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Study of construction convergence technology for performance improvement in functional building materials

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ABSTRACT

When using internal building materials, hazardous substances that affect indoor air quality are emitted from not only the material itself, but also from subsidiary materials such as construction adhesives. For wallpaper and flooring material, emissions from adhesives exceed the emissions from the material itself.

Recently, functional building materials with absorption properties have been widely used in board products, inorganic paints and wall-papers. These materials remove chemical substances from indoor air through physical sorption or chemical reaction and control humidity through capillary condensation. These materials have been used as countermeasures to sick building syndrome.

This study was conducted on inorganic paint, which is a functional building material that received New Excellent Technology certification for its moisture absorption and desorption performance. This moisture property affects the humidity in the indoor air and adsorbs formaldehyde and volatile organic chemicals. In this study, a construction convergence technology that can improve performance by at least 30% is proposed based on the principles of moisture absorption and desorption.

The findings of this study confirmed the importance of convergence technology that organically interconnects manufacturing and construction technologies to improve and maintain the performance of functional building materials.

1. Introduction

Global climate change has brought a diverse of changes in the residential environment. For example, in Korea, as the hot and humid rainy season gets longer, the indoor humidity becomes higher and the mold is increasingly and rapidly generated. As the residential environment changes, there is a growing demand for building materials containing moisture absorption and desorption properties that may control the indoor humidity. In addition, to comply with the energy-saving housing policy, there is a growing market demand for building materials with desorption performance that can reduce indoor harmful substances without opening windows for a lengthy time or operating ventilation facilities.

Building materials that affect indoor air environment include wallpaper, flooring materials, molding, paint, and adhesives. With regard to indoor building materials, hazardous substances generated in the construction process and those generated by the building materials themselves affect indoor air quality [1]. For wallpaper and flooring materials, the adhesives that are used during construction emit more hazardous materials than those emitted by the building materials themselves. Consequently, interest in the construction process is increasing. Furthermore, with the recent general awareness of life-cycle assessment (LCA) that evaluates the effects of pollutants emitted during the entire process of raw material, manufacturing, construction, and use of building materials, interest in hazardous materials generated during the construction process is increasing. However, the Eco Label, which is a certification by the Ministry of the Environment of South Korea for environmentally-friendly building materials, only measures hazardous materials emitted from building materials, with no consideration of hazardous materials emitted from the construction process.

Recently, functional building materials are required to develop in order to control humidity and adsorb indoor harmful substances according to the needs of the market. However, the existing functional building materials with the moisture absorption/desorption performance or HCHO adsorption performance up to now are mostly boards or tiles, and most of them are supplied at high prices, which makes it difficult to use them in practice.

Paints, relatively inexpensive finish materials, are difficult to develop as functional materials for interior finishing materials. There are two problems here. First, in general, a binder which is an adhesive

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component must be added as an essential component in order to apply with a roller or a brush, but the binder blocks the micropores of the porous material. Second, the thickness of the material itself should be secured to some extent in order to have moisture absorption/desorption performance or HCHO adsorption performance on a porous structure and it is difficult for the liquid type paint to form such a thickness. That is, in order to develop a functional building material having a moisture absorption and adsorption performances, it is necessary to develop both a 'manufacturing technology' to produce a product made of a porous material that has microspores, but excludes a chemical raw material such as a binder, and 'application technology' that maintains open micropores and at the same time forms a certain depth of film in the process of the application.

The two research questions are drawn to solve in this research. If products are manufactured without binders in order to prevent the micropores of the porous material from clogging, it is not possible to work by paint application method. Is it possible to develop paint application techniques without binders? Is it possible to propose a convergence technology that combines manufacturing and application technology, so that open micropores can be maintained while forming a constant thickness of paint? To find answers to the questions, we set the objective of this study as follow.

The purpose of this study is to propose a convergence technology that combines manufacturing technology with construction technology. Manufacturing technology is to produce functional building materials such as paints, that can have moisture absorption and desorption performance and humidity control by using mainly inorganic materials of porous structure which has been verified from previous studies, at the same time, that have desorption performance of formaldehyde as a water soluble compound. Construction technology is to maintain the given performances in the application process at the construction site.

This paper is organized as follows. In Section 2, it will investigate previous studies on porous materials and applications with moisture absorption and desorption performance and adsorption performance. In Section 3, it will analyze the core technology of porous materials and define the manufacturing technology of inorganic coatings that have both moisture absorption and desorption performance. In Section 4, it will propose Construction Convergence Technology (CCT) that combines manufacturing with application technology by developing the technique that can maintains the given performance in the construction process. In Section 5, it will verify that inorganic layer of the porous remains unobstructed on the actual surface where paints are applied.

Therefore, this study was conducted on inorganic paint, which is a functional building material that received New Excellent Technology certification for its moisture absorption and desorption performance. This moisture property affects the humidity in the indoor air and adsorbs formaldehyde (HCHO) and volatile organic chemicals (VOCs). In this study, a construction convergence technology that can improve performance by at least 30% is based on the principles of moisture absorption and desorption.

2. Literature Review

Rapidly progressing global climate change caused by global warming has a great impact on residential environment. Especially, to respond to the various problems such as mold and condensation which are generated when the humidity increases, it has driven to develop the building materials with humidity control performance. Studies on exchange of moisture absorption and desorption by micropores and adsorption of harmful substances have already been applied in real life. Typical examples are the studies on air purifier using microporous porous filters [2–4]. However, researches in the field of interior building materials have not been started until recently. As research on porous materials has actively conducted, its result has only begun to apply to interior building materials.

A typical porous material applied to interior building materials is a porous silica gel. Porous silica gels have very high adsorption performance on their own. Higher adsorption performance can be achieved when combined with silica gel-calcium chloride composite adsorbents [5]. Research has also been conducted on the development of low-cost porous materials. Sepiolite extracted from seashells can be used to make new TiO2-sepiolite nanocomposites that can both absorb moisture and decompose harmful substances [6]. Sepiolite is an inorganic tile, but when it is added to inorganic paints as an element, the strength of the surface coating is improved after application. However, sepiolite can be harmful when levels of asbestos in the human body exceed the standard value [7]. In Korea, when asbestos content exceeds 0.1% of the product weight in 2009, it is classified as suspected carcinogenic substance and it is prohibited to use. Unfortunately, sepiolite is subject to this limit.

With utilization of the humidity control performance of the various porous materials, researches on the development of building materials that may improve the indoor air quality are also being conducted. A study on the moisture absorption and desorption cycle of cement concrete and high performance moisture absorption and desorption building materials has found that high performance moisture absorption and desorption building materials made of calcium silicate hydrate as a raw material have a great influence on the indoor humidity control than the ordinary construction materials [8]. Researches on porous building materials containing calcium silicates have been continued afterwards. A study on how the adsorption performance and relative humidity of porous building materials containing calcium silicate can affect to formaldehyde, water-soluble compounds and toluene, an insoluble compound indicates that partition coefficient for formaldehyde was higher when the relative humidity is 80% than when it is 50%. It also finds that some material with higher adsorption performance may contain higher harmful substances [9]. This also means that the migration of water-soluble formaldehyde is closely related to the relative humidity. Uncoated gypsum boards and wood panels and built-in furniture do not have as high a humidity control performance as the construction materials of porous materials, but they play a similar role to change indoor humidity [10], while coating finishes may degrade indoor humidity control [11]. Recent studies have shown that the use of building materials with humidity control saves the energy consumption when mechanical ventilation systems are operated to improve indoor air quality as well as to absorb moisture and reduce harmful substances. This heightens the need for application of functional building materials [10].

Research on various porous materials has been promoting the development of building materials with moisture absorption and desorption performance. Furthermore, recent studies on the performance measurement methods in the indoor space where these building materials are applied have influenced the development of various building materials [12–14]. Particularly, 7 types of building materials including activated carbon, gypsum board mixed with activated carbon, board made of activated carbon, porous ceramic humidity control material, humidity control calcium silicate, ceramic tile and general gypsum board were tested of their desorption performance by breakthrough of adsorption ability test method. These building materials were measured of adsorption isotherm curves of indoor VOCs for benzene, xylene and styrene. This measurement shows that building materials with desorption performance has a favorable effect to mitigate VOCs and is effective when it is applied to the construction field as well as for the application of functional building materials [13].

However, most of the porous building materials with moisture absorption and desorption performances to date are mostly concentrated on boards and tiles, but hardly applicable to paints. This is because a binder, an adhesive component, must be added as an essential component to the paints when it is applied, which is generally done with a roller or a brush, however the micropores of the porous material are clogged and performance is difficult to achieve. In addition, the thickness of the material should be about 3 mm in order to have moisture absorption/desorption and HCHO adsorption perfor-