EUROGYPSUM

THE VOICE OF THE EUROPEAN GYPSUM INDUSTRY

Living with Gypsum: From Raw Material to Finished Products

"…processed and used by Man in construction or decoration in the form of plaster and alabaster since 9000 B.C…"

I. INTRODUCTION

1. Gypsum, one of the Oldest Raw Materials used in Construction

Gypsum is a rock like mineral commonly found in the earth's crust, extracted, processed and used by Man in construction or decoration in the form of plaster and alabaster since 9000 B.C. Plaster was discovered in Catal-Huyuk in Asia in an underground fresco, and in Israel Gypsum floor screeds were found from 7000 B.C. During the time of the Pharaohs, Gypsum was used as mortar in the construction of the Cheops Pyramid (3000 B.C.). In the Middle Ages and the Renaissance, decorations and artistic creations were made of plaster. Since then, the range of construction-related uses have continued to multiply.

Gypsum can indeed also:

- Be added to some bread and dough mixes as a Calcium source and baking aid.
- Be used as a filler and fire retardant in plastic products.
- Be used in Portland cement and special cement products for set and expansion control.
- Be a source of Calcium and Sulphate Sulphur for plant growth.
- Be used as a modelling material for tooth restorations.
- Be an ingredient in many patching compounds.
- Be used with glass to fabricate large, lightweight architectural decorations.
- Be used as a mould material to fabricate custom body parts for trucks and automobiles.
- Be an aid in juice extraction of some fruits and vegetables.

2. The Modern Use of Gypsum in Construction: Plasterboard

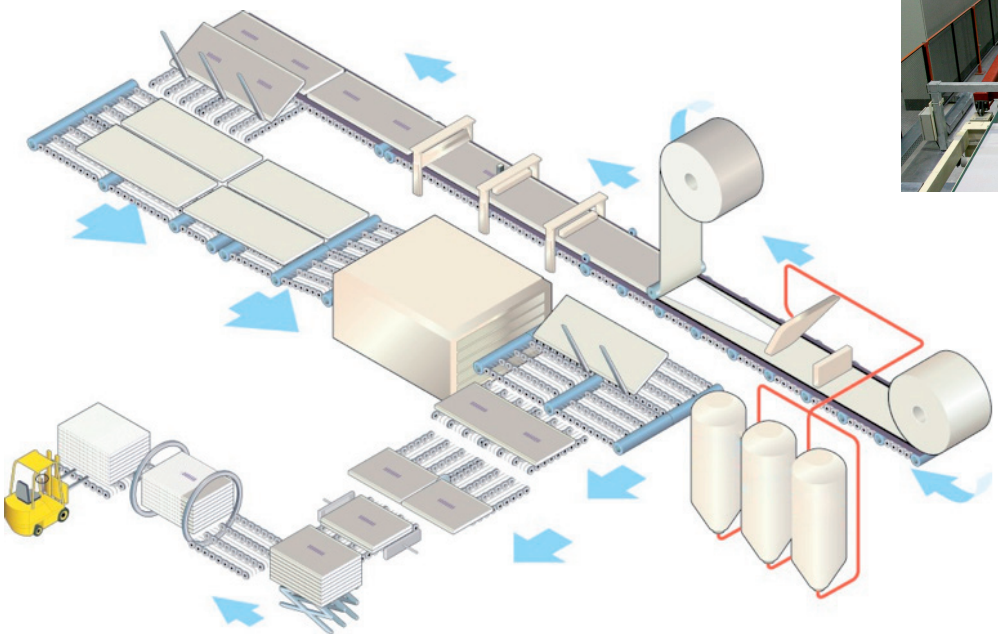
The modern use of Gypsum as a building material was discovered in 1888 when the American Augustine Sackett invented a machine for producing plasterboards (also known as wallboards and dry walls) composed of several layers of paper with Gypsum in-between.

The first plasterboard plant was built in the USA in 1901. In 1908, the plasterboard technique was improved by the American Stephen Kelly

who patented plasterboard with a Gypsum core and one layer of paper on the front and back side. The modern plasterboard was born. Since then plasterboard technologies have developed to include new properties (acoustic and fire resistance) maintaining, however, the basic technique invented by Stephen Kelly.

In Europe, the first plasterboard plant was built in Liverpool in 1917 and the second one in London in 1926. In continental Europe, the first factory was completed in Riga in 1938.

Nowadays, the manufacturing of plasterboards is increasing worldwide. In Eastern and Western Europe, there are currently more than 200 factories producing plasterboards.



3. Uses of Gypsum Products in Home Interiors

More than 1,500 million m² of European interior surfaces are covered every year with plasterboards, blocks or plaster.

A. Plasterboards

- Plasterboard is used for partitions and the lining of walls, ceilings, roofs and floors. The properties of plasterboard can be modified to meet specific requirements, such as fire resistance, humidity resistance, impact resistance, etc.

B. Decorative Plaster

- Plaster powder, mixed with water, manually or through the use of silo-supplied spray systems, is used to create an effective and aesthetically-pleasing lining for brick and block walls, and for ceilings.
- Gypsum's adaptability in application lends itself to moulding and shaping. Since time immemorial, Gypsum has been used by skilled craftsmen to create decorative plaster mouldings.

C. Building plaster

- Gypsum plaster is used for walls and ceilings.

D. Plaster blocks

- Gypsum blocks are used for partitions and Gypsum tiles for ceilings.

E. Gypsum-based self-levelling screeds

- Anhydrite or Alpha-Hemihydrates are used in the production of self-levelling floor screeds.

F. Gypsum Fibreboards

- Gypsum fibreboard is used for partitions and the lining of walls, ceilings, roofs and floors. Standard Gypsum fibreboard offers good performance when it comes to impact resistance, sound insulation and humidity resistance.

II. GYPSUM CREDENTIALS

1. Unequalled as a Material for Interiors

Gypsum is virtually indispensable for the interiors of homes and offices, and indeed all types of building where people congregate such as schools, shops, airports, etc. Its superior performance in providing everyday comfort, in fire resistance, thermal and sound in insulation, heralds an ever greater role for it in buildings of the future. In fact, the safety and protection of people and property against fire, and the effective thermal and acoustic insulation of buildings depends, more often than not, on the unique properties of Gypsum. And many of the attractive features of modern interiors would be impossible without the versatility of Gypsum as a building material.

2. Gypsum Products' Unique Properties

1. Fire Properties

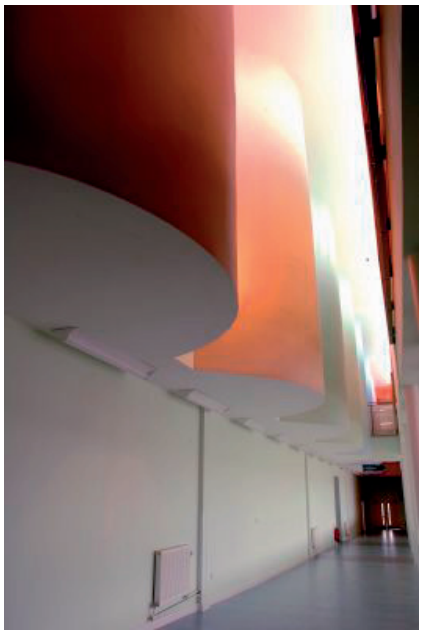
- **Fire Resistant**

Due to the natural composition of Gypsum, gypsum plasterboards are inherently fire resistant. It offers a high qualitative solution to prevent the spread of fire in buildings and effectively protect the householder from fire.

The chemical formulation of Gypsum is **$CaSO_4,2H_2O$ - Calcium Sulphate Dihydrate -.** In nature, Gypsum occurs in the form of crystals**.** Thanks to the presence of water in Gypsum (H_2O), one square meter of plasterboard of 15 mm thickness contains around 3 litres crystal water. Through the action of fire, the crystal water evaporates and a protective layer of Gypsum is formed. Behind this layer, the material under fire attack remains at constant temperature around 100°C as long as water is released from the Gypsum, impeding the spread of a fire to other parts of the building.

The inclusion of glass fibres in Gypsum boards enhances their fire protection performance by maintaining the integrity of the board in a fire. So Gypsum is a powerful fire retardant element in the construction sector due to its non-combustibility and ability to delay for up to 4 hours - according to the number of plasterboards in the corresponding system - the progression of fire.

"…plasterboard technologies have evolved to include innovative properties…"



- **Non-combustible**

The European Classification System (Euroclasses), devised for the classification of reaction to fire, is part of the ongoing harmonisation of European standards.

Reaction to fire has traditionally been assessed using at least 30 different national standards across Europe. Not only is the Euroclass system new, but it includes new tests designed to better evaluate the reaction of building products to fire.

Euroclasses predict the performance of construction products in end-use conditions in a real fire more accurately than the 30 above-mentioned standards. Gypsum products are intrinsically fire-safe products and generally fall into the higher Euroclass classifications.

The Euroclass test methodology is built around the Single Burning Item (SBI) test method which is an intermediate scale test to evaluate the rate of fire growth from a waste paper basket fire positioned in the corner of a room. Other tests used in the classification system are the non-combustibility test, bomb calorimeter and direct small flame impingement test.

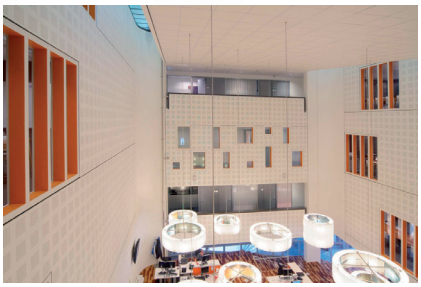
Plasterboard is subject to a classification without further test decision[1]. Essentially this means that any type of plasterboard is classified A2 (material of limited combustibility) so long as the paper grammage of the liner does not exceed 220g per m^2. Any plasterboard product that has a paper-liner in excess of this grammage is required to be tested.

- **Why Gypsum is so effective in Fire**

Gypsum plasters and plasterboards provide good fire protection in buildings due to the unique behaviour of Gypsum when exposed to fire. Pure Gypsum ($CaSO_4$, $2H_2O$) contains nearly 21% chemically combined water of crystallisation, and about 79% calcium sulphate, which is inert below a temperature of 1200°C.

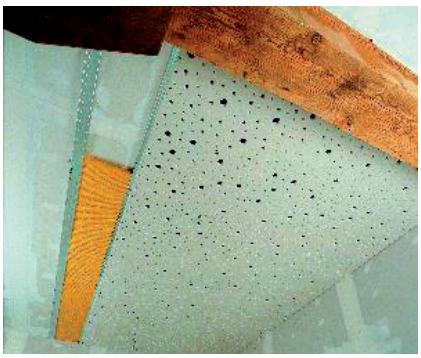
When Gypsum protected elements are exposed to fire, the chemically combined water is gradually released in the form of water vapour. If sufficiently high temperature is maintained, eventually all the water of crystallisation will be expelled. The process of dehydrating Gypsum by

heat is known as “calcination”. This condition is caused in general use if the board or Gypsum finish is continuously exposed to temperatures over 50°C. It commences at the surface exposed to the fire and proceeds gradually through the gypsum layer i.e. the thickness of the Gypsum plaster covering the core of the plasterboard.



The covering of the calcined Gypsum formed on the exposed faces adheres tenaciously to the uncalcined material and serves to retard the calcination process, which becomes progressively slower as the thickness of calcined material increases. While the process continues, the temperature directly behind the plane of calcination is only slightly higher then that of boiling water (100°C). Therefore, until all the water of crystallisation has been liberated, the temperature of materials adjacent to, or in contact with, the unexposed side will not exceed 100°C. This temperature is well below that at which materials used in building will ignite and far below the critical temperature for structural components. Once the Gypsum layer is completely calcined, the residue (Calcium Sulphate) continues to act as an insulating layer for as long as it remains intact. The inclusion of glass fibres and shrinkage inhibitors within the Gypsum core of certain plasterboards improves the cohesive properties and fire integrity performance. This enables a much higher fire protection to be achieved compared to standard wallboards.

So Gypsum is a powerful fire retardant element in the construction sector due to its non-combustibility and ability to delay the spread of fire up to 4 hours according to the number of plasterboards in the corresponding system.



2. Acoustic Properties

All building types need the acoustic performance of their internal spaces to be carefully considered. Unwanted noise from outside the building, from adjacent buildings and from other internal spaces, can have a detrimental effect on the quality of the internal environment.

The Gypsum Industry has a beneficial impact on noise reduction as it produces special acoustic grade plasterboard which offers greater sound attenuation (between 2 and 4 dB) which can be applied where a particularly high performance is required[2].

"...plasterboard technologies have evolved to include innovative properties..."

There are two types of sound. 'Airborne' sound is the noise of people talking, from musical instruments or music systems. 'Impact' sound is created when a neighbour bangs on a wall or when someone walks or stamps on the floor above you. The further away you are from a sound source, the less you are likely to hear it. Putting a barrier between yourself and the sound - in the form of a partition or floor - reduces the amount of sound you hear.

The effectiveness of that barrier is only partly to do with its thickness. A solid mass, such as a masonry wall, may allow sound to pass readily through it if it reverberates, has the wrong density or provides no 'sound break' to interrupt the flow of sound waves.

Drywall systems provide effective sound insulation because they are designed to provide a physical barrier to sound, incorporate a sound break and minimise reverberation. The boards used are formulated to have the correct density to block sound. Between the two sides of the partition there is an air cavity, which interrupts the flow of sound. This applies irrespective of whether or not additional insulation material is included. Because the two sides of the partition are separate it is harder for impact sound to pass through.

These characteristics mean that a typical drywall partition in a house can be only 75mm thick. A comparable masonry wall would need to be 110mm thick to achieve the same sound performance[3].

3. Thermal Properties
The importance of good thermal insulation in buildings in order to reduce heating costs cannot be over-emphasised.

Lightweight building techniques (plasterboard on framework) can supply excellent thermal performance since the construction has a cavity that can be filled with the required amount of insulation. The interior plasterboards protect the insulating material and contribute, together with the vapour barrier, in preventing indoor humidity from getting in, or being trapped in, the insulation material.

- **Gypsum equilibrates humidity and heat peaks**

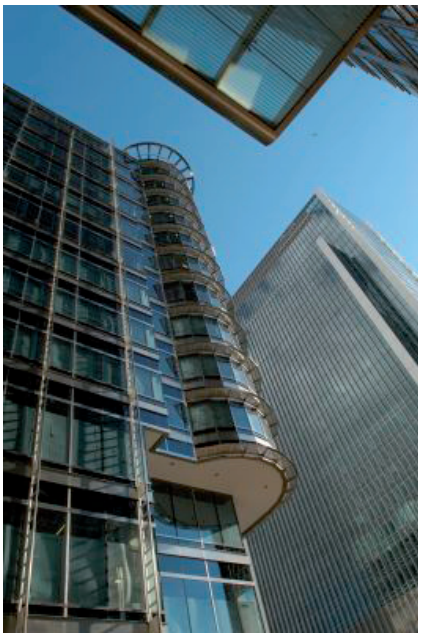
Gypsum is capable of storing humidity when a room is humid and automatically releasing this humidity if the indoor air becomes too dry.

Plasterboards have also a "heat-storing" ability. Small temperature increases are absorbed and radiated back later when the temperature in the room decreases.

4. Aesthetics and Design
A richness of forms can be created in plasterboard or stucco. For architects, building with gypsum products allows them to unleash their creativity thus allowing them to answer, even more dramatically, to the demands of their customer while remaining within an affordable budget. In short, Gypsum allows the creation of stunning interiors in any and all styles, from the Classical to the Modern.

5. Ease of Installation
Since the mid-1980s, plasterboard sales in Western Europe have risen by around 5% per year. One of the principal reasons for this rapidly growing popularity is ease of installation. To construct an internal wall, for example, a frame is erected, plasterboard is fitted to it, joints are filled, and the wall is created. The operation is clean, dry and uncomplicated. A gypsum finish can also be applied to the surface of the plasterboard in order to achieve a superior finished appearance.

6. From Products to Solutions
Plasterboard is manufactured in hundreds of variations, satisfying a vast number of technical and aesthetic requirements. In order to assist architects, contractors and specifiers in choosing the right solution for any given situation, manufacturers offer a wide range of systems. A specifier no longer has to search around and put together different components and then have the system tested. Approved packages, which include the appropriate product and the relevant accessories, such as framing components and finishing products, are available, along with any necessary technical assistance.



III. SOURCING AND PROCESSING GYPSUM

A. Sourcing

1. Natural Gypsum

Gypsum is an abundant rock-like mineral commonly mined from numerous deposits found mainly in the following European countries: Germany, UK, France, Spain, Italy, Turkey and Poland. The main producers of Gypsum outside of the European Union are the USA, China, Canada, Iran and Thailand. World reserves of natural Gypsum probably exceed trillions of tons, sufficient to meet future demand. Identified reserves are capable of sustaining decades of output at current rates of extraction. The rise in consumption of synthetic material (i.e. FGD Gypsum) in Europe and North America is slowing the rate at which natural Gypsum reserves are exploited. A further factor that may reduce the demands on natural Gypsum in Europe in the future would be an increase in the amount of recycled plasterboards[4].

What is natural Gypsum and where does it come from?[5]

Calcium Sulphate ($CaSO_4$) resources were deposited in large sedimentary basins up to 230 million years ago. The formation of Gypsum deposits usually involved the deposition of the Calcium Sulphate mineral Anhydrite, which was then hydrated to form Gypsum. The depth of hydration can range from the surface of the deposit down to three hundred metres, depending on climate, topography and the structure of the deposit. Anhydrite is often mined in conjunction with Gypsum, but is comparatively limited in its technical applications. The content of Gypsum in the sedimentary rock varies from 75% to 95%, the rest being clay and chalk.

2. Natural Gypsum Substitute: FGD Gypsum (Flue Gas Desulphurisation Gypsum)

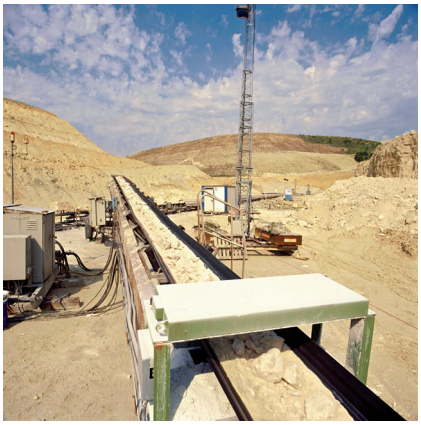
Synthetic Gypsum is produced as a by-product of an industrial process. In the case of FGD Gypsum, this is obtained from the desulphurisation of gases in coal-fired power stations.
The combustion of sulphurous fossil fuels such as hard coal, lignite (and fuel oil) produces Sulphur Dioxide (SO_2) which, if it is not removed in a

flue gas desulphurisation plant, escapes into the atmosphere with the flue gases.

In 1983, the German authorities enacted a law to protect the quality of the air making it compulsory for fossil-fuel power plants to be fitted with flue gas desulphurisation (FGD) facilities. From that year on, a partnership between the Gypsum Industry and the Electricity Industry has been formed to develop the best available techniques to convert the Sulphur Dioxide present in the flue gases into Gypsum ($CaSO_4.2H_2O$) via the use of limestone (CaO_3). This form is called FGD Gypsum. It has the form of a powder and is a direct substitute to natural Gypsum without further processing. A fruit of this long term collaboration is the published "Eurogypsum Quality Criteria and Analysis Methods for FGD Gypsum"[6] which clearly classifies FGD Gypsum as a product.

In 2006, the production of FGD Gypsum was 14.8 millions tonnes in 18 countries but only 3.2 millions in 1992.

France's energy programme does not rely on coal-fired power plants as in Germany, but mostly on nuclear power plants that do not emit Sulphur Dioxide. Therefore, FGD Gypsum production and consumption in France is low.

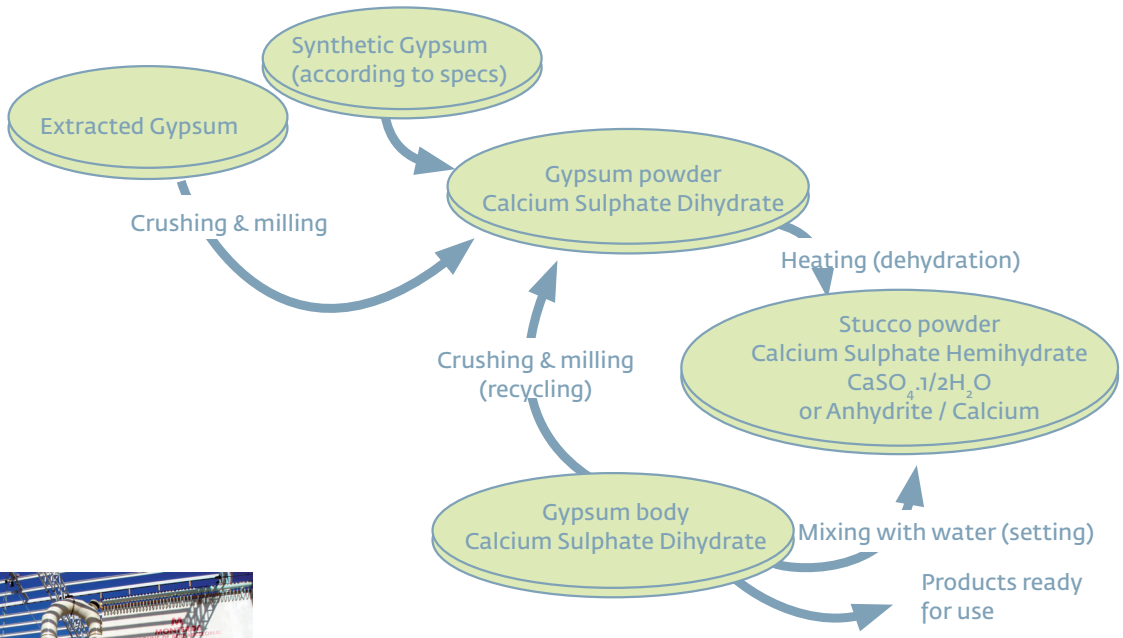


B. Processing

1. Natural Gypsum

Gypsum is usually white, colourless or grey, but can also be shades of red, brown and yellow. When calcined, it is partially dehydrated and becomes a fine white powder - commonly known as the 'Plaster of Paris' - which hardens when moistened and allowed to dry. This form is known as natural Gypsum. The gypsum process is quite simple: when Dihydrous Calcium Sulphate, also known as crude Gypsum, is exposed to certain thermal processes, Calcium Sulphate phases with little or no water of crystallisation are produced, and these later combine with free water to again form dehydrated set Gypsum. These processes, known as dehydration or rehydration, form the basis of Gypsum technology.

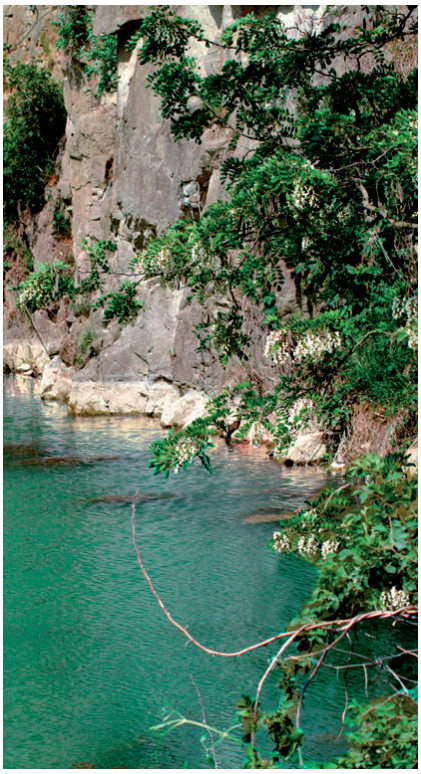
Basic principles of Gypsum processing



2. How FGD Gypsum is formed

Of the flue gas desulphurisation processes available, limestone-based scrubbing processes have proved the most popular. The desulphurisation process takes place in scrubbing towers in which the flue gases are brought into contact with an aqueous suspension containing powdered limestone or slaked lime as its alkaline component. The SO_2 is washed out by the water, oxidised to Sulphates SO_4 in the aqueous solution, and precipitated with Calcium from the limestone/slaked lime into Dihydrate Calcium Sulphate (**$CaSO_4,2H_2O$**), Gypsum. The Gypsum crystals are separated out of the suspension as a moist, fine crystalline powder with the aid of centrifuges or filters.

IV. GYPSUM AND WATER



At 25°C a liter of water saturated with Calcium Sulphate contains 1.45g of Sulphate (SO_4^{2-}) and 0.65g of Calcium (Ca^{2+}). When the water is saturated, an addition of Calcium Sulphate will not change the concentration of Sulphate. This concentration can only increase if another Sulphate (e.g. Magnesium Sulphate) is added into the water. An example is seawater, which contains 2.65g of Sulphate.

The concentration of Sulphate in groundwater depends mainly on the nature of the ground: in Gypsum areas, groundwater may be saturated (1.45g of Sulphate per liter) and in this case the addition of Gypsum will not change the Sulphate concentration.

Groundwater values of up to 2950mg of SO_4^{2-} per liter are reported in Belgium and up to 4300mg SO_4^{2-} per liter in France. In South-East Lower Saxony, a maximum value of 1455mg SO_4^{2-} per liter is found, while 28.5% of the drinking-water production installations show Sulphate concentrations of over 250mg/l. In Thuringia[7], maximum values of up to 2496mg SO_4^{2-} per liter (Muschelkalk) are reported, as well as an arithmetical average of 683mg SO_4^{2-} per liter (Keuper).

Sulphate is proven to have no adverse effect on health, and some bottled mineral waters provide evidence of this:

	Concentration in mg/l		
	Sulphate	Calcium	Magnesium
Orée du bois (Delhaize)	641	235	66
Contrex (Pavillon)	1163	464	80
Hépar	1539	572	116

600 million bottles of Contrex mineral water are sold worldwide each year.

In Austria, the term 'Mineralwasser' can only be used for water with a minimum concentration of 200mg SO_4^{2-}/l. In Germany new federal states, 20% of the measured sulphate concentration in drinking water is higher than the norm of 240mg/l[8].

V. OVERVIEW OF THE GYPSUM INDUSTRY

1. The Gypsum Economics[9]

Global extraction of Gypsum and Anhydrite rose from about 42Mt in 1960 to a peak of around 112Mt in 1999, an average annual growth rate of around 2.6%. World output then declined to around 108Mt in 2001 before rising to 111Mt in 2003 .

Rising demand for plasterboard and cement over the last twenty years has led to an increase in Western European natural Gypsum production. Production varied between 20.7Mt in 1993 and 25.7Mt in 2001 but remained flat between 1998 and 2003. One reason for the very low growth in extraction was that much of the increase in demand for Gypsum after 1998 was met by increasing use of synthetic material (i.e. FGD Gypsum). Total production in Europe of FGD Gypsum reached 14.8Mt in 2006. Reserve calculations now have to take account of the potential for producing synthetic Gypsum from flue gas desulphurisation (FGD).

Prices of crude Gypsum rose between 1998 and 2000 following high demand from the domestic construction sector. Competition with imported material and FGD Gypsum, which is less costly than natural Gypsum, led to a fall in the price of domestic natural Gypsum after 2001[15]. The average value of calcined Gypsum continued to rise after 2000 when that of crude material started to fall, partly caused by rising fuel costs.

2. The European Gypsum Industry

The European Gypsum industry is one of the ***few fully integrated industries*** within the construction products field. The companies which mine Gypsum also process it and manufacture the value-added products (plasterboards, building plasters, special plasters, Gypsum blocks, etc.) and systems used extensively in construction. ***The industry covers the whole life-cycle of a product from cradle to grave and beyond.***

The European market for Gypsum products is mature. In 2007, it was estimated that the European Gypsum industry market had a total estimated turnover of ***10 billion Euros***.

"...plasterboard technologies have evolved to include innovative properties..."

Thirty years ago, the Gypsum Industry was made up of many SMEs mainly producing building plaster and stucco for local markets. The emergence and growth of the plasterboard and the plasterboard solutions market in the 1980s - requiring high capital investments, equipment, R&D and securing access to natural resources - led to a consolidation process within the European Gypsum Industry. We currently have three main operators covering 80% of the gypsum product market. SMEs are very active in Spain in plaster powder manufacturing, with a direct employment of more than 2,300 employees, operating 26 quarries and 33 plants (powder plants, plaster blocks and ceiling tiles). There are also SMEs active in plaster blocks and plaster powder markets in other European countries.

So, we have global and small operators of European origin and know-how with national markets to serve with local resources and production. As the costs of transporting plasterboards overseas are prohibitive, the production is done in Europe, with each Member State meeting the needs and legal requirements of local customers. We can say that the Gypsum Industry is "here to stay and to grow" boosted by the European Lisbon Strategy policies.

"...building value for society..."

VI. FROM RAW MATERIAL TO FINISHED PRODUCTS

The Gypsum Industry is working towards building value for society by offering safe, economic and recyclable products for the home owner using substitutes to natural Gypsum whenever possible, in order to lower the pressure on natural resources.

As the Gypsum Industry covers the whole spectrum of the economics of a product, its responsibility covers the following aspects:

- Raw material extraction: management and use of natural resources in a sustainable way.
- Products standards: safety and quality of plants and products.
- Waste management and recycling at the end of the product life cycle.

A. Raw Material Extraction: Managing the Use of Natural Resources in a Sustainable Way[10]

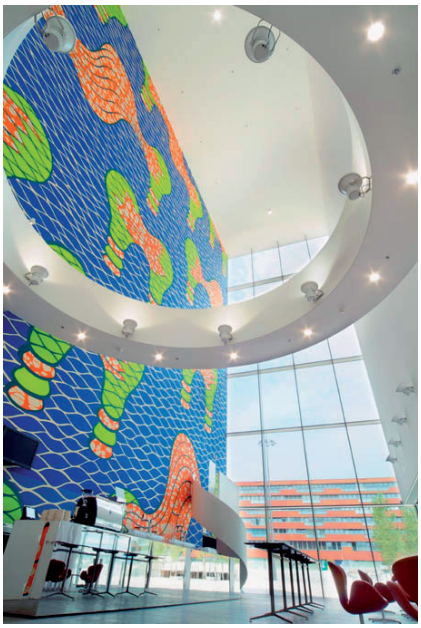
1. Background

Despite the fact that quarrying in some form or other has been carried out since the Stone Age and counts - along with the procurement of food and housing - as one of the basic activities of human beings, people still tend to regard this kind of activity with distrust and fear its effects on the local environment . Furthermore, nowadays, citizens and governments are looking carefully at how natural resources are used and in what quantities, to ensure security of supply. The two main questions to answer are: how to recover natural resources at the end of the product life cycle (i.e. at the recycling phase), and how we can safely substitute the natural resources.

2. Complying with Legislation

Quarry operators in the Gypsum Industry, either through voluntary agreements or through regulation, are complying with an increasing number of measures to minimise the potential for harmful effects.

These measures include, amongst others, Environmental Impact Assessment (EIA), permit procedures, restoration plans, investment in more technically advanced equipment, limit values for noise and dust, new roads to overcome traffic problems, etc. The Gypsum Industry favours dialogue with the local population on the opening and running of quarries, since it allows the operator to take corrective action, and gives the local residents the certainty that their views are really being taken into account. Living together satisfactorily requires mutual respect and dialogue.



3. Minimising Noise and Vibration

There are two types of noise, which arise from the quarrying of Gypsum: continuous and intermittent.

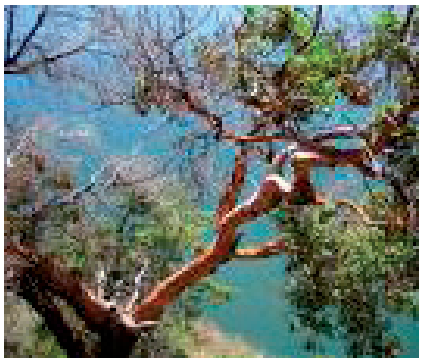
- Continuous noise can be generated by dust extractors and conveyor belts. With the adoption of mitigation measures, the levels of continuous noise are low. For example, at 50m from a crusher in a closed plant, the level of noise has been measured as being equivalent to the ambient noise in an office.
- Intermittent noise is produced by specific operations, for example, blasting (which is required to break down the Gypsum rock) and the starting of engines. To minimise this noise, well managed quarries have taken effective measures such as the use of screening mounds and the installation of special low noise starters.

Vibration from quarries derives mainly from blasting and from the use of large primary crushers and plant screening equipment. In quarries, significant progress has been achieved in the quality of explosives and delay detonators, blast design and monitoring, all of which have contributed to reducing vibration. At the plant, foundations are designed to minimise vibration from crushing and screening operations.

4. Minimising Dust

Dust is produced during the mining of Gypsum and during the stages of crushing and calcining. Unlike some types of dust, Gypsum dust presents a very low health risk since it is soluble and does not persist in the environment.

"...caring for growth, people and the environment..."



5. Minimising Visual Impacts

Among the potential negative aspects of mineral extraction, the visual impact of quarrying deserves special attention. Here, we need to consider that the sites total surface normally ranges from 10 to 150 hectares, areas which are distinctly visible. In certain cases, the effect on the landscape can be significant and unpleasant to the eye. The importance of good design and effective landscaping to minimise visual impact has long been recognised by the Gypsum quarry operators. In flat and semi-flat areas, extremely good visual protection can be achieved through the creation of screening mounds, possibly in association with the planting of vegetation. Reducing the overall quarry surface through the rapid restoration of areas already worked is another means of reducing the visibility of a site.

6. Promoting Biodiversity

Although industrial development can cause negative impact, more often than not the extractive industry creates new and diverse habitats. To a certain extent, quarries can compensate for the disappearance of the original habitats, generating diversified biotopes for rare species of amphibians, reptiles, insects, birds, flowers and plants.

German Gypsum Association[11]

In the context of a research contract awarded by the German Association of the Gypsum Industry, studies were carried out on the development of vegetation sequence in 15 Gypsum quarries.
It emerged that many small-scale structures developed, which are determined by, amongst other things, quarrying, strata beds, geomorphology. Because of different microclimates, hydrologic balances and nutrition conditions, this can result in a very diverse biotope mosaic. In addition, different sequence stages develop because of the time factor. The existence of a total of 350 plants was demonstrated for the quarries studied. The lowest for any quarry amounted to 136 and the highest 294. The plant numbers are also certainly dependent on the size of the quarry. In relation to the fern and flowering plants found in Germany, the presence of almost 12% of all species could be demonstrated. In accordance with the various conservation regulations and categories of endangered species at both Federal and State levels, 90 species of these are protected.

In addition to the plant species, the different plant categories were also recorded. These increase within a time span of 30 years from the cessation of quarrying, but after this period, fall drastically when the plant cover becomes thicker and woody plants appear. The sequence generally ends on the terrestrial surfaces with a number of trees appearing. Besides plant species and categories, many protected biotopes also develop in the quarries, such as open and low-nutrition rock formations, block and debris heaps, verge categories in hot, dry sites, as well as different aquatic biotopes.

From this study of vegetation development in Gypsum quarries various recommendations can be made for recultivation or natural rehabilitation: before actual quarrying, biotopes can be created temporarily by shifting the plant and soil cover. Diversity should be maintained in quarries, no topsoil should be brought in and the natural sequence should be given priority.

7. Quarry Restoration and Aftercare

For citizens and for local authorities, landscape conservation is of growing importance. A large quarry, whether it is located in a rural area or near an urban agglomeration, can no longer be closed down without restoration. In

many countries, there are increasingly specific requirements for restoration, although these are usually pragmatic in terms of terracing, mounding, tree planting and lake formation. Generally speaking, restoration plans need to be reviewed every year. Authorities in an increasing number of countries require financial bonds or taxes to ensure restoration is achieved in practice.

A ten year programme to restore a large open-pit quarry Vaujours-Caubron Quarry (France) [12]

The important programme of restoration for this disused open-pit Gypsum quarry (135 ha) started in 1995 and was completed by 2005. It has been subdivided in two main phases: backfilling of the excavation by inert materials and vegetalisation of these spaces with grass, timber, orchards and ponds.

Between November 1994 and July 1996, 1.3 million m^3 of earth was used to backfill the Vaujours-Caubron quarry. After that, it was necessary to reshape the topography and to reconstitute the surface soils.

To the north of the quarry a network of wet ditches and ponds have been created to drain the field and to give the landscape a more attractive perspective. Consolidated marls were used to ensure the ponds did not leak.

To the south, the old site of excavation was backfilled by a thick plant-soil that was worked and prepared before planting. Following the zones, a belt of diversified vegetation was prepared.
Ten species of graminaceae and leguminous plant were planted to recreate grasslands with the aim of promoting growth of a spontaneous flora especially adapted to this surface soil.

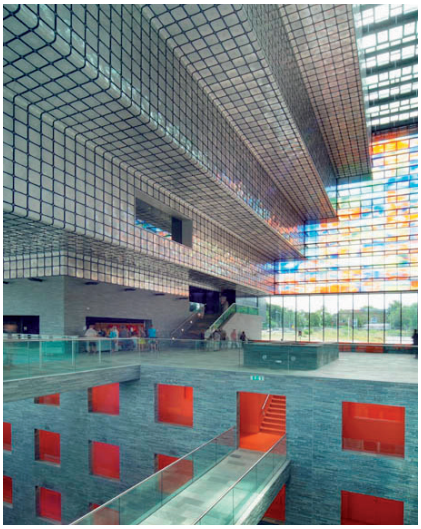
The children from the nearest village planted 300 trees of the 18,000 that have been planted for this project. Six species of tree (oak, ash, maple, wild cherry, birch), selected for the timbering, were bordered by bushes such as viburnum, dogwood, hazel tree, etc. An orchard with apple trees, plum trees and aquatic plants for wetlands completed the scenery.

The restoration project was carried out on 76 ha between 1994 and 1998. A further 60 ha has been restored between 1998 and 2004.

"…thinking globally and create wealth locally…"

8. The Conservation of Natural Resources through the Development of FGD Gypsum

As we have already highlighted above, the production of FGD (Flue Gas Desulphurisation) Gypsum in power plants has made available a raw material identical to natural Gypsum in both specifications and quality standards. Thanks to the acceptance of FGD Gypsum as a raw material, geologically lower-quality natural Gypsum can be used with FGD Gypsum, whose purity is very high, in the production of Gypsum products. The continued use of FGD Gypsum will remain an important task for the European Gypsum Industry in the future as a product enabling the sustainable use of natural Gypsum. However, the Gypsum Industry keeps in mind that FGD Gypsum is not an everlasting raw material source. Therefore, it gives priority to ensure access to natural Gypsum deposits and to obtaining new mining permits. Currently, a reliable use of FGD Gypsum is only possible if we can also at the same time secure a reliable supply of natural Gypsum.



B. Quality and Safety of Plants and Products

1. Introduction

Increasingly, regulatory agencies, customers, end-users and the general public are taking an interest in their direct environments and the environment in general. Several trends emerge:

- The trend towards sustainable construction in all its aspects;
  - Environmentally sound,
  - Length of use,
  - Ultimate recyclability,
  - Energy efficient,
  - No emissions,
  - Safe to use.
- The trend towards a higher quality build.
- The trend to increasing use of plasterboards and plaster-based products worldwide[13].

2. Production of Gypsum Products

In general terms, emissions from the manufacturing processes of Gypsum products derive either from the Gypsum rocks that contribute directly to the processes or from the fuels that provide the energy for processing. Other than emissions from the burning of fuels, the only emission during calcination is harmless water vapour.

The burning of fuels used in Gypsum processing generates Carbon Dioxide, Carbon Monoxide, Nitrous Oxides and Sulphur Dioxide. Although within required limits in Europe, these emissions can have adverse environmental effects. The industry is working to minimise the emissions of these gases. This has involved many plants switching from oil to natural gas, resulting in lower emissions of these types of gases. Many older factories, especially calcining installations, are being entirely rebuilt or radically modernised, partly in order to deliver improved energy efficiency standards as well as decreasing emissions. To this end, recovery of energy through use of air/air exchanges, optimisation of the drying process, and the substitution of oil by gas are being developed.

3. International and European Standardisation of Gypsum and Gypsum-based Products

a. International Standards (ISO)

The International Committee for Standardisation (ISO) set up in 1972 the ISO/TC 152 "Gypsum, Gypsum plasters and Gypsum products". The secretariat was provided by the French Standardisation Body (AFNOR). The aim of this Technical Committee (TC) was the standardisation of:

- Definitions, classifications, nomenclatures, etc.
- Testing and measuring methods.
- Specifications of all kinds (geometrical, mechanical, physical, chemical characteristics, performances, field of application, precautions to be observed in use, if any, etc.).

Concerning on the one hand, the Gypsum plasters and prefabricated Gypsum components which are mainly used in building and civil engineering and, on the other hand, the Gypsum plasters for technical

use and the raw materials such as Gypsum rock, etc., this TC has produced the following standards:

ISO 1587	1975	Gypsum rock for the manufacture of binders-specifications
ISO 3048	1974	Gypsum plasters-general test conditions
ISO 3049	1974	Gypsum plasters-determination of the physical properties of plaster
ISO 3051	1974	Gypsum plasters-determination of mechanical properties
ISO 3052	1974	Gypsum plasters-determination of water of crystallisation content
ISO 6308	1980	Gypsum plasterboard-specification

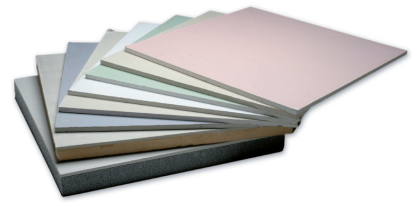
Those ISO published standards were drafted on a voluntary basis. Their objective was in line with the ISO definition, which is to define means of communication between the manufacturer and the customer providing the customer with quality assurance and product reliability.

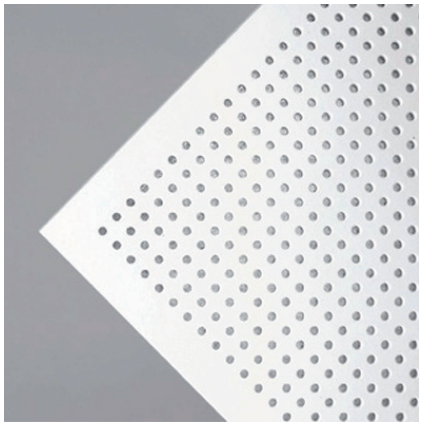
b. European Standards (CEN)

European standards are drafted by CEN (Centre Européen de Normalisation) to become the national standards of the CEN member countries. CEN is in fact the technical arm of the European Commission.

CEN - as does ISO - produces voluntary standards. In some cases, the standards produced by CEN are a result of a mandate given by the European Commission. These standards answer to those mandates and ensure compliance with the so-called "essential requirements of a Directive" and its reference appears in the Official Journal as harmonised standards.

In the construction field, those mandates are given in accordance with EC Directive 89/106/CEE on the approximation of laws, regulations and





administrative provision of the Member States relating to construction products, also known as the Construction Products Directive (CPD).

Harmonised standards diverge from "voluntary" European standards because they have an annex ZA which provide a harmonised mean to comply with the essential requirements mentioned in the Mandate and stemming from the Construction Products Directive (CPD).
In the CPD, there are six basic requirements: mechanical resistance and stability, fire protection/security, hygiene, health and environment, security of use, noise protection, energy savings and thermal insulation.

When a product complies with the harmonised part of the standard (i.e. the annex ZA), the conformity of the product with the provisions of the CPD is guaranteed and thus allow for the application of CE-marking, which is compulsory for placing the product on the market.

CE-marking is the visible sign showing that the product conforms to the essential requirements of the Construction Products Directive. It indicates that the products can freely circulate, and then be sold, across Europe (the European Union and the European Free Trade Zone). CE-marking for construction products does not imply however that these products meet building requirements, which are under national laws.

CE

CE conformity marking, consisting of the "CE"-symbol given in directive 93/68/EEC

AnyCo Ltd
PO Box 21, B-1050

Name or identifying mark of the producer and its registered address

03

The last two digits of the year in which the CE marking was affixed

A-12.5 - EN 520

Type and thickness of the board and number of the European Standard

Information on regulated characteristics

Reaction to fire: A2-s1,d0 (C1)
Shear strength per fastener: NPD
Water vapour resistance factor: 10
Thermal conductivity: 0,25 W/(m.K)

Airborne sound insulation:	See producer's
Impact resistance	
Acoustic absorption:	literature

Note For Reaction to fire the annex referred to into brackets specifies the end use condition in which the board is used. For boards used in end use conditions not covered by Annex B or Annex C the conditions under which the test was carried out must be stated.

The CEN Technical Committee (TC) in charge of the draft of Gypsum products is CEN/TC 241. The scope of this TC is to:

prepare European standards for Gypsum plasters, Gypsum units, Gypsum based and ancillary products as well as for design and application of the products, definitions, performance, requirements, specifications, test methods.

Set up in 1995, TC 241 has already adopted and published the following standards:

EN 13279-2	Building plasters-Part 2: Test Methods
EN 13454-1	Calcium Sulphate floor screed-Part 1: Def & Requirements
EN 13454-2	Calcium Sulphate floor screed-Part 2: Test Methods
EN 13658-1	Metal lath & beads-Part1: Int.plastering
EN 13658-2	Metal lath & beads-Part2: Ext.rendering
EN 12859	Gypsum blocks
EN 12860	Gypsum based adhesives for Gypsum blocks
EN 520	Gypsum plasterboards
EN 13963	Jointing materials for Gypsum plasterboards
EN 14195	Metal framing compatible for use with Gypsum boards
EN 14209	Preformed plasterboard cornices
EN 14190	Plasterboards-Products from reprocessing
EN 13950	Gypsum plasterboard composite panels
EN 14496	Gypsum based adhesives for composite and boards
EN 13914-2	Design and principles of internal plastering

Standards currently under preparation are:

prEN 15318	Design and application of Gypsum blocks
prEN 15319 prEN 15303-1	General principles of design of fibrous (Gypsum) plaster works Design and application of plasterboard system on frames-Part 1: general
prEN 15283-1	Gypsum board with fibrous reinforcement-definitions requirements and test methods-Part 1: Gypsum boards with mat reinforcement
prEN 15283-2	Gypsum boards with fibrous reinforcement-definitions, requirements and test methods-Part 2: Gypsum fibreboards
prEN 14353	Metal beads and feature profiles for use with Gypsum plasterboards-definitions, requirements and test methods
prEN 14566	Mechanical fasteners for gypsum plasterboards systems-definitions, requirements and test methods
prEN 13915	Prefabricated gypsum wallboard panels-definitions, requirements and test methods
EN 520:2004/ prA1	Gypsum plasterboards-definitions, requirements and test methods
prEN 13279-1rev	Gypsum binders and gypsum plasters-Part 1: definitions and requirements
prEN 13815:2006	Fibrous plaster casts-definitions, requirements and test methods

C. Logistics and the Environment

The best way to reduce both the financial and environmental costs associated with transport is to construct manufacturing plants close to the source of Gypsum - whether this is a quarry or a power station fitted with FGD - and, ideally, also close to markets. These measures, which help to minimise the need for transport, have been widely adopted in Western Europe. They are now being applied to new plants that are being developed in Central Europe. Where the plant and the source are in close proximity, belt conveyors (with anti-dust coverings) are often used to avoid the need for movements of heavy vehicles.

Where factories are located away from the source of Gypsum, the environmental costs of transport can be minimised by using rivers, canals, or railways. Barges, for example, enable great quantities of Gypsum to be transported with very little adverse effect on the environment. When water transport is not possible, railway wagons specifically designed for the transport and unloading of humid bulk powder are often used.

Some natural Gypsum is transported over large distances. For example, Gypsum from Spain is exported to other European countries by sea. This requires unloading quays to be suitably adapted for handling the material, as seen in Great Britain, the Netherlands and the Nordic countries. In all cases, the utmost care is taken with the secondary transport from the quay to the factory. For example, covered conveyors are used at Portbury, near Bristol, England.

D. Waste Enhancing Value[14]

1. Waste Management and Recycling at the End of the Product Life Cycle

Waste can occur at various stages of the product life cycle: in quarrying and production of the Gypsum products, in the construction and in the demolition of buildings.

Gypsum products are amongst the very few construction materials where "closed loop" recycling is possible, i.e. where the waste is used to

make the same product again and not merely recovered for use in other 'down-cycling' applications as is the case with some other construction materials, e.g. waste concrete and bricks used for aggregates in road construction.

Gypsum as such is 100% recyclable. The reprocessed Gypsum powder which makes up approximately 94% of the plasterboard waste is sent back to the plasterboard manufacturer, to be used to produce new plasterboards. The paper, with related contaminants, which makes up 6% of the waste, can be reused in various ways, among others, for composting, heat generation, building materials, etc. Thereby, the Gypsum/plasterboard waste is virtually 100% recycled.

2. Mining Waste

Gypsum mining waste is that part of the extracted mineral which cannot be used or recycled due to two characteristics:

A. Very fine Gypsum particles which cannot be processed for technical reasons;
B. The rock is too impure to be processed or used as aggregate.

Gypsum mining waste facilities are usually located at the Gypsum deposit or very close to it to collect and process those wastes.

The Gypsum Industry is also minimising mining waste for economic and environmental reasons. It does this in two main ways:

A. Gypsum mining waste is used to backfill the voids, thus contributing to the rehabilitation of the quarries;
B. Gypsum rocks not usable because of insufficient purity ratios are mixed with high purity Gypsum (like FGD Gypsum), thus preventing waste.

3. Construction Waste

It is generally acknowledged that there is considerable scope within the construction industry to reduce the amount of material wasted on construction sites.

The advantages of reducing waste are greater efficiency and therefore increased profitability through:

- Lower costs of raw materials,
- Reduced handling costs,
- Avoidance of reordering delays,
- Reduced disposal costs,
- Tidier sites etc[15].

Around 5% of plasterboard used on construction sites becomes waste, mainly due to off-cuts. The industry is actively taking measures to reduce, reuse and recycle this waste.

One such measure is the availability of cut-to-length plasterboard, delivered in the exact quantities required on building sites. This helps to minimise the amount of off-cuts. Supplying plasters and screeds through on-site silo systems has also helped to reduce wastage. The unused amounts can either be used on another building site or returned to the producer. Silo systems have the added advantage of avoiding packaging waste such as paper sacks.

The national Gypsum Industry Associations also provide advice on how to reduce wastage from inappropriate storage, delivery, handling and installation of Gypsum products.

Recycling construction waste: best practices

A Dutch scheme, encouraged by stringent recycling legislation, provides for on-site separate storage of Gypsum in a special container. The waste, once collected and taken off-site, is stored at a central depot until enough Gypsum has been accumulated for transportation to a recycling facility.

A similar programme was set up in Ireland, in Dublin in spring 2005. The system has been inspected by the Irish Minister of the Environment with great satisfaction. Most customers are from the greater Dublin area, but everyday the coverage of the system is expanded.

In the UK, plasterboard producers are recycling "clean" building site scrap from some house builders.

"…the magic mineral indefinitely recyclable transformed into plaster…"

4. Demolition Waste

Gypsum products that are recovered from demolition and renovation projects are almost always contaminated with other materials, such as paint and fastenings, screws, wood, insulation materials, etc.

Therefore, it is not always possible for the Gypsum plasterboard producers to rely on their in-house recycling facilities – only suited for uncontaminated production and construction waste.
To be successful in recycling construction and demolition waste (C & D), we need the involvement of several stakeholders:

- Contractor and sub-contractor: for careful deconstruction and sorting.
- Collector: for effective logistics.
- Recycler: for a separation of paper liner and Gypsum core, allowing a high recycling ratio.
- Plasterboard producer: for reintroduction of Gypsum waste into the process.

Furthermore, to achieve a high rate of recycling, the Gypsum Industry needs in practice to combine its expertise in plasterboard production with third-party expertise in sorting, collecting and recycling Gypsum waste.

Nevertheless, the Gypsum industry has two main incentives to look further towards ***a culture of recycling***[16]***.***

- Over the next 20-30 years the ***economics for demolition waste*** is expected to change as the quantities begin to increase substantially, due to the strong increase in the use of plasterboard in construction which began in Europe in the 1960s and 1970s. Renovation and demolition work will see increasing volumes of Gypsum waste. The increasing use of dismantling or deconstruction techniques will increasingly make possible demolition collection and recycling.
- ***The economics of Gypsum waste products recycling*** will critically change in the near future, due to scarcity of landfills able to receive non-inert waste and to much higher landfill costs and taxes. Indeed, through a European Decision applicable since July 2005, Gypsum waste products have been excluded from the list of waste acceptable at landfills for inert waste without testing[17] because of the parameter Sulphate which is inherent to all Gypsum products.

VII. TOWARDS LIFE CYCLE THINKING: A COMMITMENT TO QUALITY, ENVIRONMENT AND GROWTH

In the past decade increasing attention was paid to the improvement of the environmental performance of products across their life-cycle. Eco-design, green procurement, eco-labels, environmental product declarations, product stewardship, life cycle assessment (LCA) and energy labels are all (good or bad!) examples of ways to try to achieve such an improvement, which have been supported by governments and industry in one way or another.

Environmental Products Declarations (EPDs) schemes have been developed in order to provide credible information on the environmental impact of Business to Business products. There is however a wide variety of EPD schemes. In order to avoid misleading the market, it is urgent they be harmonised. EPDs in the construction field are an essential tool in the process of determining integrated environmental building performance. Therefore, the Construction Industry has long advocated for CEN to standardise EPDs on a voluntary basis. This work started at the end of 2005 under the banner of TC 350: 'Sustainability of Construction Works'. Eurogypsum actively participates in the work of TC 350 and is highly involved in improving products performances.

For example, in 2003, the French Gypsum Association developed with ECOBILAN life cycle inventories (LCI) on generic Gypsum products (plasterboard, partitions and Gypsum blocks) within the HQE framework. The result of this work led to the production of technical documents. On this basis, the French Gypsum Association was able to prepare abridged data sheets to be used for communication purposes and characterising the various environmental impacts, as well as the contribution products make to controlling health risks in a building. Surprisingly enough, the most notable environmental impact is the production of waste.

Those actions are necessary but the sustainability of the Gypsum Industry lies in its capacity to create wealth in the indoor-built environment with

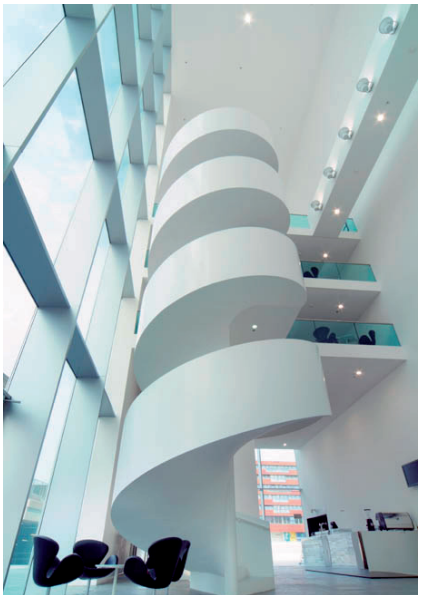
a sustainable use of natural resources, energy efficient buildings and by reconceptualising waste as products.

Industrial sustainability, which the Gypsum Industry is striving to achieve, is a logical extension of life-cycle thinking, moving from assessment to implementation. It involves "closing loops" by recycling, making maximum use of recycled materials in new production, optimising use of materials and embedded energy, minimising waste generation, and re-evaluating "wastes" as raw material for other processes.

The Gypsum Industry believes that environmental objectives can be compatible with continued technological development and wealth creation. By taking this progressive outlook, it is thus aiming at avoiding Industrial stress on the environment. The Gypsum Industry also highlights the fact that there are indeed contact points between the industry and the environment, as we see in the increased biodiversity in Gypsum quarries shown in a scientific survey carried out by the German Gypsum Federation. Our vision of the environment is expressed in terms of dynamic processes, whereby we contribute by our actions to the maintenance of the eco-system.

Progress in dematerialisation is currently occurring in the Gypsum industry. Value is increasingly being added by emphasising product quality, product-related information to handle the product adequately, and embedded knowledge in providing solutions - i.e. acoustic and fire solutions for buildings - rather than products. One of the remaining concerns is the management of Gypsum wastes at the end of their life-cycle. The Gypsum Industry is currently striving to resolve this issue by promoting design for disassembly, for ease of recycling, and by setting up internal recycling facilities for production and clean construction Gypsum waste.

Despite these advances, the Gypsum Industry is conscious of its responsibility to go further towards an eco-system approach, thereby contributing to shaping its customers' total quality of life-not merely in the products that it supplies, but also in ensuring that it does not in the process degrade other aspects of the customer's life experience. Through its products and solutions, the Gypsum Industry aims to create a world that is aesthetically pleasing, biologically stable, and economically productive.



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