



The Fundamentals of Green Sand Preparation and Control

By Scott Strobl, Vice President of Technology, Simpson Technologies Corporation

Aurora, Illinois, USA

Translated from *Modern Casting* FundiExpo 2000 edition

Understanding the raw materials, tests and equipment to reduce sand variations will optimize your green sand process for a more profitable molding operation.

A basic understanding of the materials that constitute a green sand system and the equipment required to prepare and maintain the integrity of the system are extremely important to assure quality castings. The condition and type of preparation equipment can have a pronounced effect on the type and amount of raw materials utilized in a particular operation. Furthermore, the type of alloy, size and geometry, along with core loading characteristics of the casting, also dictate the exact compositional makeup of the system sand.

The intent of this article is to briefly summarize a generic sand preparation system. It presents a basic overview of the key raw materials, equipment and instruments that are used to control and prepare green sand. To properly control and maintain a green sand preparation system, a complete understanding of the raw materials and interrelationships between these components and equipment making up the preparation system must be attained.

Testing and Control

There are a variety of laboratory sand tests to assist operators and Quality Control personnel in eliminating casting and molding quality problems. The test results quantify important sand properties and characteristics to benchmark the system and ultimately help to reduce variation of the sand and incoming raw materials. These same tests are also extremely useful in assuring the efficiency and accuracy of both production machines and on-line control devices. It is extremely important that lab technicians follow standard testing procedures and maintain a regular instrument calibration program to ensure the accuracy of the laboratory results.

Moisture is an extremely critical sand additive that can greatly impact casting quality and the operation of a sand preparation system. Compactability testing is the best method to control the water addition at the muller. The water addition will vary, since the amount of water added to sand is a function of the composition and processing variables. Controlling compactability accounts for slight changes in sand composition and insures that a proper water addition is made to achieve constant molding properties. If the amount of water changes drastically to maintain a target

compactability number, it would indicate another component within the sand has gone out of control. Automatic online compactability controls on the muller reduce variation and insure proper control.

Sands

Sand is the major component within green sand. Green sands are normally made from silica (SiO_2) sand. The size and distribution of the sand grains are extremely important in controlling the surface finish of the casting. These characteristics also affect the ability of the mold to promote the evacuation of gases formed during the transformation of water to steam and the decomposition of the organic constituents of the core binders and green sand additives. The correct sand distribution is also critical in reducing the occurrence of sand expansion defects.

Refractory--A green sand mold must withstand the pouring temperature of the molten alloy. A silica sand in a pure form, 98% SiO_2 , has a fusion point of approximately 3100F (1704C). If the SiO_2 content of the sand is reduced, then the fusion will also decrease. There are several subgroups of silica-based sands, lake sand for instance, that have reduced SiO_2 percentages and corresponding fusion temperatures of approximately 2800F (1538C) depending on the sand composition. The pouring temperatures of cast irons and nonferrous alloys are generally well below these fusion temperatures.

It is more important to understand that if the silica content of system sand is reduced to a critical level, the surface finish of castings from alloys with high pouring temperatures may deteriorate due to the loss of refractory. A constant influx of new sand into the system helps to replenish the silica content of the system and flush excessive amounts of ash, fine sand and thermally destroyed clay from the system. This influx of new sand can result from incoming spent core sand that is separated from the castings at shakeout.

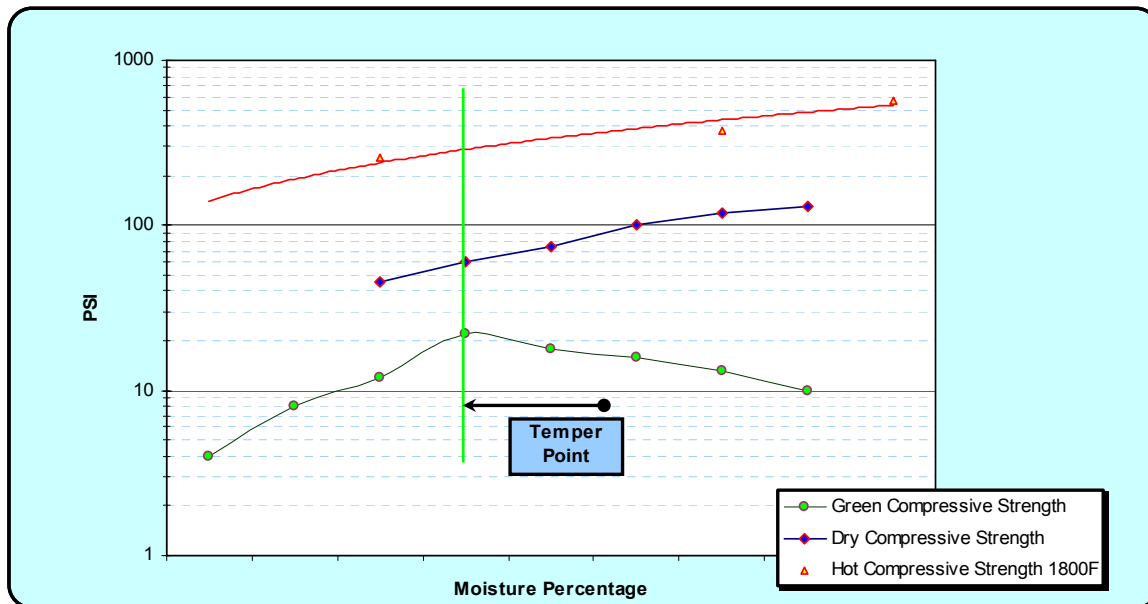
Types--Although silica and subgroups of silica constitute a majority of system sand, other sand types can be used. Depending on the geographic location of the foundry and, more importantly, due to technical merit, other aggregates may be utilized. There are a wide variety of aggregates available to the metalcaster, including olivine, chromite and zircon. These sands may be utilized as base or facing sands to reduce and/or eliminate expansion defects and metal penetration while promoting solidification.

Surface Area--Surface area of the sand and raw materials are also an important consideration in controlling and preparing green sand. Any large deviations in surface area could have profound effects on the physical characteristics of the molding sand. This would be caused by the tendency of the system to require more or less water to reach a constant compactability number. Obviously, as the size of the sand decreases, its surface area increases.

Clays

Clay is the adhesive that maintains the mold shape at both ambient and elevated temperatures. The addition of water is required to activate the clay. The moisture content of system sand is extremely critical and can affect nearly all the physical properties that are measured in a foundry. The relationship of moisture content and green, dry and hot compressive strength can be seen in **Figure 1**. Most casting and molding problems related to sand could be caused by either an excess or deficiency of moisture.

Figure 1: Compressive Strength vs. Moisture



Types--There are two naturally occurring clays—sodium and calcium bentonite—that are utilized in a majority of metalcasting operations. Again, the type of equipment, alloy and casting geometry will dictate the type or blend of clay used by a foundry.

Key Characteristics--Each enhances certain characteristics of molding sand. When comparing molding sand made of 8% sodium bentonite and similar sand at the same compactability composed of 8% calcium bentonite, the difference between the clays can be seen (see **Table 1**). The chart clearly indicates that sodium bentonite results in higher dry and elevated temperature compressive strengths. It also shows a substantially higher wet tensile strength. The elevated hot properties and high wet tensile strength of sodium bentonite are required when pouring steel and iron to avoid defects such as sand erosion, sand inclusions and expansion scabs. However, the increased hot properties could increase the energy required to remove the sand from the solidified castings, thus increasing the potential for broken and cracked castings.

Table 1: Bentonite Comparison Chart

Sand Characteristics	100% Sodium Bentonite	100% Calcium Bentonite	50:50 Blend Na:Ca
Green Compression Strength	11.8 psi	14.3 psi	12.6 psi
Green Deformation at Maximum Strength	1.3%	0.95%	1.1%
Wet Tensile Strength	0.466 N/cm ²	0.071 N/cm ²	0.346 N/cm ²
Hot Compressions Strength (1800° F)	575 psi	110 psi	320 psi

Note: Laboratory tests results were taken from virgin raw materials mulled for 10 minutes in a laboratory muller.

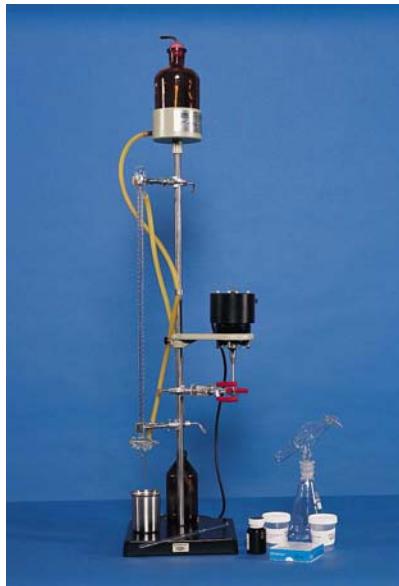
Calcium bentonites are better known for the ability to quickly develop green properties. They offer better flow than sodium bentonite (which tends to be more plastic) and lower deformation at equal moisture percentages. Therefore, they have a greater ability to flow freely through the sand system and into deep and/or tight pockets on a pattern.

Both bentonites can be blended at different ratios, which is a common practice. By blending the clays, a foundry can achieve roughly an average in physical properties.

Amount of Clay and Water--Changing the total amount of clay and water can alter the compressive strength of green sand, permeability and other physical properties. Generally, a higher clay percentage, up to 12%, will result in increased strengths. The amount of water can also have a great effect on green, dry and hot compressive strengths (see **Figure 1**). Generally, increasing water increases green compressive strength to a point, referred to as temper point. Further increases of water result in a decrease in green compressive strength. Both the dry and hot compressive strength show an increase in strength as moisture is increased within a normal range.

Control Methods--The methylene blue clay test determines the percentage of available bentonite in a sand sample. This laboratory test provides critical information regarding the proper clay additions to maintain clay levels between upper and lower control limits. The test cannot differentiate between sodium and calcium bentonite. Therefore it can only indicate the total amount of bentonite available in the system.

Unlike the methylene blue clay test, the AFS clay test is a laboratory test that indicates the total percentage of fine material in sand. This includes materials smaller than 20 microns and/or materials that settle at a rate of less than 1 in./min. in water. These materials include available clay, dead clay, fine sand grains, ash, coke, coal and cellulose. AFS clay percentages will always be higher when compared to methylene blue clay since it contains both available and thermally-destroyed bentonite along with any other extremely fine particle. By tracking the difference between the AFS clay and methylene blue clay percentages, a foundry can determine if the fine material content is increasing. This difference can be greatly affected by the new sand addition or core sand dilution. Generally, as the AFS clay percentage increases at a constant or decreasing methylene blue clay level, more water is required to maintain a constant compactability due to an increase in system surface area (see **Figures 2a and 2b**).



Figures 2a and 2b:
Photographs of the AFS and
Methylene Blue Clay Testers.

Carbons

Carbon additives are generally added to cast iron sand systems to help reduce the occurrence of metal penetration and improve surface finish. There are many theories as to why carbon additives,

such as seacoal, help to reduce penetration. These theories include helping to create a reducing atmosphere, coating the mold surface with lustrous carbon and coal expansion.

Control Methods--Both the combustible material and volatile matter are useful in determining the percentage of carbons in system sand. The loss on ignition (LOI) test indicates the total percentage of combustibles in the sand including coal, coke, residual organic core binders, cellulose, cereal and the crystalline water within the available bentonite. The volatile matter content of the coal is the ingredient that helps to reduce metal penetration. Unlike the LOI test, which measures all combustible materials including coal and coke, the volatiles test determines the amount of active coal in system sand.

Mulling

Mulling is one of the most important aspects in green sand control. A foundry can maintain all the raw materials that make up the sand within a very tight specification. If they have a poor muller and/or mulling practices, sand control problems will persist. The function of a muller is to activate the available bentonite within the sand. This is an extremely difficult task that requires an extreme amount of energy. Because a clay water mixture is extremely tenacious, the muller utilizes wheels that incorporate both compressive and shearing forces to activate the bentonite particles and smear the bentonite putty onto the sand grains. The muller wheels are extremely important to generate the proper compressive and shearing loads required to fully develop the physical properties of the molding sand. A thorough understanding of the mulling cycle sequence must be maintained to help minimize cycle time and optimize the effectiveness of the muller. Furthermore, variations in raw material additions must be minimized.

Strength Development--Green compressive strength testing is extremely useful in helping to determine the degree of mulling accomplished. An increase in green compressive strength will result as the mulling process proceeds (see **Figure 2**). To maximize the mulling efficiency, every effort must be made to maintain mechanical elements of the muller. It is extremely important to replace worn wear items, such as wheels and plows, and routinely adjust these components to recommended settings to both maximize their performance and minimize wear. A preventive maintenance program must be established to make certain the muller is effective. It is also important that both maintenance and production personnel are thoroughly trained. In today's environment of increased production and system core loading, it is imperative that every attempt be made to maximize the effectiveness of the mullers and mulling process.

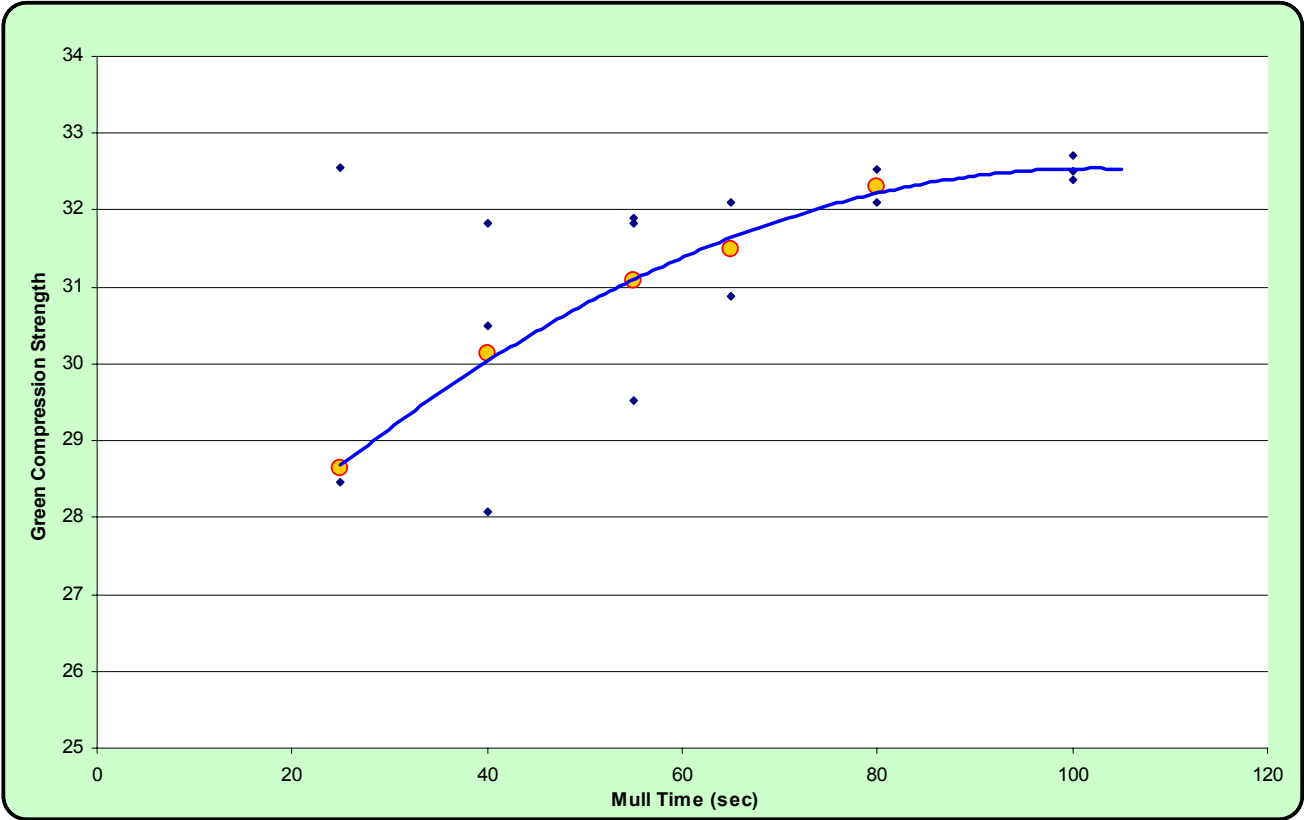
Factors Affecting Strength Development--Green compression strength can be increased or decreased by the amount and/or effectiveness of mulling. There are also a variety of other process variables that can contribute to the variation of green compression strength. These could include but are certainly not limited to: hot sand, moisture content, core sand dilution, new sand addition, clay content, clay ratio, compactability, sand grain fineness, calibration of laboratory equipment, quality and variations of raw materials, better and more efficient shakeout systems and changing sand to metal ratios.

Maintaining the System

Maintaining a sand system involves the reduction of fluctuations and variations. This requires not only a balance of incoming and outgoing materials but also a balance of energy. In other words, additions of new clay must be made to offset losses to thermal destruction, dust collection, etc. The energy required to activate the clay in the muller must be maintained and the heat energy induced

into the sand during the solidification of the casting must be removed to remain constant and in balance.

Figure 2: Strength Development Curve



Material Losses/Changes During Reuse--Green sand is always in a working state whether it is in the process of cooling, mulling, molding, holding solidifying castings or tempering in a return sand silo. The fact that green sand is constantly recycled with small additions of raw materials is one of its inherent advantages. However, to understand and control a green sand system, there are certain changes that should be understood when the sand temperature is elevated during casting pouring and cooling.

First, water is removed in the form of steam. If the sand temperature is elevated above 212F (100C) the free surface water is removed. The amount of free water removed can be estimated by the moisture content determined in the sand lab. This change is reversible. If the addition of heat were stopped at a point below approximately 600F (316C), an addition of water and mulling could restore the sand-clay mixture back to normal working properties.

Second, at temperatures greater than approximately 600F (316C) for calcium bentonite and 1200F (648C) for sodium bentonite, the crystalline water, often referred to as chemically combined water, is removed from the lattice structure of the bentonite. This stage is irreversible and the bonding power of the bentonite is lost. When sections of the sand mold reach these temperatures, bentonites within these areas are thermally destroyed and are sometimes called dead clay. A certain amount of new bentonite must be added after every cycle of the system to replace the thermally-destroyed

bentonite. Furthermore, additional clay must be added to coat incoming core sand and new sand, as well as replacing losses to dust collection and carry out.

Depending on the temperature and mold atmosphere during pouring, the carbon additive returning to the muller will consist of a combination of coal, coke and ash. If there was oxygen present in the mold, at elevated temperatures, the coal will combust and form ash particles. If the atmosphere in the mold were inert at elevated temperatures, the coal would be transformed to coke. Coke and ash are often referred to as dead forms of carbon within a sand system and must be replaced.

Special additives, such as cellulose and cereal, are thermally destroyed at temperatures of 250– 400F (93–204C). These additives must be replaced.

Hot Sand--Because green sand circulates and silica is an excellent insulator, there is a tendency for the sand temperature to increase after multiple passes. Hot sand is one of the greatest sand related problems in today's modern metalcasting facilities. Return sand entering a muller at temperatures in excess of 120F (48C) is considered hot molding sand. Hot molding sands cause a variety of problems including sand sticking in hoppers and conveyors, uncontrollable sand drying, difficult if not impossible moisture control at the muller, a loss of prepared sand properties, metal penetration, condensation, sand inclusions, broken molds, brittle sands and increased clay additions.

Sand Cooling--A cooler is the only method of cooling hot sand without changing the type of castings, sand to metal ratio, job scheduling and/or sand system storage. The installation of a cooler is often the only practical solution to a hot sand problem. Molding sand coolers utilize vaporization and evaporation as the means to reduce sand temperature. Changing the state of water from a liquid to steam requires considerable thermal energy and results in extremely efficient sand cooling. Things to consider when choosing a cooler include discharge moisture control, machine maintenance, sand pre-blending, adequate retention time, ability to maintain sand size and distribution (i.e. do not create agglomerations or remove fine material) and achieve a constant discharge temperature below 120F (48C). Atmospheric conditions, geographic location and incoming sand and water temperatures must be known to accurately assure proper cooler sizing.

Summary

Controlling a green sand system requires a detailed understanding of the raw materials, laboratory test results and production equipment. A basic understanding of sand control will optimize your green sand process for a more profitable molding operation. The intent of this article is to provide an introduction to many of these key points. To maximize the potential of a particular sand system requires a complete understanding of the raw materials and interrelationships between these components and the equipment making up the preparation system must be attained.

SIMPSON GROUP

Founded in 1912, Simpson Technologies is a world leader in foundry and process industry technologies. Within the Simpson Group are some of the world's largest and most innovative brands of metal casting technologies including the companies Simpson Technologies, Beardsley & Piper LLC, Hartley Controls Corp. as well as the brands of Dietert Automation and Simpson+Gerosa. In the metal casting industries our products include technologies in the following areas:

- Molding Sand Cooling
- Molding Sand Preparation (batch & continuous)
- On-line Controls for Sand Preparation Systems
- Flaskless, Matchplate Mold Making Equipment
- Core Sand Preparation Equipment
- Core Making Equipment
- Sand Reclamation Equipment
- Pollution Control Equipment
- Sand Laboratory Testing Instrumentation
- OEM Spare Parts and Field Service
- Laboratory Testing and Rental Equipment



751 Shoreline Drive
Aurora, IL 60504 USA
Tel: +1 (630) 978-0044
Fax: +1 (630) 978-0068
Email: sales@simpsongroup.com
Web: www.simpsongroup.com

To find a representative near you, go to: <http://www.simpsongroup.com/contacts/contacts.htm>

