CHARACTERIZING SYNTHETIC GYPSUM FOR WALLBOARD MANUFACTURE

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Keywords: FGD Synthetic Gypsum, Gypsum Wallboard, Test Methods

INTRODUCTION

United States Gypsum Company (USGC) has developed specifications and guidelines covering the chemical and physical aspects of synthetic gypsum to help predict end use acceptability in wallboard manufacture. These guidelines are based in part on past experiences with natural and synthetic gypsum. Similarly, most wallboard manufacturers in North America have developed their own guidelines based in part on its unique history and particular experiences with synthetic gypsum. While there are similarities between manufacturers' guidelines, differences do exist.

This paper discusses the importance of selected parameters contained in the FGD gypsum guidelines. In most cases, the parameters are equally relevant to other synthetic gypsums and the naturally occurring gypsum mineral as well.

USGC's general guidelines of FGD gypsum along with guidelines from the German Gypsum Association are listed in Table One. The guidelines are not an all inclusive list of every gypsum property important to the wallboard manufacturer. The guidelines serve as a starting point in negotiating sales agreements between the wallboard manufacturer and synthetic gypsum supplier. The product specification agreement at USGC is tailored to each individual source depending in large part to the percent usage at the wallboard facility, type of synthetic gypsum and capabilities of the supplier.

GYPSUM CHARACTERIZATION

Gypsum Purity. Obviously, gypsum ($CaSO_4 \cdot 2H_2O$) purity is an important attribute. Purity is key in manufacturing wallboard. Purity of mined natural rock varies widely usually from 80 - 96%. High purity is desired because lower weight gypsum board may be produced. Generally, a higher purity is desired for synthetic gypsum compared to natural rock in wallboard manufacture. Usually, high purity synthetic gypsum can be reasonably obtained by the supplier. Therefore, a higher purity synthetic gypsum will have increased value.

Impurities found in synthetic as well as natural gypsum can be quite detrimental to the wallboard produced. The higher purity reduces the chance of deleterious effects from these impurities.

Purity can be determined by several test methods including Differential Scanning Calorimetry/Thermal Gravimetry (DSC/TGA), X-Ray Fluorescence Spectroscopy (XRF) and SO_3 analysis.

Free Moisture. Many synthetic gypsums discharged from by-product manufacturers are in the form of a wet cake. The free or surface moisture of the cake is usually in the range of 6 - 25%. Natural mined rock will vary from 0 - 3% moisture. Often, the amount of synthetic gypsum that a wallboard plant can blend in with the natural rock will be dictated by the thermal capacity of the rock drying system. High moisture reduces the amount of synthetic gypsum that can be blended. This reduces its value.

Often a wallboard manufacturer will enter a sales agreement with a supplier prior to the availability of the synthetic gypsum. When the actual free moisture is significantly greater than contracted, processing capacity problems will arise. This could be due to both thermal drying limits and because of the more challenging handling characteristics of high moisture gypsum. High moisture gypsum has a greater tendency to stick and build up on conveying equipment.

Free moisture of natural and synthetic gypsum materials are determined using a simple oven weight loss method per ASTM C471. In addition, heat and moisture determining balances are used.

Impurities. The type and quantity of impurities have the greatest impact on qualifying the use of a synthetic and natural gypsum. The guidelines list the predominant impurities found in FGD gypsum. Discussion of selected impurities follow.

Residual Carbonates. Unreacted limestone ($Ca/MgCO_3$) is the predominant impurity found in many synthetic gypsum sources. Limestone is a common impurity in natural gypsum as well. Fortunately, limestone remains chemically inert through the board conversion process. However, increased wear on processing equipment results when encountering high amounts of limestone (Mohs value 3 - 4) since it is a harder substance than gypsum (Mohs value 1.6 - 2).

Limestone quantity can be determined through XRF oxide analysis of calcium and magnesium in conjunction with carbon dioxide (CO_2) analysis by coulometric titrimetry. Alternatively, CO_2 can be quantified through DSC scans.

Flyash. One concern with flyash in FGD gypsum is the chemical variability associated with burning different fuel sources (e.g. various coals and Orimulsion™). Flyash can affect paper to core bond during wallboard manufacture. The variability can cause intolerable problems in wallboard conversion. Also, flyash laden with silica and iron causes increased wear on process equipment.

An important concern with flyash is the amount of trace elements that may accompany it. This can raise serious industrial hygiene issues. Trace elements and the analysis will be discussed in a later section.

Flyash is easily detected using a scanning electron microscope (SEM). By using image analysis, an estimate of the amount of flyash present can be established. Fly ash can also be calculated by determining the mass balance around the scrubber and dust collection system. Figure One is an SEM photo of flyash impurity in a FGD gypsum sample.

Silica (SiO_2). Silicon dioxide is an important impurity from an industrial hygiene perspective and a process issue for all mineral industries. Silica is common in both natural and synthetic gypsums. It can be part of a clay, flyash or quartz impurity.

High quantities of respirable (0 - 4 microns) silica could present an industrial hygiene issue.

Crystalline silica or quartz is a very hard substance (Mohs value 7). Even low amounts (1-2%) can cause dramatic accelerated wear on gypsum processing equipment.

Amorphous silica is also contained in a variety of clays. Clays negatively impact the amount of water required to form a fluid slurry and thus, create a higher thermal demand to drive off the excess water in the board conversion process.

Silica can be quantified using XRF. X-Ray diffraction (XRD) is used to identify whether the SiO_2 present is amorphous or crystalline in nature. In addition, ASTM C-471 describes a wet chemistry method to determine SiO_2 and insoluble matter.

Calcium Sulfite ($CaSO_3 \cdot 1/2H_20$). FGD systems may be designed to produce unoxidized gypsum or calcium sulfite instead of calcium sulfate dihydrate. This material is always landfilled. Sulfite impurities are a much greater concern at the gypsum producing FGD systems because they lead to scaling and other processing problems. The fine particle size of sulfite will cause cake washing and dewatering problems. Calcium sulfite is an unwanted impurity in any gypsum.

Thermal analysis and XRF will detect sulfite above 0.1%. Titration procedures are considered a better method to determine sulfite. A titration procedure is listed in EPRI-Method 40 (EPRI CS-3612. Project 1031-4. Final Report dated July, 1984).

Soluble Salts. Soluble salt impurities are one of the most important parameters affecting the physical properties of gypsum wallboard. Salts are a common impurity in natural and several different types of synthetic gypsums. It is common practice to mine around natural gypsum rock seams high in salt content. Chloride salts are common in natural and some synthetic gypsums. In addition, high amounts of magnesium salts can end up in some synthetic gypsums. Magnesium can originate from limestone sources used to neutralize waste acid and in desulfurization systems.

Salts readily go into solution when the calcined gypsum (stucco) is mixed with water and other additives in the board mixer. During the drying of the gypsum board in the kiln the salts migrate to the paper - core interface and interrupt the paper to core bond. Salts are very hydroscopic and cause moisture to deposit in the critical bond area of the board. On exposure to high moisture from joint finishing and wallpaper products the drywall paper can detach itself from the core.

The four soluble salt ions typically monitored are magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+), and chloride (Cl^-). Soluble salts are analyzed by several different methods. Atomic absorption is used for the determination of magnesium. Atomic emission is used for the determination of potassium and sodium. Ion-selective electrode (ISE) is used for the determination of chloride. ISE can also be used for sodium and potassium determinations.

Table Two shows a typical soluble salt analysis for a synthetic gypsum sample. Total salts are based on a mathematical reconstruction. This mathematical reconstruction is based on the theoretical solubility of the ions.

Trace Elements. Trace elements and pH are evaluated on all natural and synthetic gypsum sources for industrial hygiene purposes. Trace elements normally evaluated are shown in Table Three. Trace elements are unwanted impurities. They arise from flyash contamination and increase process equipment wear. Also, trace elements are commonly found in most naturally occurring minerals including gypsum and limestone.

Trace elements can be determined through several methods including Atomic Absorption/Emission (AA) with a graphite furnace option, wet chemistry methods, Inductive Coupled Plasma (ICP) and XRF.

Organic impurities. Although not listed in the FGD guidelines, organic impurities even at trace (ppm) levels can have a dramatic effect on gypsum board operations. Organics are unwanted impurities in gypsum. The effects of organics found in natural and synthetic sources are observed during gypsum rehydration in the board conversion process. They can easily cause the rehydration time to dramatically lengthen and cause the board line to slow down and reduce production. Organics adversely affect crystal growth and reduce strength development of the gypsum core.

Residual organic impurities in synthetic gypsum from waste acid neutralization processes such as citric and lactic acid production can strongly retard the hydration of gypsum stucco.

Organic impurities can be identified through several methods including coulometric titrimetry, Infrared Spectroscopy (IR), Nuclear Magnetic Resonance (NMR) and High Performance Liquid Chromatography (HPLC).

Physical Properties. Although chemically the same, there can be significant physical property differences between natural and synthetic gypsums. It is well publicized that there are significant differences in particle size and shape between natural roller milled ground gypsum rock (land plaster) and most synthetic gypsums.

Particle Size. Most synthetic gypsums are formed in a solution environment supersaturated with respect to gypsum and accompanied with vigorous agitation. Under these conditions, the gypsum particles precipitate fairly uniformly in particle size and shape. The particular size and shape depends on the process conditions of the unit operations. USGC FGD guidelines list a 20 micron minimum median particle size. More commonly, synthetic gypsums have median particle size is in the 35 - 45 micron range.

Many synthetic gypsums have narrow or monolithic particle size distributions. Typical roller milled natural gypsum has a much broader particle size distribution. Figure Two shows SEM photomicrographs of natural and FGD gypsum. Figure Three shows a comparative particle size histogram between natural and a FGD gypsum.

A monolithic particle size distribution with a large mean particle size (40 - 60 microns median) for synthetic gypsum is preferred even though it creates processing challenges at the wallboard facility. Large particles (low surface area) will readily dewater. Low free moisture is a desired quality because of lower drying costs. Also, as free moisture is reduced through dewatering, the quantity of water soluble impurities will be reduced.

In general, synthetic gypsums that have poor dewatering characteristics also have high surface moisture and high surface area. In addition, the material has more challenging material handling properties and causes increased amounts of process water to be used during the continuous casting of gypsum board. The later point causes a higher thermal demand in drying the gypsum board.

Therefore, it is preferred that the gypsum supplier design the synthetic gypsum system to produce gypsum particles that will readily dewater. Despite engineering design challenges at the wallboard plant, synthetic gypsums with large particles are desired because they impart good dewatering properties.

Particle size is measured using laser scattering or sedimentation technique. The two methods do not always yield the same results. Figure Five shows particle size distribution for natural and synthetic gypsums using laser light scattering and sedimentation. Note that for both samples the laser technique yields a higher mean particle size then sedimentation.

Surface area is another method to measure particle fineness. The Blaine surface area technique is a common measuring method used for powders. The Fisher™ subsieve sizer is used as well. The surface area of natural roller milled gypsum is typically 2000 - 3000 cm^2/gram. Wallboard grade FGD gypsum is commonly below 1000 cm^2/gram.

Aspect Ratio. Some wallboard manufacturers will include an aspect ratio guideline (usually 10:1:1 - 20:1:1 maximum) on particle shape. The aspect ratio guideline is usually put into product specifications to insure against contending with problems associated with needle-like gypsum crystals in processing, calcining and wallboard manufacture. Since gypsum particles retain their shape after calcination, high aspect ratio particles can cause an increase in water demand during board conversion.

The synthetic gypsum producer needs to concern itself with aspect ratio because of its influence on internal processing issues. Needle shaped gypsum particles are more difficult to dewater than large blocky shaped crystals. Thus, under the same processing conditions, gypsum with a high aspect ratio will contain higher surface free moisture and water soluble impurities. It may also be more expensive to process in order to meet finished product guidelines. Hence, the material will have reduced value.

The aspect ratio of natural gypsum is generally 1: 1. The particle shape of gypsum can easily be determined using the SEM.

Bulk Density. Large monosized gypsum particles of many FGD gypsums tend to exhibit a high bulk density. Often, the synthetic gypsum is to be purchased sight unseen by the gypsum company. This can present engineering and process challenges to the wallboard manufacturer in designing suitable material handling systems due to the high bulk density. Loose bulk density of natural gypsum is about 50 pcf. The bulk density of synthetic gypsums can vary widely from less than 40 pcf to over 70 pcf. Table Four lists bulk densities of selected natural and synthetic gypsums used by USGC. Bulk density is easily measured through the weighing of a known volume of material.

SUMMARY

Over the years of using natural and synthetic gypsums, USGC has developed and employed several methods of characterizing natural and synthetic gypsum. Synthetic and natural gypsum are chemically the same. The kind and amount of impurities will vary from source to source for both natural and synthetic gypsums. Chemical and physical property testing techniques are the same for natural and synthetic gypsum. It is the physical properties that commonly distinguish synthetic from natural gypsum.

In general, synthetic gypsum has a narrow particle size distribution. Natural gypsums are ground and have a much broader particle size distribution. Other physical properties differences such as surface area, bulk density and aspect ratio are related to the narrow particle size distribution of synthetic gypsum.

Synthetic gypsum is received at the wallboard plant in a wet cake form. It is important to the wallboard manufacturer that the gypsum be as low as possible in free moisture within the capability of the supplier. Lower free moisture reduces wallboard manufacturing costs.

REFERENCES

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TABLE ONE **FGD GYPSUM GUIDELINES**

	USG	German Gypsum Association
Purity ($CaSO_4 \cdot 2H_2O$) (%, min)	95	95
SO_3 (%, min.)	44.2	—
Free Moisture (%, max.)	10	10
Flyash (%, max.)	1.0	---
SiO_2 (%, max.)	1.0	---
Calcium Sulfite (%, max.)	1.0	0.25
Chloride (max. ppm)	120	100
Total Water Soluble Salts (max. ppm)	600	---
Average Particle Size (min. microns)	20	---
Surface Area (cm^2/gram)	3500 max.	---
pH	6 - 8	5 - 9

TABLE TWO **SAMPLE SOLUBLE SALT ASSAY**

Soluble Salts:	**Synthetic** (ppm)		**Natural** (ppm)
Potassium (K)	1		13
Sodium (Na)	7		15
Magnesium (Mg)	26		29
Chloride (Cl)	32		23
Reconstruction			
KCl	2		24
NaCl	17		19
Mg(Cl)2	27		0
Ca(Cl)2	0		0
K2SO4	0		0
Na2SO4	0		23
Mg2SO4	94		143
Total	141		209
Equivalent lbs/ton	0.28		0.42

TABLE THREE **TRACE ELEMENTS**

Zinc
Cadmium
Chromium
Nickel
Cobalt
Copper
Lead
Tin
Molybdenum
Fluorine
Arsenic
Antimony
Mercury
Selenium
Vanadium
pH

TABLE FOUR BULK DENSITY

	Loose Bulk Density
Natural Gypsum	50 pcf
Synthetic Gypsum #1	75 pcf
Synthetic Gypsum #2	45 pcf
Synthetic Gypsum #3	53 pcf
Synthetic Gypsum #4	62 pcf

FIGURE ONE SEM Photograph of Flyash Impurity in Synthetic Gypsum

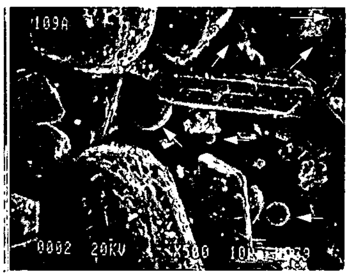

FIGURE TWO SEM Photographs of FGD and Natural Gypsum

FGD GYPSUM **Natural Gypsum**

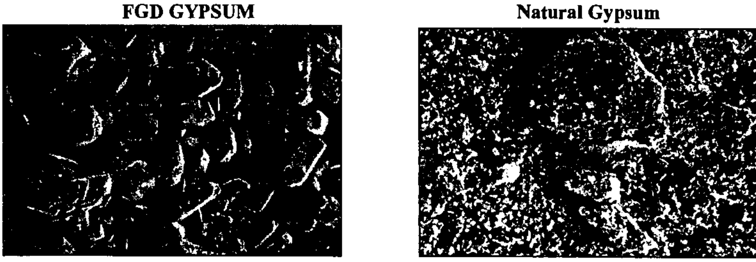

FIGURE THREE

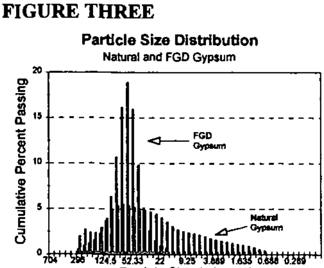

FIGURE FOUR