



## Mechanical and Thermal Performance of Cement Mortar Incorporating Super Absorbent Polymer (SAP)

Md Mahfuzur Rahman <sup>a\*</sup>, Laila Tul Zannat Jyoti <sup>a</sup>, Snahashish Paul <sup>a</sup>, Al-Ishmam <sup>a</sup>,  
Md Akhtar Hossain <sup>b</sup>

<sup>a</sup> Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna 9203, Bangladesh.

<sup>b</sup> Centre for Infrastructure Performance and Reliability, The University of Newcastle, Callaghan, NSW 2308, Australia.

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### Abstract

Super Absorbent Polymer (SAP) is a favorable admixture which can influence various properties of cementitious materials. It mainly improves the water retaining properties of cement-based construction materials. In this paper, an experimental program was carried out to determine the mechanical and thermal performance of cement plaster containing SAP. Firstly, the absorption capacity of SAP was determined in different loading conditions and chloride solutions. Thereafter, the optimum dosage of SAP for cement plaster was also determined from five different proportions of SAP (0.05, 0.1, 0.3, 0.5 and 1% of cement mass) based on the compressive strength test results. The mortar incorporating 0.05% SAP of cement mass was selected as the optimum dosage, which yielded the highest compressive strength. Two slabs of 1×1×25 mm with 0.05% SAP and two slabs of 1×1×25 mm without SAP were cast to determine the thermal performance of the cement mortar with and without SAP. For this purpose, a wooden chamber of 2×1×1 m was constructed and the slab was placed in the middle of this chamber to carry out the thermal performance test of cement mortar. The slabs with 0.05% SAP showed promising results for acting as a thermal barrier in buildings compared to slabs without SAP.

**Keywords:** Absorption Capacity; Cement Mortar; Compressive Strength; Super Absorbent Polymer (SAP); Thermal Performance.

### 1. Introduction

Cement mortar has been extensively used for plastering works to provide a uniform surface on brick or concrete elements of various structures. The purposes of plastering are to provide a better appearance as well as a base for taking paints. However, mortar plaster can also be considered as moisture and thermal barrier between the outside and inside environment of a building.

Although cement plaster is not considered as a part of the structural elements, it is required to satisfy the strength and durability requirements according to ACI 524R in the United States. Water curing is therefore crucial to maximize the hydration reaction of cement in mortar and consequently, attain the strength and durability requirements. Either lack of moisture content or loss of excessive moisture from the cement mortar to the atmosphere will cause shrinkage and cracking in mortar and eventually, will deteriorate the growth of strength and durability of mortar. Moreover, plastering is done commonly on vertical walls of a building which makes it very challenging to ensure timely and adequate water curing.

\* Corresponding author: mahfuz11@ce.kuet.ac.bd

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As an alternative, superabsorbent polymer (SAP) can be considered as an internal water curing agent because of its water or other solutions absorb and storage capacity, which can readily supply water when needed for hydration or to prevent moisture loss in mortar. SAP could absorb and reserve water and other solutions up to several hundred times of its own weight due to its hydrophilic cross-linked networks [1–3]. However, the absorption capacity of SAP in the cement paste is greatly compromised and lies within the range of 8–30 g/g [4]. Dry superabsorbent polymer powder could absorb water present in mortar due to its water absorption properties and increase in volume to take more space in mortar matrix [5–7]. This phenomenon triggers SAP to be used as an additive in mortar applications to modify the rheological properties of fresh mixes of mortar [8–10].

SAP could desorb the absorbed and stored water into the mortar with the progress of cement hydration over the time under the effects of capillary tension generated by the change in volume and number of pores present in mortar. Internal relative humidity decreases with time due to the utilization of water in cement hydration reaction and moisture loss to the environment. Moreover, differential moisture loss produces humidity gradient since moisture loss is higher at the surface of the plaster compare to that of in the core of mortar plaster. The osmotic pressure increases with the decrease in humidity inside the mortar and the water absorbed by SAP is progressively released once the relative humidity of the mortar declines below 90% [11, 12]. As a result, SAP contributes to maximize the cement hydration in cement mortar [13–15]. On the other hand, the volume of pore structures in cement mortar grow as the swelled volume of SAP starts to return to its original state due to the water desorption phenomenon of SAP [16–18]. Consequently, those macro voids produced by the absorption and desorption progression of SAP can be used to entrain air into mortar [4,19]. Therefore, artificially created pores in mortar can be employed to improve the freeze-thawing resistance of mortar [19–21]. It is also worth noting that the released water from SAP helps in the prolongation of cement hydration to produce more cement gel and as a result, the pores developed at an early stage of mortar decreases with time at the later stage [17].

The desorption of absorbed water from SAP also conserves high internal relative humidity of mortar and thereby mitigate shrinkage of mortar [11, 21, 22]. Various methods have been investigated to produce self-healing concrete incorporating mineral admixtures as well as bacteria [23, 24]. SAP also can be applied to reduce the potential cracking [25, 26] as well as to induce self-sealing [27–29] of cementitious materials due to the characteristics of SAP, i.e. absorption and expansion. Addition of SAP in mortar would also reduce the coefficient of thermal expansion [30].

A significant increase in compressive strength of mortar can be observed when mixing with SAP in the presence of additional supplementary cementing materials [31, 32] or without any additional water considering the absorption capacity of SAP [4, 33]. Few researchers also reported that there is no adverse effect on the compressive strength of mortar mixing with SAP [7, 34].

However, the cross-sectional area of mortar decreases due to the introduction of a large number of pores developed as a result of the absorption and desorption characteristics of SAP [35–37]. Moreover, the hydrogel, produced as a result of water absorbed by the SAP, has very low stiffness compare to the hydrated cement matrix [2] and thereby decreases the overall compressive strength of cement mortar [5, 38]. Therefore, major work in this field suggested that most of the SAP mixtures have an adverse effect on the compressive strength of mortar compared to the reference mixture [12, 39, 40], particularly at the early phase of mortar age [41]. The decrease in compressive strength also attributed to the overestimation of the absorption capacity of SAP [36].

Therefore, the lack of unified design procedure of cement-based materials leads to inconsistent results regarding the compressive strength of SAP cement-based materials. Therefore, comprehend the influence of various dosage of SAP on the behaviour of cement mortar is a major concern. In this context, the selection of an appropriate absorption capacity of SAP in cement mortar considering the interior phase and load of cement mortar is vital to play a positive role in cement-based materials. Adoption of optimum dosage based on appropriate absorption capacity will lead to the compensation of probable reduction in compressive strength of mortar due to the macropores generated as a result of desorption of SAP, as well as improve the beneficial properties of cement mortar.

The influences of absorption-desorption behaviour of SAP on the performances of cement mortar with a water-cement ratio (w/c) of 0.485 were examined in this paper. Firstly, the absorption capacities of SAP were determined in different solutions with and without load. Thereafter, the mechanical property was evaluated by means of compressive strength test of cement mortar cubes containing SAP. To identify the optimum dosage of SAP in cement mortar, a range of 0 to 1% SAP of cement mass in the mortar was adopted. The setting times of cement and the workability of fresh mixtures of mortar were also studied with a selected optimum dosage of SAP to conform to the relevant code requirements. In the second part of this paper, an experimental setup to determine the thermal performance of cement plaster incorporating SAP and the results are presented. In this context, four cement mortar slab samples were prepared; two were considered as control samples and two samples incorporating SAP with optimum dosage. The thermal performance of cement mortar incorporating an optimum dose of SAP was investigated in a small-scaled rectangular shape wooden chamber.

## 2. Experimental Program

A flowchart has been presented in Figure 1 to demonstrate the research methodology adopted in this paper. This flowchart provides systematic approach to select the optimum dosage of SAP based on the mortar compressive strength and utilized the selected optimum dosage to prepare the samples for evaluating thermal performance of mortar containing SAP.

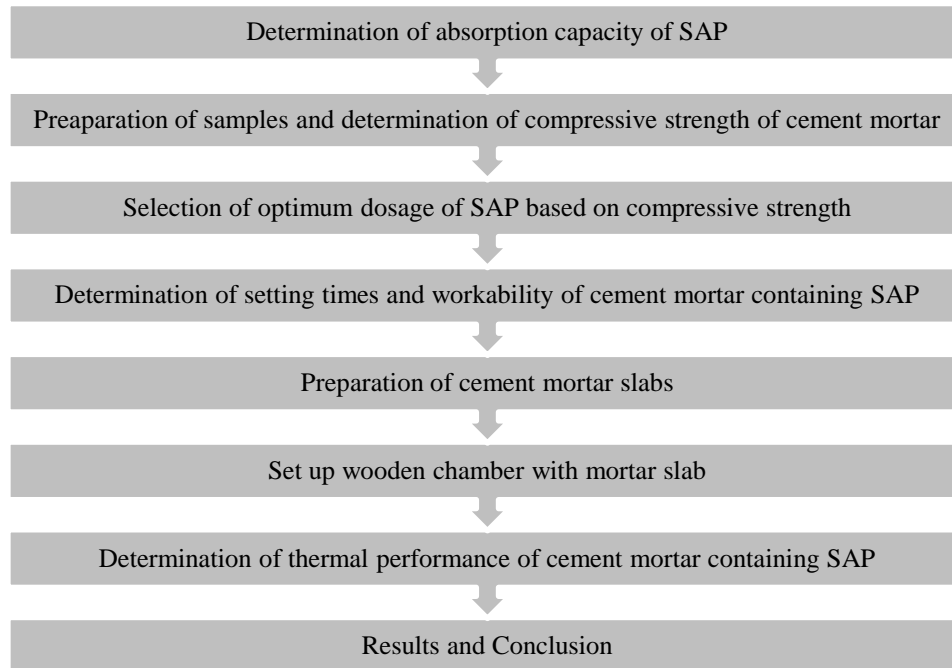


Figure 1. Flow diagram of adopted research methodology

### 2.1. Materials

Portland cement (CEM I) was used in this experiment with a specific gravity of 3.14 for the preparation of all specimen. Sand with fineness modulus of 2.56, unit weight of 1556 kg/m<sup>3</sup>, a specific gravity of 2.46 and absorption of 4.11% has been used for the preparation of cement mortar mixes.

In the literature, the most common SAP dosing has been used in the range of 0.25–0.6% by mass of cement [31, 42, 43]. This range has been preferred in the literature to demonstrate the use of the internal curing agent in the range of 0.2–0.7% of cement mass [7, 17, 44]. However, a higher dosage of SAP content up to 1% of cement mass is also used [38, 45], on the contrary, very low SAP dosages which lie between 0.05–0.2% of the cement mass has also been used [46] to investigate the effect of SAP on the performance of cement mortar.

In this study, SAP dosage ranges from 0 to 1% was considered to cover a wide range of possible dosing to identify the impact of SAP on the properties of cement mortar.

### 2.2. Mixing Procedure

To study the influence of various dosages of SAP on the performances of cement mortar, dry SAP powder was added during the cement mortar mixing. Although the addition of SAP in cement mortar mix by a pre-absorbed technique was also implemented by other researchers [47–49], dry SAP powder was added during the mixing of mortar to ensure the uniform disperse of SAP powder within the mix and also to ease the mixing procedure by avoiding the steps involved in activating the SAP and maintaining the required water content.

Cement and dry SAP powder were placed and dry-mixed for 30s at low speed (140 rpm) to confirm a homogeneous dispersion of the SAP in the cement. Then the required water was added to the mixture and the rest of the mixing procedure was followed as ASTM C309. The proportion of cement and sand was in the ratio of 1:2.75 for all mortar mixtures. In the calculation of the required water amount, additional water considering the absorption capacity of SAP was also taken into account to compensate for the water absorption by the SAP.

### 2.3. Specimen Preparation

Total six mix designs were evaluated in the present study consist of one with no SAP and other five groups with different SAP dosing ranges from 0.05 to 1% mass of cement. In the preparation of all specimen, clean tap water was used as mixing water, as well as curing water.

50 mm cubic samples of mortar were prepared for compressive strength test according to ASTM C109. The w/c ratio was 0.485 and percentage of SAP used were 0% (no SAP), 0.05%, 0.1%, 0.3%, 0.5% and 1.0% of the cement mass, as summarized in Table 1. Extra water in addition with mixing water was added into the mortar mix containing SAP based on the absorption capacity of SAP in cement solution under load.

To compare the influence of SAP on the properties of cement mortar, all samples incorporating SAP and one group of samples without SAP were air-cured and one group of samples without SAP was also water cured from the demolding of the samples at 24 hours of mortar age. The temperature during the curing period was maintained at  $20 \pm 2$  °C until the test.

**Table 1. SAP dosage and curing method of cubic samples**

Sample ID	SAP (%)	Curing method
Ref	0	Water
S (0%)	0	Air
S (0.05%)	0.05	Air
S (0.1%)	0.1	Air
S (0.3%)	0.3	Air
S (0.5%)	0.5	Air
S (1.0%)	1.0	Air

Slab samples, made of cement mortar, were used in this research work to investigate the influence of SAP on the thermal properties of cement mortar. Therefore, total of four mortar slabs, two without SAP as control samples and two incorporating SAP with optimum dosing obtained from compressive strength test performed in this paper, were cast. All samples were identical in shape having a dimension of 1000 mm × 1000 mm × 25 mm. The thickness of mortar samples was considered to be the representation of wall plaster. Similar to the cube samples, mortar slabs without SAP were water cured and mortar slabs with SAP were air cured after the demolding of the sample until the test.

## 2.4. Free Absorption Capacity of SAP

The free absorption capacity of SAP in cement solution is greatly reduced due to the highly electrochemically active nature of the solution compare to that of in distilled water [46]. Therefore, adoption of the absorption capacity of SAP in distilled water will result as an overestimation of the absorption capacity in the cement mix. In this context, a dilute cement paste solution with a water-cement ratio of 5–7 [4] or a representative water solution containing chloride ion present in cement paste [50] has been used to determine the absorption capacity of SAP to be used in the preparation of cement mortar. Therefore, absorption capacities of SAP were determined in four solutions, i.e. distilled water, tap water, NaCl solution and cement solution, in this study to investigate the behaviour of SAP in different solutions. NaCl solution was prepared by adding the required amount of NaCl into distilled water to produce a solution having similar chloride concentration to cement solution. Cement solution was extracted from cement paste prepared with w/c ratio of 0.6.

Absorption and desorption capacity of SAP has been estimated in different solution by means of various test methods found in the literature [3]. However, considering the simplicity, reliability and reproducibility of the test results, “tea-bag method” [50] has been adopted in this experimental program to identify the free absorption capacities of SAP in different selected solutions.

An amount of 0.2 g of SAP dry powders were placed into an empty nonwoven heat-sealed bag of 60 × 80 mm<sup>2</sup>, which is denoted as the mass of SAP ( $m_1$ ). To confirm the reliability and reproducibility of the results, the absorption capacity of SAP has been determined three times for each solution. The nonwoven heat-sealed tea-bag containing the SAP has been saturated in a beaker filled with the solution at  $25 \pm 1$  °C. The beaker was securely covered to avoid any evaporation of the solution from the beaker during the test. After 30 minutes from the contact of the SAP and solution, tea-bag filled with solution-soaked SAP was removed and weighed (mass  $m_3$ ). Subsequently, the tea-bag was placed on a dry cloth and softly wiped with another dry cloth to remove the extra surface water from the surface of the tea-bag. The absorption capacity of SAP in each solution has been calculated following Equation 1:

$$\text{Free Absorption Capacity} = \frac{m_3 - m_1 - m_2}{m_1} \quad (1)$$

Where,  $m_2$  is the mass of the pre-wetted tea-bag.

## 2.5. Absorption Capacity Test of SAP under Load

Similar to the tea-bag used in the determination of free absorption capacity of SAP, heat-sealable nonwoven

material made tea-bags were used for absorption capacity test of SAP under load. A square mesh frame set-up was prepared using steel mesh, thin flat steel bars and screws. A steel mesh (#100) was cut in  $150 \times 150 \text{ mm}^2$  and flat steel bars were attached with it on both sides using screws. Its height was about 1 inch from the bottom surface on which it was kept, allowing the solution to penetrate from the beneath.

A clean and dry bowl was taken and the square mesh set-up was placed in the bowl. Then, the solution was poured into the bowl until the square mesh was immersed in the solution. After that, the tea-bag filled with dry SAP was slowly placed on the square mesh frame totally immersed in the solution. It was pushed very slowly until the whole tea-bag becomes evenly wet and eliminated the entrapped air-bubble carefully. Then immediately a weight was placed on the tea-bag so that the weight exerts a pressure of  $50 \text{ gm/cm}^2$  [2] on the tea-bag containing SAP. The tea-bag under load kept immersed in the solution for 30 minutes. After 30 minutes, the tea-bag was removed immediately from the solution and was kept suspended freely for 1 minute. Then the outer surface of the tea-bag was wiped with a soft piece of cloth very cautiously without applying any pressure. After this, the mass of the wet tea-bag containing SAP ( $m_4$ ) was recorded immediately. Average of three measurements were considered for each solution. The absorption capacity of SAP was calculated by using Equation 2:

$$\text{Absorption Capacity under load} = \frac{m_4 - m_1 - m_2}{m_1} \quad (2)$$

## 2.6. Compressive Strength Test

Compressive strengths of 50 mm cube cement mortar samples prepared with and without SAP were determined at mortar ages of 7, 28 and 56 days according to ASTM C190. Five specimens for each group and age were tested for the compressive strength test.

## 2.7. Flowability Test of Cement Mortar

Mixing of SAP dry powder into the cement mortar without considering additional water in account of absorption capacity of SAP diminishes the flowability capacity of the cement mortar. Therefore, the flowability of cement mortar with and without SAP was determined by the flow table test following ASTM C1437. Dosage of SAP in case of mortar with SAP was considered only the optimum one from compressive strength test. Cement mortar was prepared with w/c ratio of 0.485.

## 2.8. Thermal Test of Cement Mortar

A small-scaled chamber was prepared with wooden pieces of 25 mm thickness having dimensions of  $2 \text{ m} \times 1 \text{ m} \times 1 \text{ m}$  ( $L \times H \times W$ ) as shown in Figure 2. Inside the box, there were two pairs of wooden brackets at the middle to hold the slab specimen upright, which divided the chamber into two compartments. One of the compartments accommodated heat source (Heat source side) while the other was represented as an interior of a room. GLS (GLS Incandescent Light) bulb were used as the source of heat to perform the entire test, as shown in Figure 2.

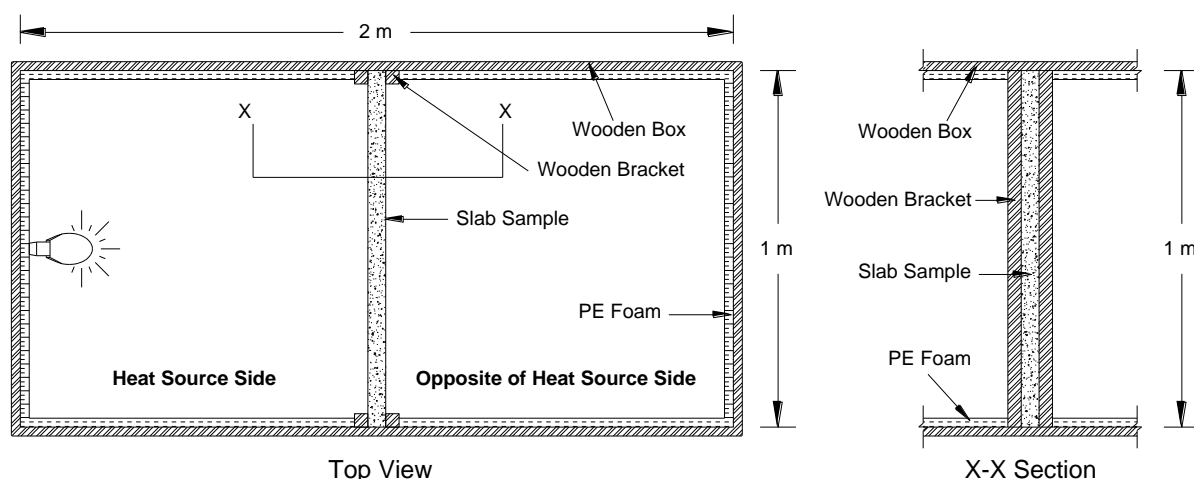


Figure 2. Small-scaled rectangular shape box

The inner portion of the wooden chamber was covered with PE foam to ensure no exchange of heat from inside of the box to outside and vice-versa. This also to ensure heat will pass from heat source compartment to next compartment only through the mortar slab sample. The temperature of the outer surface of the box was monitored, particularly at joints of the chamber to examine the insulation of the test box before each test and ensured that no heat loss will occur during the test from inside the box to the environment.



Temperature was maintained constant at  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}$  in the heat source compartment of the box by means of a temperature controller. Six temperature sensors were used to record the temperature at every 5 seconds, three of them were attached on the heat source face of the mortar slab and three sensors were attached on the opposite face of the slab as shown in Figure 3 and Figure 4. The temperature sensors can record  $-40$  to  $80^{\circ}\text{C}$  temperature readings with  $\pm 0.5^{\circ}\text{C}$  accuracy. The temperature controller was used in this study to control the temperature throughout the duration of the test, which continued for 250 minutes. The temperatures recorded with the temperature sensors were calibrated to  $25^{\circ}\text{C}$  just before starting of the test so that the time required to transfer the heat from heat source side to opposite side of the tested mortar slab can be determined.

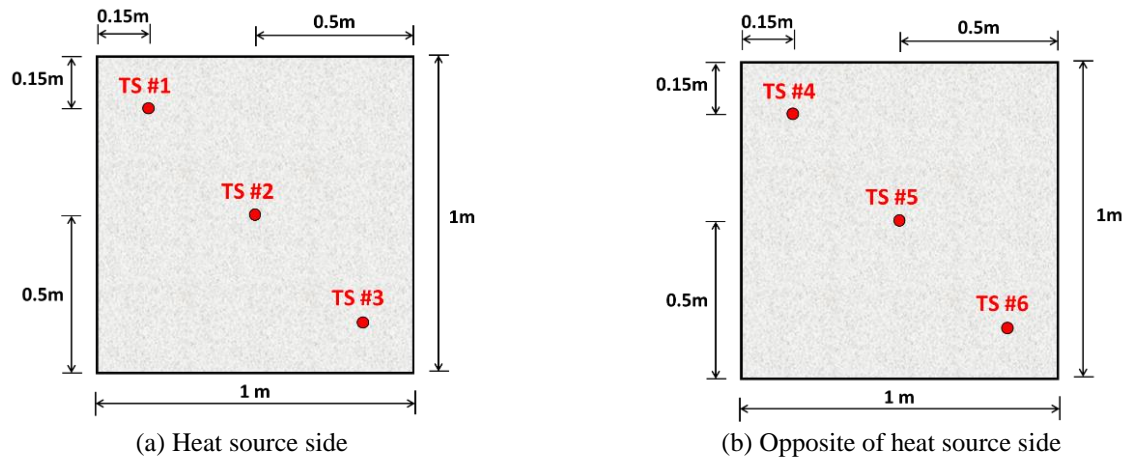


Figure 3. Position of sensors on the surface of the mortar slab specimen

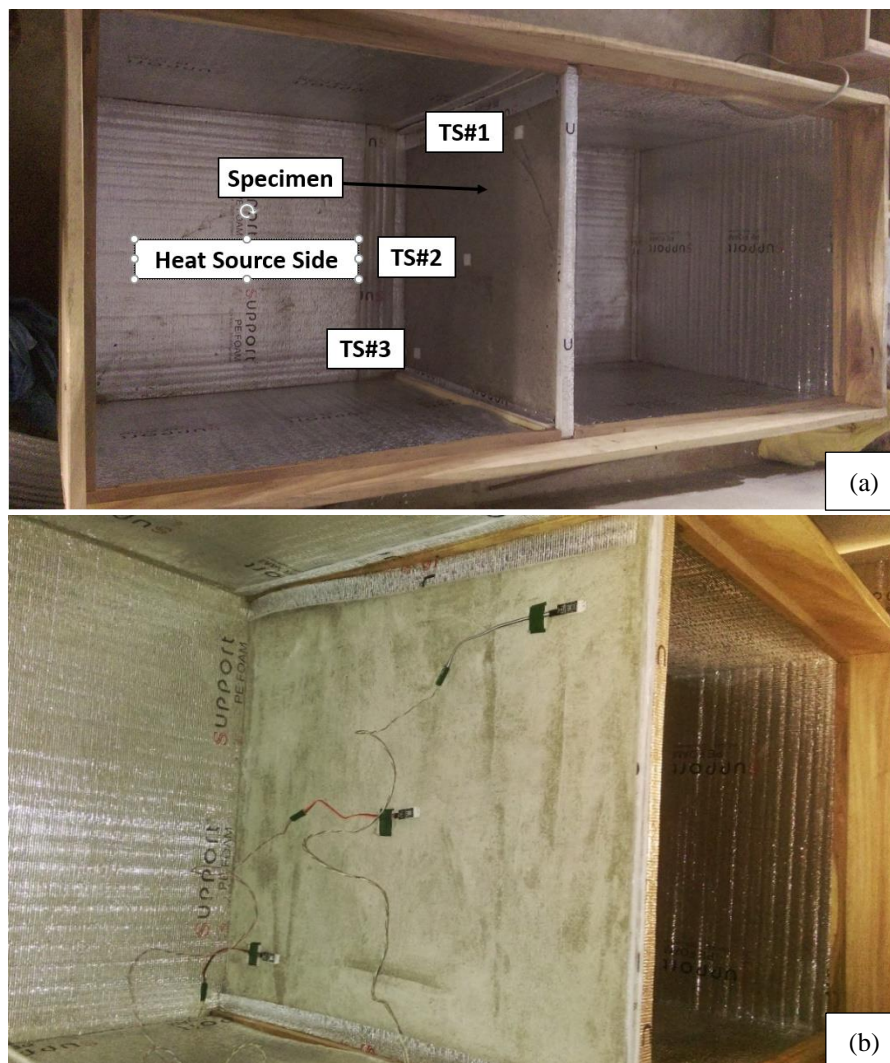


Figure 4. Photo of thermal test set-up a) Picture of wooden box; b) Location of temperature sensors

### 3. Results and Discussions

#### 3.1. Absorption Capacity of SAP

The absorptivity of SAP was measured in distilled water and tap water as well as strong alkaline solution in this paper, likewise found in the literature [26,27,51]. Therefore, the absorption capacity of SAP with and without any load was determined for tap water, NaCl solution, distilled water and cement solution. The result is shown in Figure 5 along with their chloride content.

The absorption capacity of SAP without any load is strongly impaired by the chloride concentration of the solution. In particular, the absorptivity measured in cement filtrate solution without any load was about one-fourth of that measured in distilled water due to the presence of high chloride concentration in the cement solution which reduced the osmotic pressure and consequently, the absorption capacity of SAP, which agrees strongly with the results found in the literature [52].

However, absorption capacity of SAP under load is less susceptible to the presence of chloride content in the solution. Absorption capacity of SAP under load varies from 10.7 to 13 gm/gm as shown in Figure 5. Absorption capacity of SAP with and without load in cement filtrate solution 10.7 and 13.2 gm/gm, respectively. This absorption capacity of SAP under load can be considered as the equilibrium state of SAP in cement mortar matrix and considered as the absorption capacity to be used for the preparation of all samples in this paper.

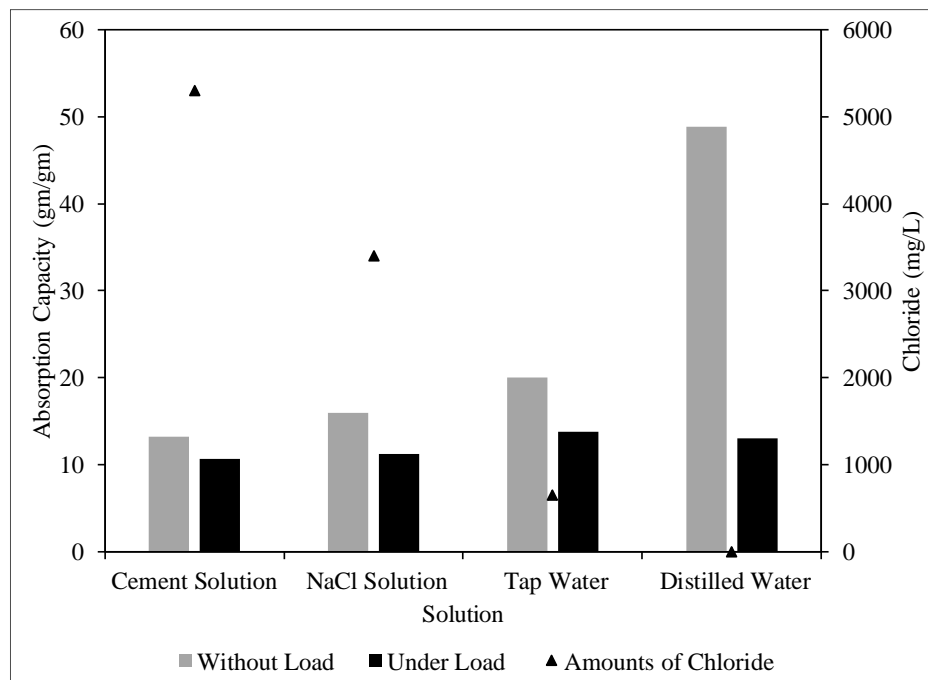


Figure 5. Absorption capacity of SAP in different solutions

#### 3.2. Compressive Strength

Degree of hydration of mortar is a function of the total w/c ratio of mortar [53,54]. Therefore, the water released from SAP had an influence to facilitate the hydration of cement in cement mortar samples. As a result, reduction in the compressive strength due to voids left by SAP may be counteracted due to the maximization of cement hydration by SAP internal curing.

In this paper, 50 mm cubic mortar samples were tested for compressive strength containing 0%, 0.05%, 0.3%, 0.5% and 1.0% of SAP at 7, 28 and 56 mortar ages. The test results are presented in Figure 6, from which it can be seen that after 7 days, the compressive strengths of all samples were close to each other, except S(1.0%). This is maybe due to the fact that all samples contain enough water content to facilitate the cement hydration until that point of time. Despite the fact, the water content became so large that water bleeding occurred for sample S(1.0%) with 1% SAP of cement mass and exhibited lower compressive strength compare to the other samples.

A decrease in compressive strength was recorded at an early age of time (< 28 days), while a gradual increase in the compressive strength of mortar incorporating SAP with the increase of age compare to reference mortar was observed from the test results. The differences in the compressive strengths between mortar with S(0.05%) and the reference mortars decreased over time; which shows that role of SAP as an internal curing agent gradually increases with time [55].

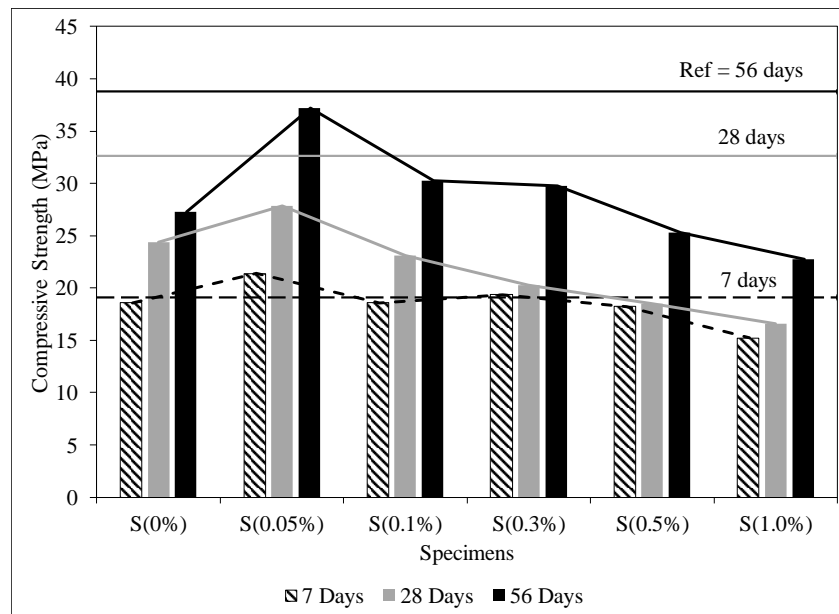


Figure 6. Compressive strength of cubic mortar samples at 7, 28 and 56 days

The compressive strengths of samples S(0.05%) under air curing condition nearly reached to the compressive strength of reference mortar under water curing condition at a later age ( $> 28$  days). After 56 days of curing, the compressive strength of samples having 0% SAP cured in water had the value of 38.78 MPa with an increase rate of about 19% compared to its 28 days strength. The compressive strength of air cured samples with 0% SAP was 27.26 MPa, whereas, the maximum compressive strength showed by the samples containing SAP was 37.18 MPa obtained from the samples with 0.05% SAP with an increase rate of about 33% compared to its 28 days strength. In terms of compressive strength, samples containing 0.05% SAP of cement mass showed the best result among the SAP incorporated samples with air curing and considered to be the optimum dose in this paper.

### 3.3. Setting Times of Cement

Influence of SAP on setting times of cement were determined to ensure that the presence of SAP in mortar will abide by the requirement set by ASTM C191. Therefore, initial and final setting time of cement containing 0 and 0.05% SAP were recorded (Table 2) and showed that the initial and final setting times of cement with 0.05% SAP of cement mass is 13 and 20 min, respectively, higher than that of cement without any SAP. Four mortar slab samples, two without SAP (Test #1 and Test #2) and two 0.05%SAP (Test #3 and Test #4) were tested to evaluate the thermal performance of the samples. Setting times of cement incorporating 0.05% SAP of cement mass also conform to the requirements of ASTM C191.

Table 2. Setting times of cement

Designation	SAP Proportions	Initial Setting Time (minutes)	Final Setting Time (minutes)
0%SAP-Test #1 and #2	Cement without SAP	145	260
0.05%SAP-Test #3 and #4	Cement with 0.05% SAP	158	280

### 3.4. Flowability of Mortar

Flow table test was done to determine the workability of mortar. This test was done for mortar containing 0% SAP and 0.05% SAP with w/c ratio of 0.485 and the result was recorded as 13 and 22%, respectively. Therefore, mortar modified with the optimum dosage of SAP considering strength would give better workability in terms of workability compare to mortar without any SAP.

### 3.5. Thermal Performance of Mortar

Thermal performance of cement mortar was carried out by measuring the capacity of heat transfer from heat source face to the opposite face of the mortar slab samples. At the beginning of the test, the temperature at both surfaces of the slab samples were 25°C. The variations of the temperature of the tested mortar slab specimen at different temperature sensor location were recorded over time and presented in Figure 7. It was observed that the maximum variation of temperatures at the two corner temperature sensors at both side (TS#1, TS#3, TS#4 and TS#6) with middle sensors (TS#2 and TS#5) for any particular time is 7%. Based on this outcome, it can be assumed that the temperature throughout the wall surface was uniform. Thus, temperatures recorded with sensors TS#2 and TS#5 were



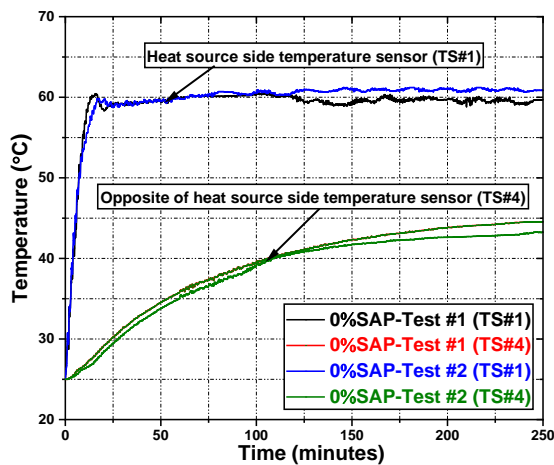
used for further analysis and shown in Figure 8. It was also observed that the time required to reach 60°C in heat source side was in between 10 and 17 minutes as illustrated in Table 3.

**Table 3. Time required to reach 60°C in the heat source side**

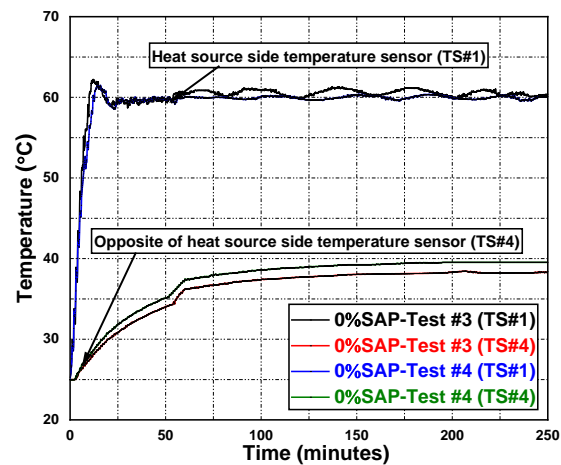
Mortar slab specimen	Time required to reach 60°C in heat source side (minutes)			Remarks
	TS#1	TS#2	TS#3	
0%SAP-Test #1	13.08	13.17	13.08	Approximately 13 minutes
0%SAP-Test #2	17.00	16.67	17.00	Approximately 17 minutes
0.05%SAP-Test #3	10.08	10.00	10.00	Approximately 10 minutes
0.05%SAP-Test #4	12.33	12.17	12.42	Approximately 12 minutes

Figure 7 and Figure 8 show that the recorded temperatures at the source face of the mortar slab were maintained at about 60 °C throughout the test duration, whereas the temperatures at the opposite face were in the range of 43.3~44.5 °C and 38.4~39.5 °C for the 0% SAP samples and samples incorporating 0.05% SAP of cement mass, respectively, at the end of the test. Therefore, samples containing the optimum dose of SAP (0.05% of cement mass) allowed on average 4.95°C less heat flow than that of samples without SAP. The reduction in thermal conductivity of mortar incorporating SAP can be attributed to the increase in total porosity due to desorption properties of SAP [56] and this result suggests that the plaster incorporating optimum dosage of SAP would act as a convenient and practical thermal barrier for buildings.

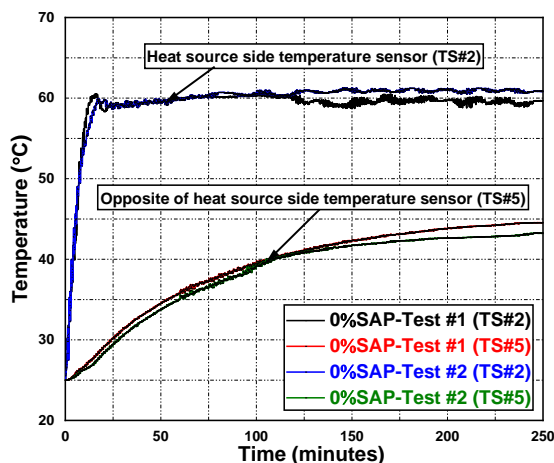
In this study, time required to reach the temperature from heat source side to the other side of the specimen was also evaluated and analyzed. The variation of temperature over time at the beginning of the test (up to 5 minutes) were presented in Figure 9 and Table 4. The time required to pass the temperature through slab thickness (conduction heat transfer) is approximately 1.5 minutes and 2.67 minutes for 0%SAP samples and 0.05% SAP samples, respectively. These findings also indicate that addition of SAP to the mortar slabs specimen reduces the rate of conduction heat transfer. Further studies can be done to observe the influence of partial replacement of SAP on the rate of conduction heat transfer of the specimen.



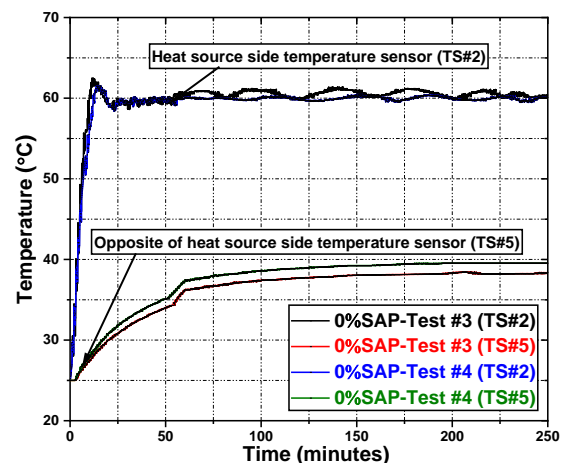
a) TS#1 and TS#4 of 0% SAP



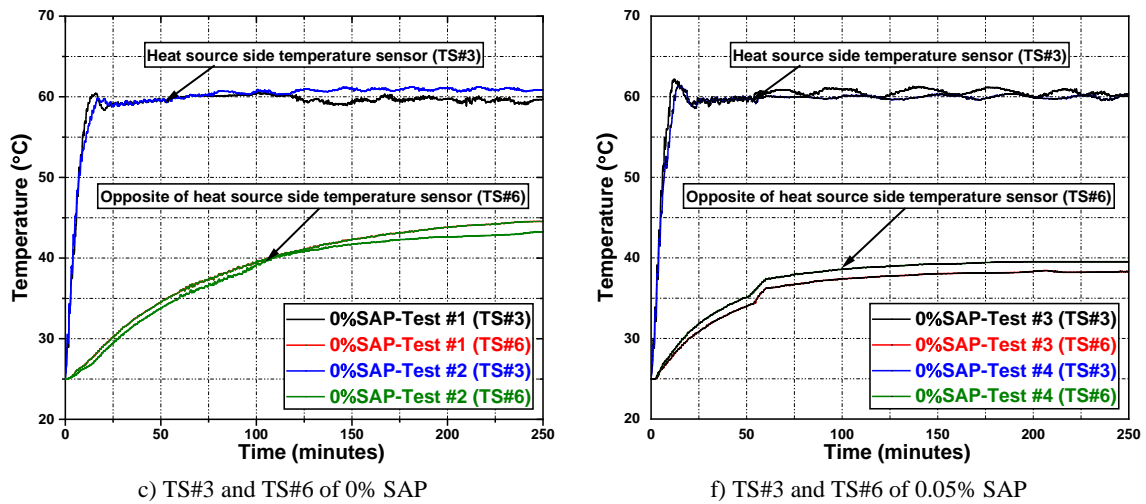
d) TS#1 and TS#4 of 0.05% SAP



b) TS#2 and TS#5 of 0% SAP



e) TS#2 and TS#5 of 0.05% SAP



c) TS#3 and TS#6 of 0% SAP

f) TS#3 and TS#6 of 0.05% SAP

Figure 7. Variation of temperature over time at different temperature sensor locations

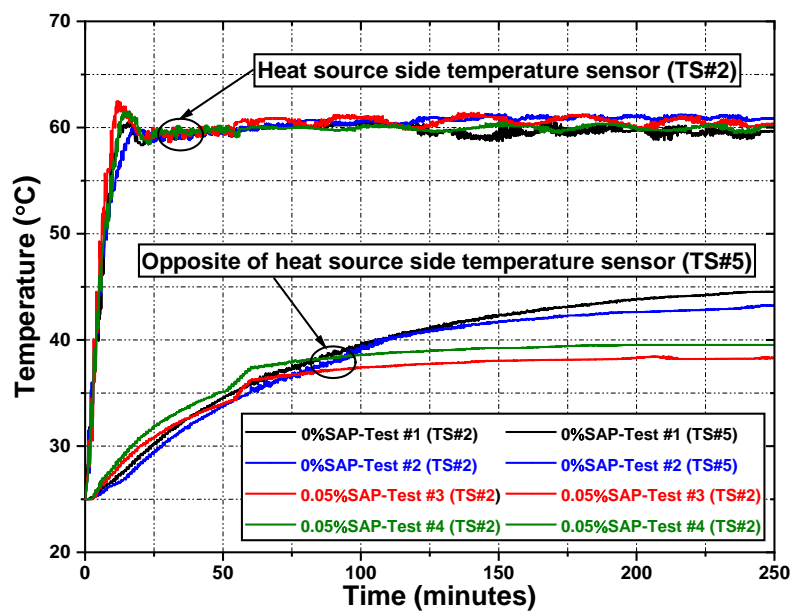


Figure 8. Temperature variations over time for all the tested 0% and 0.05% SAP samples

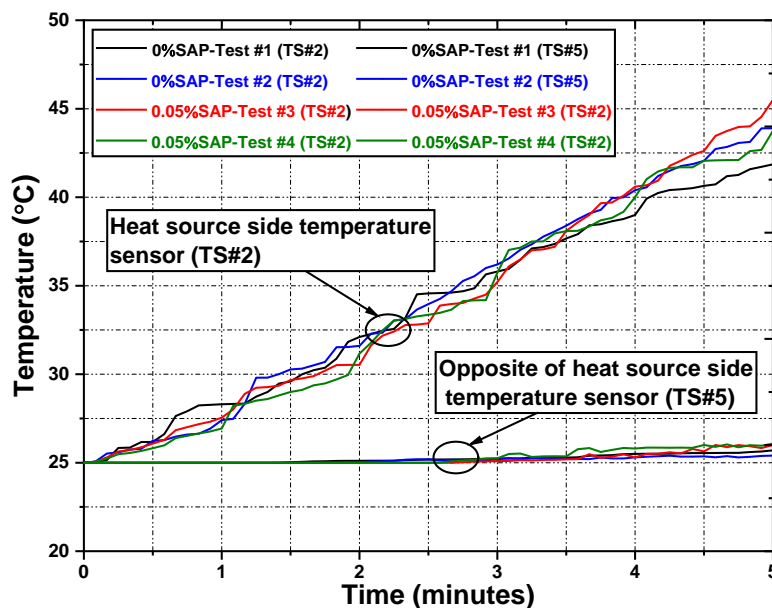


Figure 9. Temperature variations over time for all the tested 0% and 0.05% SAP samples up to 5 minutes

**Table 4. Temperature variation at the beginning of the test**

Time (minutes)	Temperature in °C							
	0%SAP-Test# 1		0%SAP-Test# 2		0.05%SAP-Test# 3		0.05%SAP-Test# 4	
	TS#2	TS#5	TS#2	TS#5	TS#2	TS#5	TS#2	TS#5
0	25	25	25	25	25	25	25	25
0.25	25.834	25	25.582	25	25.633	25	25.482	25
0.50	26.171	25	26.241	25	26.078	25	25.821	25
0.75	27.908	25	26.591	25	27.007	25	26.522	25
1.00	28.300	25	27.400	25	27.544	25	26.933	25
1.25	28.730	25	29.802	25	29.237	25	28.506	25
1.33	28.999	25	29.806	25	29.276	25	28.598	25
1.50	29.586	25.032	30.270	25	29.674	25	28.997	25
1.58	29.994	25.046	30.312	25	29.759	25	29.110	25
1.75	30.367	25.082	30.693	25.004	30.201	25	29.479	25
2.00	32.100	25.107	31.600	25.036	30.530	25	31.167	25
2.25	32.562	25.117	33.028	25.100	32.412	25	33.037	25
2.50	34.569	25.174	33.961	25.191	32.876	25	33.358	25
2.67	34.610	25.184	34.691	25.162	33.967	25	33.649	25.078
2.75	34.687	25.189	35.269	25.159	34.023	25.025	34.126	25.118
3.00	35.800	25.232	36.200	25.200	35.200	25.091	35.733	25.247

#### 4. Conclusions

This experimental work was conducted to observe the absorption capacity of SAP and the effect of SAP on the mechanical properties of cement mortar in comparison with conventionally cured mortar. It also aimed at observing the thermal properties of the mortar plaster with and without SAP.

The differences in compressive strengths between the reference mortar samples and samples with the optimum dose of SAP decreased as a function of the mortar age. At an early age, the mortar mixed with SAP did not have a significant effect on internal curing. The compressive strength of the samples with SAP after 7 days was almost close to conventionally water cured samples. Subsequently, the internal curing effect of SAP gradually began to work with time. Nevertheless, all of the samples containing SAP did not demonstrate good results compare to the reference sample at later age except sample with 0.05% SAP of cement mass. Among the samples with different percentage of SAP, samples containing 0.05% of SAP showed the best result in comparison with the reference samples in terms of compressive strength. The compressive strength of sample S(0.05%) was higher than the compressive strength of reference samples after 7 days and sample S(0.05%) showed compressive strength close to the compressive strength of reference samples after 56 days. Therefore, it can be concluded that SAP has a promising role as an internal curing agent and an alternative to the conventional curing method.

The initial and final setting times of cement paste containing SAP was higher than that of reference samples because of added extra water considering the absorption capacity of SAP. Similarly, the workability of mortar with SAP was also higher than that of samples without SAP. Though the addition of SAP reduced the mechanical properties of mortar, adoption of a correct dose of SAP would eliminate the requirement of water curing in the expense of a slight reduction in compressive strength of concrete. It was also found that thermal performances of mortar containing SAP were much better than that of 0% SAP sample and it was evident that addition of SAP reduces the conduction heat transfer. This indicated that mortar incorporated with SAP can be readily adapted to make buildings more thermally energy-efficient

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#### 6. Conflicts of Interest

The authors declare no conflict of interest.

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