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Original Article

Usage of wet blue shaving in sand-cement blocks: An approach towards solid waste management in tannery

Shammy US[1*], Abedin MZ[2] and Rahman MS[2]

[1]M.S. Candidate and [2]Professor, Department of Farm Structure and Environmental Engineering, Bangladesh Agricultural University, Mymensingh-2202

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***Corresponding Author**

Shammy US,
E-mail: shammy.aub19@gmail.com

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ABSTRACT

The experimental study was conducted to investigate the feasibility of wet blue shaving-sand-cement blocks as an alternative building material for conventional clay brick that can be a better management system for solid wastes in the tannery industry. Wet blue shaving (WBS) is one of the highly generated solid wastes from tanneries. There is no significant utilization of this waste. Preparation of building blocks from WBS incorporated with sand-cement would be a promising avenue for this waste management. Wet blue shavings mixed with sand-cement (cement:sand=1:5) in various proportions (0%, 1%, 2%, and 4% by total dry weight) were used to prepare total 48 building blocks (254mm x 127mm x 76.2mm) and their feasibility as a construction material was appraised based on their physical and mechanical characteristics. The Bangladesh Standards and the American Society for Testing Materials standards (ASTM) were used to assess the engineering qualities of the prepared blocks. Among all the composite block specimens, blocks with 1%, and 2% WBS show 17.65MPa, and 13.87MPa compressive strength, respectively in 28 days of water curing. The costs (1292 BDT/100 blocks) of this type of waste management method were found to be favorable. Due to the usage of clay bricks in abundance with the construction sector, the world requires alternatives to prevent the exploitation of the topsoil that makes the soil lose its fertility. As a result, the wet blue shaving composite block is regarded as an environment-friendly alternative among all disposal methods and would be a potential substitute for fired clay brick.

Introduction

The leather industry is one of the oldest industrial sectors in Bangladesh. According to the Export Promotion Bureau, leather and leather products is the 2nd largest foreign currency earner after Ready-Made Garments. Leather products are one of the major external trade sectors which contribute 3.4 percent of the total country's export earnings (Mamun *et al.*, 2016) Bangladesh was exported leather and leather products worth $941.67 million in the FY 2020-2021 (Islam, 2022).

A large quantity of fibrous solid waste generates from leather industries in the form of wet blue shaving (WBS). WBS is generated during the shaving process of wet blue leather based on the required thickness (Tesema, 2018). There are about 600,000 tons of solid wastes being produced worldwide by the leather industry and approximately 40-50% of its WBS is formed to bring off the desired thickness (Kamaraj *et al.*, 2017). The chromium content present in the wet blue stage of chrome shavings is chromium trivalent (Fatima *et al*, 2012). These wastes are stable and not subject to putrefaction. In the European Union, wet blue shavings are classified as non-hazardous waste (Lakrafli *et al.*, 2012). A huge amount of WBS waste is generated and there are limited disposing methods available so handling is more challenging for tanners (Tesema, 2018).

Some major ways of solid waste management are incineration, landfill, and pyrolysis (Rahman *et al.*, 2017). Louhab *et al*. (2006) suggested that WBS may be treated by thermal incineration. During thermal incineration, the chromium (III) from leather shavings waste can form chromium (VI) that is carcinogenic and mobile (Kizinievič *et al.*, 2020). Landfills accept this type of waste, nevertheless, the cost of dumping is high and keeps increasing (Rahman *et al.*, 2017). The effect of the double pyrolysis safe disposal method was suggested by Sethuraman *et al.* (2013) which is expensive. WBS has become a serious environmental burden for Bangladesh with limited safe disposal options. Some treatment methods have been experimented with by the researchers to utilize WBS waste for other useful purposes such as WBS on cement and plaster-based materials (Lakrafli *et al.*, 2012), chrome tanned leather shaving-gypsum composite materials prepared (Morsy & Nasr, 2018). One of these useful purposes is to produce a composite using WBS as well as make a valuable material.

On the other hand, there are about 45,000 brick kilns in Bangladesh which produce about 17.2 billion bricks per year (World Bank, 2011). Fire Brick or burnt clay brick is the main construction component. A huge amount of agricultural topsoil is being used in the production of traditional fire bricks, which is a threat to our food security (Kumar *et al.*, 2020). Around 240 tonnes of coal is used for producing one million bricks (Khan *et al.*, 2013). In the Dhaka region about 302,000 tons of carbon monoxide, 1.8 million tons of carbon dioxide also other substances emitted from a brick kiln every year which is extremely harmful to human health (Bhat *et al.*, 2014). The increasing demand for using a construction material that has a minimal cost and with no negative impact on the environment makes researchers look for a way to produce an alternative sustainable building material that meets the standard set for the construction materials and benefits the environment (Tesema, 2018). It provides an alternative way to minimize the amount of wet blue shaving wastes dumped into the environment and it also provides for a viable option to use this waste as raw material for alternative construction material production as well as the high cost of construction.

The study aims (i) to investigate the suitability of WBS incorporated sand-cement block manufacturing that can contribute as an alternative sustainable building material, (ii) to utilize WBS wastes for the production of alternative construction materials become a better solution to manage solid wastes in tannery industry.

Materials and methods

Construction materials

In this study, wet blue shavings (WBS) coming from leather industries were used as raw materials (Fig.1). The samples were collected from Bovine Leather, 94 Hazaribagh old tannery area, Dhaka-1209, Bangladesh. The samples were conveyed stored and in stacks of plastic at room temperature before use. Ordinary Portland cement (Brand: Bashundhara) (Type-1) passing ASTM 300-micron sieve was used. The local river's moderately fine sand was used for manufacturing wet blue shaving-sand-cement blocks that are available in the district of Mymensingh.

Fig. 1. Raw wet blue shaving waste

Fig. 2. WBS-sand-cement blocks prepared in the laboratory

Characterization of wet blue shaving

The collected wet blue shavings (Fig.1) were analyzed for the following parameters: Chromium (III) concentration using Atomic Absorption Spectrophotometer (AA-6800 Atomic Absorption Spectrophotometer, shimadzu), total nitrogen using the Kjeldahl method, ash (loss on ignition for 2 hr at 550^0C), and moisture content using APHA method (APHA, 1995), and pH using pH meter at Bangladesh Council of Science and Industrial Research (BCSIR).

Characterization of sand

Uniformity of Coefficient, $C_u = D_{60}/D_{10}$

Coefficient of Curvature, $C_c = (D_{30})^2/ (D_{60} \text{ X } D_{10})$

The average diameter (D_{av}) of sand particles was determined from the Fineness Modulus (FM) of sand by using the following empirical equation: $D_{av} = 0.10414[2]^{FM}$. The Fineness modulus (FM) of the sand was determined by using the sieve analysis method at the Concrete and Materials Testing Laboratory in Bangladesh Agricultural University, Mymensingh.

Blocks specimen preparation

The collected wet blue shavings were cut into small pieces about 0.5 cm in size using a chaff cutter and soaked in water for 1 hour. Total 48 block specimens (length 254 mm, width 127 mm, and height 76.2 mm) of the wet blue shaving-sand-cement mixture in different proportions (0%, 1%, 2%, 4% wet blue shaving of total dry weight) were prepared in the laboratory as described in Table 1 (also see Fig.2). The volume of water added in each proportion was measured based on the 60% dry weight of cement in each proportion. Cement and sand were mixed in the proportion of 1:5. Twelve 100% sand-cement block specimens were prepared as reference specimens. The Hand-molding method was used for preparing block specimens (Juel *et al.*, 2018). Obtained composite materials were kept at room temperature for 1 day until weight stabilization. After 1 day of natural drying, Curing is used for raising the hydration of cement and consists of control of temperature and moisture movement. Gunny bags were used for the curing process as shown in fig.3. The blocks were kept for 28 days in such moisture by spraying water. The room temperature varied from 18-23^{0}C and relative humidity was 54-65%.

Table 1. WBS-sand-cement block compound compositions.

Treatment	Wet blue shaving (%by total dry weight)	Wet blue shaving (kg)	Cement (kg)	Sand (kg)
1	0	0	10.56	50.4
2	1	0.61	10.56	50.4
3	2	1.22	10.56	50.4
4	4	2.44	10.56	50.4

Fig. 3. Blocks under water curing

Fig. 4. Block under compression test with Digital Display Compression Testing Machine

Physical and mechanical properties

The objective of experimenting with varying wet blue shaving proportions was to determine the effect of wet blue shaving quantity on various physical and mechanical characteristics of blocks and also to roughly find out the threshold wet blue shaving quantity that would allow having desirable engineering properties as a construction material. Data were taken at different stages of the curing process: 7, 14, and 28 days. Molding compounds' properties were determined by the following standard testing methodologies: Density was measured by using the following expression: Density, D= $\frac{M}{V}$. where, D is the density of block specimen (kg/m^3), M is the dry mass of block specimen (kg), and V is the volume of block specimen (m^3); water absorption and compressive strength were determined following ASTM (ASTM C 67-02c, 2002). Digital Display Compression Testing Machine as shown in figure 4 was used to measure compressive strength. The engineering properties of the block specimens were compared with the Bangladesh and ASTM Standards (BDS 208, 2009) (Juel *et al.*, 2017) (see Table 2).

Table 2. BDS 208 (2009) and ASTM C216-10 criteria for bricks for specific use.

Name of the test	BDS 208 (2009)			ASTM C216-10	
	Grade S	Grade A	Grade B	Grade SW	Grade MW
Compressive strength (MPa)	≥ 24	≥ 15	≥ 10.3	17.2	15.2
Water absorption (%)	≤ 10	≤ 15	≤ 20	20	25

Note: Grade S: This type of brick may be used for breaking into aggregate for plain and reinforced concrete and for making the base course of pavement. Grade A: This type of brick may be used in the construction of buildings of a long duration. Grade B: This type of brick may be used for a one-storied building, a temporary shed, where the intended durability is not very long; Grade SW: resistance to severe weathering. Grade MW: resistance to moderate weathering.

Cost analysis

The overall cost items detected for block constructions were as follows:

1. Variable costs: The costs vary with the quantity of the product. These include: sand, cement, wet blue shaving, transportation, and human labor costs.
2. Fixed cost: The costs do not vary with the quantity of the product. These include: tools, and gunny bags costs.

Results and Discussion

Characterization of wet blue shaving

Table 3 shows the properties of collected wet blue shaving. The obtained values were fairly similar to other researchers' literature (Morsy & Nasr, 2018; Tesema, 2018).

Table 3. Characteristics of wet blue shaving.

Parameter	Value
Moisture content	9.87%
Cr_2O_3	2.10%
Inorganic ash	7.29%
Nitrogen	13.51%
pH	3.12

Characterization of Sand

From Fig.5 Uniformity coefficient (C_u) of sand, particle was 2.35, and the coefficient of curvature (C_c) was 1.41. The average diameter (D_{av}) was 0.33mm. The Fineness modulus (FM) of this sand 1.68 was determined by using the sieve analysis method.

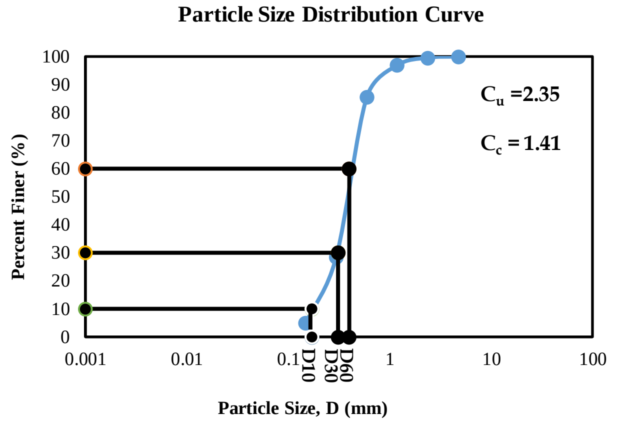

Fig. 5. Gradation curve of sand

Specimen weight

The block specimens were weighed at 7, 14, and 28 days from the time of their manufacture and for the four (0%, 1%, 2%, and 4%) wet blue shaving contents at room temperature (Fig. 6). It can be shown, specimen weight decreases with increasing wet blue shaving content. Similar nature of weight with similar construction materials manufactured with different percentages of wet blue shaving content has been shown previously in other studies (Lakrafli *et al.*, 2012) (see also Table 3). In Bangladesh, the weight of a standard clay brick (240 mm X 115 mm X 70 mm) is around 3.70 kg (ASTM C., 2012). Whereas, 1%, 2%, and 4% wet blue shaving composite blocks (254 mm X 127 mm X 76.2 mm) weight after 28 days of curing, were 4.13kg, 4.02kg and 3.12kg respectively. The wet blue shaving composite block was lighter in weight than standard clay brick. Lightweight building materials can be more beneficial in construction for their lower dead load, savings in transportation costs, and ease of handling (Aziz, 1995).

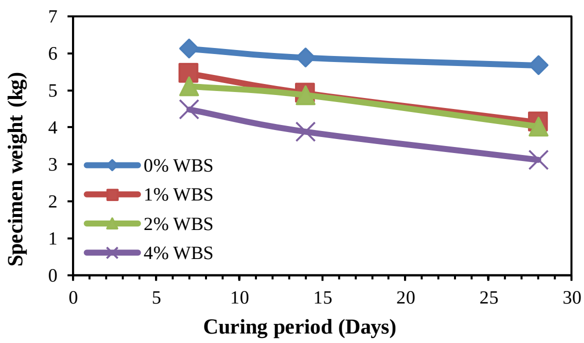

Fig. 6. Variation of specimen weight with curing period

Density

The variation of density was observed in terms of different percentages of wet blue shaving content as shown in Figure 7. An inverse relationship was observed between the density and the amount of wet blue shavings added to the composite mixture. As the amount of wet blue shaving was increased, the density of the elaborated specimen decreased considerably, especially in the case of the 4% wet blue shaving content block specimen. It can be seen that density reduction (from day 0 to day 28 curing) was ~ 45.04% (from 2307 to 1268 kg/m^3) as the wet blue shaving content was increased from 0% to 4%. Similar trends of density have been reported in the case of cement and plaster-based materials containing wet blue shaving (Lakrafli *et al.*, 2012) and Chrome tanned leather shaving-gypsum composite specimens (Morsy and Nasr, 2018) (see also Table 3). The density equivalent of a standard brick in Bangladesh is roughly 1920 kg/m^3 (ASTM C., 2012). Therefore, the density for all wet blue shaving composite specimens cured for 28 days was lower than 1920kg/m^3. Building materials, such as wet blue shaving content composite blocks with low density also have good thermal insulation properties (Aziz, 1995).

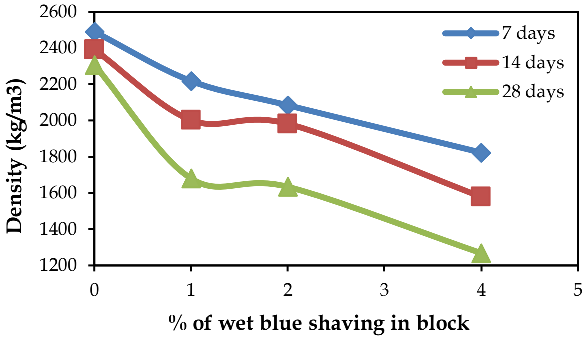

Fig. 7. Variation of density at different percentages of wet blue shaving

Water Absorption

Fig.8 shows the water absorption test results as a function of Wet blue shaving content at varying proportions. It has been seen that the water absorption of the blocks increased with increased wet blue shaving addition. While several factors such as the type of raw materials used and the technique of block manufacturing affect the longevity of blocks (Liew *et al.*, 2004), the tendency of blocks to absorb water is also an important factor. Less the amount of water penetrates the blocks, the more will be the durability of the bricks (Shathika *et al.*, 2013). According to ASTM C62, Water absorption shall not exceed 15% of the dry weight of the brick. For all wet blue shaving contents tested, water absorption is less than 15% as shown in Figure 8. Considering water absorption standards stated in BDS 208 (2009) (see also Table 1) blocks made with 1% wet blue shaving can be regarded as the Grade-S category. All block specimens satisfy the ASTM requirement of water absorption for Grade SW and MW category bricks.

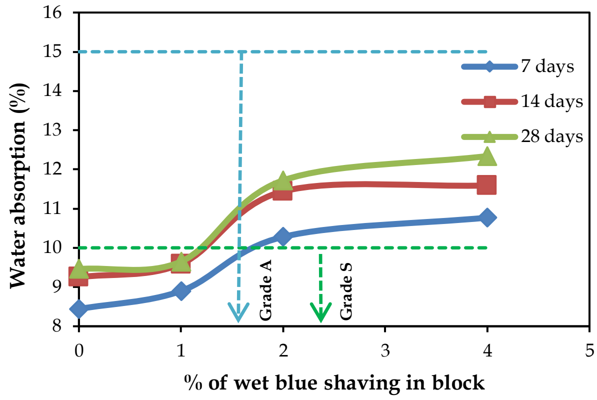

Fig. 8. Variation of water absorption at different percentages of wet blue shaving

Compressive Strength

The compressive strength is the core parameter to make sure the engineering quality of construction materials. The variation of the compressive strength as a function of wet blue shaving (WBS) content in cement/sand composites and curing periods are shown in Fig.9. Compressive strength has been identified to be inversely proportional to the wet blue shaving content and directly proportional to curing period. Obtained results revealed that for all wet blue shaving contents tested, compressive strengths are less than a control sample (0%WBS). This may be due to the additional porosity introduced by wet blue shaving fibers. Similar characteristics of compressive strength with wet blue shaving content have been previously reported in Lakrafli *et al.* (2012) and Morsy & Nasr (2018) (see also Table 3). According to BDS (2009) standards, 1% of WBS blocks can be considered a Grade-A category after 28 days of curing, and 2% WBS blocks can be considered a Grade-B category after 14 days of curing, respectively.

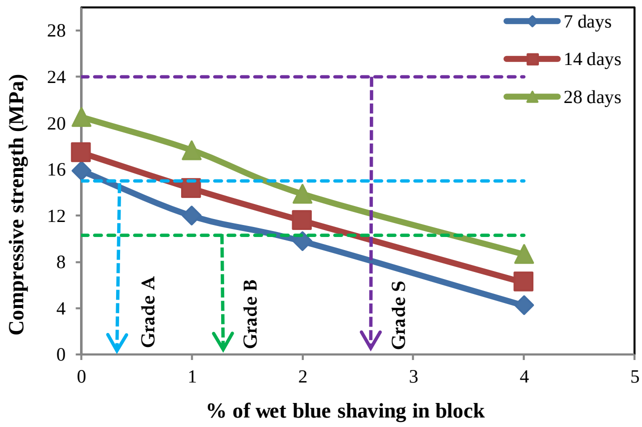

Fig. 9. Relationship between compressive strength and curing periods at varying proportions of wet blue shaving content

Table 3. Performance comparison for different percentages of wet blue shaving incorporated sand-cement blocks with other waste utilization attempts involving wet blue shaving. The % increase/reduction indicates how much the specific parameter changed compared to the reference specimen (i.e. 0%WBS).

Physical and Mechanical properties	Present study		Previous study		
			Chrome tanned leather shaving(CTLS)-gypsum composite specimens (Morsy & Nasr, 2018)	Wet blue shaving on the thermal conductivity of cement and plaster (Lakrafli *et al*., 2012)	
	1% WBS-sand-cement blocks	2% WBS-sand-cement blocks	5% CTLS- gypsum composite specimens	1% WBS-sand-cement blocks	2% WBS-sand-cement blocks
Compressive strength (MPa)	17.65 (13.99% reduction)	13.87 (32.41% reduction)	6.1 (12.86% reduction)	24	17
Water absorption (%)	9.65 (6.65% increase)	11.72 (23.88% increase)	-	-	-
Density (kg/m3)	1680 (27.18% reduction)	1634 (29.17% reduction)	1680 (14.29% reduction)	1950	1800
Specimen weight (kg)	4.13 (27.16% reduction)	4.02 (29.10% reduction)	-	0.52	0.47

* test carried out after 28 days of curing in water.

Cost analysis

The production cost of 100 wet blue shaving composite blocks has been interpreted in Table 4.

Table 4. The total cost of 100 blocks production.

Item of variable costs	Total amount of raw materials	Rate	Cost(BDT/100 Unit)
cement	42.24 kg	500 BDT/50kg	354
sand	5.1984 ft^3	65 BDT/ft^3	338
wet blue shaving	4.27 kg	-	-
transportation	-	-	100
human labor	1	400 BDT/person	400
Item of fixed costs			
tools	-	-	50
gunny bags	1 m^2	50 BDT/m^2	50
Total			1292

*rate of sand and cement was considered in the April, 2022 local market price.

Conclusions

Based on the study, the following conclusion can be drawn:

- Compressive strength decreased and water absorption increased with increase in percentages of WBS addition in the sand-cement blocks but one percent and two percent WBS-sand-cement blocks satisfied the standards of compressive strength and water absorption as per BDS and ASTM, except in the case of four percent WBS-sand-cement blocks.
- Due to lighter weight of the WBS-sand-cement blocks, it is ease to handle as a construction material.
- Two percent of WBS-sand-cement blocks (13.87MPa, after 28-days of curing) introduce as Grade-B category that can be used for a low load bearing wall construction, also a temporary shed, where the intended durability is short.
- The preparation of WBS-sand-cement blocks can be an alternative option for resolving the management problem of wet blue shaving in tannery industry.

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