ISSN: 2633-4828 Vol. 5 No. 4, December, 2023

International Journal of Applied Engineering & Technology

Properties of Functional Heating Paint using Activated Clay for Indoor Air Quality

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Date of Submission: 04th September 2023 Revised: 18th October 2023 Accepted: 02nd November 2023

How to Cite: Lee, Jeon-Ho et.al., (2023), Properties of Functional Heating Paint using Activated Clay for Indoor Air Quality, International Journal of Applied Engineering and Technology 5(4), pp. 1-6.

ABSTRACT: The most of inspections are made in some of the exposed areas that are removable, such as ceilings, stairwells, etc., as inspections for the safety diagnosis of steel members can't be carried out due to interior finish materials. Accidents often occur due to such poor inspections, raising the need to secure a technology that can check whether or not structures are in a safe condition by conducting simple inspections. In addition, The spray-on insulation method, which is used for solving the problem of steel structures featured by high thermal conductivity, directly affects the environment by generating volatile organic compounds (VOCs), so it is necessary to devise measures required to solve the problem. Therefore, this study aimed to develop a functional heating paint to improve the disadvantages of the spray-on insulation method and steel structures. Moreover, It tried to frequently check the safety of the structures by using thermal imaging cameras with a heating paint. It conducted the evaluations of the constructability of the functional heating paint and of a reduction in VOCs. As the addition rate of the activated clay increases, the viscosity also increases, so it is impossible to meet the evaluation criteria for the constructability of the paint at the addition rate of 16% or more. That's why it selected the maximum addition rate of 15%. As the addition rate of the activated clay increased, the coating layer thickness and thermal conductivity increased, but there was no significant change in the dry time. The adsorption test results of VOCs showed that they were reduced by about 62% at the activated clay's maximum addition rate of 15%.

Keywords: Activated clay, VOCs, Adsorption, Heating paint, Air quality

1. INTRODUCTION

In fact, the most of inspections are made in some of the exposed areas that are removable, such as ceilings, stairwells, etc., as inspections for the safety diagnosis of

steel members can't be carried out due to interior finish materials. According to 「detailed guidelines for the safety control and maintenance of establishments by Korea Authority of Land & Infrastructure Safety, it is stipulated that the sheath (finish material) of main structural parts be first removed prior to carrying out the investigation, but inspection agencies try not to remove the interior finish materials as much as possible due to the noise, dust, etc. that may occur when the finishing material is removed. As a result, the internal finishing material is not removed as much as possible, so a separate inspection agency is required to prevent the removal of the internal finishing material. In this way, investigations on the same structural members are frequently conducted in limited places, resulting in poor inspections. For example, in 2018, Building A in Gangnam-gu, Seoul, was considered a small building with 15 floors or less, and therefore it had not been subject to legal safety management until then. The building had an A rating in its pre-collapse visual inspection report, indicating no safety problems, but several structural defects were found, such as cracks, the separation of the sheath, etc. from columns, during the demolition of finish materials for interior construction. And, it eventually had an E rating (limited use), the lowest rating, in an emergency safety inspection conducted thereafter. If there was no interior construction, it would have been a case in which many lives were lost due to the collapse of the building. Therefore, it is necessary to secure a technology that can check the safety of structures, even with simple inspections, for the prevention of such accidents.

According to the investigation of energy consumption in Korea, buildings accounted for about 30 to 40% of total energy consumption. And it was derived that the main cause was the poor cross section of building envelopes. The amount of energy lost in the buildings themselves is large because steel frames are often exposed in steel structures, such as factories, warehouses, gymnasiums, etc., and even in houses, the thermal conductivity of steel materials (53W/m℃) is 13.7 to 37.8 times higher than that of concrete materials (1.40 to 3.86W/m℃). This can lead to additional problems such as thermal bridges, etc. The spray-on insulation method is used to solve the high thermal conductivity of steel structures. The spray-on insulation method not only spoils the beauty of buildings and is inefficient and uneconomical because it is based on manual construction, but also generates dust and other harmful substances indoors, so there should be methods to solve such problems.

Therefore, it tried to analyze the properties of a functional heating paint that can absorb VOCs by using the heating paint and adding the activated clay in order to confirm structural safety just with a simple inspection to improve the disadvantages of steel structures.

Fig 1: Column collapse in site

Fig 2: Spray method

2. LITERATURE REVIEW

In the 'Basic study for the development of the road snow melting system using a heating paint', a snow melting system using a heating paint was developed, which in turn led to studies on power supply and control systems.

It selected a heating film, that is to say a system that require power, capable of achieving the maximum efficiency, compared to electric energy, and there seems to be a lack of studies on the self-heating effect of the heating paint that does not require external electrical stimulation. In the 'Evaluation of improving the indoor air quality of hardened materials using the activated clay as an adsorbent material', it made an adsorption-type hardened material with the activated clay added for an experiment to improve air quality after identifying harmful substances that cause indoor air pollution. As the addition rate of the activated clay increased, the concentration reduction rate of harmful substances increased. However, as the addition rate of the activated clay increased, the flexural and compressive strengths tended to decrease. Here, it was judged that the high porosity of the activated clay reduced the strength of the specimen.

3. EXPERIMENTAL PLAN AND METHOD

3.1. Experimental Plan

It was intended to examine the characteristics of a functional heating paint with the activated clay added. Table 1 shows the results of experiments on viscosity based on some addition rates of the activated clay 0, 5, 10, 15, 16, 17, 18, 19, 20 (%). And dry time, coating layer thickness, thermal conductivity and adsorption of VOCs according to a total of four addition rates of the activated clay 0, 5, 10, 15 (%), after conducting the experiments on viscosity.

Table 1: Experimental factor and level

Experimental factor	Experimental level		Remarks	
Target object	**Steel frame**		1	
Basic material	**Heating paint**		1	
Additives	**Activated clay**		1	
Addition ratio	0, 5, 10, 15, 16, 17, 18, 19, 20 (%)	0, 5, 10, 15 (%)	**9**	**4**
Experimental item	Viscosity (fall time)	Dry time, Thickness, Thermal conductivity, VOCs	**1**	**4**

3.2. Using Material

3.2.1. Activated Clay

The activated clay is one of the types of montmorillonite-based clay minerals equivalent to the 'porcelain clay' in Korea.[2]

It is a natural mineral that improves catalytic, adsorption, and decolorization capacities through the activation process for selected activatable gemstones and that is used for the refinement, adsorption, edible oil and fat, and catalyst of petrochemical products. The activated clay is white and porous with a large surface area. Figure 3 and Table 3 show the activated clay and its chemical components, respectively.[1]

Table 2: Chemical composition of activated clay

Chemical composition (%)					
SiO_2	Al_2O_3	MgO	Fe_2O_3	Na_2O	CaO
63.1	20.7	3.2	5.9	1.6	3.2

3.2.2. Heating Paint

The heating paint is a gray paint with a mechanism to emit heat directly from the paint after absorbing ambient temperature for heat generation and then going through a thermal radiation process. Figure 4 shows the heating paint

Fig 3: Activated clay

Fig 4: Heating paint

3.3. Experimental Method

3.3.1. Viscosity

An experiment on viscosity (time of falling) was conducted based on the KS M ISO 2431 (Paints and varnishes — Determination of flow time by use of flow cups). According to the KS standard, the range from 30 to 100 seconds is considered meaningful data. To explain the measurement method, as shown in the picture, block the hole at the bottom of a flow cup and then pour the functional heating paint so that the flow cup is full. After that, measure the time as soon as you open the blocked hole at the bottom of the flow cup.

Fig 5: Viscosity tes

3.3.2. Dry Time

An experiment on the dry time was conducted based on the KS M 5000 (Testing method for organic coatings and their related materials). The experiment was conducted based on 'complete drying'. At the complete drying, it is difficult to scratch a coating layer with, or the coating layer is not easily scratched with a fingernail or a knife

3.3.3. Thickness

The coating layer thickness was measured by its dedicated measuring instrument. It is a functional heating paint with the activated clay added, so the average of the measured values at a total of 10 points on one surface was calculated.

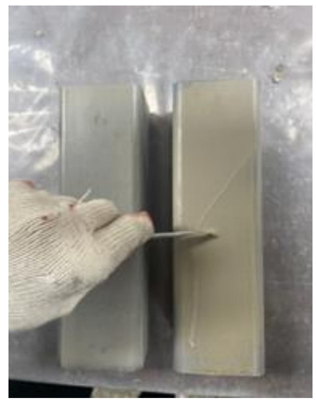

Fig 6: Dry time test

Fig 7: Thickness test

3.3.4. Thermal Conductivity

An experiment on thermal conductivity was conducted based on the ISO 22007 standard. A TPS method-based Hot Disk M1 (German) was used as a measuring instrument for thermal conductivity. The figure shows a measuring instrument for thermal conductivity

Fig 8: Thermal conductivity

3.3.5. VOCs Adsorption

An experiment on the adsorption of VOCs was carried out according to the method presented by Hanbat National University. To explain the measurement method, prepare the chamber (500X500X500 (mm)), mineral oil, measuring instrument for the concentration of VOCs, thermo-hygrometer, and pan. Afterwards, put the steel frame, coated with a functional heating paint, and the mineral oil into the chamber and then cover the chamber and then cover the chamber to conduct the experiment.

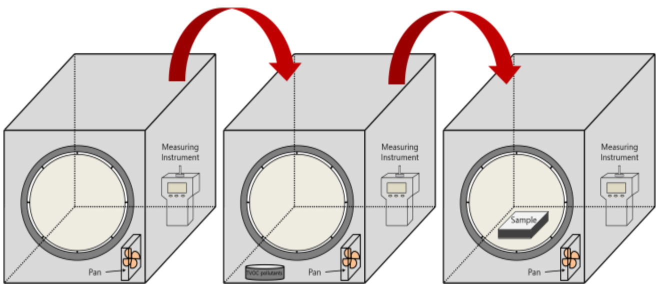

Fig 9: VOCs adsorption method

4. EXPERIMENTAL RESULT AND ANALYSIS

4.1. Viscosity

Figure 10 shows the viscosity according to the addition rate of the activated clay. As the addition rate of the activated clay increased, the viscosity tended to decrease. At the activated clay's addition rate of 16% or more, the viscosity decreased within 10 seconds and therefore did not meet the ideal criteria for the viscosity. It was judged that the agglomeration of activated clay particles had caused the accumulation of those particles in the hole of the experimental device, leading to a drastic decrease in the viscosity time.

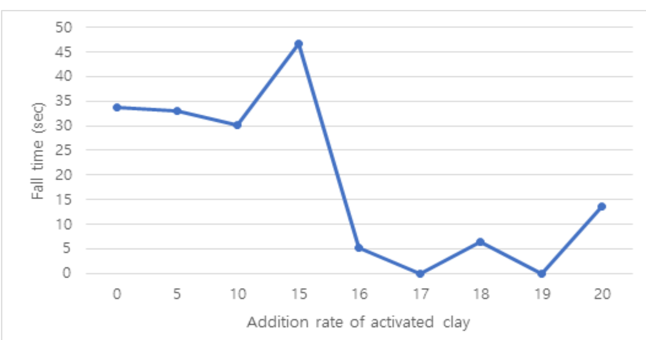

Fig 10: Viscosity (fall time)

4.2. Dry Time

Figure 11 shows the dry time according to the addition rate of the activated clay. It was judged that an increase in the addition rate of the activated clay had no significant effect on the dry time.

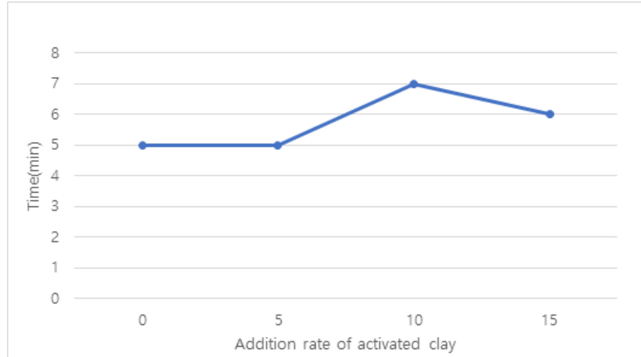

Fig 11: Dry time

4.3. Thickness and Thermal Conductivity

Figure 12 shows the coating layer thickness and thermal conductivity according to the addition rate of the activated clay. As the addition rate of the activated clay increased, the coating layer thickness tended to increase. It was judged that as the average of the measured values at a total of 10 points on one surface was calculated, the activated clay irregularly attached to the surface of the steel structure increased the average.

As the addition rate of the activated clay increased, the thermal conductivity tended to decrease. It was judged that as the addition rate of the activated clay increased, the amount of micropores increased to such an extent that pores were formed inside the specimen, leading to a decrease in thermal conductivity.

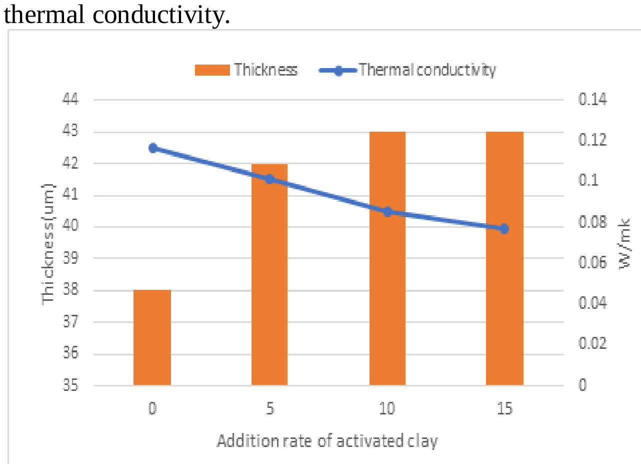

Fig 12: Thickness and thermal conductivity

4.4. VOCs Adsorption

Figure 14 shows experimental results for the amount of VOCs emitted for 24 hours according to the addition rate of the activated clay. Figure 15 shows experimental results for the amount of VOCs emitted for 7 days according to the addition rate of the activated clay. As the addition rate of the activated clay increased, the amount of VOCs emitted tended to decrease. It was judged that the concentration of VOCs was reduced by physical adsorption caused by increasing the specific surface area through the acid treatment of montmorillonite, the main component of the activated clay.

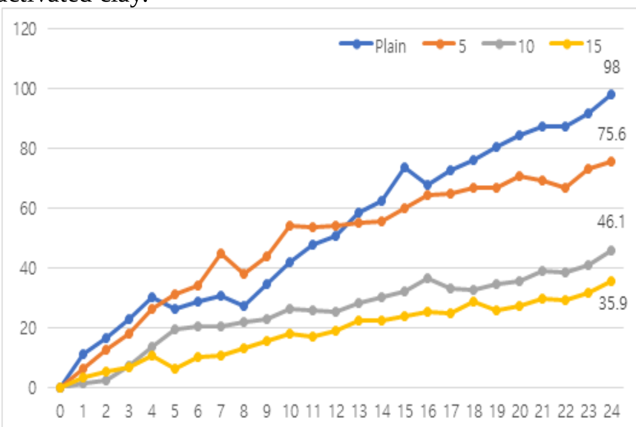

Fig 13: VOCs adsorption (24 hours)

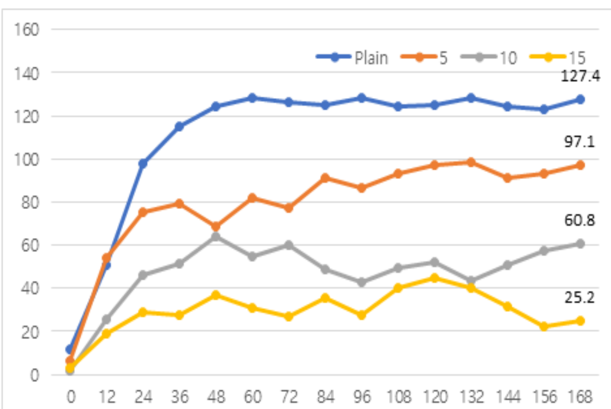

Fig 14: VOCs adsorption (7 days)

5. CONCLUSION

This study is a basic study for developing a functional heating paint that can absorb VOCs while compensating the defects in the spray-on insulation method and thermal conductivity of steel members. It conducted experiments according to some addition rates of the activated clay. As the addition rate of the activated clay increased, the viscosity decreased, and when it was 16% or more, it did not meet the ideal criteria for the viscosity time. Therefore, it selected the activated clay's maximum addition rate of 15% for the experiments. An increase in the addition rate of the activated clay had no significant effect on the dry time. Therefore, It has been judged that all of 0, 5, 10, and 15 (%) can be used for the addition rate of the activated clay if only the dry time is considered in improving constructability. As the addition rate of the activated clay increased, the coating layer thickness increased. It was judged that the activated clay irregularly attached to the surface of the steel structure increased the average of the coating layer thickness calculated by experiments. According to experiments conducted for 24 hours, the amount of VOCs emitted was reduced by about 62% when the addition rate of the activated clay was 15%, compared to when it was 0%. Therefore, it was judged that the most suitable addition rate of the activated clay to secure the ideal viscosity, dry time, and coating layer thickness and adsorb VOCs was 15%.

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