Effectively briquetting carbonaceous materials (including coal, char, and charcoal made from coal, sawdust, and various types of biomass and agricultural wastes) and steel wastes typically requires a binder such as starch, cement, molasses, lime, or some combination of these to hold the briquette together and improve its durability. Binders have been used to briquette coal and charcoal for more than 100 years. Using cement to bind wastes from steel-making operations is a more recent application. In this column, I’ll discuss the different types of binders used to briquette carbonaceous materials and steel wastes and what you should consider when selecting a binder for your briquetting application.

The key to a suitable binder is its cost-effectiveness. Starch, cement, molasses, and lime are widely used because they’re inexpensive and readily available. Other binders, such as alkali cellulose or phenol aldehyde resins, may offer improved performance or additional benefits, but they often cost more and may be less readily available because of location or supply constraints.

A company will typically use the most cost-effective binder in the smallest concentration that will produce briquettes with acceptable durability and weathering characteristics. Durability is especially important for steel-waste briquettes, which need to hold together under high-temperature and reducing conditions. When the briquetted product can command a premium price, there’s more flexibility regarding the binder type and concentration. Nickel fines are often briquetted using a small amount of expensive organic liquid binder and sold on the London metal exchange, for example, and in barbecue briquettes — which are typically only affordable in the US and other developed and oil-rich countries — the starch binder can cost 10 times as much as the charcoal or char.

Background on binders

Starch came into prominence as a binder for coal and charcoal in the 19th century with the large-scale development of briquetting. In England in 1858, John Piddington received a patent for using 36 pounds of starch along with 8 percent water per ton of coal. In 1897, in Pennsylvania, Ellsworth Zwoyer patented a process for briquetting coal fines with a starch binder and set up plants in New York and Massachusetts. Henry Ford and E. G. Kingsford had greater success in the 1920s using wood waste from Ford’s automobile plant to make charcoal pillow briquettes based on a process patented by University of Oregon chemist Orin Stafford. The operation later became the Kingsford Company, and starch is still used today as a binder for barbecue briquettes.

Common starches used as binders include maize (corn starch), potato, and wheat, but less-common starches derived from rice and tapioca are also used. Typically, a starch needs to be gelatinized by thorough cooking in water at 55°C to 85°C (131°F to 185°F), depending on the starch. This
disrupts the intermolecular bonds, creating hydrogen-bonding sites for attaching additional water molecules and making the starch soluble in cold water. After cooking, the starch is dried in a spray dryer, drum dryer, or extruder. You can buy pregelatinized starch, but it’s substantially more expensive than raw starch.

Cement was used as a binder thousands of years ago by the Egyptians, Greeks, and Romans, but its use expanded greatly during the industrial revolution. A key factor was Isaac Johnson’s development in 1845 of modern Portland cement by firing a mixture of chalk and clay at 1,400°C to 1,550°C (2,552°F to 2,822°F). Cement was later used as a binder for briquetting coal, char, and charcoal and subsequently for briquetting iron and steel wastes.

Molasses has long been used on its own or with lime — particularly slaked lime (calcium hydroxide [Ca(OH)_2]) — to briquette coal and similar materials as well as steel wastes. Derived from sugarcane or beets, molasses’ composition can vary widely depending on where the plant was grown, how it was processed, and seasonal factors. Molasses is highly viscous but becomes more fluid when heated, allowing it to be more easily mixed with slaked lime prior to briquetting coal or char fines. Typically, a binder’s ratio of molasses to lime is between 2-to-1 and 4-to-1.

Binder types

Binders have been classified in many ways, including by binding mechanism (molecular forces, electrostatic forces, magnetic forces, or free chemical bonds), physical state (liquid, semisolid, or solid), function (matrix or film), chemical type (organic, inorganic, or compound), and behavior. In 1983, Carl A. Holley outlined the following comprehensive five-group classification system and listed several examples of materials in each group.

Inactive film. An inactive film binder is typically a liquid solution that uses surface tension to pull the material’s particles together. It can also be a dry solid that’s mixed thoroughly with the material to be briquetted before a solvent, such as water or alcohol, is added. In this case, the solid acts as both lubricant and glue, forming a solid bridge between particles when the solvent dries. Examples of inactive film binders are water, alcohol, oils, various starches (maize, tapioca, potato), wheat flour, molasses, casein, glucose, dextrin, alginates, and gum arabic.

Chemical film. A chemical film binder coats a material’s particles with a thin film and causes a brief chemical reaction that bonds the particles together. The resulting briquette is often waterproof when a chemical film binder is used. Examples include sodium silicate and dilute acid and sodium silicate and lime.

Inactive matrix. An inactive matrix binder embeds the material to be briquetted in a matrix (or framework) of binder. Some inactive matrix binders, such as coal tar pitch, need to be heated to reduce their viscosity during briquetting but will then set hard when allowed to cool. Examples of inactive matrix binders are petroleum asphalt, carnauba wax, paraffin, wood tar, colloidal alumina, and metal stearate.

Chemical matrix. A chemical matrix binder uses a chemical reaction between two binder components to bind the material’s particles together. Examples are quick lime (calcium oxide [CaO]) and water, molasses and slaked lime, Portland cement and water, and plaster of Paris.

Chemical reaction. A chemical reaction binder uses a chemical reaction to form a strong bond between the binder and the particles to be briquetted. Examples include electric furnace dust mixed with a water and quick-lime binder and fly ash (which contains lime) from a power plant mixed with water. A reagent such as dilute sulfuric or phosphoric acid is
sometimes added to improve the cured briquette’s strength.

Selecting a binder

Your material’s characteristics, including average particle size, particle size distribution, moisture content, and binding characteristics, influence which binder will work best for your application.

A material with a wide particle size distribution, for example, will tend to bind more easily than a material with a narrow particle size distribution because smaller particles fill the gaps between larger particles. For some applications, precompacting your material will release trapped air and reduce the gaps between particles.

Water can be integral to the binding process, either directly, as part of the binder formula, or indirectly, as a flow aid to help distribute the binder evenly throughout the material to be briquetted. In either case, your material’s moisture level, both before and after binder is added, will affect the resulting briquette’s “green” (uncured) strength. The ideal moisture level depends on the agglomeration process and the binder. For bituminous and subbituminous coal, for example, the mixture’s moisture content before briquetting in a double-roll press can range from 8 to 12 percent.

Optimal binder concentration depends on the binder type, the material’s characteristics, and the characteristics of any added components, such as biomass. Using pregelatinized starch to bind bituminous coal fines, for example, I’ve been able to use as little as 2 percent binder by weight. In another study with coal chars, the starch amount ranged from 2 to 7 percent, with strong briquettes produced at 4 percent. I’ve achieved acceptably strong and waterproof coal and char briquettes using binder mixtures from 6 percent molasses and 3 percent slaked lime up to 10 percent molasses and 5 percent slaked lime.

To determine the best binder type and amount for your application, you should test various options using your material, asking the following questions:

- Is the briquette strong, durable, and weather resistant?
- Is the binder environmentally benign and compatible with your material?
- Is the binder easily and plentifully available?
- Is the binder effective at a reasonably low concentration?
- Is the binder cost-effective in relation to the briquettes’ expected selling price?

Your material’s characteristics and the binder type will also affect the briquettes’ curing time and method. For example, coal briquettes with calcium aluminate binder — a type of hydraulic cement formed by sintering quick lime and alumina — cure rapidly, while coal briquettes with molasses and lime binder cure more slowly.

For further reading

Find more information on agglomeration and binders in articles listed under “Agglomeration” in Powder and Bulk Engineering’s article index (in the December 2014 issue and at www.powderbulk.com).

References


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