PROPERTIES OF THE WATERPROOFING MATERIAL MADE FROM RECYCLED POLYSTYRENE

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Abstract: *This paper studies the use of recycled polystyrene, an industrial and domestic waste, to produce the waterproofing material. The components of this material consist of recycled polystyrene, cement, sand, rice hush ash, and sodium silicate, which are popular materials in Vietnam. The properties of waterproofing material are investigated including surface drying time, completed drying time, adhesion, heat resistance and water permeability. Test results indicate that this material satisfies all requirements of waterproofing material stipulated by Vietnam standard.*

Keywords: *Waterproofing material, recycled polystyrene, drying time, adhesion, heat resistance, water permeability.*

1. Introduction

Along with the construction of the building, protecting them from the destruction by environmental factors such as rain water, moisture, sunlight, temperature, corrosive chemicals, etc is also very an important task. Especially in Vietnam, with high rainfall and high humidity, the quality and longevity of the building declined by water intrusion. Therefore, the waterproofing for buildings is very essential. However, most waterproofing materials in the market are imported from abroad, thus the waterproofing cost of buildings is high.

After ten research years, the Department of Chemical Technology, Hanoi University of Science and Technology, has successfully made the waterproofing material suitable for humid tropical climate condition in Vietnam [1]. Nguyen (2013) has studied the waterproofing paint,

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which has a high compressive strength, abrasion resistance, adhesion, and water resistance [2]. Pham et al. (2003) has selected suitable surface coating materials for chemical permeable resistance [3].

In Vietnam, the research on waterproofing materials is limited, while the publication of international research is also limited because researchers keep their work in secret for commercial exploitation. This paper studies the use of recycled polystyrene to produce a waterproofing material. The properties of this material as surface drying time, completed drying time, adhesion, heat resistance and water permeability are also investigated.

2. Experimental program

2.1. Materials

Ingredients to make the waterproofing material include polystyrene, cement, sand, rice hush ash and sodium silicate, which are popular materials in Vietnam. Especially, polystyrene and rice hush ash are domestic, industrial and agricultural wastes. Studying to use these materials contributes to protect the environment, reduce construction cost and use resources effectively.

Polystyrene is a light material with high chemical and water resistance. It was collected from industrial and domestic waste, then washed, dried and dissolved with a sufficient amount of gas to become the liquid gel. Cement used in this study is Nghi Son PC40 with specific gravity of 3.12. In Vietnam, rice hush is available as by-product of agriculture with a large amount of volume. Depending on the burning condition, rice hush ash powder consists of high amount of reactive silica. In this research, rice hush was burned in the furnace at a temperature of 850^{o}C for 3 hours, then was sieved to get the particles with the size of less than 0.15 mm. The physical and chemical properties of cement and rice hush ash are given in Table 1. Natural sand was washed to remove dust, then dried at a temperature of 105-110^{o}C for 6 hours. After that, it was sieved to get the particle with the size ranged from 0.15 mm to 0.25 mm. Sodium silicate was used to increase the workability and heat resistance of the waterproofing material.

Table 1. *Physical and chemical analysis of cement and rice hush ash*

Items		**Cement**	**Rice hush ash**
Physical properties	Specific gravity	3.12	2.16
Chemical compositions (%)	SiO_2	22.38	89.74
	Al_2O_3	5.31	0.96
	Fe_2O_3	4.03	0.52
	CaO	55.93	1.96
	MgO	2.80	1.41
	Loss on ignition	1.98	0.33

2.2. Mixtures

Many mixtures were produced with different mass ratios to find out the optimal ratios. This paper presents five successful mixtures as shown in Table 2. M1 is the basic mixture with the combination of cement, polystyrene and sodium silicate. Sand was added to mixtures M2 and M3. In mixtures M4 and M5, sand was replaced by rice hush ash. Note that the role of sand and rice hush ash are to take part in reaction with cement and are referred to as auxiliary materials. The mass ratio of the components was adjusted to get flexible paste for easy construction. The water resistance of these mixtures is provided by polystyrene, while adhesion strength of them is generated by cement reaction. High polystyrene content leads to low adhesion strength of waterproofing material. Thus, the ratio between cement and polystyrene is suggested not less than 1 and not greater than 5.

The process to make the waterproofing material is as follows: the dried ingredients as cement, sodium silicate, sand, and rice hush ash were mixed first by a glass rod. Then, the polystyrene gel was added and mixed until achieving a homogeneous paste as shown in Figure 1(a). In order to test the properties of the waterproofing material, which has just mixed above, concrete samples were also prepared. Concrete sample surface was covered by a thin waterproofing material layer of 1-2 mm as shown in Figure 1(b). The production and construction processes of this material are simple like cement paste.

Table 2. *Mass ratio of mixtures*

Mixture No.	Cement	Polystyrene	Sodium Silicate	Sand	Rice hush ash
M1	2	2	1	0	0
M2	2	6	1	4	0
M3	2	4	1	4	0
M4	2	10	1	0	4
M5	2	8	1	0	4

(a) (b)

Figure 1. *a) Waterproofing material; b) concrete sample*

2.3. Test methods

All experiments were conducted at Construction Material Laboratory of Engineering and Technology Department, Hong Duc University. The characters of waterproofing material were tested including surface drying time, completed drying time, adhesion, heat resistance and water permeability, which have to satisfy the requirements stipulated by TCVN 6557-2000 [4]. The testes of surface drying time, completed drying time, heat resistance and water permeability were performed in accordance with TCVN 6557-2000 [4], while adhesion test was performed in accordance with TCVN 2097-1993 [5].

3. Test results and discussion

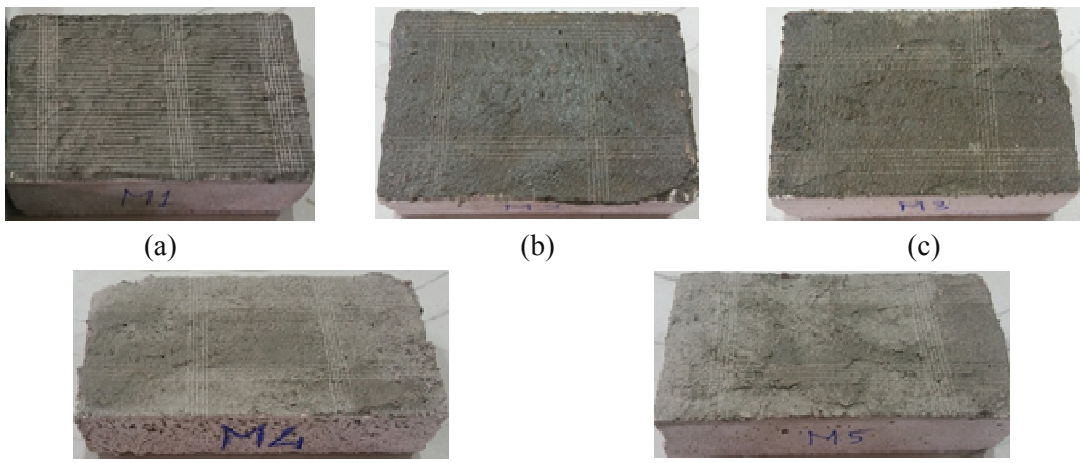
3.1. Surface drying time and completed drying time

Table 3 shows the surface drying time and completed drying time of all mixtures. Test results indicated that the highest drying time for surface and entire layer of the waterproofing material are 6 and 30 hours, respectively. These are much less than 24 and 72 hours as stipulated by TCVN 6557-2000 [4], respectively.

Table 3. *Surface drying time and completed drying time*

Mixture No.	Surface drying time (hours)	Completed drying time (hours)
M1	4	24
M2	6	30
M3	5	28
M4	4	24
M5	4	24

3.2. Adhesion



(a) (b) (c)

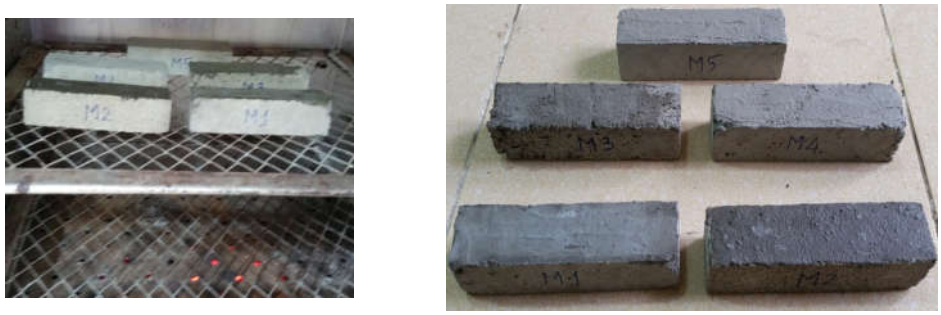
(d) (e)

Figure 2. *Adhesion test of mixtures: (a) M1; (b) M2; (c) M3; (d) M4; and (e) M5*

Figure 2 shows the adhesion test results of all mixtures on concrete surface. Note that, this test was conducted on concrete samples of 150 mm × 100 mm × 50 mm. The cuts by a sharp knife on the surface of the waterproofing material are almost smooth with no peeling membrane. The total area of peeling membrane is less than 5% for all mixtures, satisfying the requirement by TCVN 2097-1993 [5].

3.3. Heat resistance

Figure 3 illustrates the heat resistance test. The picture of all samples after 6 hours in dried oven at 100ºC ± 1ºC is shown in Figure 3(b). It is clear that no blistering bubbles were observed in the surface of samples. In other words, the waterproofing material on the surface of concrete samples was not destructed, even harder than before. The same result was obtained since putting these samples into dried oven for additional 24 hours. This finding proves that all waterproofing mixtures can sustain a heat at 100ºC more than 6 hours, satisfying the requirement by TCVN 6557-2000 [4].



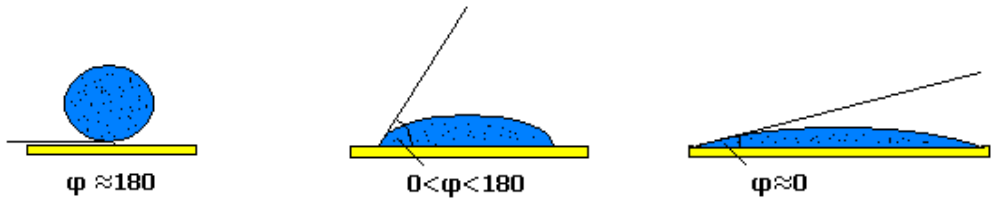
(a) (b)

Figure 3. *(a) Heat resistance test; (b) samples after heat resistance test*

3.3. Water permeability

3.2.1. Observation

The waterproofing ability of material is characterized by the shape of a liquid on the material surface. For example, the shape of water on the lotus leaf, duck feather, etc is spherical, which is due to the surface tension phenomenon as shown in Figure 4.



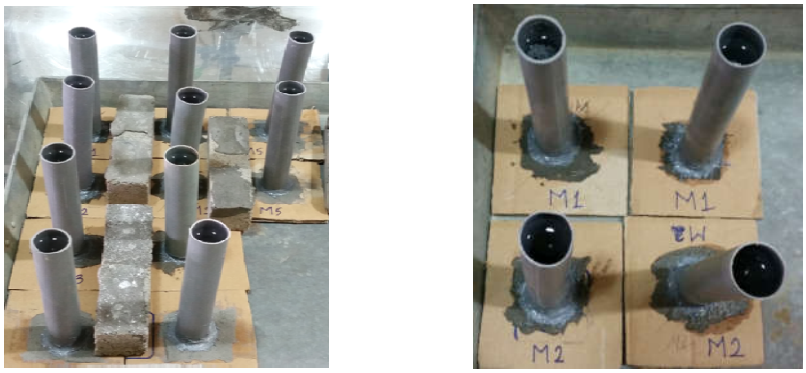
(a) (b) (c)

Figure 4. *a) impermeability, b) permeability, c) full permeability [6]*

Figure 5. *Observation of a water on material surface*

Figure 5 shows the shape of water on the M4 and M5 mixture surfaces, and on the normal concrete surface without waterproofing material. The shape of water on M4 and M5 is spherical, similar to the shape of water on the lotus leaf, while on normal concrete surface it is irregular with permeable region in outer border of water. The result is similar to waterproofing mixtures M1, M2 and M3; the shape of a water is spherical. This finding proves that all mixtures are water impermeable materials as lotus leaves and duck feathers.

3.2.2. Water permeability



(a) (b)

Figure 6. *Water permeability (a) after 7 days, (b) after 10 days*

Figure 6 shows the water permeability experiment. This experiment was conducted on carton covered by waterproofing materials. The pressure caused by a water column of 15 cm was put on a carton surface. Test results show that the cartons were still dry after 7 days as shown in Figure 6(a). It means that water can not permeate through the waterproofing material to the carton. After 10 days, the water permeated through the carton for samples covered with the layer of 1-1.5 mm waterproofing materials; however, for samples covered with thicker than 2 mm, waterproofing materials are still impermeable (Figure 6b). It means that the water resistance depends on the thickness layer of waterproofing materials. According to TCVN 6557-2000 [4], the water permeability index requirement is not less than 24 hours. Thus, all waterproofing mixtures in this study possess much greater waterproofing ability than this requirement.

4. Conclusions

This paper studies to make the waterproofing material using the recycled polystyrene. This material also exploited popular materials as cement, sand, rice hush ash and sodium silicate. The production and construction processes of this material are simple. Test results indicate that all waterproofing mixtures in this study satisfy the requirements stipulated by Vietnam Standard of surface drying time, completed drying time, adhesion, heat resistance, and water permeability. Especially, this material is impermeable under a water column of 15 centimeter during 7 days. If the layer thickness of the waterproofing material is greater than 2 mm, it is still impermeable after 10 days.

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