# Studies on Fabrication of High-Strength Material from Residue of Hot-Compressed Water Extraction of Biomass

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（加圧熱水抽出したバイオマスからの高強度素材の製造に関する研究）

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# 論 文 内 容 の 要 旨
# Thesis Summary

Traditional building materials such as cement and steel, cause massive energy consumption and environmental problems. Wood particle boards have been widely applied in constructions and building materials due to their specific light weight, low production cost and renewable property. However, such continuing application of wooden products will inevitably consume abundant forest resources, which will affect the sustainable applications, especially in the case of a long growth cycle (more than 10 years) of trees. Therefore, it is significant to substitute wooden boards with non-wood lignocellulosic biomass partially. In order to increase the strength of the densified material, the pretreatments to overcome the recalcitrant structure of raw biomass seems to be necessary. Unlike the commonly used mechanical, chemical, and enzymatic treatment, the hydrothermal treatment represented by hot-compressed water (HCW) presents a green and efficient process. This study aims to develop high-strength densified materials made from non-wood biomass through an environmentally friendly procedure.

Chapter 1 introduces the background, significance and objectives of the development of non-wood lignocellulose boards. It briefly discusses the properties of lignocellulose biomass, including rice husk (RH) and bamboo. The classification of biomass boards, the pretreatment of biomass and the densification process are reviewed

Chapter 2 describes preparation of high-strength plate from RH pretreated in HCW. Traditional particleboards involve formaldehyde-based resins, which easily release toxic formaldehyde. All-natural densified materials have drawn increasing attention. As an agricultural, RH has abundant production but is usually discarded and incinerated. This work proposes processing of RH into high-strength material without external binder after pretreatment in HCW. RH was treated in flow-type HCW at 140–200 °C in

a tubular percolator, dried, pulverized, and then molded into rectangular or circular plates by hot pressing without a binder. The obtained plates of HCW-treated RH had greater tensile and flexural strengths than those of the original RH, while having smaller water uptake and swellability. The plates of RH pretreated at 160 °C had the best properties such as tensile strength of 26 MPa (2.8 times that of the nontreated RH), flexural strength of 21 MPa (2.6 times), fracture energy of 1453 mJ (7.8 times), water uptake of 40 wt % (0.74 times), and swelling ratio in water of 1.37 (0.92 times). These properties were attributed mainly to greatly improved pulverizability, resulting occurrence of fibrous reinforcement material, and optimized fractions of cellulose and silica (as reinforcement materials) and those of hemicellulose and lignin (as the matrix and binder).

Chapter 3 describes preparation of high-strength plate from HCW-treated RH blended with polyvinyl alcohol (PVA). To further improve the strength and water resistance of densified RH, it is reasonable to introduce an environmentally friendly binder into RH-based materials. This work proposes fabrication of high-strength RH-based composite materials with PVA via densification by hot pressing. RH was pretreated in HCW prior to pulverization and blending with PVA or PVA/glycerol (GL). The incorporation of PVA greatly improved the strength, toughness and water resistance of the composite plate. The tensile strength, flexural strength and toughness of a composite of HCW treated RH, PVA and GL with a mass ratio of 80:20:2 were 42 MPa, 81 MPa and 5.9 MJ/m3, respectively. The HCW treatment and blending with PVA and GL improved those properties of the hot-pressed original RH plate by factors of 2.5, 2.3 and 6.7, respectively, and reduced water uptake and swelling ratio in water by 57% and 53%, respectively.

Chapter 4 focuses on preparation of high-strength plate of residue from HCW treatment of bamboo. In order to expand the utilization of different biomass resources and investigate the influence of HCW treatment time, fast-growing bamboo is selected to prepare binder-free plates. The process involves a sequential batch-type hydrothermal treatment (HT), pulverization, and hot-press molding. The effect of HT time (2–137 min) on the strength of the plates and the corresponding mechanism was investigated. The strength of the plates was maximized for pretreatment at 77 min corresponding to the tensile strength (28 MPa), which is 1.9 times that of the nontreated bamboo plate. Hemicellulose, lignin and solvent-soluble matter contributed to the strength as binder/matrix, while bamboo fibers provided the reinforcement.

Chapter 5 gives general conclusions of this thesis and outlooks for possible future research.