Title of Thesis Kenaf Silica Gel Wall
Development of a Breathing Passive Adsorptive Building Material

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Executive Summary

The production method of most of the modern building materials rooted in the Post-War period, where buildings have become tighter and more energy-efficient, environment was severely manipulated and natural resource was exploited. In Japan over 42 millions inhabitants have suffered from various forms of allergies. One of the causes could be rooted in the Sick House. With the high temperature and humidity level in summer season of Japan, biological allergens such as mold regenerate rapidly. Tobacco smoke, human precipitation and food odor are other forms of indoor pollution. Besides, modern building materials and products are typically more processed and may contain chemical compounds (VOCs) that are irritants to some people when used under certain conditions.

To ensure the safety of living environment and availability of natural resources in the future, a change appears to be necessary, not only to improve the quality of existing materials, but to develop new eco- building materials to improve the existing polluted interior space. Considerable investigation of ecological materials in architecture and urban planning discipline has been conducted on a theoretical level or urban scale; however, the goal of sustainability ought to be translated into action and result. This research is a case study of developing a new material “Kenaf Silica Gel Wall” and examining its environmental benefits in the architectural scale of “Room” and “Detail”. A multi-disciplinary approach is adopted in which different experts from university and industries are accumulated to collaborate in this research (Chapter One).

The question I would like to pose is – Can a breathing, passive adsorptive building material relieve pollutant concentration effectively?

This research objective is to develop a breathing, passive adsorptive building material that aids to regulate relative humidity at 60-70%, adsorb and decompose captured VOCs, improve energy and resource efficiency of building and create a light-weighted and movable wall.

To achieve the four objectives, a matrix of mainly two materials were selected - kenaf, for its ecological value, and silica gel, for its adsorption capability. The adsorption capacity of silica gel was improved, and the two materials were interwoven together to form Kenaf Silica Gel Paper with papermaking technique. Experiments were conducted to assess its performance on relieving humid and polluted interior, and potential applications of the new material were examined

The thesis is divided into six main components:

1) Define ecological material and sick house syndrome (Chapter Two)
2) Study the potential of different composite materials (Chapter Three)
3) Examine the adsorption Properties of silica gel and kenaf Fibre (Chapter Four & Five)
4) Investigate the processing methods of Kenaf Silica Gel Paper/Wall (Chapter Six)
5) Analyze the performance of Kenaf silica Gel Wall (Chapter Six)
6) Examine Potential Applications for Kenaf Silica Gel Wall (Chapter Seven)

1) Define Ecological Material and Sick House Syndrome (Chapter Two)

The new material, Kenaf Silica Gel Wall, attempts to achieve energy efficiency by reduce the use of air cleaner and dehydrator in buildings. It also maximizes resource efficiency by utilizing raw materials, kenaf and silica from renewable/plentiful source. The new wall has identifiable recycled content and it is manufactured with resource-efficient papermaking processes to minimize energy consumption.

Nevertheless, ecological design should imply more than environmental protection. For a building material to be ecologically-sound, the new material ought to be developed to relieve an environmental problem persisted in 21st century buildings - Sick House Syndrome, with the improvement of occupants' health being the target of this research.

2) Study the potential of different composite materials (Chapter Three)

In an attempt to find the most appropriate combination of raw materials to make a breathing wall, a series of potential composite materials were examined. The investigated materials were classified into five typologies: cement matrix, fabric,

nonwoven, glass and fibreboard. In-depth investigations were carried out with kenaf-reinforced PLA resin (cement matrix), kenaf-water glass matrix (cement matrix), kenaf-glass fibre membrane (fabric), kenaf-silica gel paper (nonwoven) and kenaf-optic fibre particleboard (fibreboard). After evaluating all materials with environmental performance tools based on LEED, a composite of mainly kenaf fibre and silica gel, with the use of the modified papermaking technique, were proven to be the most appropriate combination to make a breathing, adsorptive wall.

Kenaf is recognized as an environmentally friendly plant, as it removes the most carbon dioxide and nitrogen in the air among all plants on Earth. With the use of long and porous Kenaf bast fibres (2.6 – 5.0 mm) in processing Kenaf Silica Gel Paper, semi-transparency could be achieved; Natural light and air flow through gaps between fibres, allowing the partially emerged silica gel to be in direct contact with air to carry out sorption and photo-catalysis effectively. Its tensile strength (58,000 PSI) and lightness provide adequate strength to form a light-weighted, non-bearing wall with the honey-cone structure.

3) Examine the Adsorption Properties of silica gel and Kenaf Fibre (Chapter Four & Five)

Silica gel is a porous form of silica synthetically manufactured from sodium silicate. The structure of each granule is composed of a network of inter-connecting microscopic pores, which hold and release moisture by physisorption and chemisorption. The context of a building interior is very unique, with an ever-changing and continuous accumulation of moisture content and VOCs. Consequently, moisture control and durability of silica gel in terms of large adsorption capacity and reuse are essential. Nitrogen Isotherm experiments showed that most of the silica gel samples belong to Type IV isotherm, in which mespore (4-8nm diameter pores, multi-adsorption layers) and capillary condensation would take place. With the comparison with activated carbon (type I, micropore, 0-1nm diameter pores, mono adsorption layer), silica gel type B is more appropriate to be used for an interior wall due to its superior water, VOCs and ammonia adsorption capability and its ability to regulate relative humidity of indoor air.

Out of all the silica gel samples, Below Tatami Type (sample no.8) stands out for its water adsorption volume. With the technology of Photocatalysis, TiO2 Silica Gel and Sb/porphyrin Silica Gel adsorb ultra-violent light or visible light respectively

to decompose captured organic compound. With the addition of amino group and re-adjustment of pore size, the modified photocatalysis silica, Hi Cartiact TiO2 and NH Porphyrin Antimony B type silica gel, contain outstanding adsorption capacity and capable of regulating humidity at around 60%, adsorbing and decomposing HCHO (Chapter Four).

4) Investigate the processing method, diffusion characteristics and conditions inside Kenaf Silica Gel Wall (Chapter Six)

The wet nonwoven - papermaking technique was modified and employed in the processing of Kenaf Silica Gel Wall. The conditions inside the Kenaf Silica Gel Paper was thoroughly investigated to ensure that silica gel and kenaf fibres complementing rather than negating the strength of each other. Three phenomena often occur during papermaking might reduce the adsorption volume of silica gel; silica granule is crushed by water immersion, it sediments to the bottom of the papermaking tank due to its weight, and its pores get filled up by solvable glue, which is commonly used in papermaking to increasing the floating ability of plant fibres.

Consequently, two processing methods of Kenaf Silica Gel Wall were successfully developed with different kenaf - silica gel matrix. The first specimen involved the sandwiching of two kenaf paper with a layer of 0.05-0.15mm silica granules. Another specimen was achieved with the mixing of kenaf, kozo and silica gel all in water before interweaving them together into a paper. The inherent floating ability of kozo embodied silica granules; enabled the formation of a nonwoven without the use of chemical glue.

5) Analyze the Performance of Kenaf Silica Gel Wall (Chapter Six)

All adsorption data generated from this research and other related researches were complied together to assess the performance of Kenaf Silica Gel Wall in a building interior. Results showed that 1 m^2 of Kenaf Silica Gel Paper AP0051 can adsorb 57 grams of water, or 13 grams of benzene (S.T.P.), or 15 grams of toluene (S.T.P.). All the ammonia generated by 5 pieces of cigarette, or formaldehyde generated by 24 pieces could be eliminated for the first 1 hour.

Kenaf Silica Gel Paper has significantly more water adsorption capacity per gram than other tested adsorptive building materials. However, in a case where an adsorptive material is furnished in all walls, floor and ceiling of a 20m2 room, Kenaf

Silica Gel Wall has less overall water adsorption amount than some of other adsorptive materials such as diatom plasterboard, since it is not commonly be used in large quantity as other building materials. Calculations showed that using a combination of wood and kenaf silica gel paper in all furnishing surfaces is estimated to have sufficient adsorption capacity to regulate relative humidity of 20m2 room at 70% throughout the year.

6) Examine Potential Applications for Kenaf Silica Gel Wall (Chapter Seven)

Not only the finished product could be used for interior wall, Kenaf Silica Gel Paper could be further designed as a variety of architectural fittings such as interior movable wall/screen, ceiling panels, shoji doors and lampshade.

Places where public health is emphasized for building users, such as home, restaurants and office, would be suitable for Kenaf Silica Gel fittings, as they improve indoor air quality, sustain the well-being of occupants, while adding character to building interior.

This dissertation is intended to present the potential of Kenaf Silica Gel Wall to address some of indoor pollution problems that existing buildings are currently facing, and provide information and stimulate discussion on innovative building material research. Nonetheless, achieving the objective of sustainable indoor environment is dependent upon the success of implementing an overall ecologically sustainable plan at the building level, which integrates Kenaf Silica Gel Wall and other natural/mechanical systems together.