Binders are required in some types of bulk solids agglomeration to produce strong final agglomerates. By permanently bonding particles, a binder allows the agglomerates to withstand the rigors of storage, handling, packaging, and shipping. This article first discusses binder types and their applications, then explains how to select a binder for your process. The article also discusses lubricants, another common agglomeration additive.

Binders: How they work and how to select one

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The term agglomeration commonly describes all size enlargement methods that gather fine, intermediate, and even coarse particles into larger masses. In agglomeration, binding forces must act between individual particles. Several binding mechanisms exist: solid bridges, liquid bridges (interfacial forces and capillary pressure at freely movable surfaces), viscous bonding (adhesion and cohesion forces in binders that aren’t freely movable), attraction forces between solid particles, and interlocking particles (form-closed bonds).
The expressions binding force and binder can mean either an inherent, built-in component of or an additive to particles that provides bonding between them. When a material contains a built-in binder such as a resin, wax, or wood lignin, the material is considered to be self-binding. Compaction methods that use pressure alone — such as briquetting — can compact these materials into strong final agglomerates without requiring that you add a binder. In some processes, you can use heat before or during compaction to activate the material’s built-in binder. 

[Editor’s note: See the article “Using a roller press to compact your low-moisture byproducts for recycling” in the July 2001 issue for more information on compaction. See also the references listed at the end of this article in the “For further information” section.]

Even in tumble-and-growth agglomeration, a process in which very fine particles are pelletized, balled, or granulated without applying external pressure to the particles, adding a binder isn’t always required. In this type of agglomeration, you can pre-grind spherical particles into irregular particles to help them pack better and aid agglomeration. You can also allow binderless tumble- and-growth agglomeration by using two-stage processing, in which the fine particles are pre-conditioned by adding a liquid before they are agglomerated.

However, if your material can’t be agglomerated without adding a binder, you need to select a binder that will give the final product enough strength to withstand future handling, including packaging, shipping, short- and long-term storage, and in-process use. Your binder choice is important because adding a binder to your material can constitute as much as 50 percent of your total processing cost. In fact, whether you find a cost-effective, efficient, compatible binder for your material can determine the success or failure of your agglomeration process and final product.

**Binder types**

Binders can be classified by physical state, chemical type, or function:

- The physical states include liquid (such as water, oil, and sodium silicate), solid (such as bentonite and corn starch), and semi-solid (such as tar).

- The chemical types include organic — both hydrophobic (such as tar, pitch, and bitumen) and hydrophilic (such as starch, lignosulfonate, and molasses) — and inorganic — both insoluble (such as cement, clay, and lime) and water-soluble (such as sodium silicate).

- The functions include that of a matrix binder (such as tar, pitch, and cement), film binder (such as water, starch gel, and bentonite), and chemical binder (such as two-component binders like molasses combined with hydrated lime, sodium silicate combined with carbon dioxide, and magnesium oxide combined with magnesium chloride).

These binder types and functions were first defined by K.R. Komarek. He describes matrix, film, and chemical binders as follows: A matrix binder embeds the particles in a continuous matrix of hardening binder. This mechanism requires a higher percentage of binder than other types. Tar and bitumen coal briquets, cement in concrete aggregate, and asphalt ready-mix are examples. A film binder coats the particles with a film and is most often used in tumble and growth agglomeration. Examples are water, alcohol, solutions or dispersions, and solvents.

A chemical binder affects agglomerate strength by chemical reaction between two binder components or between the binder and material. Examples are a molasses-with-hydrated-lime binder (used in briquetting ores, minerals, and by-products) and acids, pre-reacted solutions, and ammonia (used in granulating N-P-K fertilizer). Another chemical reaction binder is a silica-calcium-magnesium cementitious binder compound used in hydrothermal processes; this is also considered a cold-bonding or self-curing binder.

**Binder applications**

Many different binders of various physical states, chemical types, and functions are available to handle a range of agglomeration applications.

**General-use binders.** Some common binders that are well-documented in industrial reference books and commonly used in agglomeration equipment supplier’s labs are listed in Table I. Some are used in high-tonnage mineral and chemical applications, and other, more expensive binders are used in specialty chemical, pharmaceutical, food, and other applications. Some recently developed specialty binders are listed in Table II.

**Pharmaceutical granulation and tableting.** Binders play an especially critical role in preparing pharmaceutical compounds. The binders aid in milling, mixing, wet tumble-and-growth granulation, dry compaction-granulation, and tableting.

A pharmaceutical product’s active ingredient — that is, the drug dosage — is only one part of the product. Most of the product is made up of an excipient, an inert substance that gives the product its desired form or consistency. An excipient contains bulking agents or fillers as well as functional additives. These additives can be binders, disintegrants, stabilizers, colorants, pH modifiers, release-rate modifiers, and lubricants. For successful granulating and tableting, you
must carefully select and control each additive for its compatibility with the active ingredient and its particle size, density, viscosity, surface tension, solubility, and purity.

Common pharmaceutical binders include sucrose, glucose, sorbitol, acacia, alginic acid, sodium alginate, gelatin, starch, ethyl cellulose, methyl cellulose, polyvinyl pyrrolidone, polyvinyl alcohol, and ethylene glycol, lactose, dicalcium phosphate, crospovidone, and croscarmellose. Some of the same binders that are applied in pharmaceutical granulation and tableting are used — often in less pure forms — in other agglomeration applications, including minerals, fuels, and bulk chemicals. Despite their obvious differences in quality control standards and operating mode (with pharmaceutical granulation and tableting operating in batch mode and most high-tonnage agglomeration applications in continuous mode), both pharmaceutical and high-tonnage agglomeration applications may require similar processing equipment and flow schemes.

Factors to consider when selecting a binder

You need to consider your process, the environment, cost, and post-treatment when selecting a binder.
**Processing, environmental, and cost factors.** Processing factors to consider are the binder’s bulk density, viscosity, pH value, adhesiveness, solubility, color, and odor. You also need to consider the particle size of the material you’ll be agglomerating.

Environmental factors can also play a role. For example, in coal briquetting, a binder that contains sulfur or ash can increase the coal’s sulfur and ash content; this can cause these components to be released into the environment at unacceptable levels when the coal is burned.

Cost is a major factor in choosing your binder. In fact, this factor alone can eliminate your selection of an otherwise perfect binder. Once you’ve determined the lowest effective percentage of binder you can use in your agglomeration process to achieve your desired product quality, you need to calculate the binder’s purchase and shipping costs, based on its availability and how many tons you need at what frequency.

One way to reduce your binder cost is to select a waste or processing byproduct as a binder rather than a commercially available binder, as long as the byproduct suits your agglomeration process. Some common examples are:

- Fly ash from coal-burning power plants, which is used as a cement substitute in aggregate.
- Lignosulfonate, a waste byproduct from kraft pulp and paper processes that’s used to form soil additive micropellets and other products.
- Brewery waste, which has been used instead of molasses or lignosulfonate to pelletize limestone, dolomite, and gypsum.
- Finely ground waste paper, which is used as a binder in briquetting materials such as metallurgical dust.
- Sawdust from lumber mills, which is used as a filler and binder to provide green strength — that is, strength for the moist, uncured agglomerates — for pellets and briquets of various materials before they are dried or fired in a furnace.
- Rice hulls from grain processing plants, bagasse from sugar cane processing plants, and other biomass residues, which provide green strength for coal, ore, and flue dust pellets and briquets.

Another way to reduce cost is to select an efficient blender to pre-mix your material and binder. This requires lab testing of
Another agglomeration additive:

**Lubricants**

It makes sense to talk about lubricants in a discussion of binders because lubricants are another important additive for many agglomeration applications. Lubricants are particularly useful in compaction (pressure agglomeration) processes such as tableting, briquetting, and extrusion. They promote good material flow into the pockets or dies in your press or extruder, and they promote the compression and plastic forming of the material and the final products’ release.

A lubricant can be internal or external. An *internal lubricant* is pre-mixed with your material, and an *external lubricant* is applied to the pockets or dies in your equipment.

Some general-use lubricants are glycerin, ethylene glycol, silicone, talc, graphite, stearic acid, and parrafin wax. Lubricants used in pharmaceutical applications include magnesium stearate, calcium stearate, wax, hydrogenated vegetable oil, talc, and starch.¹

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Post-treatment factors. Most binders require post-treatment to produce strong agglomerates. For example, a cold-bonding, self-curing cementitious binder typically requires time to harden at ambient or low temperatures. Some cold-bonding binders also require steam and pressure to cure. An example is a reactive binder, such as calcium oxide (or hydrate) combined with silica, which is mixed with steel plant dust before the dust is pelletized and hardened in a steam autoclave.¹⁰

Reference

Many other binders, especially film binders, require thermal drying or high-temperature sintering (firing). One example is agglomerates made with a sodium silicate binder, which become glass-like and waterproof when dried at 200°C or above. In another example, lignosulfonate and water are added to limestone and dolomite fines to form micropellets; the pellets are dried continuously at between 90°C and 260°C, which hardens the binder and strengthens the micropellets for shipment. When the micropellets are applied to soil as an additive for pH control, the lignosulfonate allows the gradual release of calcium or magnesium as the micropellets slowly disintegrate in contact with moisture on the soil. Another example is bentonite (montmorillonite clay), which provides green strength to iron-ore pellets for handling and transfer to a furnace, where the pellets undergo grate or grate-kiln firing at above 1,150°C to achieve their final pellet strength.

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### References


**For further information**


Find more information on agglomeration and binders in articles listed under “Agglomeration” in *Powder and Bulk Engineering International’s* comprehensive “Index to articles” in our November 2001 issue and at our website: www.powderbulkintl.com.

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