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A pilot study of the color performance of recycling green building materials

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ABSTRACT

The concept of green building integrates a variety of strategies during the design, construction and operation of building projects. The use of green building materials represents one very crucial strategy during the design and construction of a building. Recycling green building materials refer to those building materials reproduced from other materials, namely, reclaim the waste or discarded materials to produce the building materials. In Taiwan, gypsum boards are widely used in the building industry as facing materials for walls and ceilings due to their very good mechanical and thermal properties, as well as fire endurance. The goal of this study is to develop a new recycling green building material which could reuse the daily waste materials, color changeable and give inspiration to improve the characters of green building materials. In this study, six waste materials in our daily lives were mixed with the allochroic powder and gypsum powder to create thermochromic face bricks. The experiment modules were Groups A, B, C, and D, and mixed with allochroic powders of different specifications. The findings showed that Group C had the most significant RGB variation. In terms of the G value of Group C, the variations of the six materials were wood chips 81.9% > , newspaper 78% > , concrete 75.6% > , fallen leaves 66.6% > , iron powder 59.2% > , and silt 50.9%. In conclusion, allochroic faced bricks can be applied to both interior and exterior walls of different types of buildings in the future, thus, the buildings have different colors at different temperatures and times, cater to the changeful effects of future architectural appearances. Regarding the landscape, building and interior designers can construct artistic creations of shell collages.

1. Introduction

The concept of green building integrates a variety of strategies during the design, construction and operation of building projects. The use of green building materials represents one very crucial strategy during the design and construction of a building. In particular, green building materials are composed of renewable, rather than nonrenewable resources. Also, green materials are environmentally responsible because impacts are considered over the life of the product [13–15].

On the other hand, recycling green building materials refer to those building materials reproduced from other materials, namely, reclaim the waste or discarded materials to produce the building materials. [5] indicated that recycling green building material products should completely conform to the three principles of Reuse, Recycle, and Reduce. Ray et al. (2010) proposed that recycling green building materials should be tested by proven laboratories authorized by the government, and passed products should be labeled to prove the products acceptable. According to Article 321 of the Building Design-Construction Chapter, of the Building Technical Regulations in the Building Act of Taiwan, the usage rate of green building materials should be 45% of the total area of interior decoration materials, and the usage rate of exterior green building materials should be higher than 10%.

Gypsum board is regarded to be green material according to Taiwan' related building regulations. In Taiwan, gypsum boards are widely used in the building industry as facing materials for walls and ceilings due to their very good mechanical and thermal properties, as well as fire endurance. The endothermic dehydration process that takes place at high temperatures is capable of slowing down the fire spread through gypsum board based systems [8,9].

In terms of the principle of color change, [12] indicated that the color of thermochromic dye could be changed by controlling the temperature, solvent polarity, and pH values, to rearrange the molecules. New Prismatic Enterprise (2012) proposed that the product color change principle was the basic principle of low temperature

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color development and high temperature colorless, within a temperature range of −15–70 [3]. Indicated that light stability resulted in differences in pigments. Therefore, in this study, the protective measures against light were strengthened, and anti-UV waterproof weather resistant coating material, light stabilizers, and antioxidants were used to protect the chromotropic dyes. [1] indicated that in terms of photochromism, the molecular structure was changed in solar and UV irradiation, thus, the wavelength changed, which changed the color. Meer (1876) reported that the chromotropic dye crystal turned purple from colorless in the sun, and the crystal restored to colorless when placed in the dark. Hirshbergd (1950) proposed light conversion, as some substances changed apparently when exposed to the sun. [11] found that different colors were derived from mixing the color lights in different wavelengths in the light rays, and all colors could be formed by mixing red, green, and blue color lights. [2] suggested that the three primary colors were an additive mixture, where the three color lights, plus each other, equals white; and minus each other equals black; the colors between black and white are gray scale colors. Two of the three primary colors of color lights can be mixed to generate three primary colors of pigments, i.e. R+G=Yellow, G+B=Cyan, and B+R=Magenta. The International Commission on Illumination (1931) selected the standard wavelengths of the basic stimulation RGB of color mixture as 700.0 nm, 546.1 nm, and 435.8 nm, respectively. [6] used a density meter to measure the RGB color density of the tested color lumps for different parameter settings, and conducted an objective evaluation. [10] indicated that the gray balance data were the base of color change in color image reproduction. [4] indicated that the gray balance color lump referred to the color lump of the α, b' coordinates closest to the various RGB origins. According to [2], the RGB values and HSL values of body surface colors could be measured using a color analyzer, which can be used to measure the surface coating colors of different cement mortar specimens. As mentioned above, RGB can be analyzed by various software and instruments.

The goal of this study is to develop a new recycling green building material which could reuse the daily waste materials and give inspiration to improve the characters of green building materials The research purposes of this study were to investigate (1) whether the waste materials in our daily lives can be recycled to mix with the allochroic powder and gypsum powder to create thermochromic face bricks; (2) whether the thermochromic characters of the allochroic powder will be affected or even destroyed because of the mix process; (3) the color change efficiency test for the self-made thermochromic face bricks.

The research results can reduce the waste materials in our daily lives and give inspiration to improve the characters of green building materials.

2. Materials and methods

2.1. Research materials

This study was carried out in an interior laboratory of Mingdao University in Taiwan. In this study, six waste materials in our daily lives were mixed with the allochroic powder and gypsum powder to create thermochromic face bricks. Initially, six waste materials (i.e. iron powder, newspaper, fallen leaves, silt, wood chips, and cement blocks) were made into small particles. Iron powder, silt and wood chips were small particles already; therefore, they did not need further treatment. Newspaper, fallen leaves were broken to pieces by using a small bruising mill. Cement blocks were broken to pieces by using a hammer.

Secondly, the above small particles were further mixed with allochroic powder and gypsum powder to create thermochromic face bricks. The face brick made of waste materials was 1.5 cm thick, composed of a 1.19 cm thick bottom layer, a 0.3 cm thick allochroic layer, and a 0.01 cm thick surface protection coating material, from bottom to top.

The size of face bricks was unified at 5 cm × 5 cm × 1.5 cm (LxWxH). Referring to [7], the gypsum board should be fireproof and soundproof, thus, this study mixed anhydrite with allochroic powder and different kinds of waste to make face bricks. The die was a 7 × 7 × 2(cm) square hollow plastic die. The production steps of the face bricks are: (1) bottom layer: various wastes are made into small particles less than 0.3 cm, which are mixed with gypsum and water; the material ratios are 15 g gypsum (25%), 60% waste, 15% water, and 0.5 ml antioxidant and stabilizer, respectively, which are stirred for about 1 min and poured in the die, about 1.19 cm thick. According to the green building policy [5] proposed Ministry of Interior (Taiwan, R.O.C.) that the waste ratio of recycling green building materials should be higher than 50%. In order to in comply with the above policy, a waste ratio of 60% was adopted in this study. In addition, other material ratios are selected to be 25% for gypsum and 15% for water after several times of trials; (2) allochroic layer: 1.5–2 g allochroic powder (8%), 60% gypsum, and 32% water, are mixed to make the allochroic layer; the allochroic layer is 0.3 cm thick, and dried for one day; 3) surface protection coating material: 0.01 cm weather resistant surface protection coating material is painted after the experiment. The experiment modules were divided into Groups A, B, C, and D according to the allochroic powder mix ratio, and each group had the same six materials. Table 1 shows the addition of allochroic powder at different temperatures. Group A used the contrast colors of blue and orange paint (0.5 g model: acryliuqe301 poster paint) mixed with allochroic powder (blue 25 °C, 2 g). Group B contained two kinds of allochroic powders at different temperatures (yellow 31 − 1 g, blue 25 − 1 g). Group C contained three kinds of allochroic powders at different temperatures (yellow 31 − 0.5 g, blue 25 °C − 0.5 g, red 20 °C − 0.5 g). Group D contained three kinds of allochroic powders at different temperatures (yellow 40 °C − 0.5 g, blue 31 °C − 0.5 g, red 20 °C − 0.5 g).

The face bricks of the six materials of groups A, B, C, and D were produced according to the aforesaid method. The photos of the finished face bricks are shown in Table 2. In terms of experimental apparatuses, color analyzer TECPEL Tech-Link-TES 135 was used for RGB analysis. A digital thermometer was used to measure face brick temperature, and the temperature measurement range was −10 °C to +70 °C. Ice cubes were used for material cooling. The size was about 3 cm × 3 cm × 3 cm. The heating equipment was a SAMPO 10″ desktop electric radiator HX-FA10F, and the digital camera was Sony DSC-W620, with 14.1 mega pixel. Soil moisture and pH meter DM-15 was used to prepare the face brick moisture, with a measuring range of: 1–8.

2.2. Research method

2.2.1. Color change efficiency test for the green building materials of the various groups

The experimental period was from June 2012 to March 2013. Ice cubes and an electric radiator were used for cooling and

Table 1.
Allochroic powders at different temperatures of groups A, B, C, and D.

	A	B	C	D
Yellow		31 °C (1 g)	31 °C (0.5 g)	40 °C (0.5 g)
Blue	25 °C (2 g)	25 °C (1 g)	25 °C (0.5 g)	31 °C (0.5 g)
Red			20 °C (0.5 g)	20 °C (0.5 g)

Note: yellow (R255, G255, B0), blue (R0, G0, B255), red (R255, G0, B0) a, e.g. yellow allochroic powder 31, the allochroic powder turns yellow when the temperature is 31, is colorless at high temperatures, and chromogenic at low temperatures.