Influence of Size and Shape on the Strength of Briquettes*

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ABSTRACT

Char fines obtained from low temperature carbonization of a non-caking coal were subjected to surface dressing with addition of water and briquetted using 2 wt.% of starch-based compound binder on the char fines to make cylindrical and ovoid or pillow-shaped briquettes in a hydraulic and a roll press. The compression strength of the cylindrical briquettes was determined by placing them in different positions, in between the plates giving rise to surface, line and point contacts. It was observed that surface compression strength of cylindrical briquettes is generally about 10 times the strength in the other two positions. The strength of ovoid or pillow shaped briquettes did not depend on the dimensions or weight of the briquettes. The point compression strength of such briquettes was found to be about one-fifth the surface compression strength of the corresponding cylindrical briquettes of the same composition.

INTRODUCTION

Briquetting of coal fines and char fines from coal and lignite, coke breeze, charcoal fines and similar materials is an important industry for producing shaped fuel for several purposes — as a source of heat in industries as a smokeless domestic fuel on open grates of ovens and for space heating in Europe. Formed coke made from non-caking coal for use in blast furnace also involves briquetting of char fines and further processing of the briquettes.

Briquettes are made in different shapes and sizes — rectangular, ovoid, cylindrical, tetrahedral (i.e., quarter-orange), pillow and rational. There are no accepted standards for testing the strength of the briquettes though a shatter test, which is employed basically for testing coke, can be adopted with certain limitations to size and quantity of coke. Simple compression or crushing strength apparatus of briquettes, commercially used by almost all briquette manufacturers for on-the-spot testing and to know hardness and the strength for handling and transportation purposes, also lacks a standard system for

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international comparison and correlation. The resistance to crushing was determined in France by means of a Roman balance [1], which was an automatic press having two parallel and flat plates. The briquette was placed between them, and pressure applied. The load was read on a dial gauge. The Komarek-Greaves [2] tester consisting of an anvil and a spring-loaded plunger, operated by a hand wheel is used in the U.S.A. The compressive load exerted by the spring is indicated by a pointer, on a gauge, calibrated in pounds (0.453 kg).

Rieschel [3] tried to explain the difference between the compression and crushing or breaking strength of briquettes in a rational way. The compression strength (in kg/cm$^2$) is determined by crushing the egg- or pillow-shaped briquettes between two plane-parallel faces. Egg- or pillow-shaped briquettes have to be face-ground before tested. However, investigations by Rammler and Metzner [4] have shown that the ascertained strength corresponds to the actual internal briquette strength based on definite assumptions. The factors that influence the strength are the height, volume, mass as well as the dimensions of the briquette in relation to the area of the test ram and its compression speed. The crushing or breaking strength, is ascertained by destroying the briquette between two stamps. The load occurs according to the elastic behaviour of the briquettes more or less in points. The strength is indicated as the load in kg at the point of failure. A defined rupture occurs only in brittle briquettes. However, some bitumen-bound briquettes or briquettes made of clay, with an extensive plastic behaviour only deform and lose shape and hence no definite ultimate or breaking load can be measured.

Mochida and Honda [5] emphasized that the hardness of briquette is related to the mechanical properties, especially elastic and plastic properties of coal. Further, non-uniformity in a briquette (as measured by Brinell hardness Number) always exists irrespective of its shape but in cylindrical briquettes compacted in a single direction, the maximum hardness or maximum density is found in the upper portion of the cylinder near the die wall, while in the lower portion a zone of maximum hardness occurs at the centre. As such the friction effect between the powders and the die walls is the main cause of the non-uniformity in briquettes.

When ovoid- or pillow-shaped briquettes are compressed by the flat surfaces of the plunger and anvil, the load cannot be expressed as pounds per square inch because the reading of the resistance to crushing is affected by the shape and dimensions of the briquette. Therefore, comparison between briquettes of different shapes must be obtained by the method used by Parry and Goodman [6], i.e., filling parallel surfaces on the briquette to be tested or by cutting samples of cylindrical shape and standard dimensions from the briquettes to be tested.

In this paper, an attempt is made to correlate different aspects (point, line and surface contacts) of breaking strength with size and shape of the briquettes made in the laboratory and pilot plant.
MATERIALS AND METHODS

Raw materials

Char fines (\(<3\) mm) from low temperature carbonization of Singareni coal at \(650^\circ\text{C}\) were subjected to a surface dressing operation [7] in an edge runner after addition of binder fluid (2 wt.% starch-based compound binder containing water to the extent of 20 wt.% on char fines [8]) and run for half an hour. Then the briquette was air-dried and used.

The irregular shape of char particles is always accompanied with a number of surface imperfections such as micro/macro cracks, sharp and weak edges, pits etc. These in turn render the particulates weak and defective and yield low strength when formed into briquettes. This drawback could be controlled by adopting the surface dressing technique. The principle behind this dressing lies in the fact that under the load of the roller of the edge runner and also in the presence of the fluid-binder along with char fines (which acts as a lubricant), the particulates get stripped off their sharp and weak edges, pits etc. rather than being simply crushed. This effectively resulted in increase in the bulk density and decrease in per cent crumbling, void fraction and surface area of char fines which means more spheroidal particulates with less surface defects. Thus the aim of improving the strength of briquettes at low binder contents could be fulfilled effectively.

Methodology

Briquettes were made both in laboratory (500 g scale) and pilot plant (40 kg scale). Surface dressed char fines were mixed with 2 wt.% starch-based compound binder kept at 70–75°C and briquetted by applying a pressure of 310 kg/cm² in a hydraulic press and in the 500 kg per hour briquetting pilot plant. In the pilot plant, experiments on ovoid or pillow-shaped briquettes were done by installing suitable briquetting rolls. The raw briquettes were dried in an air-oven at 110°C for 6 h, cooled and then tested for strength. While making briquettes in the pilot plant, a portion (1–2 kg) of the hot fuel-binder mix was taken out and simultaneously cylindrical briquettes were made in the hydraulic press for comparison of strength.

In the hydraulic press, cylindrical shaped briquettes of 29 and 57 mm diameters were made with increased weights of fuel-binder mix which resulted in increasing length of briquettes. In the pilot plant, small ovoids (length: 50 mm, breadth: 40 mm, thickness: 25 mm and weight: 29 g) and big ovoids (70 mm, 50 mm, 40 mm and 78 g) and pillow-shaped briquettes (55 mm, 40 mm, 30 mm, and 42 g) were made respectively.
Testing procedure

The compression strength, i.e., the pressure at which the briquettes break or fracture, was measured by using the machine shown in Fig. 1. This works on the principle of continuous development of hydraulic pressure which ultimately causes fracture of the briquettes. As indicated in the photograph, when the hand wheel ‘A’ is rotated clockwise, the oil from the side arm ‘B’ is forced continuously into the cylinder ‘C’ and the hydraulic pressure is developed in the oil contained in the cylinder. This, in turn, lifts a piston having a cross sectional area of exactly $64.5 \text{ cm}^2$ (or alternately $6.45 \text{ cm}^2$) depending on the adjustment of the screw ‘S’. The increase in the hydraulic pressure is registered simultaneously, in the dial ‘D’. The movement of the piston lifts the plate ‘E’ and transfers the pressure to the briquette under test.

The briquette to be tested is kept between the plates ‘E’ and ‘F’. The plate ‘F’ can be raised, or lowered to fix the briquette. After keeping the briquette in position, the movement of the plate ‘F’ is stopped by tightening the screw ‘G’ without causing any strain on the briquette, under test. The hand wheel ‘A’ is now rotated clockwise, continuously and uniformly at regular movement and the pressure at which the briquette fractures is recorded from the dial ‘D’. Twelve briquettes were tested from each sample [9] and after rejecting the highest and the lowest readings, the average of the remaining ten is taken as

![Fig. 1. Compression testing machine.](image-url)
the strength of sample. The piston of 6.45 cm² cross sectional area was used when the strength of the briquettes was less than 20.7 kg/cm² and the 64.5 cm² piston when the strength registered was generally above 17 kg/cm².

The ovoid and pillow-shaped briquettes gave the strength mostly resulting from point compression due to point contacts involved, whereas the cylindrical briquettes because of surface contacts as much indicated surface compression strength. The following strengths of briquettes, produced in the laboratory (i.e., cylindrical) and pilot plant (i.e., ovoid and pillow) were determined by placing them in different positions in between the plates of the machine. For instance, cylindrical briquettes were tested in three ways (Fig. 2):

(i) Axially vertical (i.e., surface compression), and; (ii) Laterally horizontal (i.e., line compression), and (iii) Axially vertical with two balls placed on the top and bottom (i.e., point compression).

Similarly ovoid and pillow-shaped briquettes were also tested in three ways (Fig. 3):

(i) Flat-horizontal (i.e., point compression), (ii) Longitudinally vertical (i.e., point/line compression), and (iii) Laterally horizontal at seam (i.e., point/line compression).
In order to test the reproducibility of results, several sets of briquettes, under identical conditions, were prepared and tested. The maximum deviation from the average value of the strength of air-oven dried briquettes was found to be ±5%. This was therefore considered satisfactory for the measurement of strength of briquettes.

RESULTS AND DISCUSSION

The data on cylindrical briquettes made at 310 kg/cm² pressure in the laboratory (500 g scale) by using low temperature (L.T.) char fines and 2 wt.% starch-based compound binder are presented in Table 1. The strength (in kg/cm²) is indicated as surface, line and point compression depending on the three different positions (as illustrated above) in which the briquette is inserted between the plates of the testing machine. The following observations can be made on the behaviour of cylindrical briquettes.

(i) The surface compression strength increases with decreasing length or in other words with decreasing length/diameter \((L/D)\) ratio of the briquettes (Fig. 4). This is understandable, as the same pressure of 310 kg/cm² is being applied to a smaller weight of briquettes but with the same diameter or to a briquette with smaller lengths. The smaller the length (or half length, \(L/2\)) of briquette the denser will be the packing and according to Mochida and Honda

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Briquette dimension</th>
<th>Compression strength (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (g)</td>
<td>Length (mm)</td>
</tr>
<tr>
<td>1</td>
<td>8.50</td>
<td>11.00</td>
</tr>
<tr>
<td>2</td>
<td>12.50</td>
<td>16.25</td>
</tr>
<tr>
<td>3</td>
<td>16.75</td>
<td>22.25</td>
</tr>
<tr>
<td>4</td>
<td>20.40</td>
<td>27.25</td>
</tr>
<tr>
<td>5</td>
<td>23.91</td>
<td>32.25</td>
</tr>
<tr>
<td>6</td>
<td>32.35</td>
<td>43.00</td>
</tr>
<tr>
<td>Mean value of strength</td>
<td>95</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>47.50</td>
<td>16.00</td>
</tr>
<tr>
<td>8</td>
<td>62.75</td>
<td>21.08</td>
</tr>
<tr>
<td>9</td>
<td>95.49</td>
<td>32.31</td>
</tr>
<tr>
<td>10</td>
<td>143.66</td>
<td>47.97</td>
</tr>
<tr>
<td>Mean value of strength</td>
<td>195</td>
<td>19</td>
</tr>
</tbody>
</table>
Fig. 4. Cylindrical briquettes of varying heights/lengths under testing of strength.

Fig. 5. Cylindrical briquettes under stress during testing of strength.

[5], the harder the briquette, the higher will be its breaking strength which decreases as \( L/2 \) of the briquette increases for the same diameter.

(ii) Irrespective of the diameter, these cylindrical briquettes show similar trends with respect to their strength with increasing weights of briquettes having the same diameter (Table 1). The mean value of the surface compression strength (Axially vertical) is about 10 times that of the line compression and point compression strength of these cylindrical briquettes. This type of behaviour may be attributed to the greater contact area in between the plates and briquettes and also to the fact that the entire mass of briquette has an opportunity to get compressed and crushed ultimately. In this process of breakage, strong but equal stresses (vertical-ups) (Fig. 5) arise to oppose the action of the pressure-plate but without any effect and ultimately fracture occurs. The same action may not occur when the briquette to be tested is kept in the latter two positions, i.e., line or point compression when the action of briquettes to nullify the applied force is definitely weak on account of scattered pressure-lines inside the mass. This is the reason why the strength recorded, while the briquettes undergo line or point contact, is found to be low.

When cylindrical briquettes are tested by keeping two steel balls (diameter: 1 cm) at top and bottom of the briquettes but underneath the pressure-plates, the transmission of both the applied pressure as well as the opposing force from inside the briquette becomes difficult and indirect and therefore the recorded strength will not be necessarily true. Rather it is found to be low when compared with the point compression strength of ovoid or pillow-shaped briquettes made from the same composition. That means whenever such an exercise with
the help of balls is done to measure the strength of cylindrical briquettes it may not entirely depict the point compression. The terminology of point compression strength for ovoid or pillow-shaped briquettes, however, seems to be appropriate and reasonable from the point of view that during testing, the entire pressure-plates touch the rounded surface of the briquette at one point only and allow exchange of applied pressure (force) and opposing stress lines directly and freely.

The method of testing cylindrical briquettes may be restricted either to axially vertical (i.e., surface compression) or laterally horizontal (i.e., line compression) for knowing the strength. The surface compression strength is usually about 10 times that of the line compression.

With regard to briquettes produced in the pilot plant, irrespective of their size and shape (i.e., ovoid - small or big - and pillow-shape), Table 2 and the Plot of Fig. 6 (between the point compression strength (kg/cm² and the ratio W/Th, i.e., weight of briquette per unit thickness), reveals interesting data.

For all shapes and sizes of briquettes tested, in different positions flat-horizontal (i.e., point compression), longitudinally vertical (i.e., point/line compression) and laterally horizontal at seam (i.e., point/line compression), surprisingly show the same point compression strength of 20 kg/cm². This strength of briquettes is to be considered reasonably adequate in handling and transportation, when the briquettes are used for domestic fuel purposes.

When a portion (1–2 kg) of fuel–binder mix withdrawn from a pilot plant run was used for making cylindrical briquettes \((L/D=1.0)\) in the laboratory and these dried briquettes were tested in axially vertical position, the surface

![Fig. 6. Relation between weight/unit thickness and strength of briquettes made in pilot plant.](image-url)
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Briquette Shape Size (mm)</th>
<th>Briquette Dimensions</th>
<th>Compression Strength (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Weight (g)</td>
<td>Length (mm)</td>
</tr>
<tr>
<td>1.</td>
<td>Ovoid (small) 50 × 40 × 25</td>
<td>28.8</td>
<td>52.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Ovoid (big) 70 × 50 × 40</td>
<td>78.5</td>
<td>72.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Pillow 55 × 40 × 30</td>
<td>42.42</td>
<td>56.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 3

Data on cylindrical briquettes made in the laboratory from the char–binder mix drawn from pilot plant runs

<table>
<thead>
<tr>
<th>Briquette dimensions</th>
<th>Strength (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>Length (mm)</td>
</tr>
<tr>
<td>22.5</td>
<td>29.0</td>
</tr>
<tr>
<td>23.08</td>
<td>29.0</td>
</tr>
<tr>
<td>23.25</td>
<td>28.27</td>
</tr>
</tbody>
</table>

⁷Weight/thickness = 0.77.
⁸Weight/thickness = 0.793.
⁹Weight/thickness = 0.822.

The point compression strength of the ovoid or pillow-shaped briquettes was found to be one-fifth the surface compression strength of cylindrical briquettes. This factor of 5 in between the surface and point compression strength of briquettes corresponds fairly well with the observation of Agrawal [10]. These data therefore indicate that without going through large-scale trials for manufacturing a specified type of briquette, one can predict the quality of briquette from bench-scale experiments only.

CONCLUSIONS

Surface dressed L.T. char fines mixed with 2 wt.% starch-based compound binder, pressed at 310 kg/cm² into cylindrical, ovoid- or pillow-shaped briquettes irrespective of the size, air-oven dried at 110°C for 6 h and tested for their compression strength behave in the following manner:

(i) The surface compression strength of cylindrical briquettes increases with decreasing length, or in other words with decreasing $L/D$ ratio of briquettes.

(ii) The surface compression strength of cylindrical briquettes is about 10 times the line and point compression strengths.

(iii) (a) The ovoid- or pillow-shaped briquettes of any size produced in a pilot plant from L.T. char fines surprisingly show their point compression strength to be the same, i.e., 20 kg/cm².

(b) Briquettes (of similar composition), produced simultaneously both at pilot plant (ovoid/pillow-shaped) and at laboratory scale (cylindrical) differ a factor of 5 in their point and surface compression strengths, the point compression strength being one-fifth the surface compression.
ACKNOWLEDGEMENT

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REFERENCES


*The Regional Research Laboratory has been renamed to Indian Institute of Chemical Technology as per April 1989.