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Factors Affecting on Handling and Transportation of Biomass Briquettes

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ABSTRACT: *The bulk density, water stability, impact resistance and compressive strength of biomass briquettes are the major factors which affect the handling and transportation characteristics. The briquettes of 40 mm size found more bulk density. During the impact resistance, loss of weight in case of cotton stalk and sunflower stalk briquette is more among 40 mm size and loss of weight of Pigeon Pea Stalk briquette is more among 50 mm and 60 mm size. The 40 mm size diameter briquettes of all types found excellent water resistant as compare to other sizes. The 40 mm size briquettes of cotton Stalk has taken highest compression load to break with value 7.802 kN and 50 mm size briquettes of pigeon pea stalk briquettes has taken lowest compression load to break with value 1.380 kN. This study is useful to preserve energy characteristics of biomass briquettes during their handling and transportation.*

Keywords: *Biomass briquettes, Bulk Density, Compressive Strength, Handling and Transportation of briquettes, Impact Resistance, Water Resistance.*

INTRODUCTION

Currently, there is tremendous interest in using biomass materials for producing liquid transportation fuels, combined heat and power, chemicals, and bio-products. In addition to numerous advantages, use of biomass materials in place of fossil fuels would result in low emissions of greenhouse and acid gases. In order to make the biomass materials available for a variety of applications, the challenges with the use of biomass materials in their original form must be resolved. Because of high moisture content, irregular shape and sizes, and low bulk density, biomass is very difficult to handle, transport, store, and utilize in its original form. One solution to these problems is densification of biomass materials into pellets, briquettes, or cubes. Densification increases the bulk density of biomass from an initial bulk density (including baled density) of 40-200 kg m^3 to a final bulk density of 600-800 kg m^3 [1-4]. Thus, densification of biomass materials could reduce the costs of transportation, handling and storage. Because of uniform shape and sizes, densified products can be easily handled using the standard handling and storage equipment and can be easily adopted in direct combustion or co-firing with coal, gasification, pyrolysis and in other biomass-based conversions [5, 6].

For the success of densification process, the quality of the densified products must meet the consumer requirements and market standards. One of the important quality factors is the amount of fines present in the densified products. Therefore, to avoid fines production, densified products must withstand the rigors of handling and transportation. Forces that cause pellet (or any densified product) damage (i.e., fragmentation and abrasion of pellets) during handling, transportation and storage may be divided into three general classes: compression, impact, and shear. Compression forces result in a crushing action; impact forces result in shattering both on the surface of the pellet and along any natural cleavage planes of the pellet; and shearing forces result in abrasion of pellet edges and surfaces [7].

Therefore, testing the densified products to estimate the amount of damage or fines that could be observed at the point of utilization in terms of strength and durability would help optimize the feed material, pre-conditioning processes and densification

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equipment to produce high quality densified products.

The overall goal of this article is to know about the strength and durability factors which affecting in handling and transportation of biomass briquettes.

MATERIAL AND METHODS

Bulk Density of Biomass Briquettes

A container made of GI sheet with dimensions of 30 cm × 30 cm × 30 cm is chosen for the study. The weight of empty container is measured. The biomass briquettes are filled in to the container randomly and the weight of container with biomass briquettes is measured. The bulk density of biomass briquette is taken as the ratio of mass of briquettes and total volume of briquettes in the container. This procedure is repeated for three times and the average value is taken as the bulk density of the biomass briquettes.

Impact Resistance

Nalladurai *et al.* (2009) have conducted a test to determine the impact resistance of briquettes (or drop resistance or shattering resistance). In that method, briquettes were dropped from 1.85 m, 1.5 m, 1 m height onto a metal plate and concrete surface four times. The remaining mass is expressed as the percentage of the initial mass. It can be concluded that if the percent of the remaining mass is more, the strength of the briquettes is better.

Stability of briquettes against absorption of moisture

Nalladurai *et al.* (2009) have determined the percentage of water absorbed by a briquette when immersed in water that shows the stability of briquettes against moisture absorption. Each briquette was immersed in water for 5 min., 10 min., 15 min. and 20 min. and the ability of the briquettes to retain the original shape was determined.

Compressive Strength of Briquettes

Universal Testing Machine (UTM) UNITEK-9410 was used to find out compressive strength of briquettes (fig. 1). Briquette sample was kept horizontally between the compressing plates of UTM (fig. 3a.). The compressive load on the briquettes was increased gradually. When the first crack occurred on the briquette, the compression stopped automatically and gave the value of ultimate load.

RESULTS AND DISCUSSION

Bulk density

The bulk density of the briquettes made from the five chosen biomass was determined using the rectangular container and true density of briquettes was determined using simple geometric measurement of the individual briquette and the data are furnished in the table. 1.

From the table 1. it can be concluded that as the diameter of briquette decreases, the bulk density and true density increase. Hence, in both the cases,

Figure 1: Universal Testing Machine

Figure 2: Load indicator

Figure 3 (a,b,c,d): Behaviour of briquette during compression

briquettes of 40 mm size are found to contain the highest value of bulk density and true density as compared to 50 mm and 60 mm size. The briquettes of 60 mm size have the lowest value of bulk density. This can be correlated to the fact that as the size increases, the porosity of the briquettes in a container increases.

The bulk density of 40 mm sized briquettes is in the range of 750.0 - 801.5 kg/m^3. The cotton stalk briquette has the highest value and Cumbu Napier grass has the lowest value. The bulk density of 50 mm sized briquettes is in the range of 708.8 - 775.0 kg/m^3. The cotton stalk briquette has the highest and pigeon pea stalk briquettes have the lowest value. The bulk density of 60 mm sized briquettes is in the range of 629.0 - 754.8 kg/m^3. The cotton stalk briquette has the highest and pigeon pea stalk briquette has the lowest value.

The true density, determined by the geometric measurement of 40 mm sized briquettes, is in the range of 1401.10 - 1508.80 kg/m^3. The Cotton Stalk briquette has the highest and Cumbu Napier grass briquette has the lowest value. The true density of 50 mm sized briquettes is in the range of 1236.80 - 1424.10 kg/m^3. The cotton stalk briquettes have the highest and pigeon pea stalk briquette has the lowest value. The true density of 60 mm sized briquettes is in the range of 1110.00- 1314.40 kg/m^3. The cotton stalk briquette has the highest and pigeon pea stalk briquette has the lowest value.

It can be concluded that irrespective of the size of briquette, cotton stalk briquette has the highest value and pigeon pea stalk has the lowest value of true density. This may be attributed to the more fibrous and flexible nature of the pigeon pea stalk when compared to the other four biomass materials.

The density of briquettes depends on the density of loose biomass and binder (if used), briquetting process and the amount of pressure applied during the manufacture. The briquettes produced from biomass (Singh *et al.*, 1983) showed that their true density increased with pressure and it varied with different binding materials. Cotton stalk had the highest bulk density of 191 kg/m^3 and pigeon pea stalk had the lower bulk density of 186 kg/m^3.

Table 1
Bulk density of biomass briquettes

Briquette feedstock	*Size, mm*	*True density, kg/m^3*	*Bulk density, kg/m^3*
cotton stalk	40	1508.80	801.5
	50	1424.10	775.0
	60	1314.40	754.8
sunflower stalk	40	1425.00	766.3
	50	1396.80	760.1
	60	1174.20	702.0
Cumbu Napier grass	40	1401.10	750.0
	50	1304.80	720.8
	60	1121.60	672.9
pigeon pea stalk	40	1456.30	783.5
	50	1236.80	708.8
	60	1110.00	629.0
ground nut shell	40	1435.60	755.5
	50	1411.90	740.7
	60	1167.10	733.4

Impact resistance

For the test of impact resistance, the metal plate surface was used to drop the briquette from the heights of 1.85 m and 1 m. the values shown in the percent weight remained for the briquettes after dropping from the heights of 1.85 m and 1 m. The loss of weight in the 40 mm, 50 mm and 60 mm size briquette from the height of 1 m and 1.85 m, lies in the range of 0.02 - 0.21 per cent & 0.10 - 0.80 per cent, 0.04 - 0.41 per cent & 0.18 - 6.69 per cent and 0.03 - 0.11 per cent & 0.10 - 1.36 per cent respectively. From the Fig. 3 and 4, we concluded that as the height of dropping briquette decrease, the loss percent of weight is also decreases accordingly. From the above study it can be concluded that in the comparison among 40 mm size briquettes, cotton stalk briquettes lost maximum weight in the case of 1 m of height and sunflower stalk briquettes lost maximum weight in the case of 1.85 m of height. But in the comparison among 50 mm & 60 mm size briquettes, pigeon pea stalk briquettes lost maximum weight in the case of both the heights.

The impact resistance test may simulate the forces encountered during emptying of densified products from the truck on the ground or from chutes into the bins. Pietsch (1997) suggested that drop tests could be used to determine the safe height of pellet production. Shrivastava *et al.* (1981) and Nalladurai *et al.* (2009) used a drop resistance test to determine the durability of biomass pellets and briquettes.

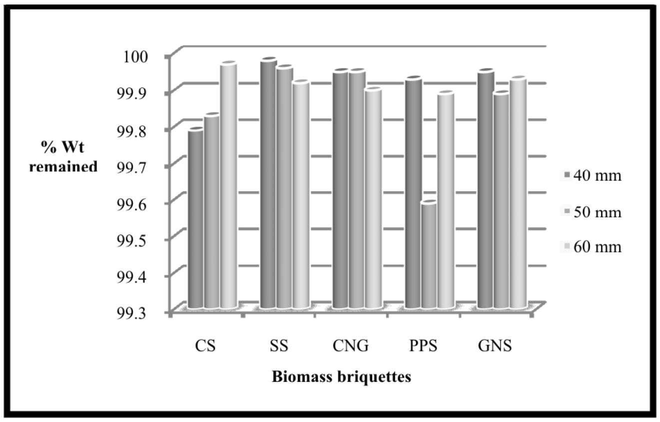

Figure 3: Briquettes dropped from height 1 m.

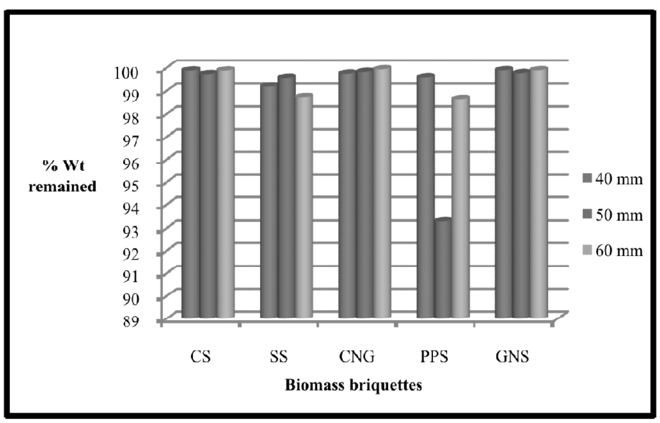

Figure 4: Briquettes dropped from Height 1.85 m.

Stability of the briquettes against the absorption of water

The stability of the briquettes against the absorption of water is shown in the Fig. 5. The water stability is the test in which briquette samples were kept in the water for 15 minutes. The duration in which briquette started to lose its shape and started to disperse its particles in water is measured. It can be concluded that the cotton stalk briquettes found to be "Excellent" in all three sizes, where as the groundnut shell briquettes are found to be "Excellent" in the case of 40 mm and 50 mm size and is found to be "Good" in the case of 60 mm size. The 40 mm size briquettes of Cumbu Napier grass, sunflower stalk and pigeon pea stalk are found to be "Excellent" and 50 mm and 60 mm size briquettes are found to be "Bad" in water stability test. The cotton stalk briquettes had less numbers of pores hence the water quantity entered in the briquette was very less as compared to the other types of briquettes. In the case of Cumbu Napier grass, sunflower stalk and pigeon pea stalk, briquettes had more pores and hence water entered in the pores and it dispersed the particles.

Short term exposure to rain or high humidity conditions during transportation and storage could adversely affect the quality of the densified products. Lindley and Vossoughi (1989) measured the water resistance as the percentage of water absorbed by a briquette (50-mm diameter and 18-mm thick) when immersed in water. Fasina and Sokhansanj (1996) determined the effect of relative humidity of the environment on the strength and durability of the pellets.

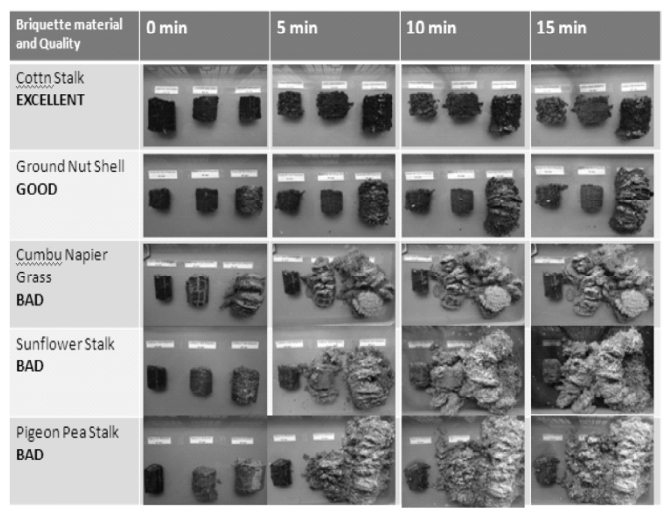

Figure 5: Water Resistance of Briquettes

Compressive strength of biomass briquettes

The compression load on different briquette and their sizes is shown in the Fig. 3a. The graph is drawn between the displacement of the pressure plate surface on the briquette sample and compression load (Fig. 6). The graph indicates that the value of compression load at which briquette is broken. The rising part of curve shows that compression load increases with the displacement of plate surface without any breakage of briquette. The downward movement of the curve shows the ultimate load value at which briquette is broken.

From the Table 2, we can conclude that maximum force required to break the briquette is in the range of 1.380 - 7.802 kN. We found the briquettes of 40 mm size require highest maximum force to break and briquettes of 50 mm size required lowest maximum force to break. The briquettes of cotton stalk of 40 mm size required highest maximum force of 7.802 kN and briquettes of pigeon pea stalk of 50 mm size required lowest maximum force of 1.380 kN to break. Here we can conclude that cotton stalk of 40 mm size briquettes are of better hardness quality and briquettes of pigeon pea stalk of 50 mm size have bad hardness quality as compared to other types.

The compressive resistance (or crushing resistance or hardness) is the maximum crushing load a briquette can withstand before cracking or breaking. The compressive resistance of the densified products is determined by diametrical compression test. A single briquette is placed between two flat, parallel plates which have facial areas greater than the projected area of the briquette. An increasing load is applied at a constant rate, until the test specimen fails by cracking or braking. Compressive resistance test simulates the compressive stress due to weight of the top briquettes on the lower briquettes during storage (Nalladurai, 2009).

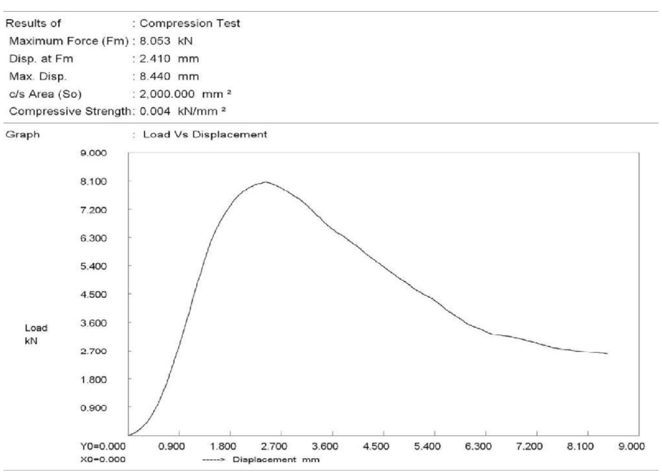

Figure 6: The compression test of biomass briquettes

Table 2
Maximum force required to break the briquette

Size, (mm)	*Maximum force, kN*				
	Cotton Stalk briquettes	*Groundnut Shell briquettes*	*Cumbu Napier Grass briquettes*	*Sunflower Stalk briquettes*	*Pigeon Pea Stalk briquettes*
40	7.802	7.235	7.565	5.941	2.734
50	6.848	6.262	5.058	4.734	1.380
60	7.584	6.695	6.182	5.234	2.907

CONCLUSION

The cotton stalk briquettes of 40 mm size has found highest bulk density and pigeon pea stalk briquettes of 60 mm size has found lowest bulk density. As per as impact resistance is concerned in the comparison among 40 mm size briquettes, cotton stalk briquettes lost more weight in the case of 1 m of height & sunflower stalk briquettes lost more weight in the case of 1.85 m of height. But in the comparison among 50 mm & 60 mm size briquettes, pigeon pea stalk briquettes lost highest weight in the case of both the heights. The cotton stalk briquettes of all sizes have found better water resistance characteristics. The compression load of briquettes at which they started to break their shape was up to 7.802 kN.

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