

DEVELOPMENT OF RAPID SET PLASTERING MORTAR FOR USING IN THE ASEAN REGION

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Abstract

Currently, a conventional plaster is widely used for wall plastering and occurs in various operational steps. The hardening time necessary for the plasters plays one of the most important roles in determining the duration of plastering work. Rapid-setting plasterers can assist in accelerating the process. However, plastering mortar with a hardened consistency is an imported product with very high shipping costs and import obligations, making it less competitive compared to local products in ASEAN. To maintain the quality and shelf life, transporting it also requires considerable time. Consequently, plaster products may agglomerate and lose their distinctive qualities. Besides, the climate in the ASEAN region differs from the country in which rapid-setting plaster products are produced. This has a direct effect on the plastering processes employed by ASEAN plasterers. This study focuses on the production of plaster mixes using raw materials in Thailand. To accelerate solidification, the addition of 3-4% calcium aluminate cement was conducted. In addition, it is compatible with Thai standards. The experimental results demonstrated that the manufactured plaster satisfied Thailand's quality and usability standards. Consideration is given to material performance parameters such as flowability, setting time, compressive strength, constructability of user field study, and carbon footprint regarding the life cycle assessment.

Keywords: CAC; Calcium Aluminate Cement; Fast Construction; Materials Properties; Wall Plastering

Introduction

The construction industry economy has been one of the nation's cores for centuries. The project system is based on durability factors such as reinforced concrete structural buildings and chloride-corroded steel structures. In the US, corrosion damage to

reinforced concrete structures results in an annual cost of over USD 276 billion. Electrochemical reactions dissolving metallic minerals (iron) and forming multiphase substances cause corrosion in conductive reinforced concrete structures. Rust is

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Table 1. Formula in the experiment.

Name	Description
NP	Local general plastering mortar
RP	Imported fast-hardening mortar
NPH1	General plaster improves properties with 1% CAC.
NPH2	General plaster improves properties with 2% of CAC.
NPH3	General plaster improves properties with 3% of CAC.
NPH4	General plaster improves properties with 4% of CAC.

formed by the weathering of iron oxides, hydroxides, and hydrated oxides on iron with suitable environmental factors (Leng *et al.*, 1998; Trading Economics, 2021). The formation of rust depends on several factors, such as the presence of oxygen, the relative humidity (RH), and the concentration of chloride. When rust forms, it can expand the volume of the affected material by 2-6 times (Wong *et al.*, 2010; Broomfield, 2017). Rust can cause corrosion to spread, and when steel is embedded in concrete, the resulting damage can reduce the concrete's high compressive strength. Although concrete is known for its ability to resist compression, electrochemical reactions on steel embedded in concrete can cause rust to expand continuously. This expansion creates tension in the concrete structure, pushing it out and leading to further corrosion (Ralph, 2009; Sereewatthanawut *et al.*, 2021). Nowadays, there are weathering erosion reports on large concrete bridges, parking structures, and buildings, especially in areas exposed to salt chloride. Until a common issue arises requiring structural and civil engineers to solve problems.

This research aims to address the high cost and short shelf-life of imported fast-hardening mortar by creating three product types, including imported mortar, imported fast-setting cement mixed with domestic sand and stone, and existing cement products. The research also aims to reduce greenhouse gas (GHG) emissions and waste generated during construction. A preliminary analysis using the embodied carbon. The ICE database method (Hohenthal *et al.*, 2019) showed that the new product could reduce carbon emissions by about 70%. This research has two goals: to test the long-term use of the rapid-set plastering (RP) mortar system in external conditions and to analyze construction costs, resource use, and GHG emissions of the new system compared to imported and existing materials.

Materials and Methods

The use of calcium aluminate cement (CAC) is also an alternative (Prasittisopin and Sereewatthanawut, 2019; Goergens *et al.*, 2020). Ettringite and monosulfate products generating heat by hydration reactions will be formed within 1 week. Therefore, the product formed and the porosity of CAC differ from those of Portland cement. But this mortar is an imported product, so the price is high depending on the freight charges at that time. This can result in the price more than 10 times higher than the normal product and reduce the service life. The quality of the mortar may be affected when the bag is opened, which can limit its use in Thailand (Trejo, and Prasittisopin, 2015; Sereewatthanawut and Prasittisopin, 2022).

Materials

General plaster. Tiger mortar was a product of Thailand and appeared as a gray powder. Its density was not specified, but it had a pH of more than 11, a bonding strength greater than 3 MPa, and a compressive strength greater than 2.5 MPa. Imported RP mortar appeared as a gray powder and had a density of 1.30. It also had a pH value of more than 12.5, a bonding strength greater than 9 MPa, and a compressive strength greater than 45 MPa. CAC (Almatis) was imported from Germany. Shown in Table 1.

Methods

To develop plastering mortar mixtures in Thailand that have the same quality and functionality as imported RP mortar, several tests were carried out including:

- 1. Setting Time for Plastering Mortar Test:** To determine the appropriate target setting time for imported RP, the Vicat testing method as per ASTM C191 was conducted to test the setting time of all mortars (ASTM, 2008). The normal plastering mortar to have the setting time close to the RP setting period by adding CAC for different dosages.
- 2. Flowability of Plastering Mortar Test:** To improve the properties of local plastering mortar so that it can be used in plastering in a way that is similar to how imported RP mortar can be used. Their flowability of mortars were conducted according to ASTM C1437 (ASTM, 2015).
- 3. Compressive Strength of Plastering Mortar Test:** All plastering mortars meet TIS 1776-2542 standard. The ASTM C109 (ASTM, 2020) compressive strength test was conducted to measure the compressive strengths of the cubed mortar mixes at 3, 7, and 28 days.

4. Constructability Test: The test panels were in the two different construction areas. Brick walls were located inside and outside the building, with a length of 1 meter, and a height of 1.5 meters. The average temperature was 30°C, sunny all day. The experiment involved five selected experienced plasterers, including Burmese, Cambodian, and Thai plasterers. In addition, interviews were conducted with users, experts, and academics to obtain in-depth insights. The waste during construction were recorded and average values were exhibited. After the first 7 days, the plaster was analyzed to determine the extent of cracking.

5. Life Cycle Assessment (LCA): To assess the environmental impacts of a product or service, it is necessary to consider its entire life cycle, starting from the extraction of raw materials and continuing through to its disposal. It identifies areas for improvements to reduce environmental impacts and considers all stages, including production, transportation, usage, and disposal. LCA evaluates indicators such as energy and water consumption, GHG emissions, and waste generation. Businesses, governments, and organizations can use LCA to improve the environmental sustainability of their products and services. The LCA process according to ISO 14040 and ISO 14044 (Finkbeiner *et al.*, 2006). Environmental impacts of raw material acquisition and plaster application were assessed using LCA with the SimaPro 9.4 software with the Eco-Indicator 99 method (Chapter 40 - Sustainable Development, 2012). Results in terms of environmental impacts and CO₂ emission of different mortar mixes were reported.

Results and Discussion

Setting Time

From the experimental results, the setting time of general plaster was improved by mixing 3% to 4% CAC per cement content. Their setting times can be improved to be close to NP plastering mortar as shown in Figure 1. CAC has a quicker hydration reaction, leading to the rapid formation of hydration products. As a result, plastering mortar with CAC has shorter setting times compared to OPC-based plastering mortar.

Flowability

From the experimental results according to ASTM C1437, the flowability of general plaster was improved by mixing 3% to 4% CAC per cement weight. The flowability can be improved to be close to NP plaster. The selected formulation is NPH3, which includes a lower CAC content to reduce the product cost.

Compressive Strength

After determining the setting time, NPH3 which have the setting time closed to the NP was selected for testing. Mortar compressive strength test results are shown in Figure 2. Results indicate that the developed NP plaster, the compressive strength was 23.64% higher than that of NP plaster at 28 days, but it was 65.50% lower than that of RP plaster can be used through the TIS 1776-2542 standard, which specifies that the plastering plaster must have a compressive strength of more than 2.5 MPa at 28 days.

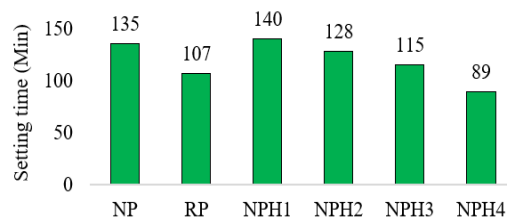


Figure 1. Setting time of experiment sample

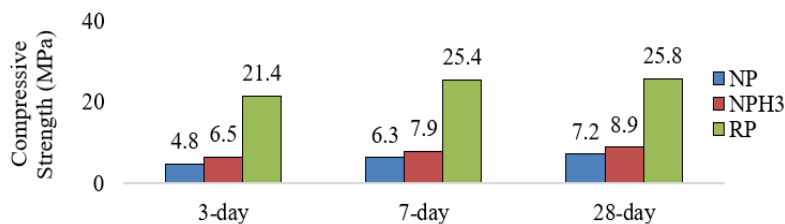


Figure 2. Compressive strength result

The quick hydration of CAC leads to the early formation of calcium aluminate hydrates, which contributes to early strength development in the mortar. CAC-based mortars achieve higher compressive strength at early stages compared to OPC-based mortars.

Constructability Analysis in Field Test

1. Crack Analysis: The crack analysis results for all three samples of plastering, both interior and exterior, were examined. When observing the time after the plastering (at 1 day and 7 days) was completed, it was found that no cracks were present in any of the samples. The test was carried out during a day with normal humid weather and warm temperatures ranging from 28 to 31°C, which is noticeable as operating in hotter weather may lead to the occurrence of cracks.

2. Waste Analysis: After the brick wall was constructed, the mixing and plastering processes were carried out. There will be a fall of plaster fragments. The amount of plaster produced compared to the initial amount of plaster is NP 25% volume, RP 10% volume, and NPH3: 25% volume. The higher adhesion is the effect of the plastering mortar more adhere to the brick. Resulting in less material falling as the construction waste.

3. Constructability Analysis: Five experienced plasterers who specialize in brick system wall plastering were interviewed to develop a worker selection model. Results shown in Figure 3 and Figure 4 show that NP and NPH3 had better workability and softness compared to RP. RP had the best adhesion and lower curing time than NP, however, NP and NPH3 had comparable ease of trowelling and low effort. RP and NPH3 resulted in a smoother wall texture compared to NP. NP and NPH3 had finer sand grains suitable for work compared to RP, which had too fine of a grain. RP had the appropriate amount of sand for work, while NP and NPH3 had comparable grain amounts.

The LCA

The results have shown in Figure 4 and Figure 5 revealed that the production of RP had a greater environmental impact during raw material acquisition due to its use of more clinker compared to NP and NPH3. The use of RP also had a greater impact during transportation due to the use of fossil fuels. In terms of GHG emissions, RP had the highest emissions compared to NP and NPH3. The Eco-Indicator 99 method provided eco-indicator scores for materials and processes used, indicating areas for product improvements.

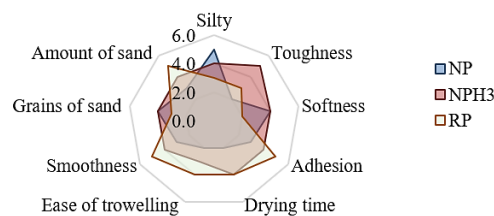


Figure 3. Setting time of experiment sample

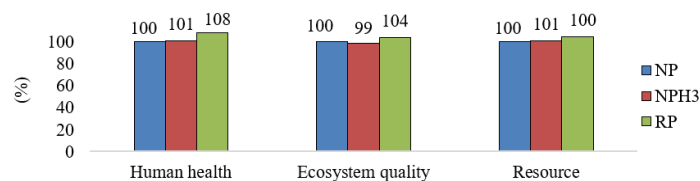


Figure 4. Compressive strength result

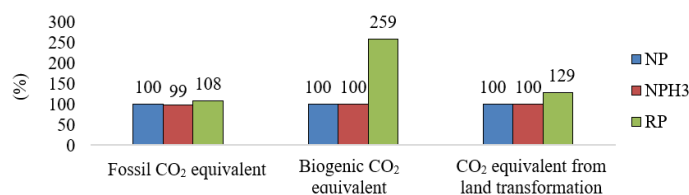


Figure 5. Emissions of CO₂

Conclusion

In conclusion, the laboratory testing of the development of RP plastering mortar in ASEAN region revealed as follows:

- The addition of 3% to 4% CAC per cement weight improved the setting time and flowability of standard plaster, making them more similar to NP and RP plaster.
- The developed NP plaster met the criteria of the TIS 1776-2542 standard for compressive strength, with a 23.64% increase in strength compared to NP plaster at 28 days.
- The CAC's quick hydration rate, high aluminate content, and reduced porosity contribute to shorter setting times and higher compressive strength in plastering mortar.
- However, the compressive strength of the developed NP plaster was 65.50% lower than that of RP plaster.
- RP plaster had higher GHG compared to NP and NPH3 plaster, which had similar carbon footprint emissions.

These findings suggest that the developed plaster has potential for use in construction projects, but further field testing is necessary to evaluate its performance in practical conditions. Additionally, the sustainability assessment revealed that the developed plaster has the potential to reduce environmental impact compared to traditional plasters, which is a promising avenue for further research and development. It is suggested that the use of NP and NPH3 plaster can be a more sustainable alternative to RP plaster, as they contribute less to GHG emissions during their entire lifecycle. This information is critical for policymakers and stakeholders seeking to promote environmentally friendly building practices and sustainable development.

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