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THE EFFECT OF SAWDUST AS SELF-CURING AGENT IN CONCRETE

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Graphical abstract

Abstract

Concrete is known as the most used material for the construction industry. It is crucial to understand the properties of concrete especially on curing interaction and process. At the water shortage areas, the production of concrete is limited as approximately 230 liters of water is needed for 1 m^3 of concrete. The insufficient of water resources has inhibited the building construction and development. Nowadays, researchers have studied and developed curing technology by implementing curing agents into concrete mixes. In this paper, the potential and properties of pre-wetted sawdust as curing agent is investigated and studied. Different curing regimes are implemented and tested to determine the properties of sawdust as curing agent. The results showed that the sawdust has potential to be used for curing agent as the concrete properties have been enhanced with strength index ratios ranging between 0.87 until 0.98. Moreover, the compressive strength and tensile properties were also developed with range ratios between 0.69 up until 0.98, respectively. Hence, the application of pre-wetted sawdust inside concrete is effective for concrete production and highly recommended to be implemented at the water shortage areas.

Keywords: Curing agent, water retention capacity, sawdust, internal curing, curing regimes

Abstrak

Konkrit dikenali sebagai bahan yang paling kerap digunakan dalam industri pembinaan. Adalah penting untuk memahami sifat konkrit terutamanya berkaitan proses pengawetan dan interaksinya. Di kawasan yang mengalami masalah kekangan air, pengeluaran konkrit adalah terbatas kerana kira-kira 230-liter air diperlukan untuk 1 m^3 konkrit. Sumber air yang terhad telah membantutkan pembangunan bangunan di kawasan tersebut. Dewasakini, penyelidik telah mengkaji dan membangunkan teknologi pengawetan dengan memasukkan agen pengawet ke dalam campuran konkrit. Dalam kertas kajian ini, potensi dan sifat habuk kayu pra-basah sebagai agen pengawet dikaji dan disiasat. Rejim awetan berbeza dilaksanakan dan diuji untuk menentukan sifat habuk kayu sebagai bahan pengawet dalam kapasiti penahanan air. Hasil kajian mendapati habuk kayu berpotensi untuk digunakan sebagai agen pengawet dan sifat konkrit telah dipertingkat dengan nisbah indeks kekuatan antara 0.87 sehungga 0.98. Selain itu, kekuatan mampatan dan tegangan juga meningkat dengan nisbah julat antara 0.69 hingga 0.98. Oleh itu, penggunaan habuk kayu pra-basah dalam konkrit adalah berkesan untuk penghasilan konkrit dan amat disyorkan untuk dilaksanakan di kawasan yang mengalami masalah kekurangan sumber air.

Kata kunci: Agen pengawet, kadar penahanan air, habuk kayu, awetan dalaman, rejim awetan

1.0 INTRODUCTION

Nowadays, concrete is one of the important construction materials that being used in the construction industry. The construction of infrastructures and buildings used to grow businesses that give people some job opportunities. Currently, the utilization of concrete especially to develop buildings and utilities has been roses due to the development of concrete technology [1, 2, 3, 4 and 5].

Concrete can be designed into any desired shape and supported in numerous ways. The fact that the components can be obtained almost anywhere makes it incredibly simple to construct. Due to its affordable price, extensive applications, and applicability, concrete has become one of the most popular construction materials in the world [6, 7 and 8]. Moreover, the characteristic of concrete which is good in compression significantly improves the functionality of the building, especially for load-carrying members. To achieve its target design strength, curing is one of the crucial steps for the concrete hydration process [9, 10 and 11].

Curing plays an important role in the development of strength and durability. Curing occurs immediately after the placement and finishing of concrete, entails maintaining the proper level of moisture. The curing process of concrete will significantly influence the strength and reduce the concrete permeability [12, 13 and 14]. Currently, the traditional curing methods such as water spray and Burlap cloth were used for the curing process in construction industry. It is a process of concrete curing by supplying water from outside onto surface of concrete for hydration process. The traditional curing method required huge amount of water for concrete production where approximately up to 230 litres of water are required for 1m^3 of concrete [15]. This high usage of water has limited the concrete production especially at the areas of shortage water supply. Hence, researchers were conducted several studies and ideas in order to solve this shortage of water supply problems. One of them is providing curing agents into concrete that served as internal reservoirs for internal curing process [16].

Initially, the concept of the internal curing is to increase the water retention capacity of the concrete for hydration process [16 and 17]. Self-curing mechanisms are also utilized in the low water cement ratio in high strength concrete (HSC) to improve the behavior of concrete [17]. Moreover, traditional curing is prone to crack and shrink due to the rapid evaporation of water from its surface, which can cause the concrete to dry out too quickly. This can lead to the formation of cracks, which can reduce the strength and durability of the concrete over time. Unfortunately, this situation is prevented in self-curing concrete where the internal curing helps to reduce the rate of evaporation and keep the concrete in moist conditions during hardening process. This internal curing process aid to reduce the risk of cracking and shrinkage and effectively improve the overall performance of the concrete.

There are many potential materials with different portions were used for curing agents such as Super Absorbent Polymer (SAP), Light Weight Expanded Clay Aggregates (LECA), sawdust, fly ash, palm oil clinker, Polyethylene-glycol (PEG), paraffin wax and ceramic aggregates. It has been noticed that the application of these curing materials has significantly increased the performance of concrete both early and late properties. The tensile as well as compressive properties of self-curing concrete has enhanced about 30% compared to control for both early and late strength of concrete properties. This is due to self-desiccation along with humidity of self-cured concrete (SCC) relatively been maintained with the help of curing agents, preventing the concrete shrinkage during hydration process [17 and 18].

This research is a part of a multistage research project focusing on the development of self-curing concrete for reinforced concrete buildings. This paper investigates the effectiveness of pre-wetted sawdust in providing internal curing for development of concrete strength under different curing regimes including air dry and outside curing conditions, respectively. The application of pre-wetted sawdust as curing agent is to evaluate the excessive sawdust product produced by wood factory nearby Kota Kinabalu, Sabah. Moreover, the capabilities of sawdust in water retention has high potential to be used as curing agents for concrete productions.

Figure 1 Sawdust materials been used in this study

2.0 METHODOLOGY

2.1 Concrete Mix Design

To determine the effectiveness of sawdust as curing agent, a trial mix design and test was conducted. This test is performed to determine the optimal ratio of pre-wetted sawdust. The sawdust was obtained from nearby wood factory at Kota Kinabalu, Sabah. The sawdust is cleaned and sieved passed through the sieve size 0.15mm before it is used in this study. From the trial test, the optimal ratio of sawdust was obtained for 0.5% from the cement weight which possessing the highest compressive strength. This is in line with the previous studies findings where the self-curing concrete has the ability to mitigate the water loss rate as well as to enhance the capacity of concrete. Moreover, the capabilities of water absorption by curing agents are about double than dry condition weight and been confirmed with previous research [12, 13 and 17]. The trial mix is crucial to identify the potential issues on mix proportions for optimization the final mix design. The nominal aggregate size of 20mm is used with 0.5 water-cement ratio. The concrete is designed for slump height ranged from 60mm up to 180mm. For the water supply, tap water is used as the main water source for concrete production. This is to ensure that the concrete production is out from impurities that will affect the strength and durability of concrete. The concrete mix design is indicated as in Table 1.

Table 1 Concrete mix design

Material	Amount (kg/m³)	
	Sawdust Concrete (CSAW)	Control Concrete (CCON)
Cement	435	435
Water	225	225
Fine Aggregate	540	540
Coarse aggregate	1200	1200
Sawdust (0.5%)	2.175	-

From previous study, it was confirmed that the provision of 0.5% of pre-wetted sawdust curing agents have significantly enhanced the concrete properties where the optimal internal curing is obtained [12 and 13].

2.2 Curing Regimes

In order to determine the effectiveness of sawdust as curing agent, different curing regimes were applied to the concrete curing process. In this research, there are two types of curing regimes that being applied to the concrete curing process which are:

a) Air dry curing condition (inside building)
b) Outside curing condition (outside building)

These curing regimes were selected in order to determine the capabilities of sawdust to reduce the water evaporation from and within the set concrete and allowing it to cure without external curing via different exposures and conditions since the application of concrete might have been applied inside and outside of the buildings. It is also believed that the added pre-wetted sawdust as curing agent could aid in moist retention which can reduce and prevent the shrinkage of the concrete [6 and 7].

2.3 Concrete Testing

Concrete test is one of the methods to evaluate the quality and strength of the fresh and hardened concrete. In this study, the concrete was tested in fresh and hardened properties up until 48th days of concrete age. Normally, concrete is tested within 7 to 28 days with respect to the concrete development days. The reason for the concrete is tested up until 48th days is to ensure that it has reached its desired strength and properties beyond its developed ages up until 28th days. Moreover, it also can help to identify on any issues with concrete mix or curing process regimes that may affected its strength and properties.

2.3.1 *Slump Test*

Slump test is performed to find the fresh as well as consistency properties of the concrete. The test is conducted in accordance with BS EN 12350-2 (2019). This test was selected due to the nominal aggregates size being used in this study is within the limit where the test is not suitable for aggregate sizes beyond 40mm.

2.3.2 *Compressive Test*

The compressive test is carried out for cube specimens with 100mm x 100mm x 100mm in dimensions, to investigate the compression strength of the hardened concrete. In accordance with BS EN 19390 (2003), the cube specimens were filled and compacted in three layers. Then, it was left hardened for 24 hours before it was placed on different curing regimes as mentioned previously in 2.2. Figure 2 shows the cube specimen tested inside compression test machine.

Figure 2 Cube specimen inside compression test machine

2.3.3 *Tensile Splitting Test*

Tensile splitting test is a test to determine the tensile properties of the hardened concrete. The tensile specimen is prepared in cylindrical shape with 100mm in diameter and 300mm in height. Similar to cube specimens, these specimens also left cured in different curing regimes before it was tested at 7th and 28th days of concrete age, respectively. The test is conducted in accordance with BS EN 12390-6 (2003). Figure 3 depicts the cylindrical specimen tested in tensile splitting test machine.

Figure 3 Cylindrical specimen tested in tensile splitting test machine

3.0 RESULTS AND DISCUSSION

3.1 Fresh Properties of Concrete

For fresh properties, a slump test is conducted to determine the workability for both CSAW and CCON. Table 2 shows the slump height for both CSAW and CCON.

Table 2 Slump height for CSAW and CCON

Types of concrete	Slump Height, mm
CSAW	125
CCON	104

From the table, it is indicated that the slump height recorded by CSAW was higher compared to CCON with about 20% differences between both specimens. This situation happened due to extraneous moisture supplied and retained by pre-wetted sawdust during concrete casting. The extra moisture has contributed to the increment in slump values, and this showed the concrete is more workable compared to CCON. The sustained water allows the concrete to remain more fluid and workable than CCON, proved that CSAW is easy to handle during placement and compaction in construction sites.

3.2 Hardened Properties of Concrete

3.2.1 *Compression Test*

There are two types of tests conducted in order to determine the hardened properties of concrete which are: a) compressive test and b) tensile splitting test. The concrete specimens were tested during early age up until it reached 48th days of concrete age. In order for the concrete specimens to achieve the target strength, the pre-wetted sawdust is ensured to be mixed well during the concrete casting. The procedure is by mixing the curing agent with water before pouring it into the concrete mixture. The well-blend concrete mixed with sawdust will provide uniform distributed internal curing inside the self-curing concrete. This process is crucial to ensure the development of concrete strength as well as concrete durability via internal curing. The tests were conducted for 3 specimens and an average value is obtained and summarized as indicated in Table 3.

Table 3 Summary of concrete compressive strength

Types of Concrete	Curing regime	Age (Days)	Compressive Strength (MPa)
CSAW	Air dry	7	17.9
		14	19.1
		28	25.1
		48	25.2
	Outside	7	16.2
		14	17.9
		28	23.1
		48	24.2
CCON	Water	7	18.3
		14	19.5
		28	26.0
		48	26.2

From Table 3, it is indicated that both curing regimes of air dry and outside has slight decreased in terms of compression strength for 7th, 14th, 28th and 48th days of concrete age compared to water curing conditions. This showed that the water cure regime has developed curing process more effective compared to the internal curing effects provided by sawdust. During the early age of 7th days, the CSAW from outside stated the lowest compressive strength with about 10% and 14% lower compared to CSAW from air dry and water curing regimes, respectively. Figures 4 until 6 showed the compressive strength developed for tested specimens.

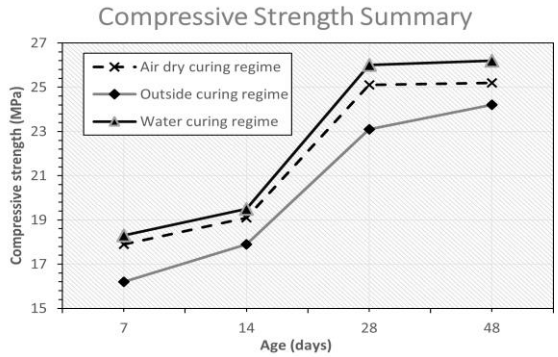

Figure 4 Summary of compressive strength of CSAW and CCON specimens, respectively

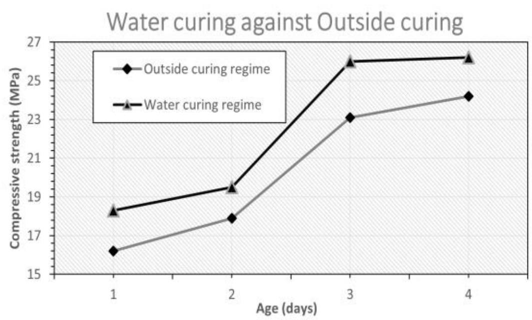

Figure 5 Water curing against outside curing of tested specimens

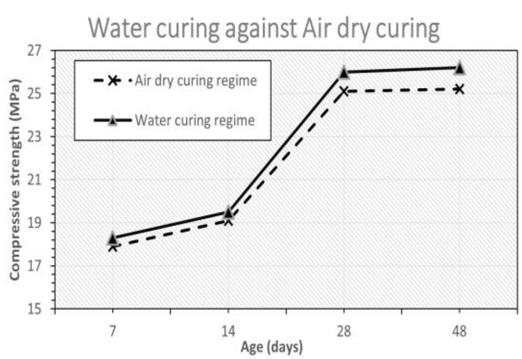

Figure 6 Water curing against air dry curing of tested specimens

From Figure 5, it is indicated that the compressive strength of outside curing has reduced compared to water curing regime of concrete aged at days 7th, 14th, 28th as well as 48th. On the 28th day, the compressive strength of CSAW possessed 23.1 MPa which was about 10% reduced compared to CCON. This situation happened due to internal moisture evaporating when the specimens were placed outside. Unfortunately, the internal reservoirs by sawdust have reduced the evaporating impacts in terms of compressive strength. These results were in good agreement with previous studies where the reduced compressive strength was about 15% less compared to the compressive strength of water curing specimens [19, 20 and 21]. The capability of sawdust enables curing from the inside out by hydrating the concrete internally without the need from outsource water. Even exposed to outside curing regime, the ability of sawdust as curing agent also in good agreement as per previous research where the strength index ratio varies from 0.87 until 0.91. This indicated that the CSAW specimen has significantly reduced the water from evaporated out by increasing the water store capacity when compared to conventional concrete [17]. Table 4 shows the compressive strength index of the tested specimens compared with water curing specimens of respected tested days.

Table 4 Strength Index ratio of specimens

Types of Concrete	Curing regime	Age (Days)	Compressive Strength (MPa)	Strength Index Ratio
	Air-dry	7	17.9	0.98
		14	19.1	0.98
		28	25.1	0.97
CSAW		48	25.2	0.96
	Outside	7	16.2	0.88
		14	17.9	0.91
		28	23.1	0.87
		48	24.2	0.90

From Table 4, it is clearly shown that the strength index of CSAW ranged between 0.87 until 0.98 for both air-dry curing as well as outside curing regimes, respectively. The internal curing of outside curing regime has reduced about 13% at the 28th days compared to CCON. Although the developed strength less compared to CCON, the percentage is still within 15%. This indicates that sawdust has huge potential to be used as curing agents especially in areas where the water supply is limited. Figure 7 depicts the strength index ratios of tested specimens.

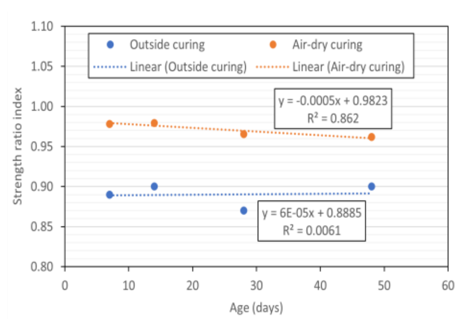

Figure 7 Strength index ratios of tested specimens

3.2.2 *Tensile Splitting Test*

Table 5 depicts the tensile splitting results of the tested specimens. The table indicates the splitting test results for water curing, air dry curing and outside curing for concrete age of 7th days and 28th days.

Table 5 Tensile splitting test

Types of Concrete	Curing	Age (Days)	Tensile Strength (MPa)	Strength ratio (%)
				7/28 days
CSAW	Outside	7 28	1.93 2.70	71.48
	Air dry	7 28	1.79 2.58	69.37
CCON	Water	7 28	2.10 2.90	72.41

From the table, the tensile splitting exhibited by CSAW from outside curing is the lowest for both 7th day and 28th day of tested specimens with about 69% of developed strength ratio. This situation is due to the incomplete hydration process that occurred inside CSAW specimen that been placed at outside curing regime. Meanwhile, the CCON indicated the highest strength ratio developed for 7/28 days with about 73% followed by CSAW of air-dry curing.

The air-dry curing of CSAW exhibited quite well as the indoor conditions have ambient conditions compared to outside curing where the specimens exposed to hot and windy conditions, promoting the moisture inside specimens to be escaped out from the concrete [20]. The moisture retention capacity of CSAW placed at outside curing regime shall be improved as the extreme weather conditions has contributed to undeveloped compressive strength of CSAW specimens.

4.0 CONCLUSION

From the analysis conducted, the following conclusions can be drawn:

The provision of sawdust as curing agent has effectively sustained and holds the moisture from evaporating out from concrete. The curing agent has provided the internal curing for concrete for both air-dry curing as well as outside curing regimes, respectively.

The CSAW of outside curing has possessed the lowest compressive strength followed with air-dry curing and water curing with about 5% and 10%differences, respectively. This is due to the hot and windy weather influencing the outside curing conditions where the internal moisture has been escaping out from the specimens and affecting less compressive strength of the specimens.

The influenced hot and windy weather conditions have contributed to the undeveloped strength for the CSAW at both 28th as well as 48th days of concrete age. The specimens experienced incomplete hydration process where the internal curing provided by sawdust is not sufficient for the specimens. Hence, the composition of the sawdust mixed with the concrete mix shall be reviewed and increased in order to improve the water retention capacity as well as concrete hydration process.

The strength index ratios of CSAW for both air-dry and outside curing regimes ranged between 0.87 up to 0.98 compared to water curing with respect to concrete aged days. This indicated that the highest differences between CCON and CSAW are 13% in terms of compressive strength, which is within the 15%limit that been proved by previous studies [19, 20 and 21]. From the results, it is indicated that sawdust has a potential to be widely used as curing agents for construction industry.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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