The Effect of Water Absorption on the Compressive Strength of Conventional Cement-sand Brick

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ABSTRACT: This research was conducted on the conventional cement-sand bricks from the market. Heavy rainfall during rainy seasons dampens building brick walls resulting having bubbling paint, crumbling plaster, powdery deposits and crack fissures on wall surfaces. The water absorption was conducted for 24 hours, 7, 14 and 28 days shows water was absorbed by conventional cement-sand bricks are 5.94%, 6.09%, 6.12% and 6.23%, results revealed conventional cement-sand bricks are porous. The compressive strength was conducted on the dry and wet conditions of conventional cement-sand bricks for 24 hours, 7, 14 and 28 days showed the compressive strength of dry conditions are 11.28 N/mm^2, 10.28 N/mm^2, 10.27 N/mm^2 and 10.27 N/mm^2 and wet conditions are 11.02 N/mm^2, 7.81 N/mm^2, 7.80 N/mm^2 and 7.80 N/mm^2. As stated by the BS 5628 1:2005, 11.28 N/mm^2 classified as M12(i), designation 50, with the strength of 11.6 N/mm^2 for 24 hours and 10.28 N/mm^2 classified as M12 (i), designation 40, with the strength of 10.0 N/mm^2 for 7, 14 and 28 days.

KEYWORDS: Rainwater, Wall surfaces, Water absorption, Compressive strength, Conventional cement-sand brick
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Original Article

INTRODUCTION

Malaysia is a tropical rainforest climate with a lot of rainfall and high temperature. The conditions are influenced by the winds blowing from the Indian Ocean of Southwest Monsoon that is from May to September, the South China Sea of North-Eastern Monsoon is from November to March. Rains and humidity are common features, at night it is fairly cool. Throughout the year, an average temperature can be in the ranges of 28° C (82° F) to 32° C (89° F) during daylight. West Malaysia receives an average of 2500 mm (98 inches) and East Malaysia thrives in 5080 mm (200 inches) of rainfall. Typically, the rainfall is 80% a year and the main rainy seasons are between November and February, the East and West Coast are the wettest in August and East Malaysia has heavy rain from November to February for climate 2010 to 2021 weather forecast referred to (Malaysian Meteorological Department/Ministry of Environment and Water, 2021).

Due to the rainy seasons, dampness developed on exposed building walls, even though they were coated with the cement mortar that dried out satisfactorily. The porosity of conventional cement-sand bricks (CCSB) affects building brick walls by keeping them wets from their long exposure to the rains. Although it was coated with a cement-mortar and painted, dampness on bricks walls developed on the exposed building walls that dried out satisfactorily and this resulted in having severe bubbling paint, crumbling plaster, powdery deposit close to the floor and crack on the wall surface because the effectiveness of porosity and permeability of bricks, has absorbed rainwater from the external wall passed thru the internal wall surfaces.

There are many building materials used in civil engineering construction one of them CCSB that are usually used for the walls. The CCSB fabrication is unfired, which helps to avoid the incurred cost and reduces the amount of smoke and haze that can contaminate the air. CCSB for the walls is an important part of the buildings. Failures of CCSB for the walls led to properties and/or life losses. Even though the building walls are not collapsed the aesthetic values can be lost due to cracks and/or other defects. The mortar plastering used does not only provide aesthetics to building walls but also serves as a control to the heat and winds, water and moistures infiltration.

The concern of building walls failures has requested the materials used for the CCSB to meet the specification requirement according to (BS EN 998-2:2010), the ranges are between 1 MPa to 20 MPa and as stated by (BS 5628-1:2005) ranges between 2.2 N/mm² to 23.9 N/mm² for the non-load bearing and load-bearing wall. Odeyemi *et al.*, (2015) stated utility values of products in comparison to their cost and its adaptability is to climatic factors that are responsible for its wide's applications. Moreover, housing is the necessity of the people for shelters and the materials that are used for the building differently around the world according to (Ajagbe *et al.*, 2013).

According to (BS 882:1992; MS 2282-3:2010) common size of CCSB is 215 mm X 100 mm X 64 mm. The component consists of cement, river sand, quarry stone chipping and/or quarry dust. Cement is material used to bond river sand and aggregates in CCSB stated by (BS EN 771-3:2011; Jayawardane *et al.*, 2012), principal cement compound is lime referred to (BS EN 197-1:2011) and generally, the type of cement used for this fabrication is ordinary Portland cement (OPC) according to (Anosike & Oyebade, 2012). CCSB fabrication used OPC complies with all the prescribed requirements referred to (BS 3148:1980; BS 410 1:1000; BS 476 22:1987; BS 882:1992; BS 5628-1:2005; BS 5628-3:2001; BS 4551-1-1998; BS EN 197-1:2011; BS EN 12390:2000; BS EN 771-1:2011; BS EN 771-2:2011; BS EN 771-3:2011; BS EN 998-2:2010; BS EN 1015-11:1999; BS EN 1015-18:2002).

CCSB is common because it eases affordability in building walls constructions (Shaik & Supit, 2015) and (Oyekan & Kamiyo, 2011) stated these products are lightweight, thermal and sound insulation. Hence, it is easily permitted ease of the nails and driving in of screw into it and it is possessing an intrinsic a low compressive strength according to (Opeyemi *et al.*, 2013). Therefore, it cannot resist too much tension. According to (Aguwa, 2010; National Research Council 1977) the compressive strength is the key criterion for the structural members to resist the compressive strength quality evaluation, it cannot resist too many loads as it tends to fail easily. As stated by (Aiyewalehimi & Tanimola, 2013) the strength of this product is dependent on factors such as mixed proportions and methods of curing.

When water is added to cement hydration occurs and releases large amounts of heat and formed a gel that binds aggregate particles together these provides water tightness and strength referred to (BS EN 197-1:2011). River sand was used referred to the (BS 882:1992) for mortar and/or concrete that work as voids filler between materials filled each other after they were sieved referred to (BS 410 1:1000) for the specific sizes, these materials are coated and bound together by cement paste in CCSB product. Aggregates as a mineral filler used either natural and/or manufactured that is occupied about 75% of volume in cement mortar and/or concrete referred to (BS 882:1992; BS EN 771-1:2011). Generally, these materials such as sand, gravel, crushed rock and other minerals are used as fillers, and it is the major component in the cement mortar and/or concrete referred to (BS EN 771-1:2011; BS EN 771-3:2011; BS EN 998-2:2010) and also to CCSB fabrication.

The objective of the research was conducted due to a problem of building brick walls that absorbed rainwater when it is exposed too long and this is related to the porosity of CCSB. The test conducted will be on the water absorption (WA) and the compressive strength (CS) of CCSB. The WA and CS were tested and compared with provisions of the British Standard (BS). The conditions of building walls as shown in Figure 1(a), dry CCSB and wet CCSB as shown in Figure 1(b) and

Figure 1(c). CCSB used in this research was obtained from Rancangan Sungai Manila at Mile 12 construction site in Sandakan, Sabah. were selected from the stack as shown in Figure1(d).

Figure 1(a). Condition of Wall Surfaces

Figure 1(b). Dry CCSB

Figure 1(c). Wet CCSB

Figure 1(d). CCSB on Site

RESEARCH METHODOLOGY

There are 24 numbers of CCSB, it was made of cement, river sand, quarry stone chipping, quarry dust and water.

Preparation of Conventional Cement-Sand Brick (CCSB) and Test Conducted

In the first stage, the CCSB has been divided into four (4) groups where each group consists of six (6) numbers as shown in Table 1. The CCSB was weighed with an electronic weighing scale due to being exposed to rainwater (the first time of weighing is to see the weight of CCSB and it is revealed insignificant due to it has not absorbed the rainwater thoroughly) as shown in Figure 2(e) and then it is dried with an electric oven-dry at the temperature of 140˚C for 8 hours as shown in Figure 2(f). After 8 hours of oven-dried, it cooled and weighed again for CCSB dry density result is shown in Table 2.

The second stage is dry CCSB was immersed into tap water at the temperature of 23° C to 26° C in a water tank referred to (Department of Standard Malaysia 2007). The CCSB was shaken, flipped and flopped until air bubbles are released or removed and it was immersed in water for 24 hours, 7, 14 and 28 days for water absorption as shown in Figure 2(g).

The third stage is wet CCSB was taken out from the water tank and wiped with a wet towel due to minimize the wet towel sips the volumes of water that were absorbed by CCSB then weighed with an electronic weighing scale resulting in the measurement of water absorbed by CCSB for wet density, after that WA was measured.

The fourth stage is 3 wet CCSB was separated from the 6 wet CCSB and then the wet CCSB was conducted for CS test. The other 3 wet CCSB was conducted for an electric oven-dry at a temperature of 140˚C for 8 hours and then the dried CCSB was conducted for CS test using compressive strength machine ADR 1500 model referred to (BS EN 12390:2000; BS EN 1015-11:1999) as shown in Figure 2(h) and Figure 2(i).

Figure 2(e). CCSB Grouped

Figure 2(f). Oven Dry

Figure 2(g). WA

Figure 2(h). CS on Dry CCSB

Figure 2(i). CS on Wet CCSB

Table 1. Mix ID of CCSB

215 mm X 100 mm X 64 mm			
Group	Mix ID	Group	MIX ID
1	A1-24hours	3	C1-14days
	A2-24hours		C2-14days
	A3-24hours		C3-14days
	A4-24hours		C4-14days
	A5-24hours		C5-14days
	A6-24hours		C6-14days
2	B1-7days	4	D1-28days
	B2-7days		D2-28days
	B3-7days		D3-28days
	B4-7days		D4-28days
	B5-7days		D5-28days
	B6-7days		D6-28days

Water Absorption (WA) Rate on Conventional Cement-Sand Brick (CCSB)

WA test was conducted by measuring volumes of water that absorbed by the CCSB pore structures by immersing it into the tap water for temperatures in ranges of 23° C to 26° C referred to (BS EN 1015-18:2002) for 24 hours, 7, 14 and 28 days. CCSB was weighed before and after emerging in tap water. Calculated using (Equation 1) where Ws is water absorption, Ms is mass after soaking (g) and Md is mass after oven-dry (g).

$$Ws = Ms – Md \div Md \times 100\% \tag{1}$$

Compressive Strength (CS) on Conventional Cement-Sand Brick

The CCSB CS test used compressive machine ADR 1500 model was conducted to determine the maximum compressive strength loads that CCSB can withstand before cracking and failing using the (Equation 2) where Cs is the compressive strength, Al is the loads applied (N) and Pa is plan area (mm^2) referred to (BS EN 12390:2000; BS EN 1015-11:1999).

$$Cs = Al \div Pa \tag{2}$$

RESULT AND DISCUSSION

The results of CCSB density, water absorption and compressive strength are as shown below.

Density and Water Absorption (WA) of Conventional Cement-Sand Brick (CCSB)

The CCSB average wet density (WD) is 2930 g, 2904 g, 2900 g and 2863 g. The CCSB average dry density (DD) is 2766 g, 2737 g, 2733 g and 2695 g. The average of water absorbed is 164 g, 166 g, 167 g and 167 g for 24 hours, 7, 14 and 28 days. The weight of water absorbed for 24 hours is 164 g near 7, 14 and 28 days as shown in Figure 3. The average water absorbed in CCSB is 5.94%, 6.09%, 6.12% and 6.23% for 24 hours, 7, 14 and 28 days. The percentage of water absorbed for 24 hours is 5.94% near to 7, 14 and 28 days as shown in Figure 4 and Table 2.

As stated by (BS EN 771-1:2011) water should not be absorbed for more than 25% formed of voids. Referring to percentages that were revealed this CCSB having pore structures due to a percentage of 24 hours near to the percentages of 7, 14 and 28 days from the data were taken and tabulated in Table 2 and as shown in Figure 4. According to (Bu *et al.*, 2017) porosity and pore sizes distributions affected the microstructures mainly in mass volumes and its grading for having the same type of aggregates. Raihana *et al.* (2019) stated pore structures involved with sizes and volumes of water interconnected to capillary pores, also during hydration reaction, pore on solid is created and allowed transportations of fluids.

As highlighted by (Van der Sloot *et al.*, 2009) permeability was affected by the pore structures of a cement paste, the liquid that transfers from the exterior surfaces into the interior surfaces. As stated by (Raihana *et al.*, 2019) effectiveness porosity and capillary pressures can change the performances of sorption. Hence, it is revealed from this research CCSB was fabricated is porous due to high water absorbed even though it not more than 25% formed of voids referred to (BS EN 197-1:2011).

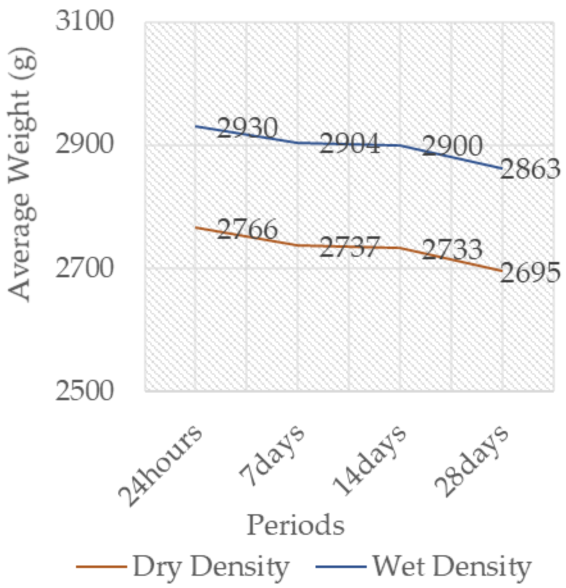

Figure 3. Dry and Wet Density

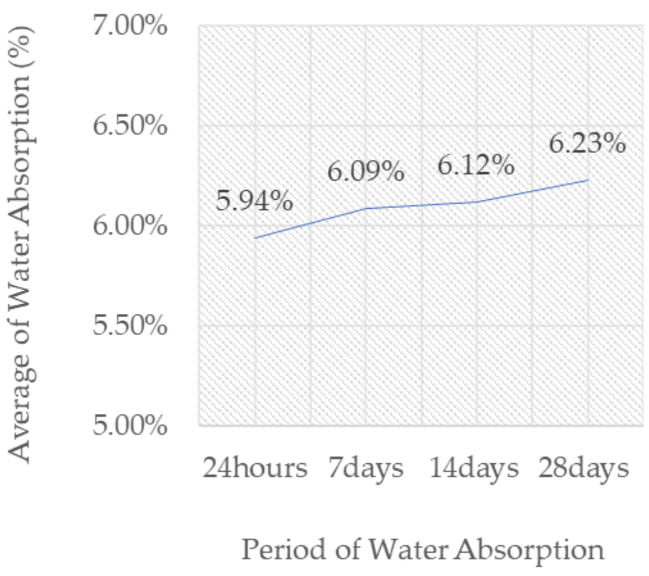

Figure 4. Water Absorption

Table 2. Water Absorption

Group	Specimen	Oven-Dry Dry Density (gram) (Md)	Soaked with Water Wet Density (gram) (Ms) 24hours	7days	14days	28days	Water Absorption (Ms – Md) (gram)	(Ws) (%)	Average Water Absorption (%)
	215 mm X 100 mm X 64 mm conventional cement-sand bricks								
	A1-24hours	2757	2925				168	6.09	
	A2-24hours	2787	2940				153	5.49	
1	A3-24hours	2724	2894				170	6.24	5.94
	A4-24hours	2757	2925				168	6.09	
	A5-24hours	2785	2955				170	6.10	
	A6-24hours	2788	2944				156	5.60	
	B1-7days	2620		2809			189	7.21	
	B2-7days	2798		2958			160	5.71	
2	B3-7days	2724		2896			172	6.31	6.09
	B4-7days	2780		2930			150	5.39	
	B5-7days	2757		2925			168	6.09	
	B6-7days	2745		2905			160	5.82	
	C1-14days	2722			2900		178	6.53	
	C2-14days	2787			2937		150	5.38	
3	C3-14days	2641			2818		177	6.70	6.12
	C4-14days	2728			2898		170	6.23	
	C5-14days	2727			2905		178	6.52	
	C6-14days	2794			2944		150	5.36	
	D1-28days	2777				2937	160	5.76	
	D2-28days	2648				2827	179	6.75	
4	D3-28days	2701				2861	160	5.92	6.23
	D4-28days	2695				2848	153	5.67	
	D5-28days	2733				2900	167	6.11	
	D6-28days	2615				2802	187	7.15	

Wet and Dry of Conventional Cement-Sand Brick on Compressive Strength (CS)

Compressive strength in wet conditions affected by 2.4%, 32%, 32% and 32% or 11.02 N/mm², 7.81 N/mm², 7.80 N/mm² and 7.80 N/mm² for 24 hours, 7, 14 and 28 days. In dry conditions compressive strength was affected by 9.7%, 9.8% and 9.8% or 11.28 N/mm², 10.28 N/mm², 10.27 N/mm² and 10.27 N/mm² for 7, 14 and 28 days as shown in Figure 5. Based on observations, the CCSB surface contains higher numbers of pores and cavities as shown in Figure 1(b) and Figure 1(c) that filled with water in wet saturated conditions. The longer CCSB submerged in the tap water the more water was absorbed as shown in Figure 4 and Table 2, this reduces the strength of CCSB in the CS test as shown in Figure 5, Figure 6 and Table 3.

According to (Ballim *et al.*, 2009) soft water attack is considered to occur in concrete infrastructures that are characterized by low dissolved ions content when the Portland cement-based concrete contact with water, calcium hydroxide ($C_a(OH)2$, portlandite) in this hardened cement matrix is leached out as soft water tries to establish ions balance, water attack aggressively measured as the rate of $C_a(OH)2$ is leached from the cement paste and this is considered increase if the water contains dissolved carbonic acid due to the presence of aggressive carbon dioxide (CO_2).

As highlighted by (McGowan, 2000) water hardness traditionally measure to a capacity of water reacts with soap that required considerably and more soap producing a lather and this water often produces noticeable deposits of precipitate (example: soaps or salts and insoluble metals) in containers including the bath ring, this is not caused by single substances but by various dissolved magnesium cation, polyvalent metallic ion and predominantly calcium with other cation that contribute example: aluminum, barium, iron, manganese, strontium and zinc. Hardness in water is commonly expressed as milligrams of a calcium carbonate equivalent to per liter and water that contains calcium carbonate at a concentration below 60 mg/l is considered as soft, 60 to 120 mg/l as moderately hard, 120 to 180 mg/l as hard and more than 180 mg/l as very hard.

Moreover, (National Research Council 1977) has stated it is dependent upon interactions with the others factors such as alkalinity and pH of hard water can cause a scale deposition in the water distribution system where insoluble metal carbonate is formed and coated the surfaces. Excessively hard water has the tendencies create corrosion and soft water not stabilized has a great tendency to cause corrosion to metal surfaces and pipes, this resulting from certain heavy metal presences in the drinking water such as cadmium, copper, lead and zinc.

As stated by (Noorwirdawati *et al*., 2018) rate of water absorption unit, bricks are closely related to porosity, higher water permeability by bricks causes swelling of particles in bricks that have been stabilized and decreases in strength. Moreover, Zhang and Zhong (2014) stated the water absorption and permeability were affected by pore structures of cement paste as liquids can transfer from external surfaces into the interior surfaces, and according to (Schutter & Audenaert, 2004) permeability has a closes relationship with characteristics of pore structures in cement paste and intensity of microcracks at cement paste interface and within paste itself. Shafiq and Cabrera (2014) highlighted interconnected pores capillary during the hydration reaction, pore and solid materials were created and formed, due to pore structure it is mainly connected with the sizes and volumes of pores productions and these allow water seeping and the effectiveness of porosity and the capillary pressures change performances of sorption.

According to (Van der Sloot *et al*., 2009) the influences from external factors are from the oxidations and carbonations on constituent releases is essential because a large pH and redox gradients occur initially and chemistry within the surrounding matrix changes with time and releases different behaviors over different time of interval. Moreover, physical stress changes the physical and hydraulic properties of materials from leaching perspectives, these releases of controlling phases are not the primary matrix mineral but the phases present in very minor quantities. However, within pore structures of cementitious materials, leaching is a complex coupling of a mass transport process through a tortuous pore system with a wide range of chemical reactions that help to retain the constituents within the matrix. Constituents in cementitious materials are generally categorized by a relative concentration of elements present in solid and characteristic chemical behaviors.

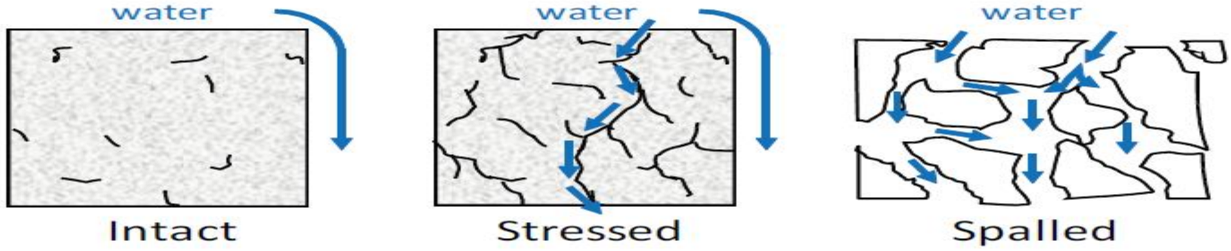

Figure 5. Physical Degradation of Cement Paste Compositions adapted from Van der Sloot *et al.* (2009).

Based on the observation the surfaces of CCSB contain higher numbers of pores and cavities that are filled with air and moistures in dry conditions. The dry CCSB had a greater cracking pattern due to the dryness of the materials composition without water existence and all compositions of materials did not stick to each other causing the dry CCSB to split more as shown in Figure 2(i). The wet CCSB had a lower cracking pattern due to the wet materials composites and the existence of water, all the compositions of materials are still sticking together causing a wet CCSB to split less as shown in Figure 2(j). Furthermore, dry CCSB was got thru a matrix ion composite got leaches by water that established the ion's balance thus affecting CCSB strengths. Moreover, wet CCSB matrix ions composite leaching causes the breakdown and softening of the matrix due to water is still existed and this affects CCSB strength.

Thus, this water from the water tap effect the CCSB matrix during water absorption on mechanical characteristics revealed the longer it is submerged in water, CCSB owing to the structural degradation reduces its bond strength to have lower CS in CCSB due to a reduction in CS of CCSB is cement paste cannot strongly grip materials in CCSB as cement paste matrix becoming soft and the matrix molecules got leaching or ionize (the processes of removing one or more electrons) when water established ions balance in hardened cement paste due to effects of immersion too that long softens the matrix makes the CCSB losing its strength. Moreover, dry and wet CCSB CS are influenced by factors of porosity, pore sizes and uniformity of materials are unable to fill into voids in CCSB that prevents the formation of good density in results affecting the CCSB strength due to pore structures of cementitious materials, leaching is a complex coupling of mass transport processes through tortuous pores systems with wide ranges of chemical reaction that can help to retain the constituents within the matrix. The cementitious materials constituents are generally categorized by relatives' concentration of element that is present in solid and characteristic chemical behaviours. This shows water contents are significantly affected the CCSB performance.

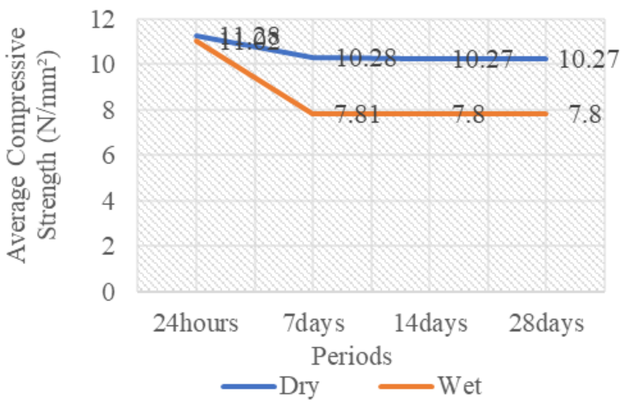

Figure 6. Dry and Wet CS

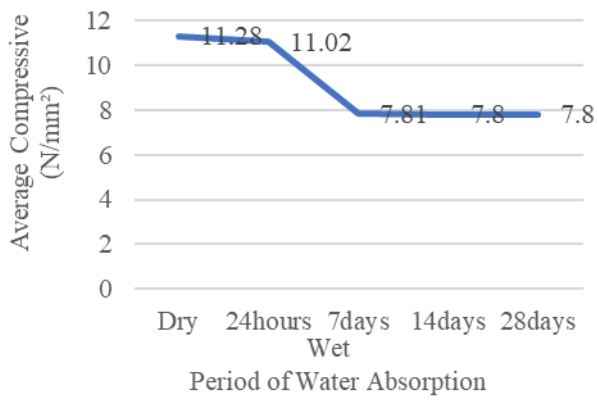

Figure 7. Compressive Strength

Table 3. Compressive Strength

215 mm X 100 mm X 64 mm conventional cement-sand bricks											
Group	Specimen	Compressive Strength (N/mm²)								Average (N/mm²)	
		24hours		7days		14days		28days			
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
	A1-24hours	11.29									
	A2-24hours	11.28								11.28	
1	A3-24hours	11.28									
	A4-24hours		10.99								
	A5-24hours		11.07								11.02
	A6-24hours		11.00								
	B1-7days			10.27							
	B2-7days			10.29						10.28	
2	B3-7days			10.28							
	B4-7days				8.80						
	B5-7days				8.82						7.81
	B6-7days				8.81						
	C1-14days					10.28					
	C2-14days					10.28				10.27	
3	C3-14days					10.26					
	C4-14days						8.82				
	C5-14days						8.80				7.80
	C6-14days						8.79				
	D1-28days							10.29			
	D2-28days							10.28		10.27	
4	D3-28days							10.25			
	D4-28days								8.79		
	D5-28days								8.82		7.80
	D6-28days								8.80		

Table 4. Mean and Standard Deviation (SD) of WA

Periods	**24hours**	**7days**	**14days**	**28days**
Mean	164.17	166.50	167.17	167.67
SD	7.60	13.38	13.63	12.93

Table 5. Mean and Standard Deviation (SD) of CS

Periods	**24hours**		**7days**		**14days**		**28days**	
Condition	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Mean	11.28	11.02	10.28	7.81	10.27	7.80	10.27	7.80
SD	0.01	0.04	0.01	0.01	0.01	0.02	0.02	0.02

Mean and Standard Deviation on the Water Absorption (WA) and Compressive Strength (CS)

CCSB mean and standard deviation (SD) on the water absorption on the 24 hours, 7, 14 and 28 days are 164.17, 166.50, 167.17 and 167.67 with an SD of 7.60, 13.38, 13.63 and 12.93 as shown in Figure 8 and Table 4. The CCSB mean and standard deviation (SD) on the compressive strength on the 24 hours, 7, 14 and 28 days in the dry condition is 11.28, 11.28, 11.27 and 11.27 and the wet condition is 11.02, 7.81, 7.80 and 7.80 with the SD in the dry condition is 0.01, 0.01, 0.01 and 0.02 and the wet condition is 0.04, 0.01, 0.02 and 0.02 as shown in Figure 9 and Table 5. Therefore, CCSB compressive strength in wet conditions affected by 2.4%, 32%, 32% and 32% for 24 hours, 7, 14 and 28 days. The compressive strength in dry conditions was affected by 9.7%, 9.8% and 9.8% for 7, 14 and 28 days respectively.

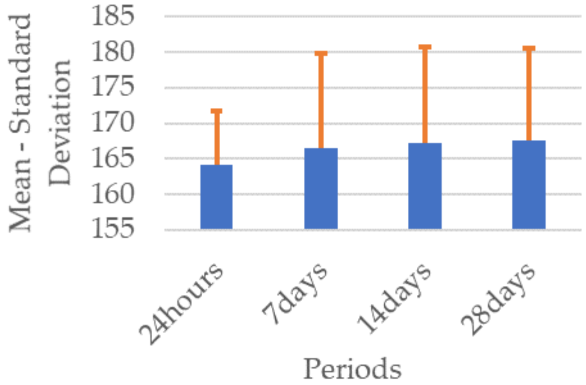

Figure 8. Mean and SD on WA

Figure 9. Mean and SD on CS

British Standard (BS)

The BS highlighted regarding the production of bricks referring to the previous specification of the materials for masonry unit, BS 3921 specifications for a clay brick and BS 6649 specification for clay and calcium silicate modular brick; the BS 6073-1 specification for the precast concrete masonry unit and the BS 187 specification of clay and calcium silicate (sand lime and flint lime) brick replaced by BS EN 771-1:2011; BS EN 771-2:2011 and BS EN 771-3:2011. Moreover, BS EN 771-1:2011; BS EN 771-2:2011 and BS EN 771-3:2011 has stated is a performances standard that is unlike the previous British Standard. Hence, it does not specify the unit sizes nor does it provide the details of unit strengths classes. Therefore, the unit sizes and the strength values are to be provided by the designers along with properties such as dimensions and tolerances, type of units, configuration, gross, net density and tolerances, compressive strengths and others.

BS EN 771-1:2011; BS EN 771-2:2011 and BS EN 771-3:2011 specifies the category I masonry units that are declared by the compressive strength with a probability of failure to reach these strengths for less than 5% and category II masonry units that do not satisfy this criterion. According to BS EN 771-1:2011; BS EN 771-2:2011 and BS EN 771-3:2011) a designer may use the classification system to specify the properties of masonry units, provided the system is based only on the single properties included within the BS EN 771-1:2011; BS EN 771-2:2011 and BS EN 771-3:2011 does not constitute the barrier to trade. However, the permit details of the classification system in current uses are to be given in the informative national annexes.

The annexes in BS EN 771-1:2011; BS EN 771-2:2011 and BS EN 771-3:2011 can be normative or informative. The normative is being part of the standard it is part of any complaint's requirements. Informative annexes are to provide the guide to the professionals and are not part of any complaint's requirements. BS 5628-1:2005 stated there are two types of mortar, dry mortar primarily consists of cement and sand and wet mortar consists of cement, sand and water with the addition of BS 410 1:1000. Hence, the role of mortar (cement-sand) as blocks or bricks used as part of a structure is important.

There are requirements to be met by fabrication of these cement sand bricks, which are both in the plastic state and hardened state, during fabrication processes the products must be working to enable the fabrication of the cement sand bricks, for any particular strength unit there is an optimum mortar strength, constituents of cement mortar generally consist of cement, sand and water, Portland cement is the principal binding agent in mortar referred to (BS 5628-3:2001). The OPC is used because of its comparatively rapid strengths gaining and quicker in the set rates. Therefore, proportions and mixing of the mortar are usually mixed in batches and controlled for good quality by the uses of the specified materials with the correct proportion from the BS 5628-1:2005 and BS 5628-3:2001. BS 5628-1:2005 stated M12/(i), M6/(ii), M4/(iii) and M2/(iv) as shown in Table 6 and applied to masonry built with standard format bricks of clay or calcium silicate conforming to the requirements of BS EN 771-1:2011; BS EN 771-2:2011; BS EN 771-3:2011 and BS EN 197-1:2011 is not more than 25% formed of voids (perforations) or 20% frog (a depression or projection to acts as the key to holding the mortar prevent the bricks from sliding).

BS EN 998-2:2010 stated the designed characteristics for compressive strength of any masonry for mortar, normally the masonry (other than manufactured stone) defined to shapes, classification and compressive strength of mortar illustrated M1, M2.5, M5, M10, M15, M20 and it is possible to have further strength of classes where the designers may declare others values into the additional classes. Therefore, the prescribed mortar batched proportions are chosen and predetermined by the designer as shown in Table 7.

Table 6. Classes and Characteristics of Compressive Strength

Class	Mortar Compressive Strength of Unit (N/mm²) (BS 5628-1:2005)										
	Designation										
	5	10	15	20	30	40	50	75	100	125	150
M12/(i)	2.5	4.0	5.3	6.4	8.3	10.0	11.6	15.2	18.3	21.2	23.9
M6/(ii)	2.5	3.8	4.8	5.6	7.1	8.4	9.5	12.0	14.2	16.1	17.9
M4/(iii)	2.5	3.4	4.3	5.0	6.3	7.4	8.4	10.5	12.3	14.0	15.4
M2/(iv)	2.2	2.8	3.6	4.1	5.1	6.1	7.1	9.0	10.5	11.6	12.7

Table 7. Classes and Characteristics of Compressive Strength (CS)

Class	M1	M2.5	M5	M10	M15	M20	M x
CS	1.0	2.5	5.0	10.0	15.0	20.0	x
x is a compressive strength greater than 20MPa as declared by the designer (BS EN 998-2:2010)							

As a guide from BS EN 998-2:2010 the masonry mortar that is documented to all mortar, it is noted that the standard is not applicable when calcium sulfate (an inorganic compound with the formula $CaSO_4$ and related to hydrates) is used as a principal binding agent (cause weakening to mortar in long-term). BS EN 771-2:2011 stated that frost inhibitors that are based on calcium chloride or calcium chloride itself should not and/or never be used due to long-term weakening of mortar and excessive corrosion to the wall ties and reinforcements. According to BS 5628-1:2005 bricks are used to denote building units made of clay.

As stated by BS EN 197-1:2011 OPC standard term CEM I consist of 95% to 100% by mass clinker with minor additional constituents 0% to 5% by mass, capable to produce mortar and/or concrete and retains its workability sufficient time after defined its period attain with a specified strength level and long-term possess volumes stability. Hydraulic hardening of CEM I cement, primarily due to calcium silicates hydrations, other chemicals compounds may also participate in hardening processes (for example the aluminate). The significance of pozzolan reactions converts high-silica materials to a calcium silicate with good cementing properties and when calcium hydroxide ($Ca(OH)_2$) reacts to the silica it produces calcium-silica-hydrate (C-S-H) paste that acts as a binder or adhesion and it increases cement-based material's strength, (Elffie *et al.*, 2020; Nurul *et al.*, 2020; Raihana *et al.*, 2019) has stated C-S-H paste helps reduce pores and improves the strength and durability.

Researchers have investigated these products in various aspects in terms of construction materials stated by (Ettu *et al.*, 2013). Moreover, the additional literature from the other researchers claimed by mixing eco-processed pozzolan (EPP) in OPC can produce goods cement mortar and/or concrete and this product can reduce water absorption issues (Elffie *et al.*, 2020; National Research Council 1977). According to (Aprianti, 2015) pozzolan materials were used to substitute cement powder for a few percentages of weight due to its pozzolanic effects can contribute into two ways (i) in compressive strength such as the filler effect and the (ii) reactions of pozzolanic. Raihana et al., (2019) was agreed by adding pozzolan in OPC is become more effective in reducing permeability rather than decreasing the water to cement ratio.

According to (Mohammed & Cheeseman, 2011) eco-friendly cement-based construction products in practices are mostly used with the features such as low shrinkage, low thermal conductivity, high density and strong compressive strength. Hence, BS EN 197-1:2011 refers to any stone or clay-based building unit that is mixed with pozzolan as cementitious mortar. Therefore, future research on EPP from palm oil waste is considered to mix with cement in the presence of water, bind sand and quarry dust to develop "eco-processed pozzolan cement-mortar brick" (Ecmb) respectively.

CONCLUSION

The finding demonstrated the porosity of conventional cement-sand brick (CCSB) made rainwater affects the building wall and components in CCSB. The mixed proportion in CCSB components having almost the same sizes of aggregates in zone 1 and zone 2 grading resulting have large pore structures. Moreover, CCSB absorbed water in the 24 hours is almost the same as 7, 14 and 28 days. Therefore, this product is highly porous with CS 11.28 N/mm^2 classified as M12(i), designation 50, with strengths of 11.6 N/mm^2 for 24 hours and 10.28 N/mm^2 classified as M12 (i), designation 40, with strengths of 10.0 N/mm^2 for 7, 14 and 28 days, categorized as loadbearing bricks referred to BS 5628-1:2005.

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