Wood Wool Cement Board (WWCB) manufacturing technology with domestic lumbers for thermal and acoustic utilization in green buildings

Woo Yang Chung1,a, Gwang Ho Jung1,b, Chun Won Kang2,c

1 Dept. of Wood Sci. and Engrg., Chonnam Nat’l University, Gwangju Korea, 500-757
2 Dept. of Housing Environmental Design, Chonbuk Nat’l University, Jeonju Korea, 561-756
a wychung@chonnam.ac.kr, bkwanghoj@naver.com, ckwon@jbnu.ac.kr

ABSTRACT

This paper focuses on the feasibility of profitable green growth industry and addresses the manufacturing technology of wood wool cement board (WWCB) for the application in green building. A device for the wool making with low grade Korean domestic lumber was designed and WWCB utilizing three Korean species was compared with existing building materials in thermal and acoustical performance. The preliminary experiment showed that the sugars and extractives of these species affect the cement setting mechanism of WWCB and must be removed by appropriate treatment prior to mixing with Portland cement. Thermal and acoustical testing results indicate that WWCB with domestic thinned lumber have sound thermal and acoustical characteristics as building materials. Dimensional variability of wool and mechanical properties of WWCB would be investigated in future study.

KEYWORDS: Green Growth, Eco-materials, Wood Wool Cement Board, Thermal and Acoustical Insulation, Domestic Lumber, Green Building

1. INTRODUCTION

UNEP (United Nations Environment Program) compared the cost of reducing greenhouse gas emission in the abatement beyond business as usual by 2030 (Fig. 1). Although the majority of those business are distressed by the cost for the greenhouse gas reduction, some business could expect the benefit of double purpose (‘One stone, two birds’) with savings from the gas abatement, which deal with mainly the energy efficiency in heating, lighting, air-conditioning and the new energy production. The insulation improvement emerges as a forerunner among them.

Wood wool cement board (WWCB) made from wood wool and cement has been accepted world-wide with its versatility, durability and main characteristics as fire resistance, wet and dry rot resistance, termite and vermin resistance, thermal insulation, acoustic performance and acceptance of a wide range of finishes (Eltomation, 2009). Korean forest is still inferior consisting of low grade trees with small diameter and cumbersome shapes. Thinning the domestic forest produces so far lots of small diameter logs, which have been used as low value goods e.g. fuel or fences to block the soil slide. Wood wool cement boards (WWCB) are considered as the new highly value-added wood products in the era of so called ‘Green growth with low carbon’ in Korea especially.

Authors made the wool making machine for themselves with their own design to adopt the low grade logs and adjusted the salt mixing ratio according to the chemical constitution of domestic species. Thermal insulation and sound absorption performance of WWCB have been
invested to compare and replace the existing building materials like solid wood, wood-based panels, and gypsum board etc for the implementation of green building.

Figure 1. Savings and costs in reducing greenhouse gas emissions (by courtesy of UNEP)

2. PRELIMINARY STUDY

Three popular domestic species – Japanese red pine, pitch pine and Japanese larch – are adopted as test materials to make wool by our own wool making machine. They are usually thinned and utilized for the production low value products as pit-prop, pulp wood or fuel due to small diameter. Each species has its own chemical constituents and especially somewhat different extractives mainly containing sugars which may inhibit the setting of the cement (Eltomation, 2009). In this preliminary test, water-soaking of milled wood flour (20 mesh) for 24 hours to remove the water soluble cement-setting inhibitors. Mixtures of wood flour, cement, water (1:1:0.25) and accelerator (CaCl₂) pre-solved in water with 4% of cement weight were stored in disposable cup at room temperature without any pressure for 48 hours.

The results showed that sound setting occurs in wood-cement mixture with Japanese red pine and pitch pine flour but did in Japanese larch mixture indicating extractives of Japanese larch could not be readily removed by cold water soaking for 24 hours and need another option for removal of the inhibitors.

Table 1. Extractives content of Korean domestic species (Shin et al. 1980) [unit : %]

<table>
<thead>
<tr>
<th>Species</th>
<th>Cold water</th>
<th>Hot water</th>
<th>Alcohol-Benzene</th>
<th>1% NaOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinus densiflora</td>
<td>3.4</td>
<td>4.6</td>
<td>3.1</td>
<td>13.5</td>
</tr>
<tr>
<td>Pinus rigida</td>
<td>3.4</td>
<td>4.5</td>
<td>2.7</td>
<td>15.2</td>
</tr>
<tr>
<td>Larix leptolepis</td>
<td>5.9</td>
<td>7.3</td>
<td>3.5</td>
<td>16.9</td>
</tr>
</tbody>
</table>
3. WOOD WOOL CEMENT BOARD MAKING

WWCB making procedure with low grade lumbers consists of log cutting into fixed length, preparing rectangular blocks, wool making, blending with cement and salt solution, pressing and clamping the wet mat, curing and post conditioning.

Japanese red pine and pitch pine blocks were cut into wood wool of 2mm x 1mm x 60mm(W x T x L) with specially devised machine. Due to the shortage of thinned log quantity of domestic species, inter-mixed wood wool were water soaked for 48 hours, washed with tab water and air dried for 2 days.

The mixing ratio of wood wool, cement, water and accelerator was same as in the preliminary test but mat-forming on the tego-film overlaid plywood, pressing with a pressure of 2 kgf/cm² with hard wood stopper, clamping with 4 corner bolts for 24 hours and 2-week conditioning operation were processed to get 20 mm and 23 mm thick WWCB with specific gravity of 0.6. Detail information for the WWCB making will be shown separately.

4. THERMAL AND ACOUSTICAL PERFORMANCE OF WWCB

4.1 Thermal insulation of WWCB

WWCB(23 mm) made from domestic lumbers were tested to compare the thermal insulation characteristics with other building materials i.e. solid wood and styrofoam.

Fig.2 is the schematic diagram of thermal insulation test for the materials. According to Fig. 3, WWCB showed superior thermal insulating property to solid wood Styrofoam. This result is assumed due to large porosity of WWCB.

![Figure 2. Apparatus for the thermal insulation test.](image)

![Figure 3. Comparison of time to raise 5 degree of Celsius.](image)
4.2 Acoustic absorption of WWCB

Acoustic absorption test mechanism with broadband random noise excitation includes measurement of sound pressure (FFT) and calculation of transfer functions with reflection factors, absorption coefficient and normalized impedance ratio (Fig. 4).

Figure 4. Apparatus for the acoustic absorption test at Chonbuk Nat’l University.

20 mm thick WWCB was compared with several solid woods, fibreboard, plywood, gypsum board of different thickness with frequency up to 6 kHz. The results indicate acoustic absorption of solid wood differs among species drastically with frequency dependency and some species have higher absorption than fibreboard (18 mm thick) and gypsum board (6 mm thick). Low absorption of fibreboard is assumed due to the dense layer of board face. In case of gypsum board, the effect of thickness was distinguished. WWCB showed peculiar sound absorption characteristics with two peaks around 1.5 kHz and 5.5 kHz. This acoustical peculiarity could give versatile usage of WWCB as the building materials, demanding further research on the effect of wood wool dimension and physical parameters of WWCB i.e., board thickness and density.

5. CONCLUSIONS

This experimental study was designed to search for the solution of low graded forest resource of Korea via eco-building materials production in the era of so called ‘green growth’ and examined the feasibility of WWCB made from domestic lumber as the building materials which can replace the environmentally harmful building materials as gypsum board and etc. A device to make wool from inferior log was developed and WWCB manufacturing procedure was standardized considering chemical constituents of domestic coniferous species and the necessity of the removal of cement setting inhibitors, i.e. sugars and extractives.

Thermal insulation characteristics of WWCB was superior to solid wood and styrofoam according to 5 degree raising test using hot plate due to porosity made by wool and cement corporation. Acoustical absorption of WWCB was quite different with solid wood, wood-based panels, and gypsum board of various thicknesses. It showed dual absorption characteristics with two peaks at lower and higher frequency (1.5 kHz and 5.5 kHz, respectively) and let authors expect versatile application. To accomplish the versatility in building design and construction, it is demanding to carry out additional research to find the influence of wool dimension and the physical parameter of WWCB, i.e., board thickness and density.
Figure 5. Acoustic absorption of solid woods, wood-based panels, gypsum board and 20mm WWCB
REFERENCES


