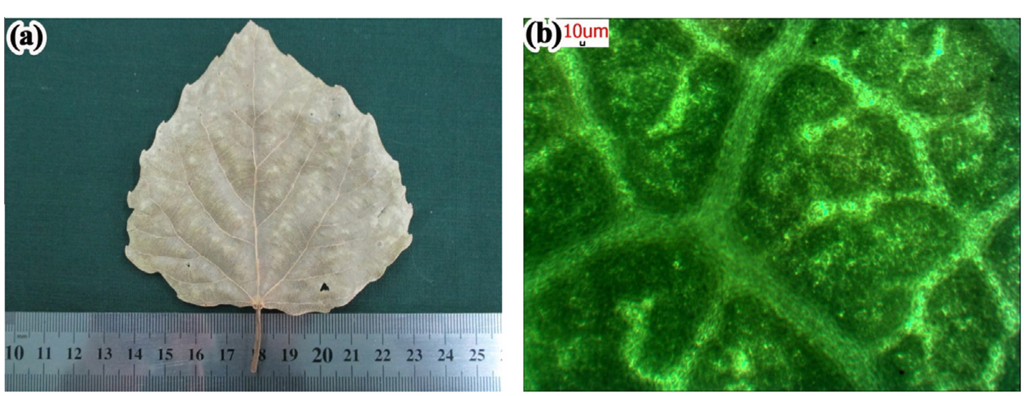


**Fig. 1.** The appearance of poplar leaf (grain size 0.3 mm). (a) A photo taken with an ordinary camera. (b) An optical micrograph (50× transmission).