RECYCLING GYPSUM DRYWALL RECOVERED FROM DECONSTRUCTION PROJECTS: A TECHNOLOGY AND MARKET OVERVIEW

Authors: Timothy G. Townsend (University of Florida, Gainesville, Florida, United States)
Kimberly Cochran (R.W. Beck, Orlando, Florida, United States)

ABSTRACT

A major component of modern buildings is gypsum drywall, also referred to as wallboard or sheet rock. Drywall is composed of 90% gypsum ($CaSO_4$-$2H_2O$) and 10% paper. Several successful drywall recycling operations exist in North America. Major markets include manufacture of new drywall, portland cement production, and agricultural amendment. Most successful recycling operations utilize post manufacturer scrap drywall or scrap from construction projects. Those interested in recycling of gypsum wallboard from deconstruction projects face additional challenges. This paper presents an overview of the existing technologies used to recycle gypsum drywall, the primary markets, and the hurdles to wide-scale implementation of drywall recycling. Issues surrounding recycling of drywall from deconstruction projects are discussed, including environmental issues such as lead-based paint and asbestos.

KEYWORDS: Gypsum Drywall; Recycling; Wallboard; Sheetrock

INTRODUCTION

Gypsum drywall is a major component of most modern buildings, yet it often is one of the least likely components of the waste stream produced from building construction, demolition or deconstruction to be recycled. Several gypsum wallboard recycling facilities successfully operate in North America at the current time, but in some areas (Florida for example) drywall recycling is relatively nonexistent. This paper provides an overview of the current state of gypsum drywall recycling in North America and includes a discussion of issues such as markets and processing techniques. In addition, most of the drywall recycled at the present time is post-manufacturer waste or scrap from new construction activities. Those interested in recycling drywall recovered as a part of deconstruction activities must also consider several environmental issues such as asbestos and lead-based paint. These issues are also discussed. Much of the background information for this paper, including a complete set of references, can be found in Townsend et al. (2001) and Cochran (2002).

DRYWALL BASICS

The mineral gypsum possesses many attributes that make it an attractive construction material. Calcined gypsum can be wetted to form a paste that can be directly applied to a structure's surface or that can be molded into a desired shape; the gypsum hardens upon drying. Gypsum is naturally fire resistant. Gypsum drywall, often referred to as gypsum wallboard or sheet rock,

replaced gypsum plaster as the major material used for interior wall surfaces because of its ease of installation. Gypsum drywall consists of approximately 90% gypsum and 10% paper facing and backing. Gypsum is composed of calcium sulfate ($CaSO_4$) and water (H_2O). Also referred to as hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$), gypsum is mined from deposits formed by ancient seabeds as a raw material for many different manufacturing, industrial, and agricultural uses. Over 80% of the gypsum mined is used in manufactured products such as drywall.

Drywall is manufactured by first calcining the gypsum, a process that heats the mineral to remove part of the water (resulting in $CaSO_4 \cdot 1/2H_2O$). The stucco that is formed is then rehydrated by mixing with water, and the slurry created is spread onto a moving continuous sheet of paper and sandwiched between another layer of paper. This continuous sheet of wallboard is allowed to harden for several minutes, cut into panels and sent to a kiln for final drying. It is trimmed to the dimensions required, bundled, and is then ready for shipment. Drywall comes in many different types and sizes to meet specific construction needs. Several specialty products are manufactured including moisture resistant drywall (greenboard) and Type X drywall. Type X drywall contains small glass fibers designed to increase the board's ability to withstand high temperatures from fires for a longer period of time and thus, would be used in projects that would require higher heat resistance than regular drywall would provide.

Drywall enters the solid waste stream in several different locations. These include the manufacturing facility, new construction sites, renovation activities and when a building is demolished or deconstructed. Debris from construction sites is typically encountered as large pieces that can be somewhat easily removed from the other debris components. Because of its friable nature, gypsum wallboard is very difficult to recover from mixed debris resulting from standard demolition practices. It can, however, be recovered through deconstruction using the appropriate removal techniques. Renovation debris is generally a mix of construction and demolition debris.

The amount of waste drywall produced during a deconstruction project varies as a function of the structure. Composition studies on construction debris find that gypsum wallboard makes up 5% to 25% of the waste stream (Cochran, 2001). A typical rule of thumb for drywall generation from construction activities is one pound of drywall per square foot of construction (Yost, 1993). When the National Association of Homebuilders (NAHB, 1997) deconstructed of a multi-family residential home in Baltimore County, Maryland, they tracked the mass of materials removed. Plaster over gypsum lathe boards accounted for 17% of the weight of materials removed (21.6 tons; see Figure 1). Tansel et al. (1994) examined the components of residential houses in South Florida and estimated drywall to be present at 6 lb per ft^2.

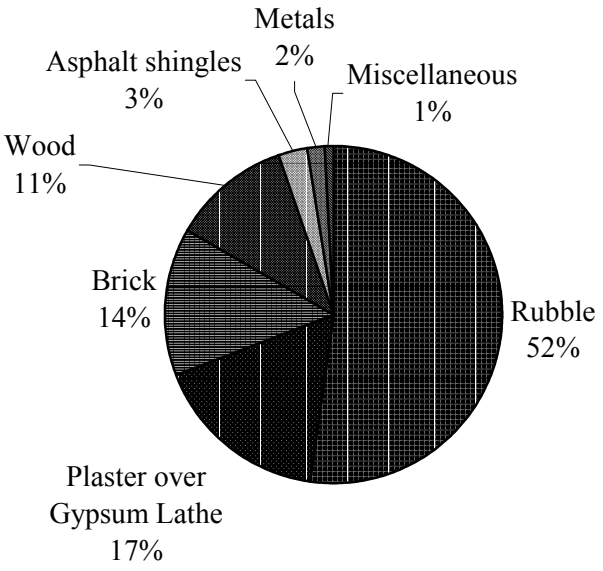

Figure 1. Composition of Materials (by weight) from a Building Deconstruction in Maryland [NAHB 1997]

RECYCLING MARKETS

Several different markets have been proposed for recycling gypsum drywall. These are summarized in Table 1. The primary markets that are reviewed here are the ones most commonly practiced in North America: use in the manufacture of new drywall, an ingredient in portland cement manufacture, soil amendment, and an additive to compost. Drywall programs have been most successful in recycling scrap drywall from new construction activities because of the ease of separation and the lack of contamination with other materials. While it is certainly feasible to recycle wallboard from deconstruction activities, quality issues must be addressed.

New Drywall Manufacture

Gypsum from waste drywall can be recycled back into new drywall. Many wallboard manufacturers currently recycle their own post-manufacturer scrap material at their facilities.

Table 1. Summary of Major Markets for Recovered Gypsum Wallboard

Market	Use
Manufacturing Processes	Manufacture of new drywall
	Manufacture of portland cement
	Manufacture of new construction materials (blocks)
Land Application Markets	Plant nutrients (calcium and sulfur)
	Improving soil structure (aids drainage in clayey soils)
	Reclamation of sodic soils
	Correction of subsoil acidity
	Plant disease prevention
	Reducing phosphorous leaching from manure-loaded soils
Other	Animal bedding
	Compost
	Bulking and drying agent
	Settlement of dirt and clay particles in turbid water
	Absorbent for greases
	A material for road base construction
	An ingredient in flea powder and similar products

While a small amount of paper is acceptable, the majority must be removed. Recycled gypsum will typically represent as much as 10% to 20% of some manufacturers' gypsum feedstock. Recycling of scrap post-consumer gypsum wallboard at drywall manufacturing facilities is currently being practiced in several areas of North America, most notably by the New West Gypsum Company in the Northwest US and Southwest Canada. As a result of regulations banning the disposal of drywall in landfills in some parts of Southwest Canada[1], New West Gypsum has been able to provide the needed end-market for discarded drywall, and this has spread into Washington and Oregon.

It is worth noting that in some areas of North America, new wallboard is being manufactured with synthetic gypsum. Several industries produce synthetic gypsum as a by-product of their manufacturing processes. The most common is the by-product of air pollution control technology at coal-fired power plants used to remove sulfur from the gas stream. The gypsum industry is moving toward the use of synthetic by-product gypsum as a source of the raw mineral. This, along with the recycling of post-manufacturer scrap, may limit the ability (or desire) of some plants to recycle post-consumer scrap drywall.

Portland Cement Manufacture

Gypsum is an ingredient in the manufacture of portland cement. Gypsum is added to the cement to control the setting time of the concrete. Gypsum, along with the cement clinker (coming from the cement kiln), is processed in a ball mill, grinding the mixture to a very fine powder. Typical

[1] The presence of gypsum drywall in landfills has been linked to the production of hydrogen sulfide (H_2S). H_2S is a malodorous gas that has caused numerous complaints at landfills around North America. While drywall is not currently banned from landfill disposal by any state in the US, several locations are considering placing restrictions on the amount of drywall that may be land disposed.

gypsum contents in portland cement range from 5 to 10%. The gypsum used at a typical cement kiln is mined gypsum, a very different physical form than that resulting from processed drywall. The materials feed system at the plant may therefore require some adjustment. Paper should be removed. The purity of gypsum in the wallboard is a major concern. The gypsum purity in typical wallboard should be high; care should be taken during the collection of the wallboard to minimize the amount of impurities such as soil that are introduced. In addition, processing the wallboard should take care in removing the paper backing, as there is not much tolerance in this end market for paper contamination.

Application to Soil

Gypsum is a common soil amendment, and is used for several different purposes. Gypsum provides a source of calcium and sulfur for plants. Gypsum is commonly applied to peanut crops in the Southeast US as a source of calcium. A typical application rate for gypsum applied to peanut crops is 600 to 800 pounds per acre. Applications rates for other crops have been reported as much higher. Many vegetables, including potatoes and corn, have been shown to benefit from gypsum application. Unlike lime, gypsum does raise the pH of soils and it is therefore preferred for crops that require calcium but where the soils are already alkaline (and cannot accommodate pH adjustment). Gypsum has been found useful for reclaiming very salty soils; the calcium in the gypsum substitutes for the sodium in the soils, allowing the sodium to leach away. The application of gypsum has thus been found to benefit road-side soils that have been contaminated as a resulting of deicing salt. Gypsum has the ability to flocculate clayey soils and to promote drainage where problems such as “hard-pan” occur.

The processing requirements for gypsum drywall that is applied to soil may differ somewhat from those required in the industrial processes such as portland cement or new drywall manufacture. While foreign materials such as nails and corner beads should be removed during processing, agricultural uses can tolerate some ground paper and soil in the mixture. The presence of trace components (such as lead from lead based paint) might be of greater concern when land applied (relative to the industrial uses) because of the potential for human contact and soil or groundwater contamination. Thus, wallboard from sources such as renovation, demolition, or deconstruction activities should be monitored and may be limited for this market. The method of mechanical gypsum application to the soil will dictate the size of the material and the degree of processing needed. With some application techniques, larger pieces of drywall may cause damage to plants as the gypsum is “thrown” from the spreader at high velocities. If the drywall is being tilled into the soil, large sizes may be permissible as size reduction will also occur during the application process and plant damage from application is not a concern.

Use in Compost

Gypsum drywall has been proposed as an amendment in composting systems in a number of locations. The paper fraction of the drywall should certainly biodegrade along with the other degradable organic matter in the compost feed stream. The gypsum itself, however, will not biodegrade to any major extent; it will instead be incorporated into the final compost product. The result is a calcium- and sulfur-rich compost, which may have a benefit for some crops (as described above). Gypsum also offers the potential to bind up odors associated with ammonia. On the other hand, if the composting system is not kept aerobic, anaerobic microorganisms can result in the production of H_2S. The key is to keep the compost pile aerobic. The application of

gypsum wall board to mechanically agitated compost systems (e.g. a windrow turner) tends to work better than static systems (e.g. a forced air static pile) because the mixing and physical breakup of the gypsum that occurs. Ground drywall placed in static piles along with yard trash and food waste has been observed to be relatively intact at the end of the composting process.

PROCESSING SYSTEMS

Several different processing methods have been utilized for preparing gypsum drywall for recycling. As discussed above, the type of processing required will be dictated by the source of the wallboard and the required quality of the end-market. The major objectives of processing are separation of the wallboard from other components of the waste stream, separation of the gypsum from the paper, and the size reduction of the gypsum. Separation of drywall from other waste stream components can be achieved by manual sorting, but for the most part, the key is to recover the gypsum wallboard when it is produced. In most construction and deconstruction activities, the majority of the drywall will be produced over a short time frame. If the recovery system is designed appropriately, relatively contaminant-free loads of drywall can be obtained. However, some degree of inspection and manual clean-up may always be required.

A big issue associated with drywall processing is dust. Dust is either addressed by containing as much of the processing system as possible (enclosing the processing equipment in a container or a building) or by providing water in the form of a mist to minimize emissions. Drywall processing systems will, in many cases, require an air permit (appropriate regulatory authorities should be contacted). Several vendors market self-contained drywall processing equipment. Many of these operate using some type of grinder followed by a screening system and a dust collection system is typically included. Standard size reduction devices found at many waste processing sites (e.g. tub grinders, horizontal mills) can be used to process drywall. Dust issues may need to be addressed and screening will normally be necessary. Trommel screens are frequently used screening devices. Trommel screens have, in fact, been used as stand-alone operations were drywall is both separated from the paper and size reduced. The gypsum recovery efficiency is not as high as can be obtained by a combination of grinding and screening, but recoveries greater 60% are certainly possible. A preliminary size reduction step using a loader or compactor has been found useful for obtaining better efficiency in trommel-only systems.

A recent development worth noting is the use of small grinders directly at the construction site. These grinders are portable and small enough to bring directly to the construction site to grind the drywall (as well as other components such as wood and brick). The drywall can then be land applied if the soil demonstrates the agronomic need. The contractor saves in terms of container and hauling costs. While this technology has not yet been applied to deconstruction projects, it is certainly possible that it could be in the future.

ENVIRONMENTAL CONSIDERATIONS

As with the recycling of most construction materials, environmental and human safety issues must be addressed. The biggest environmental issue that most people in the waste management industry are familiar with regarding gypsum drywall is the production of odors in landfills. This should not be a great concern for those recycling gypsum drywall, with the possible exception of gypsum's use in composting systems (see previous discussion). It is noted that the authors have heard drywall processors comment that large piles of stock-piled gypsum drywall have been found to have some odor problems when stored out of doors for a long period of time. This has not been a major issue, however.

When dealing with drywall from deconstruction or demolition projects, several other potential environmental issues must be explored. The presence of paint, particularly lead-based paint, could limit the recycling of wallboard, especially for soil application purposes. Since most paints that contained a large amount of lead were used on doors, window sills, and on exterior walls, most drywall should not be heavily coated with lead. Lead might be more of a concern for markets such as land application and compost. Samples of suspect drywall should be tested for lead content and compared to appropriate risk-based clean soil concentrations. For example, in Florida, the soil cleanup target level for lead (for residential exposure settings) is 400 mg/kg. Mercury has been reported to have been used as a fungicide by some wallboard manufacturers in the past. Thus for markets such as land application, analysis of mercury might be needed. Asbestos, an issue that is always of concern when dealing with the renovation, demolition or deconstruction of buildings, was not widely used for the manufacture of gypsum drywall in the past. Asbestos may, however, be encountered in the joint compound associated with the wallboard installation. Requirements for the identification and management of asbestos containing materials are outlined in the Clean Air Act regulations. While these issues do certainly require added attention, with proper care and testing (with the final market in mind), drywall removed from deconstruction projects should be able to be recycled.

As a final note, questions have been raised concerning the glass fibers found in Type X drywall. Wisconsin researchers have reported that Type X drywall was not harmful to soil organisms (earthworms). Concerns have also been raised about the possible impact of the glass fibers on the human respiratory system. The drywall industry asserts that the size of the fibers is too large to have an impact to those cutting type X drywall; the impact of grinding operations has not been examined. Research is currently underway to examine this issue.

BARRIERS

The recycling of gypsum drywall is technologically feasible. This is certainly true for scrap drywall from new construction activities (where asbestos and trace metal contaminants are not an issue). And with proper care, testing, and market selection, recycling of drywall from deconstruction and demolition activities should also be feasible in many situations. Several barriers, however, may limit drywall recycling and are thus worth discussing briefly. First and foremost is the economic viability, an issue familiar to those in the deconstruction industry. In many cases, the cost of landfilling is so small that the cost of separating the drywall from the rest

of the waste stream and its subsequent processing is more expensive. This is true in many locations for construction and demolition (C&D) debris as a whole. In Florida, US, for example, C&D debris can still be disposed in unlined landfills with very low tipping fees. While a dramatic policy decision such as a landfill ban on drywall would open up recycling markets, the lack of existing markets dampens enthusiasm for this approach. An innovative solution that some jurisdictions in California, US, have implemented is the requirement of a deposit by contractors when retrieving a permit. The deposit is only returned if the waste produced by the project is recycled.

Another barrier encountered with the implementation of drywall recycling program is the necessity to change the status quo. The contractors who produce the waste stream and those that manage the waste stream have a system in place that has historically worked, and requiring changes such as separation of drywall from the rest of the waste stream, even if it does not result in any additional cost or labor, can be hard to accomplish. Education and dialogue are required. Even many of the potential end users (e.g. cement plants, farmers) are reluctant to use recycled gypsum. Again, education and demonstration projects are needed.

SUMMARY

Gypsum drywall is a construction material that has recycling markets that are technologically feasible. The primary markets are use in new drywall manufacture, portland cement manufacture and as a soil amendment. Minor markets include use as a compost amendment and for animal bedding. Though drywall from deconstruction projects can be recycled in many of the same manners as drywall from new construction projects, this material must be evaluated more closely because of the possible presence of trace contaminants. In addition to those environmental considerations, recycling program implementation barriers must be addressed. Continued education and demonstration of drywall recycling is needed; in many cases policy and regulatory changes may be required before gypsum drywall recycling reaches its full potential.

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