Türk Mühendislik Araştırma ve Eğitimi Dergisi
Turkish Journal of Engineering Research and Education

2(1), 67-72, (2023)

RESEARCH ARTICLE

An Experimental Study on the Total and Capillary Water Absorption of Mortar Containing Phragmites Australis Ash

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Received / Geliş: 04.04.2023
Accepted / Kabul: 17.05.2023
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ABSTRACT: The use of biomass ashes as cement replacement have become a notable and trending aspect due to the huge increase in the pollution levels caused by the manufacturing process of cement. Phragmites Australis Ashes (PAA) can be an eco-friendly alternative to cement since it can be burnt in a closed container decreasing the CO2 emissions into atmosphere. Also, PAA is considered an economical material since it is available locally and grows massively on the banks of the rivers in Lebanon. The performance of mortar mixes produced by a partial replacement of cement were evaluated in this paper revealing a big potential for PAA to be used as cement replacement. Cement in mortar specimens was replaced by 0, 10, 20 and 30% by weight PAA. Mix proportions and water to binder ratio were set constant for all casted mixes. Durability properties, including total water absorption and capillary water absorption, containing different PAA percentages were evaluated at 1, 7, 28 and 90 days of curing ages in comparison to the control specimen. The test results show an increase in the total water absorption percentages as PAA percentage is enhanced in mixes. The same trend was also obtained for capillary water absorption test.

Keywords: Sustainability, bio-ash, Phragmites Australis ash, carbon footprint reduction, cement replacement

ÖZ: Biyokütle küllerinin çimento yerine kullanılması, çimento üretim sürecinin neden olduğu kirlilik seviyelerindeki büyük artış nedeniyle dikkate değer ve son yıllarda araştırmacılar tarafından önem verilen konular arasına girmiştir. Phragmites Australis Ashes (PAA), kapalı bir kapta yakılarak atmosfere salınan CO2 emisyonunu azalttığı için çimentoya çevre dostu bir alternatif olabilir. Ayrıca PAA, yerel olarak bulunduğundan ve Lübnan'daki nehirlerin kıyılarında yoğun bir şekilde büyüdüğünden ekonomik bir malzeme olarak kabul edilir. Kısmi çimento ikamesi ile üretilen harç karışımlarının performansı, PAA'nın çimento ikamesi olarak kullanılması için büyük bir potansiyel ortaya koyan bu yazıda değerlendirilmiştir. Harç numunelerindeki çimento, ağırlıkça %0, 10, 20 ve %30 PAA ile değiştirilmiştir. Karışım oranları ve su/çimento oranı tüm dökülen karışımlar için sabit tutulmuştur. Farklı PAA yüzdeleri içeren toplam su emme ve kılcal su emme dahil olmak üzere dayanıklılık özellikleri, kontrol numunesine kıyasla 1, 7, 28 ve 90 günlük kürleme yaşlarında değerlendirilmiştir. Test sonuçları, karışımlarda PAA yüzdesi arttıkça toplam su emme yüzdelerinde bir artış olduğunu göstermektedir. Aynı eğilim kılcal su emme testi için de elde edilmiştir.

Anahtar Kelimeler: Sürdürülebilirlik, biyo-kül, Phragmites Australis külü, karbon ayak izinin azaltılması, çimento ikamesi

1. INTRODUCTION

Concrete is considered as the most commonly used material in construction processes due to the fact that concrete have good strength and durability properties [1,2]. Typical concrete mixes consist of aggregates, cement and water [3]. Cement is one of the main constituents where it plays a significant role in binding all materials together [4].

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The production of ordinary Portland cement (OPC) is done by burning some naturally occurring raw materials and combining them together. These materials are known as clay and limestone [5]. The production of cement requires a very high temperature, around 1450 °C, where it consumes a lot of energy [5,6]. So, one of the main contributors for carbon dioxide emissions is the process of producing cement where it is responsible for around 8% of the globally CO_2 emissions and 7% of greenhouse emissions where around 30 to 40% results from burning fossil fuels and 60 to 70% results from decarbonation to get cement [7-9]. Each ton of cement manufactured and produced emits around 900 kg of CO_2 into the atmosphere [7,10].

The construction industry is being pressurized to find an alternative for cement after the global warming reached enormous levels, the increase in carbon footprint and the depletion of renewable resources where construction process requires around 60% of natural materials [7,11-13]. So, the trend aspect now is by moving towards utilizing and inventing green concrete to overcome the problems in the traditional construction projects after the sustainable development became one of the pioneering issues and the goal of most nations [14,15]. Green concrete conserves natural resources, reduces environmental pollution, lower CO_2 emissions and reduce waste disposal issues and may enhance some concrete properties [16,17].

So, bio-ash materials can be a good alternative instead of throwing them or burning them in open air and increasing pollution levels [18]. There are many bio-ash materials that can be used as fibers or as cement replacement in concrete/mortar mixes including shells, leaves, wood, etc [19-21]. Some examples are rice husk ash, wheat straw ash, saw dust ash, sugarcane baggase ash, etc [7,22]. These bio-ash materials, also known as agro-wastes, are considered to be ecofriendly materials and inexpensive [23-25].

Studies showed that a slight decrease is obtained when using sugarcane bagasse ash as cement replacement for capillary absorption test [26]. Also, absorption test was done on mixes containing Bermuda grass ash, results reveals a slight decrease in its values [27].

This paper will evaluate the total and capillary water absorption tests on mortar specimens after replacing cement with PAA by 0, 10, 20 and 30% at 1, 7 28 and 90 days of curing ages. Correlation between total and capillary water absorption at all curing ages were also examined.

2. EXPERIMENTAL

2.1 Materials

Portland cement Type I conforming EN 197-1 standards was used. The sand used in this mix was passing through 4.75 mm and retaining on 200 μm. After burning PAA and grinding it, it was sieved through 300 μm. Tap water was also used.

2.2 Chemical Composition

The main chemical contents that were found in cement and PAA are SiO_2, CaO and Al_2O_3. Table 1 illustrates the chemical composition percentages.

Table 1: Chemical composition (%).

Chemical Composition	Cement	PAA
SiO_2	18.1	76.15
CaO	61.55	6.15
Al_2O_3	4.29	0.84

2.3 Mix Proportions

Four different mortar mixes were casted with different percentages of PAA as cement replacement from 0% up to 30% in increment of 10. The binder: Sand ratio used was 1:3. The water to binder ratio for all mixes was 0.55. The details of quantities are shown in Table 2.

Table 2: Mix proportions.

	Quantities (kg/m³)			
Mix ID	**Cement**	**PAA**	**Sand**	**Water**
0% PAA	475.0	0.0	1425	262
10% PAA	427.5	47.5	1425	262
20% PAA	380.0	95.0	1425	262
30% PAA	332.5	142.5	1425	262

2.4 Testing

2.4.1 Compressive Strength

Mortar cubes with dimensions 50x50x50 mm were casted for compressive strength test. After the curing time passes, cubes were removed from water and test was applied. The following equation was used to calculate the compressive strength:

$$f'c = \frac{P}{A} \quad (1)$$

f'c: Compressive strength (MPa)

P: Load (N)
A: Area (mm^2)

2.4.2 *Total Water Absorption*

Mortar cubes of 100x100x50 mm size were casted, cured for a specific period, removed from water and dried at 80° C in the oven until reaching the mass of each specimen become constant. The test were then performed and the total water absorption (TWA) percetange were calculated according to the following formula:

$$TWA = \frac{M30-Md}{Md} \times 100 \qquad (2)$$

TWA: Total water absorption (%)
M30: Mass at time 30 min (kg)
Md: Mass for dry specimen (kg)

2.4.3 *Capillary Water Absorption*

Specimens of size 100x100x50 mm were used to test for capillary water absorption (CWA). Specimens were cured to specific period, placed also in oven at 80° C until reaching a constant mass and then removed and test was conducted. The specimens were placed in a shallow tray on 2 supports and then water was added gradually to 2 mm level above the mortar face as shown in Figure 1. CWA were then calculated based on the following formula:

$$CWA = \frac{Mt-Md}{A} \qquad (3)$$

CWA: Capillary water absorption (g/mm2)
Mt: Mass at time t (kg)
Md: Mass for dry specimen (kg)
A: Area of specimen (mm^2)

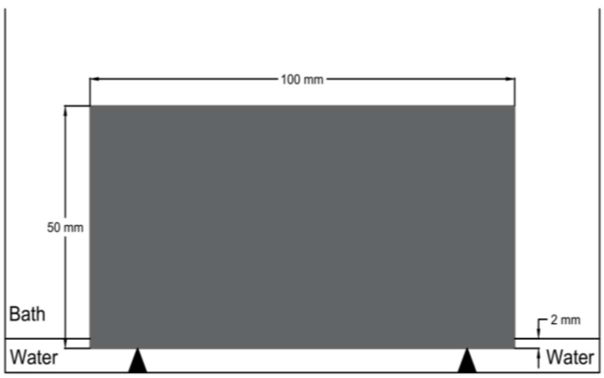

Figure 1: Capillary absorption test.

3. RESULTS AND DISCUSSION

3.1 *Compressive Strength*

The compressive strength results are displayed in Table 3. The compressive strength decreases as the percentage of PAA is enhanced in the mortar mix from 10% to 30%. For 10% PAA, the compressive strength results are approximately similar to that of control mix. However, as curing time increases, the compressive strength increases for all casted mixes.

Table 3: Compressive strength with different PAA replacements at different curing ages.

	Compressive Strength (MPa)			
Mix ID	**Day 1**	**Day 7**	**Day 28**	**Day 90**
0% PAA	3.939	9.776	14.309	17.560
10% PAA	3.652	10.610	15.634	18.300
20% PAA	3.132	8.128	12.100	13.988
30% PAA	2.789	7.320	11.111	12.316

3.2 *Total Water Absorption*

The total water absorption percentage at 30 min versus PAA percentage is shown in Figure 2 at 1, 7, 28 and 90 days of curing respectively. The results show that the control mix and mix with 10% PAA recorded approximately the same values at most curing ages. As PAA replacement percentage increases in the mix, TWA values increase. However, TWA percentage decreases for all mortar mixes as the curing period is enlarged. The TWA is inversely proportional to compressive strength; as the compressive strength increases, the TWA decreases.

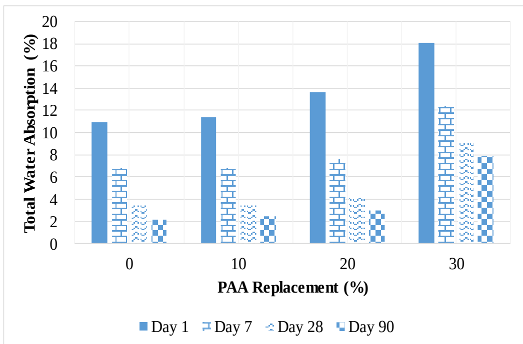

Figure 2: Total water absorption with different PAA replacements at different curing ages.

3.3 Capillary Water Absorption

Figure 3 shows the capillary water absorption results at 30 min versus PAA percentage for the different four mortar mixes at curing ages 1, 7, 28 and 90 days respectively. The water absorbed per unit area increases at all curing ages as the percentage of PAA replacement increases in the mix. Also, as curing time increases from day 1 to day 90, the water absorbed per unit area decreases for all mortar mixes tested. Regarding CWA, the trend is similar to that obtained for TWA. As the compressive strength increases, the CWA decreases.

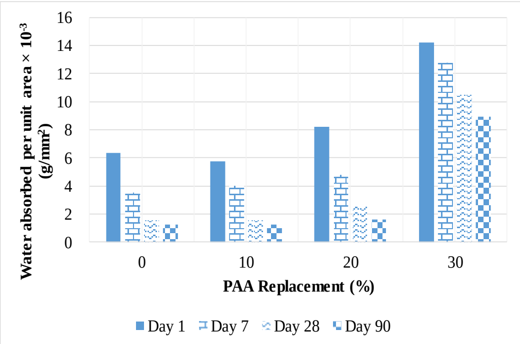

Figure 3: Capillary water absorption with different PAA replacements at different curing ages.

3.4 Correlation between Total Water Absorption and Capillary Water Absorption

Figure 4 plots the relationship between total water absorption and capillary water absorption for all mortar mixes containing 0% to 30% PAA as cement replacement at different curing ages 1, 7, 28 and 90 days. There is a linear relationship between both parameters with high correlation coefficient (>0.97).

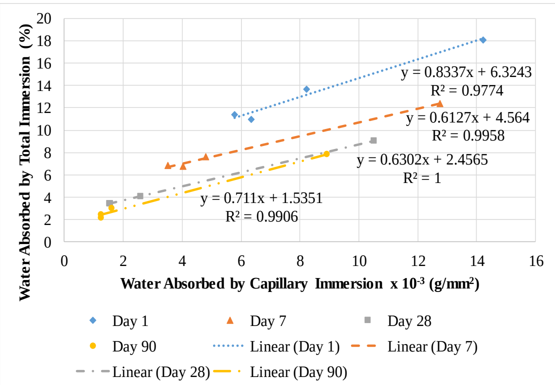

Figure 4: Correlation between Total and capillary water absorption at different curing ages.

4. CONCLUSIONS

Based on the results of the experimental tests done, it was concluded that:

There is a high potential for Phragmites Australis ashes (PAA) to be used as partial cement replacement.

For 10% PAA, the compressive strength is approximately similar to the control.

Beyond 10% replacement, he compressive strength decreases with the increase in PAA percentage in the mortar mix.

The absorption by total immersion and capillary action for the control mix and the mix with 10% PAA is approximately the same.

Beyond 10% PAA replacement, there is an increase in the absorption values for both total and capillary absorption as PAA percentage increases in the mix. As the compressive strength increases, the water absorption by total immersion and capillary action decreases.

There is a good linear relationship between total and capillary water absorption with high correlation coefficient above 0.97.

Author Contributions: Lelian W. ElKhatib and Jamal Khatib contributed to the literature review, experimental studies and the realization of the study while Adel Elkordi and Seyhan Firat contributed to the content determination and proof reading.

Acknowledgement: Special thanks for technical staff in the Faculty of Engineering Beirut Arab University.

Conflicts of Interest: As the authors of this study, we confirm that there is no conflict of interest with any institution/organization or person.

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