การศึกษาความต้านทานต่อการชะล้างด้วยฝนของวัสดุฉาบภายนอกด้วยดินผสมยางพารา สำหรับผนังบ้านดินภายใต้การจำลองสภาพอากาศแบบเร่ง

The Study of the Rain Washing Resistance of External Rubber-Clay Plaster of adobe walls under Accelerated Climate Condition Simulating

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บทคัดย่อ

งานวิจัยนี้ทำการศึกษาความต้านทานต่อการชะล้างด้วยฝนภายใต้การจำลองสภาพอากาศแบบเร่งของวัสดุฉาบภายนอกด้วยดินผสมยางพาราสำหรับผนังบ้านดิน และทำการเปรียบเทียบผลกับดินฉาบภายนอกสูตรดั้งเดิม การจำลองสภาพอากาศแบบเร่งประกอบด้วย ก) การฉีดพ่นด้วยน้ำแบบเร่ง และ ข) การฉีดพ่นด้วยน้ำแบบเร่งสลับกับการทำให้แห้งด้วยอุณหภูมิ 70 80 และ 90 องศาเซลเซียส

ผลการทดสอบพบว่าการชะล้างด้วยฝนของวัสดุฉาบแปรผันตรงกับปริมาณน้ำที่ตกกระทบพื้นผิว โดยได้รับผลกระทบอย่างมีนัยสำคัญจากวัฏจักรเปียกสลับแห้งและการเกิดออกซิเดชัน วัฏจักรเปียกสลับแห้งเป็นปัจจัยสำคัญที่ทำให้อัตราการกัดกร่อนสูงขึ้น การเกิดออกซิเดชันของฟิล์มยางทำให้ดินฉาบสูตรผสมยางพารามีน้ำหนักเพิ่มขึ้นและอาจทำให้อัตราการกัดกร่อนสูงขึ้นบ้างเล็กน้อย เมื่อทำการเปรียบเทียบผลการทดสอบพบว่า วัสดุฉาบภายนอกด้วยดินผสมยางพารามีความต้านทานต่อการชะล้างด้วยฝนสูงกว่าดินฉาบภายนอกสูตรดั้งเดิมอย่างมาก ซึ่งจะช่วยเพิ่มอายุการใช้งานของผนังบ้านดินให้มากขึ้นได้

คำสำคัญ: ความต้านทานต่อการชะล้างด้วยฝน ยางพารา วัฏจักรเปียกสลับแห้ง สภาพอากาศจำลองแบบเร่ง บ้านดิน

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Abstract

In this study, the rain washing resistance of the rubber-clay plaster under accelerated climate condition simulating was studied, and compared with the results of traditional clay plaster. The accelerated climate condition simulating included a) only accelerated spray test, and b) the accelerated spraying and drying cycle test at 70, 80, and 90°C drying temperature.

The results showed that the rain erosions of plasters were linearly depended on impacted water intensity with the significant effect of wetting and drying mechanism, and oxidation. The wetting and drying cycles was the main factor that increased the rate of erosion. The thermal oxidation of rubber films caused weight gain and may slightly increase the rate of erosion. The comparative results showed that the rubber-clay plaster had the rain washing resistance much more than the traditional clay plaster. Thus, the external rubber-clay plaster can assure a longer service life of adobe walls.

Keywords: Rain washing resistance, Rubber, Wetting and drying, Accelerated climate condition simulating, Adobe

Introduction

Around 30 to 50% of the world's citizen lives or works in adobe (Rael, 2009), typically a mix of sand and clay. Improving the water resistance and strength of adobe walls or external plaster can extend its service life and can promote the adobe in Thailand or any humid area.

Natural rubber latex has an ability to improve mechanical properties (compressive strength, flexural strength, and impact resistance) and water resistance of adobe. (Laokomain, 2004; Ruthankoon *et al*., 2006; Hinchiranan *et al*., 2008, Banjongkliang *et al*., 2015). From these previous researches, the authors (Banjongkliang *et al.*, 2015) have proposed to use sodium silicate as a rubber pH stabilizer for solving the problems from rapid agglomeration of rubber latex during mixing. The results have shown that adding 3-5% sodium silicate maintained the pH and liquidity of rubber latex during mixing (Banjongkliang *et al.*, 2015). This alkalined-stabilized rubber latex significantly increases the compressive strength and flexural strength of rubber stabilized adobe (Banjongkliang *et al.*, 2015). However, the rain erosion mechanism of sodium silicate–rubber-clay adobe has not been mentioned before.

The primary cause of loss of functionality in adobe wall is loss of surface area due to erosion by wind driven rain. Wetting and drying cycles increase surface stress in adobe and can lead to a more rapid breakdown than that due to a constant stream of rain Heathcote (2002).

Natural rubber is very prone to thermal oxidative degradation which commonly deteriorates its physical properties both in the raw and vulcanized forms. The rate of oxidation will increase with temperature. Increase in service temperature will thus accelerate the degradation of rubber (Suaysom, 2005). Ahmed et al. (2012) stated that “For a long service or storage of the cured rubber materials, it is recommended to age them at 70°C and 100°C from 3 days to 6 days and find out the aged values of mechanical properties of the cured rubber”. Choi et al (2006) also investigated the influence of the ageing temperature (50–90 °C) on the thermal ageing behaviors of vulcanized natural rubber. There fore, in this study, the accelerated ageing of rubber-clay plaster was investigated only on the thermal ageing at 70–90 °C.

This research aimed to study the rain washing resistance of the rubber-clay plaster under accelerated climate condition simulating, and compare its results with the results of traditional clay plaster. The accelerated climate condition simulating included a) only accelerated spray test, and b) the accelerated spraying and drying cycle test at 70, 80, and 90°C drying temperature.

Objectives of research

1. To investigate the rain erosion of the traditional clay plaster under accelerated climate condition simulating.

2. To investigate the rain erosion of the rubber-clay plaster under accelerated climate condition simulating.

3. To compare the rain washing resistance of the traditional clay plaster and the rubber-clay plaster under accelerated climate condition simulating.

Scope of research

1) Soil was taken from T. Mae-Rim-Tai, A. Mae-Rim, Chiang Mai province, Thailand. The collected soil was classified as sandy clay loam soil, according to the Unified Soil Classification System (USCS). The soil contained the clay content of 26.53% by weight of soil. Fine sand, following ASTM C778 (2011), was taken from Ping river resource, Chiang Mai province.

2) Rubber-clay plaster was the clay adobe stabilized with 10% commercial casting compound–prevulcanized rubber latex and 3% sodium silicate (Na_2SiO_3), developed by the authors in previous study (Banjongkliang *et al.*, 2015). It had the highest compressive strength and had no rapid agglomeration of rubber film during mixing.

3) The rain erosion was measured in the weight loss (%) of specimen after spray testing.

4) Accelerated climate condition simulating included a) only the accelerated University Technology of Sydney (UTS) spray test developed by Heathcote and Moor (2010), and b) the accelerated UTS spraying and drying cycle test at 70, 80, and 90°C.

Conceptual framework

The conceptual framework in this study was shown in Figure 1.

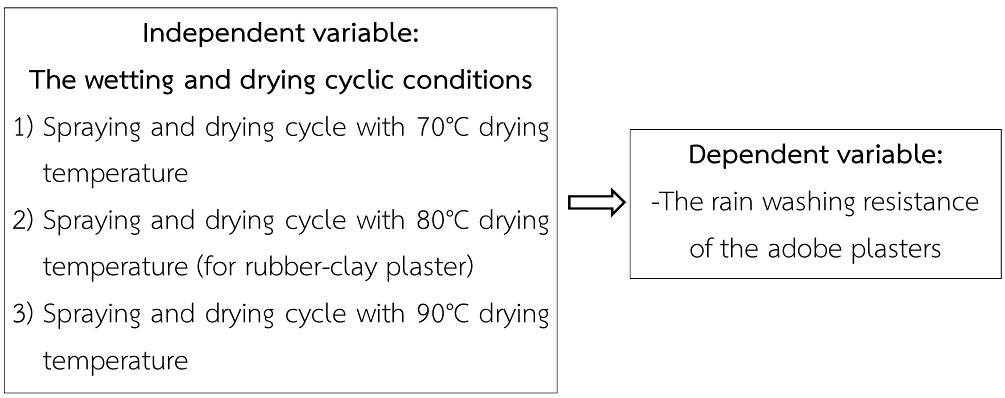


Figure 1 The conceptual framework of research

Research methodology

Specimen preparation

According to the specimen preparation of Banjongkliang *et al.* (2015), soil and sand were dry mixed in a mortar-mixing machine for 5 minutes at low speed, and mixed with water at medium speed for 3 minutes. When mixing rubber-clay plaster, the sodium silicate was mixed with water before pouring into the soil-sand dry mix. The rubber latex was added last. Water was added (around 0.16–0.25% by weight of soil and sand) to provide a practical fresh adobe with an initial flow of 60–70%, according to ASTM C1437 (2011). The plaster specimens were sun-dried in the molds and the molds were removed after 1–2 days. The specimens were sun dried for a further 3 days and then oven dried at 60 °C for 4–7 days until their weights were constant. The final moisture content of the specimens was around 2%, within the 2–5% equilibrium moisture content of adobe materials (Mortan, 2008). The mix proportions are summarized in Table 1.

Table 1 The mixture proportions of plasters.

Type of plaster	% by weight of sand and soil		Proportion		Note
	Rubber	Sodium silicate	Sand	Soil	
Traditional clay plaster	-	-	1	1	Proportion by weight
Rubber-clay plaster	10	3	1	1	Proportion by weight

Research frame work and data analysis

The research framework was shown in Figure 2. The rain washing resistance of the rubber-clay plaster under accelerated climate condition simulating were investigated and compared with the results of traditional clay plaster.

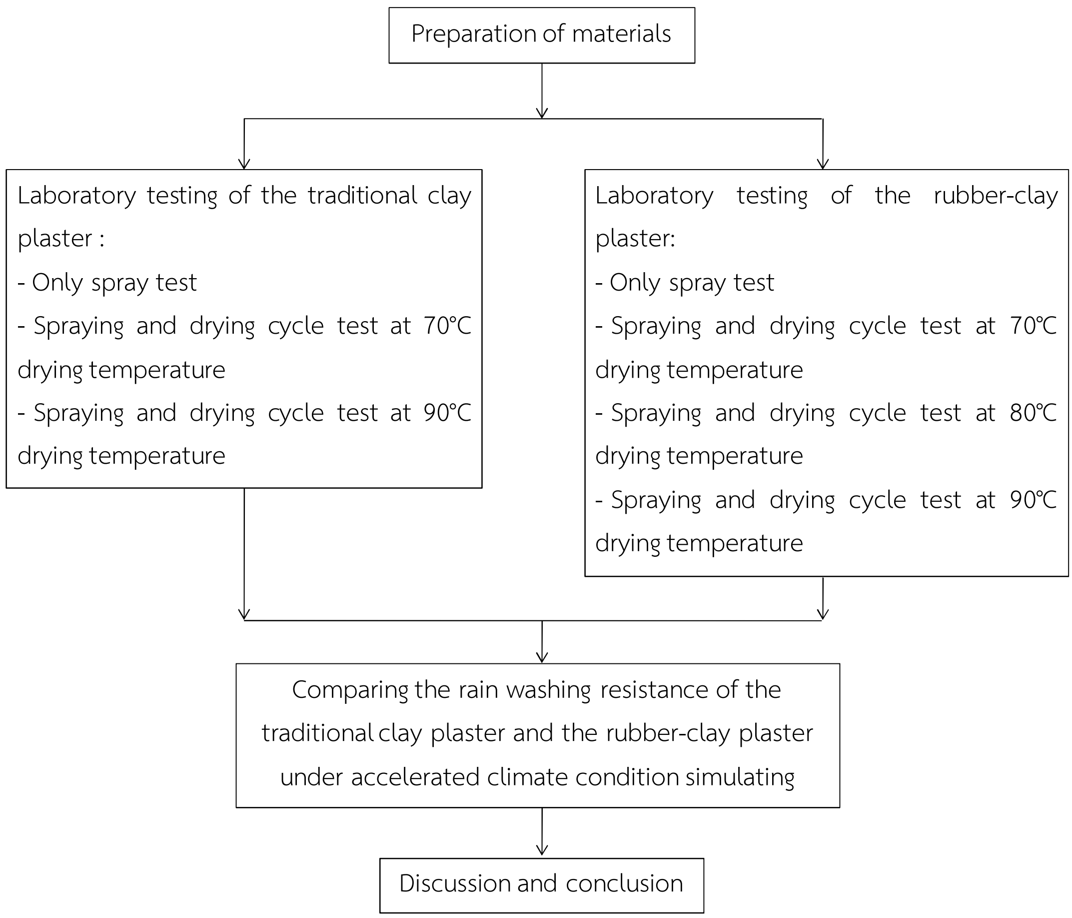


Figure 2 Research framework

Research Instrument

In this study, the UTS spray test apparatuses (Figure 3) developed by Heathcote and Moor (2010) was used to investigate the rain washing resistance of adobe plasters.

For the accelerated spray test, the dried specimens were sprayed in the UTS spray test for 5, 10, 20, 40, 60 and 90 minutes. After finishing spray test at any period, specimens were 60°C oven dried for seven days, and then, the dry weights were measured. Three specimens were tested for each duration of spraying. Weight loss (erosion) of specimens at any period of spraying was calculated according to Equation 1:

Weight loss (%) = (A–B)×100/A (1)

Where A was a 60°C oven dried weight (g) of specimen before sprayed. B was a 60°C oven dried weight (g) of specimen after sprayed

For one cycle of the spraying and drying cycle test, the dried specimens were sprayed for one minute. Next, the eroded specimens were oven dried at 70 for 7 days, or 80 for 7 days, or 90°C for 2 days, and then, the dry weights were measured. The drying duration at any temperature of oven drying was difference to ensure the constant dried weight of specimens. After at least 12 cycle test, the weight loss (erosion) of specimens at any cycle test was calculated according to Equation 1. Three specimens were tested and averaged for each data.

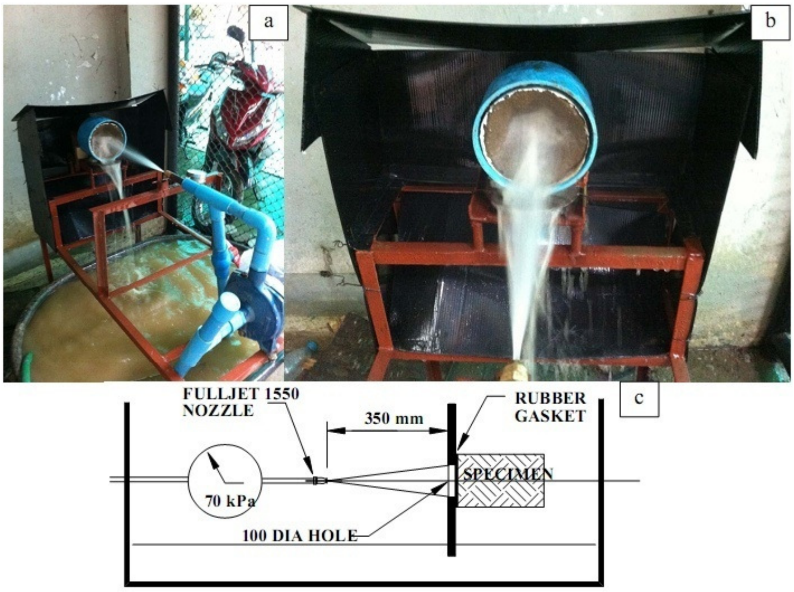


Figure 3 The accelerated UTS spray test a), b) actual test and c) schematic view (Heatcote and Moor, 2010).

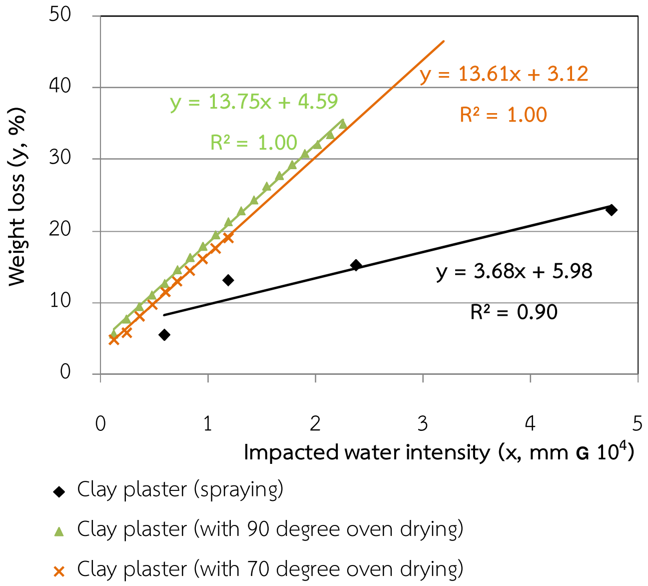
Results and discussion

The rain washing resistance of the traditional clay plaster under accelerated climate condition simulating

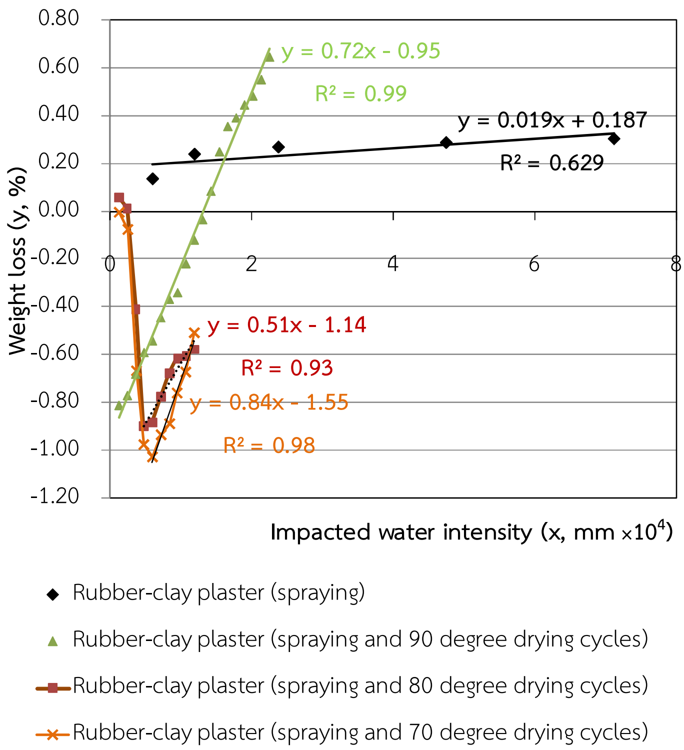
As shown in Figure 4a, the results support the findings of Heatcote (2002) by clearly showing that the rain erosion of traditional clay plaster under accelerated climate condition simulating was linearly dependent on the volume of sprayed water with the significant effect of wetting (water spraying) and drying cycles. The rate of rain erosion obviously increased from 3.68 weight loss percentage per 10^4 mm of impacted water intensity, in spraying test to 13.75 weight loss percentage per 10^4 mm of impacted water intensity, in spraying and drying cycle test. The effect of drying temperature between 70 and 90 °C was insignificantly difference in both erosion and rate of erosion.

The rain washing resistance of the rubber-clay plaster under accelerated climate condition simulating

As shown in Figure 4b, the results clearly show that the rain erosions of rubber clay plaster under various accelerated climate condition simulating are linearly dependent on the volume of sprayed water with the significant effect of wetting and drying cycles and thermal ageing. Thermal ageing caused oxidation degradation and the combination of wetting/drying cycles and thermal ageing increased rate of erosion. At initial time (Figure 4b), there were the reductions of weight loss or weight gain due to the oxidation of rubber films in matrix (Lucas et al., 2001; Ohm et al., 2002; Sommer, 2009). This is due to the fact that rubber films contain double bonds in backbone (unsaturated backbones) which are prone to attack by oxygen and ozone (Sommer, 2009). For the cycle test, after the maximum weight gains were reached, the water erosions were linearly increased with respected to water intensity. The rate of rain erosion obviously increased from 0.02 weight loss percentage per 10^4 mm of impacted water intensity in only spraying test to 0.84, 0.51, and 0.72 weight loss percentage per 10^4 mm of impacted water intensity in accelerated spraying-drying cycle test with 70, 80, and 90°C drying temperature, respectively. These could be concluded that the rate of erosions between the wetting/drying cycle test at 70 to 90°C was not different, when compared with an significant increase in rate of erosion from the only accelerated spray test.



(a)



(b)

Figure 4 The relationship of weight loss and impacted water intensity, under accelerated climate condition simulating, of (a) traditional clay plaster and (b) rubber-clay plaster.

Referred to the previous results of traditional clay plaster, the wetting/drying cycles was supposed to significantly increase the rate of erosion of rubber-clay plaster, however, the effect of oxidation of rubber films on the rate of erosion could not specified in this study. Nevertheless, Datta and Huntink (2008) proposed that "During the oxidation process, chain scission mechanism can weaken and soften vulcanized rubber film. While, rubber film becomes hard and brittle when it is completely oxidized upon progressive aging and the cross-linking mechanism starts to dominate again."

According to the results that the oxidation of rubber-clay plaster caused weight gain, this study recommend that, on the future work, the thickness change and thickness loss should be measured as an another indicative erosion for the durability study in the case of rubber-clay plaster.

Comparison between the rain washing resistance of the traditional clay plaster and the rubber-clay plaster under accelerated climate condition simulating

The accelerated erosions of any plasters were the same linearly dependent on the volume of sprayed water with the significant effect of wetting and drying cycles. Moreover, the oxidation degradation by thermal ageing was occurred in rubber-clay plaster.

As shown in Figure 4a and 4b, rubber-clay plaster had rain resistance under accelerated climate condition simulating much more than traditional clay plaster. This indicated the successful of adding rubber latex in clay plaster to improve its rain resistance. The rate of erosion under spray test of tradition clay plaster was 185 times of rubber clay plaster. The rate of erosion under cycle test with 90°C drying of tradition clay plaster (13.75 weight loss percentage per 10^4 mm of impacted water intensity) was around 20 times of rubber clay plaster (0.72 weight loss percentage per 10^4 mm of impacted water intensity). The maximum erosion of plaster occurred after the 19^{th} cycle of the accelerated UTS spraying and 90°C drying cycle test (this test provided the 22,562.5 mm of impacted water intensity equaling to 492 years of annual effective rainfall intensity). The weight loss after 19^{th} cycle test with 90°C drying of tradition clay plaster was 34.94% or equaled 54 times of rubber clay plaster (0.65 weight loss percentage).

Conclusion

1. The rain erosion of traditional clay plaster was linearly depended on impacted water intensity with the significant effect of wetting and drying mechanism. The wetting and drying cycles was the main factor that increased the rate of erosion.

2. The rain erosion of newly developed rubber-clay plaster (10% prevulcanized rubber latex and 3% sodium silicate) was linearly depended on impacted water intensity with the significant effect of wetting and drying mechanism, and oxidation. The wetting and drying cycles was the main factor that increased the rate of erosion. Moreover, the thermal oxidation of rubber films caused weight gain and may slightly increased the rate of erosion.

3. The results from accelerated climate condition simulating showed that the newly developed rubber-clay plaster had the rain washing resistance much more than the traditional clay plaster. These indicated the successful of adding rubber latex in clay plaster to improve its rain washing resistance. The rubber-clay plaster was suitable to apply as an external plaster to extend the service life of adobe walls. Under accelerated UTS spraying and 90°C drying cycle test, the rate of erosion of tradition clay plaster was around 20 times of the rate of erosion of rubber clay plaster. After the 19^{th} cycle test, the maximum erosion of tradition clay plaster was around 54 times of weight loss of rubber clay plaster.

Recommendations for the future research

Future work on the durability and durability prediction of rubber-clay plaster are recommended by measuring dimension change, thickness loss (depth of penetration) and weight loss as indicative erosion. The effect of oxidation of rubber films on the rate of erosion should be studied in the future. Moreover, the prediction for service life may be the superposition of weight loss and weight gain (due to oxidation) under climate condition. The durability in climatic exposure should be determined.

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