

GTOG: From production to recycling: a circular economy for the European gypsum Industry with the demolition and recycling Industry



EUROPEAN HANDBOOK ON BEST PRACTICES IN DECONSTRUCTION TECHNIQUES

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Foreword

The European Gypsum Industry has undergone a major transformation over the last 20-30 years, having being the gypsum pasteboard systems increasingly used, and consequently a deconstruction forthcoming issue.

The present European handbook aims to promote the implementation of best practices for a controlled deconstruction process of such gypsum-based systems, which might ease recovery.

The document is organized as follows:

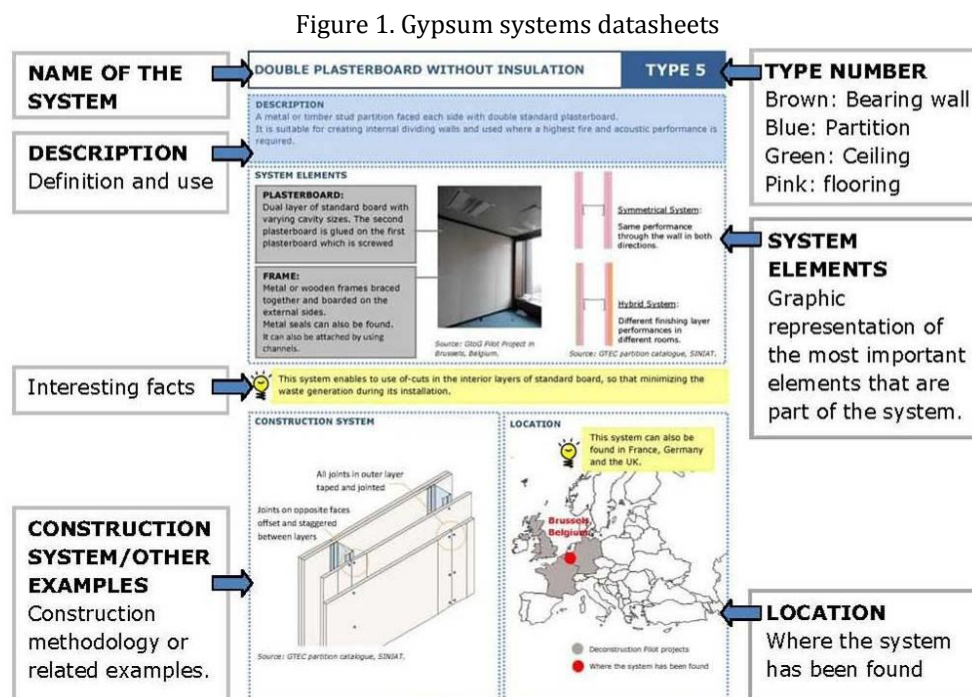
- The most common gypsum-based systems that can be encountered on a deconstruction project are described; along with the waste acceptance criteria of the recyclers that are partners of the GtoG project are detailed. The compliance with these criteria ensures that the gypsum-based waste can be used without compromising the quality of the recycled gypsum.
- Although a gypsum-based material may be recyclable according to the recyclers' specifications, it has to be properly deconstructed and separated from the other materials that constitute the gypsum-based system so as to allow its recycling. Best deconstruction techniques to be applied to the different GtoG gypsum-based systems are described in this sense. These provisions are a result of the project's evaluation, describing the deconstruction methods that would be most suitable for each particular case, and including their relevant advantages and disadvantages.
- In the choice of deconstruction techniques versus demolition of the systems, the total cost of the two options is a decisive parameter. Deconstruction versus demolition costs are therefore compared for a particular case.
- Finally, not only the demolition companies play a key role in allowing gypsum-based materials to be recovered but also plasterboard manufacturers, project owner, project managers, waste transfer station and construction companies have a key role to improve the gypsum-based system recyclability. Design, installation, deconstruction practices are essential when closing the recycling loop.
Therefore, some recommendations for the improvement of the recyclability process are given towards these different players.

1. State of the art of the recyclable and non-recyclable gypsum-based systems

1.1. DESCRIPTION OF THE SYSTEMS

This section is based on the information obtained during the GtoG deconstruction projects, in addition to the analysis of different resources and literature on current standards. It should be noted that it doesn't cover all possible configurations of systems in all possible construction works, as it is exclusively limited to the cases under study. However, the most common systems that can be found today on a deconstruction jobsite, in the countries covered by the scope of the GtoG project, are covered.

The information is presented in datasheets, organised as follows:



All system descriptions contain a general explanatory note about their major components, basic construction details, location under the project scope, as well as cross-section details in some cases.

The systems are assigned a type number and a colour code according to three major categories, casing of: bearing walls, partitioning and ceiling as described in the catalogue (DB2_Database).

THERMAL LAMINATED PLASTERBOARD

TYPE 1

DESCRIPTION

This plasterboard system consists of plasterboard bonded to a variety of different types and thicknesses of insulation, in order to provide a thermal and sound upgrade. It is suitable for use upon bearing walls or internal lining.

CONSTRUCTION SYSTEM

Direct bonding system, applying adhesive to be glued straightforward on the wall.



Source: GtoG Pilot Project in Paris, France.

Both materials can be recycled when they are separated by hand or knife. If mechanical processes are used, only plasterboard can be recycled.



SYSTEM ELEMENTS

INSULATION

The insulator is mainly EPS (95% of the systems). Other types that can be found are:

- ✓ Mineral glass wool
- ✓ Rock wool
- ✓ Polyurethane (PU)

PLASTERBOARD:
Standard board



Source: GtoG Pilot Project in Paris, France.

LOCATION



This system can also be found in Germany.



Paris,
France



GtoG Project Area



GtoG Reference Deconstruction Site

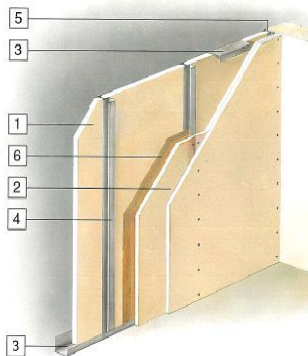
PLASTERBOARD WITH INSULATION TYPE 2 TYPE 3 TYPE 7

DESCRIPTION AND USE

A metal or wooden stud partition infilled with mineral wool, or other insulation materials, faced each or just one side with double standard plasterboard.

It is suitable for partitions, upon bearing walls and used as a thermal insulation system.

SYSTEM ELEMENTS



COMMON SYSTEM ELEMENTS:

INSULATION:

Glass wool, rock wool or other insulation

PLASTERBOARD:

Glass wool, rock wool or other insulation

FRAME:

Metal or wooden frame can be found.

Plasterboard is screw, fixed or nailed to the frame.

This partition receives in its cavity mineral wool to increase thermal comfort.



TYPE 2- Wooden bearing framework

Source: GtoG Pilot Project in Graben, Germany.

TYPE 3 Plasterboard system with a non-accessible face

Source: Siniat France

- 1: Standard plasterboard
- 2: Dual layer of standard board
- 3: Metallic uprights/channel
- 4: Metallic frame
- 5: Metallic uprights
- 6: Mineral wool insulation

OTHER EXAMPLES

TYPE 7 Partition

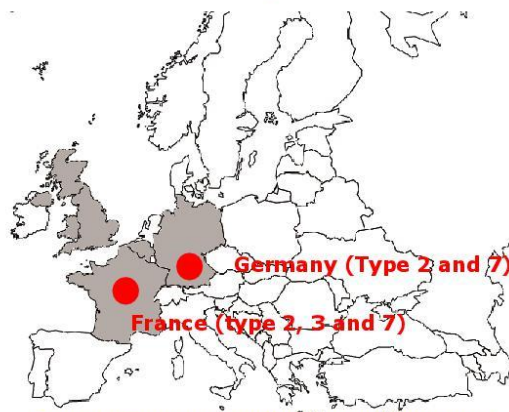


Source: GtoG Pilot Project in Ulm, Germany.

LOCATION

● GtoG Project Area

● GtoG Reference Deconstruction Site



Type 7 can be also found in Belgium and the UK.

PLASTER PARTITION BLOCKS

TYPE 4

DESCRIPTION

Gypsum partition blocks are pre-molded plaster parallelepipeds with slab to slab joints and different thickness. They are normally used for inner lightweight partition as fire-retardant or to improve acoustic insulation, and their surface is suitable for all kind of finish.

SYSTEM ELEMENTS

GYPSUM BLOCKS:

Gypsum blocks require no sub-structure for erection.



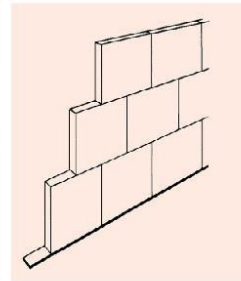
Source: Rigips products catalogue Saint Gobain.



Source: GtoG Pilot Project in Paris, France.

CONSTRUCTION SYSTEM

Gypsum blocks are assembled matching the pieces together. An adhesive is used as bonding agent. They can be covered with a coat of finish.



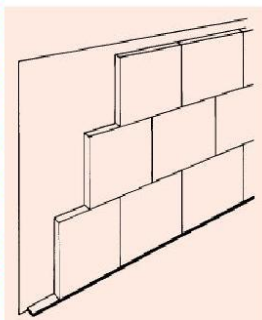
Source: Rigips products catalogue Saint Gobain.

The use of gypsum partition blocks allows to reduce the time and material expenditures compared to the use of traditional materials (bricks, cellular concrete blocks). Moreover, blocks are fully recyclable.

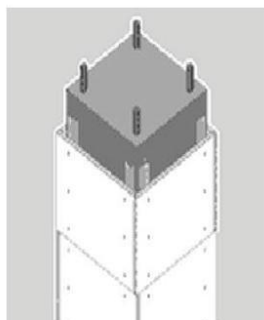


ALTERNATIVE CONSTRUCTION SYSTEMS

Inner lining



Column protector

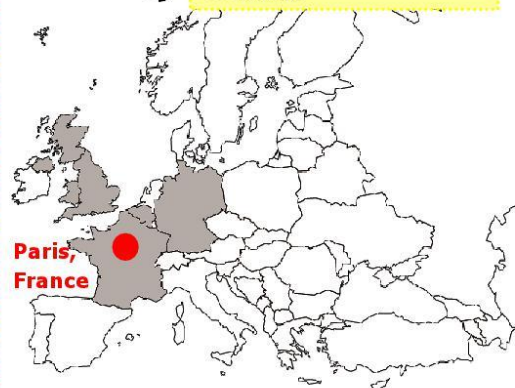


Source: Rigips products catalogue Saint Gobain.

LOCATION



This system can also be found in Belgium and Germany.



● GtoG Project Area

● GtoG Reference Deconstruction Site

DOUBLE PLASTERBOARD WITHOUT INSULATION

TYPE 5

DESCRIPTION

A metal or timber stud partition faced each side with double standard plasterboard. It is suitable for creating internal dividing walls and used where a highest fire and acoustic performance is required.

SYSTEM ELEMENTS

PLASTERBOARD:

Dual layer of standard board with varying cavity sizes. The second plasterboard is glued on the first plasterboard which is screwed

FRAME:

Metal or wooden frames braced together and boarded on the external sides. Metal seals can also be found. It can also be attached by using channels.



Source: GtoG Pilot Project in France



Symmetrical System:

Same performance through the wall in both directions.

Hybrid System:

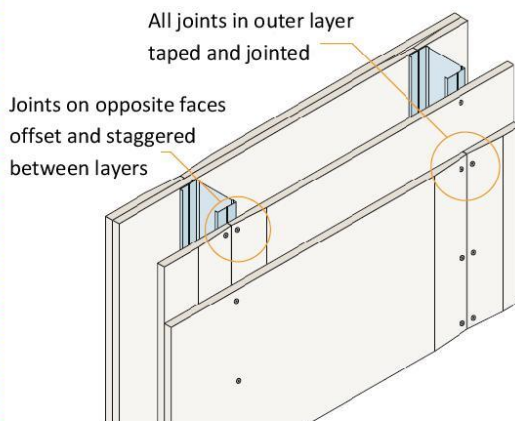
Different finishing layer performances in different rooms.

Source: GTEC partition catalogue, SINIAT.



This system enables to use of-cuts in the interior layers of standard board, so that minimizing the waste generation during its installation.

CONSTRUCTION SYSTEM

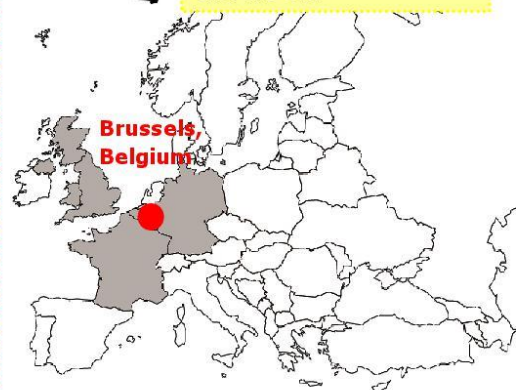


Source: GTEC partition catalogue, SINIAT.

LOCATION



This system can also be found in France, Germany and the UK.



● GtoG Project Area

● GtoG Reference Deconstruction Site

HONEYCOMB PLASTERBOARD PARTITION

TYPE 6

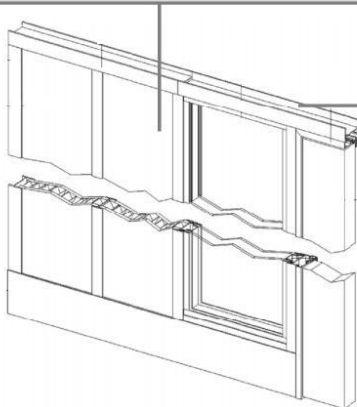
DESCRIPTION AND USE

Gypsum plasterboard panels with a cellular paperboard core. It is used as a lightweight partition and interior lining. It can be found in commercial buildings and, less commonly, in residential buildings.

SYSTEM ELEMENTS

HONEYCOMB INSULATING MATERIAL

The plasterboard itself is an insulating material made from cardboard.



FRAME

Wooden frame support. Generally screws are used as mechanical fixing.



Honeycomb plasterboard waste. Source: GtoG Pilot Project in London, the UK and RECOVERING SARL, France.



At present, the European Standard EN 13915:2007 specifies the characteristics and performance of plasterboard panels with a cellular paperboard core



Source: Building Materials
<http://www.buildingmaterials.co.uk/honeycomb-panel.html>

LOCATION



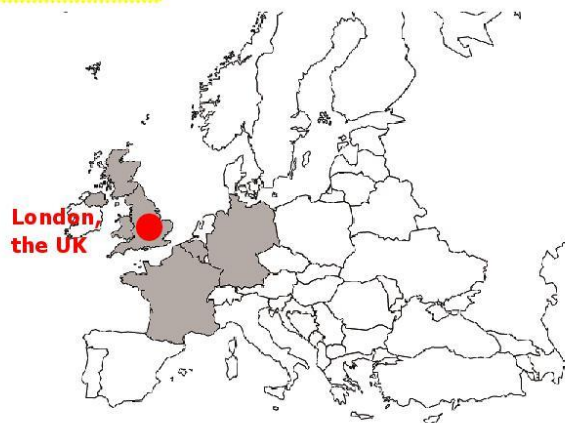
This system can also be found in France.



GtoG Project Area



GtoG Reference Deconstruction Site



PLASTERBOARD TILES SUSPENDED CEILING

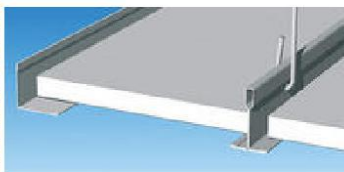
TYPE 8

DESCRIPTION AND USE

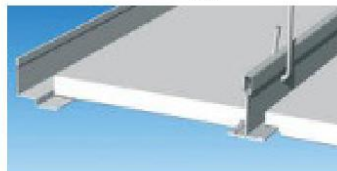
This suspended ceiling consists of plasterboard, metal frame and hanger. It is a demountable lay-in tile. No further finishing is usually required. It is mostly found in offices, schools, shopping centers, show rooms, hotels, etc.

OTHER EXAMPLES

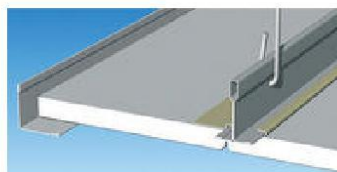
Visible ceiling grid



Semi-visible ceiling grid



Hidden ceiling grid



Source: Gyproc Saint-Gobain

SYSTEM ELEMENTS

PLASTER TILE

Different types of paper faced or non-faced board can be part of this system.



As plasterboard is just placed horizontally over the metal frame (not screw-fixed or nailed), its removal becomes easier and the gypsum waste doesn't get contaminated by other waste fractions.



Source: GtoG Pilot Project in Paris, France.

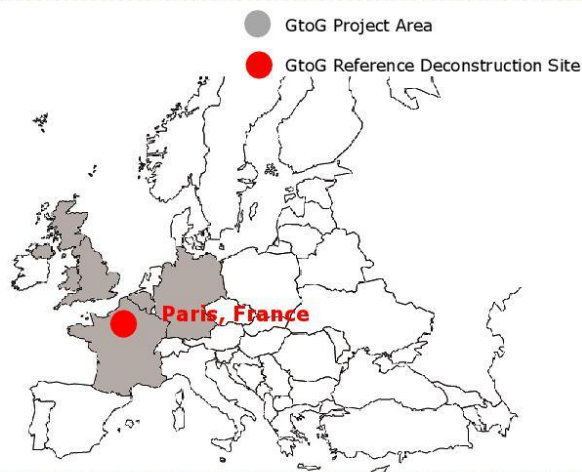
METAL FRAME / CEILING GRID

The ceiling grid is used to support the tile system. It is suspended by metal hangers, providing variable cavity depth.

LOCATION



This system can also be found in Belgium and Germany.



PLASTERBOARD CEILING/FLOORING

TYPE 9

TYPE 10

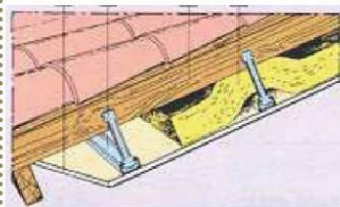
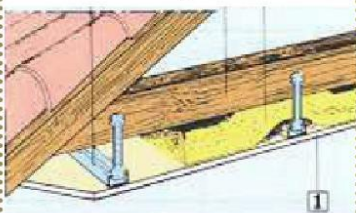
DESCRIPTION

This system consists of plasterboard, metal frame and hanger, timber frame and insulation. It is suitable either for ceilings or flooring systems.

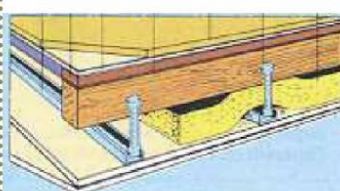
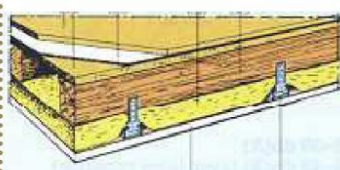
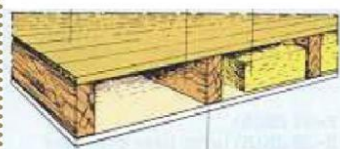
CONSTRUCTION SYSTEM

CEILING:

Under-attic ceiling



CEILING and FLOORING:



Source: Siniat France



Deconstruction and on-site segregation of the different waste fractions increases the recyclability of plasterboard by avoiding its contamination.

COMMON SYSTEM ELEMENTS

METAL FRAME

It is usually suspended by metal hangers or placed upon floors, giving variable cavity depth.



Source: GtoG Pilot Project in Graben, Germany.

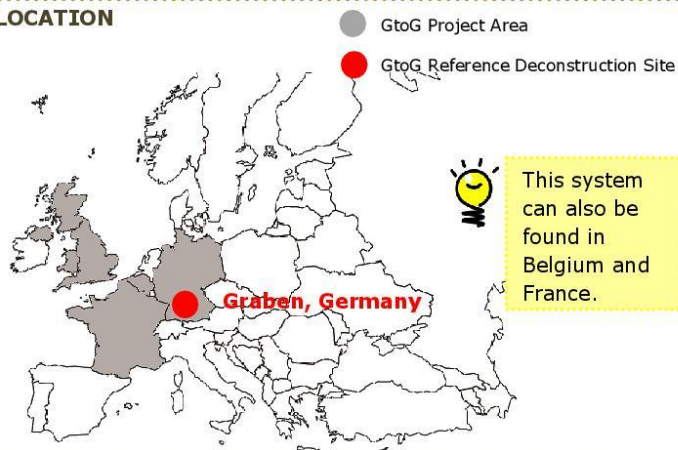
WOODEN FRAME OR JOIST

This is the traditional way in which this ceiling is found in some EU regions. Plasterboard can be screw-fixed, nailed or just embedded between plasterboards.

INSULATION

Different types and thickness of insulation are installed in a continuous layer between timber joists and metal frames. Mineral wool is the most common insulation material for this system.

LOCATION



This system can also be found in Belgium and France.

1.2. ACCEPTANCE CRITERIA FOR GYPSUM-BASED WASTE IN THE COUNTRIES UNDER STUDY: BELGIUM, FRANCE, GERMANY AND THE UNITED KINGDOM

The specifications given below have been developed by the plasterboard recyclers and manufacturers in the GtoG project team, in consultation with other relevant stakeholders and it has also been based on the developments from the DA1 deliverable and annexes.

The requirements defined in this section are used by recyclers when accepting gypsum-based waste to be processed into recycled gypsum at the recycling facility. Recycling acceptance criteria are essential for the achievement of a quality-recycled gypsum.

A certain range of impurities and moisture content, are found to be the most common issues that might affect the gypsum-based waste and must be subjected to an acceptance assessment. Hereunder they are explained and their effects are outlined:

Moisture content

The moisture content of the gypsum-based waste influences the separation of the paper from the gypsum material. Additionally, presence of moisture may cause an increased use of fuel for processing the waste or even the blockage of the machine mechanisms. If a gypsum-based waste fraction has a particular high level of moisture, it can be mixed with a dryer fraction in order to decrease it, and leave it storage on the plant's tipping floor until it gets dry enough to be processed.

Impurities in the gypsum-based waste and their effects on recycling

Gypsum waste cannot be recycled when there is a certain level of impurities (table 1), which might be difficult to separate and can affect both the gypsum recycling process and the subsequent quality of the recycled gypsum.

It is important to distinguish endogenous "impurities" as the manufacturer may have the possibility to make them disappeared from the exogenous impurities such as plastic wall paper added on the plasterboard.

Before the gypsum waste is received at the recycler's facility, it must have been pre-sorted of large amounts of impurities such as metal, plastic and other debris on-site. Although most of these elements are separated at those stages, tiny parts may be found mixed with the gypsum-based waste at the recycling facility when unloading or storage and removed by visual check.

When dry gypsum waste is loaded into recycling equipment, some recyclers implement another quality control while it passes the sorting belt.

The most common impurities and their effects are presented below:

- **Plastics, foils and insulation materials (stone/glass wool)**
These materials are sorted out before they decrease the quality of the output fraction. In particular plastics, stone and glass wool insulation materials that can contaminate the recycled gypsum powder may end up in the paper output fraction.



Figure 1: examples of plasterboard systems with frequent impurities: plasterboard bonded to insulator (left), fiberglass coating (middle), plasterboard bonded to vapour barrier (right) – Source: Siniat France specifications

- Steel rails and bars

Although nails and other small metal parts are not problematic, as they are easily removed during the processing by magnets, bigger metal parts such as steel rails and bars should be avoided or sorted out prior the recycling process as they can block the machines and cause a breakdown.

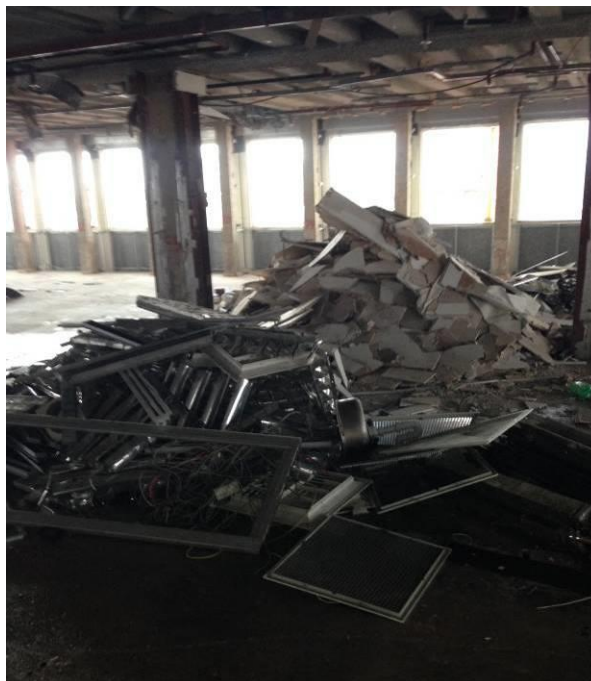


Figure 2: Example of large metal pieces that can be found mixed with gypsum waste – Source: Cantillon jobsite, Chiltern St, London UK

- Wood

Big pieces of wood can also be a threat to the machine and block it and should be previously removed. However, once the gypsum-based waste is processed, smaller wooden impurities, unnoticeable for a visual check, might end up in the paper fraction.

Other impurities:

- **AAC Autoclave Aerated Concrete**

Autoclave aerated concrete (AAC) and gypsum-based waste are often perceived as the same waste fraction and, therefore, commonly collected together by accident. As part of the collecting and pre-sorting it has to be made sure that AAC is not present in the gypsum-based waste fraction as a mix of the two is not accepted in gypsum recycling facilities.

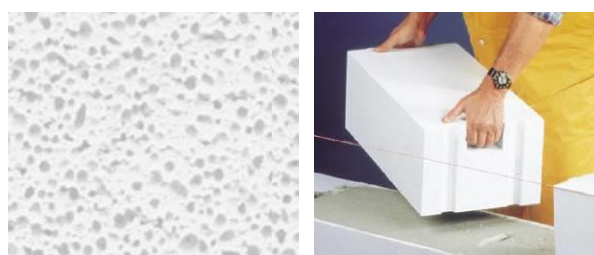


Figure 3: Autoclaved Aerated Concrete (AAC) blocks – Source: European autoclaved aerated concrete association

- **Anhydrite**

Calcium Sulfate Anhydrite (CaSO_4) can mostly be found in some blocks or moulds. Unlike gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), calcium sulfate has no crystal water and cannot be turned into an active material that can be calcined, meaning that this material should be avoided in order to keep a high quality of the recycled gypsum powder.

The following table (Table 1) provides an overview of the acceptance criteria specified by the recyclers in the project team, divided by country.

ACCEPTANCE CRITERIA PER COUNTRY (only valid with the recyclers participating in the GtoG project and their area of coverage)		FR	BE	UK	DE
GENERAL ISSUES	Free moisture content	Not limited			<10% in weight
	Max percentage of IMPURITIES (insulation material, wood, metal, plastic, foils, concrete, sand, wallpaper, glass tissue and other wall coverings...)	2%			2-3%
GYPSUM BASED	Plaster ceilings and floors	✓	✓	✓	✓

PRODUCTS	Ceiling plaster tiles*	✓	✓	✓	✗
	Glass reinforced gypsum (GRG) products	✓	✓	✓	✓
	Moulds / cove	✓	✓	✓	After approval
	Moulds used in foundry*	✓	✓	✓	After approval
	Plaster powder	✓	✓	✓	✓
	Plaster block	✓	✓	✓	✓
	Honeycomb plasterboard	✓	✓	✓	✓
	Plasterboard bonded to expanded polystyrene(EPS) , glass or rock wool, polyurethane (PU) **	✓	✗	✗	✗
FINISHING	Wallpaper	✓	✓	✓	✓
	Glass fibre wallpaper and vinyl lining	✗	✓	✓	✓
	Lead based paint	✗	✗	✗	✗
OTHER	Autoclaved aerated concrete (AAC)	✗	✗	✗	✗
	Hazardous materials, e.g. Asbestos	✗	✗	✗	✗
	Fibreboard*	✓	✓	✓	Limited
	Hardened boards (e.g. Rigidur®, Ladura®)	✓	✓	✓	✗
	Cement bound boards* (e.g. Promatec®)	✓	✓	✓	✗
*In these cases gypsum waste isn't accepted by SINIAT FR.					
**Plasterboard can be recycled when it is separated from the insulation. Nevertheless the recyclers involved in the GtoG project don't accept insulated plasterboards.					

Figure 4: Gypsum-based waste acceptance criteria per country

From the table, it can be observed that there are minor differences among countries. The maximum percentage of impurities permitted ranges between 2% and 3%, and generally there is not a reference value set for the limit of moisture content, but for Germany, which restricts it



GYPSUM TO GYPSUM



up to 10% in weight. Nevertheless some recommendations to keep the loads dry are made by some recyclers.

Gypsum blocks, gypsum boards and tiles from ceilings, floors and walls, moulds and glass reinforced gypsum products are accepted by most of them. In the case of moulds for foundry, gypsum is highly calcined, hence not retaining its properties and in certain countries its recycling is submitted to approval.

Plasterboards with cement or high organic content (such as cement bound, fibreboard etc.) are not accepted in some cases, as they are considered to reduce the quality of the recycled gypsum. Autoclaved aerated concrete is often perceived as gypsum waste fraction on the deconstruction site, although it is not a gypsum product, and therefore not suitable for the gypsum recycling process.

Paint is usually not an issue, with the exception of lead based paints and vinyl lining or glass fibre wallpapers. Hazardous waste is always forbidden in the load (e.g. asbestos).

2. Technical and economic aspects of recyclable gypsum-based systems deconstruction

2.1. BEST DECONSTRUCTION PRACTICES TO ENSURE THE VALORISATION OF THE MATERIALS CONSTITUTING THE GYPSUM-BASED SYSTEMS

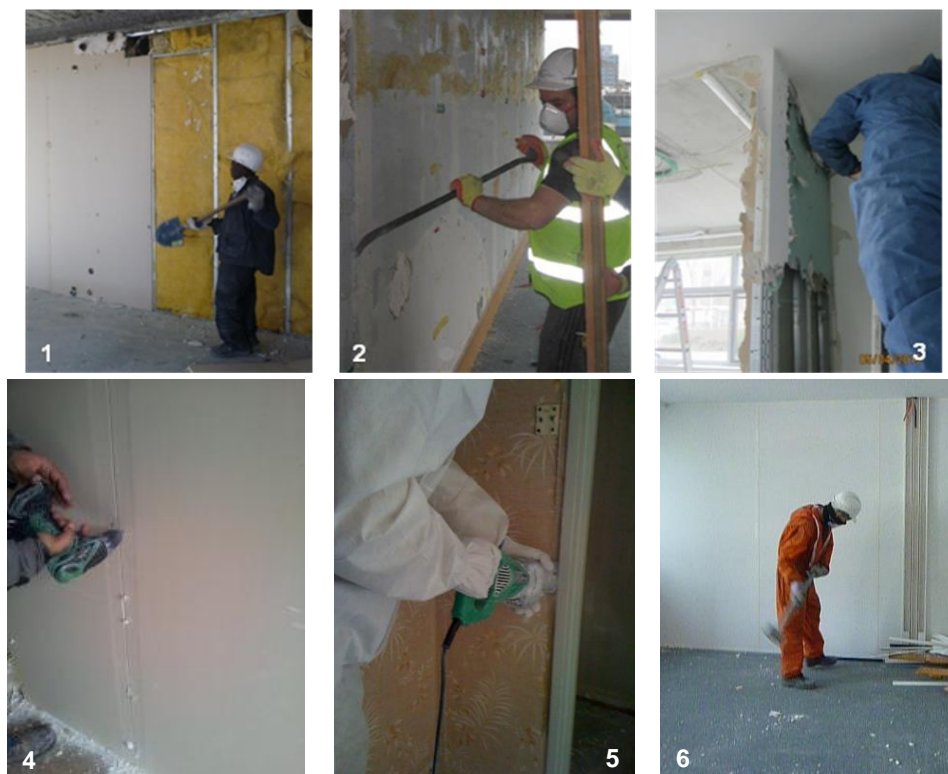
2.1.1. Tools and machines generally used to deconstruct gypsum-based systems

Although deconstruction techniques can slightly differ from one demolition company to another and from one country to another, some tools and machines are commonly used for the deconstruction of gypsum-based system.

Some tools present obvious advantages to deconstruct a given system but the use of a given tool or another will also mainly depend on the habits of the workers.

Manual tools are used to lever up, to unscrew, to cut or to break some parts of the system so as to separate the different materials of the gypsum-based systems. A **shovel**, a **spade** or a **crow bar** can be used to separate the frame from the plasterboard. A **cutting chisels** can also be used to cut and lever up the plasterboard from the frame. An **automatic screwdriver** can be used to unscrew the screws from the frame and thus separate the plasterboard. To cut properly a plasterboard partition and isolate it from the frame, a **saber saw** is sometimes used. To break plaster blocks (or eventually to separate the frame from the plasterboard) a **pickaxe** or a **sledgehammer** can be used.

The above mentioned tools are presented in the pictures below.





Figures 5 to 11: manual tools generally used to deconstruct gypsum-based systems.
Tools used from the figure 5 to the figure 11: shovel, crowbar, chisels, automatic screwdriver, saber saw, sledgehammer, pickaxe – Sources (in the order of the figures): Pinault&Gapaix (France), Cantillon (UK), KS Engineering (Germany), Pinault&Gapaix (France), Recovering Sarl (France), Occamat (France), Pinault&Gapaix (France)

Some demolishers prefer to use small machines as **hydraulic machines, compact excavators or other** to deconstruct the gypsum-based systems. Some pictures that have been taken on the Belgian reference jobsite are shown below:



Figures 12 and 13: mechanical deconstruction of plasterboards – Source: Recycling Assistance (Belgium)

When choosing the use of machines, the floor overload must be taken into account. Plus it is not always possible to enter in the different rooms with these machine.

2.1.2. Description of the most appropriate deconstruction techniques according to the gypsum-based systems

To allow the recovery of the different materials that constitute the gypsum-based systems, they must be deconstructed properly. Several techniques have been tested and identified as the most appropriate to deconstruct the different types of systems according to the way they are arranged or attached to the bearing framework. The advantages and disadvantages of each technique are assessed as much as possible also that, as mentioned before, the choice also depend on the habits of the company worker.

2.1.2.1. Deconstruction techniques for plaster blocks partition

Three main techniques using manual tools are generally used to deconstruct plaster blocks partitions:

- The cutting and breaking of the partition with a pickaxe. The cone point of the pickaxe allows the cutting of the blocks when breaking it.
- The breaking of the partition with a sledgehammer.
- The cutting of the partition using a saber saw.

The use of a pickaxe allows the cutting of the blocks which facilitate their segregation and loading. The sledgehammer does not allow the proper cutting of the blocks: it produces a lot of small pieces that will need time to collect.

The using of a saber saw generates bigger pieces that will be collected quicker but it generates more dust than the use of a pickaxe or a sledgehammer. Moreover, contrary to the two other tools, the saber saw must be put up, which necessitate time.

The pictures below show a plaster blocks partition deconstruction using a pickaxe.



Figures 14 to 16: plaster blocks partition deconstruction with a pickaxe / Plaster blocks partition under deconstruction / Plaster blocks on the floor after deconstruction by a pickaxe and before collection – Source : Pinault&Gapaix (France)

Mechanical deconstruction does not seem to be adapted to deconstruct plaster blocks partitions. Besides the general constraints linked to the size and the weight of this type of machine mentioned in the previous part, this type of machine presents other constraints linked to the type of system considered. Indeed when using a machine to deconstruct a plaster blocks partition, a big weight will fall on the floor at one time.

2.1.2.2. Deconstruction techniques for systems glued on a wall

Regarding systems that are glued on a wall, the techniques consist of ungluing the system from the wall with the help of a manual tool.

A spade or a shovel or eventually a crowbar are common tools that can be used to lever up the plasterboard. Whichever tool used as a lever, once the system has been removed, pads of glue are remaining on the wall (see the pictures below). They can be removed using an electric hammer.

The pictures below illustrate the deconstruction of a sound and thermal insulator made of plasterboard and insulating expanded polystyrene glued together and glued on a load-bearing wall, using a shovel.



Figure 17(left): deconstruction of a board made of polystyrene and plasterboard glued together on a load-bearing wall using a shovel to lever up the system from the wall.

Figure 18 (right): board made of polystyrene and plasterboard glued together after having being unglued from the load-bearing wall.

Source: Pinault&Gapaix (France)

Systems that are glued on a wall are generally made of plasterboard glued to polystyrene, glass wool, rock wool or polyurethane. The tool chosen must not damage the system to avoid the spreading of the insulating material on the jobsite which will necessitate more time to clean-up. From this point of view, the use of a spade or a shovel seems to be a better option than the use of a crowbar.

For the same reason, the use of small machine is not recommended. It would crumble the system, tear the insulation and spread it on the jobsite.

2.1.2.3. Deconstruction techniques for system fixed to a framework

This part concerns systems that are fixed to a metallic or a wooden framework by screws or nails. The deconstruction techniques consist to separate the plasterboards from the framework using different tools.

When a system is attached to the framework by screws, it can be unscrewed properly using an automatic screwdriver.

When the plasterboards are nailed on the framework, the nails can also be removed properly using a crowbar.

Whichever way the plasterboards are attached to the framework, another technique consists of cutting the plasterboards using a saber saw. A shovel can also be used to split the plasterboard along the structure. Then the plasterboard is pulled by hand. The nails or the screws remain on the framework.

These techniques allow collection of the plasterboards in one piece which saves time on the jobsite to segregate and load the waste and allows the optimization of the room in the skips.

The above described techniques are equivalent in terms of performance. The choice of one technique instead of another will mainly depend of the habit of the worker and the tools available on the jobsite.

Techniques that consist of cutting and breaking the plasterboard using a crowbar or a cutting chisels generate more pieces of boards and can necessitate more time to collect and segregate the plasterboards.

The technique that consists of breaking the plasterboards using a sledgehammer is not recommended. It generates a lot of small pieces of plasterboards and damages the eventual insulator. The different materials that constitute the system are mixed in small pieces on the floor. It necessitates more time to segregate the different materials and increases the risk of pollution by the other materials. Finally some plasterboard pieces can remain on the floor.

As mentioned before, mechanical deconstruction can be used taking into account the constraints linked to the machines mentioned before. Nevertheless as put forward above it will mix the different materials that constitute the system in small pieces on the floor and necessitate more time to segregate and collect the waste with a risk of bad sorting quality.

Some techniques that have been presented above are illustrated below for different systems.

Deconstruction of a double plasterboard partition with glass wool screwed on a metallic framework using an automatic screwdriver:

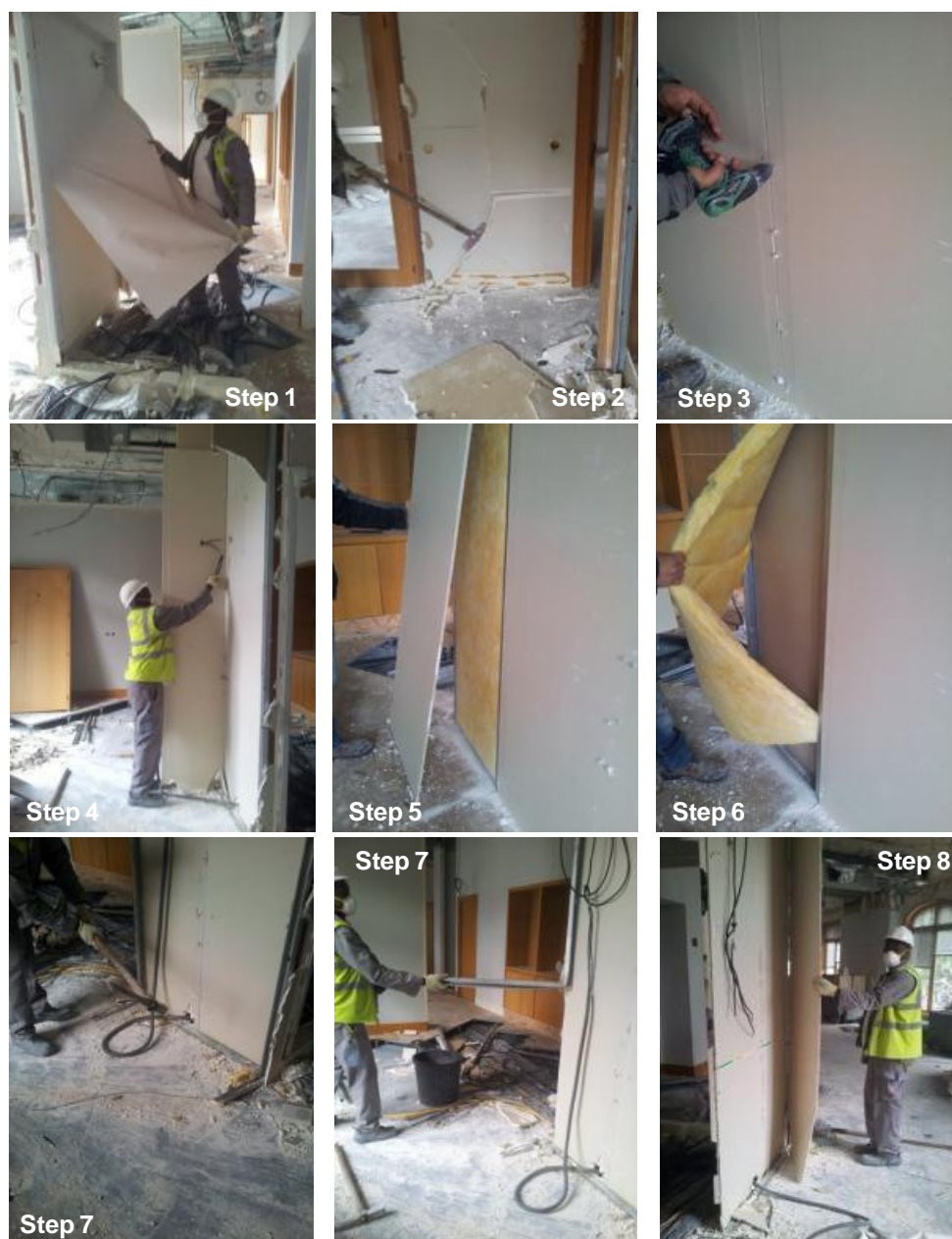
The technique described below concerns a double plasterboard partition with insulator screwed on a metallic frame. The second plasterboard is glued to the first one which is screwed to the uprights as shown on the following pictures:



Figure 19: transverse views of the system with the metallic vertical frame and after having removed it – Source: Occamat (France)

The deconstruction steps are the following:

- Step 1: removal of the wallpaper to clear the screws
- Step 2: “second plasterboard” breaking using a pickaxe
- Step 3: unscrewing of the “first plasterboard” using an automatic screwdriver
- Step 4: removal of the electric wires and plastic boxes by hand
- Step 5: removal of the “first plasterboard” by hand
- Step 6: removal of the insulator (glass wool) by hand
- Step 7: removal of the metallic frame using a pickaxe and manually. The screws remain on the frame
- Step 8: the last two plasterboards are removed entirely by hand (no breakage)



Figures 20 to 28: manual deconstruction of a double plasterboard partition with mineral wool screwed on metallic rails – Source: Pinault&Gapaix (France)

The above mentioned steps can apply to plasterboard partition systems made of simple or double plasterboards with or without insulator screwed on a metallic or a wooden framework but the deconstruction steps can slightly differ according to the presence of some materials (wallpaper or insulator for instance) or not and in the case of simple or double plasterboard partition. Thus in the case of simple plasterboard partition, the step 2 is not carried out.

Deconstruction of a simple plasterboard partition with mineral wool nailed on a wooden framework using a crowbar:

The following steps concern the deconstruction of a partition system made of plasterboard and insulator and nailed on a wooden framework:

- Step 1: plasterboard cutting and breaking using a crowbar or a cutting chisel. Removal of the plasterboard by hand
- Step 2: removal of glass wool by hand or removal of wood wool using a pickaxe or a sledgehammer and by hand.
- Step 3: removal of the wooden framework using a pickaxe or a sledgehammer and by hand
- Step 4: plasterboard breaking using a crowbar or a cutting chisel. Removal of plasterboard by hand.



Figures 29 and 30: manual deconstruction of a simple plasterboard partition with wooden wool nailed on a wooden framework – Source: KS Engineering (Germany)

Deconstruction of a honeycomb plasterboard partition nailed on a wooden framework using a saber saw:

As mentioned before, a saber saw can be used to cut properly a plasterboard system. This technique is illustrated below for honeycomb plasterboard:



Figures 31 to 36: deconstruction of a honeycomb plasterboard partition using a saber saw – Source: Recovering Sarl (France)

Deconstruction of a plasterboard system for ceiling with mineral wool nailed on a wooden framework using a crowbar:

In the case of a system for ceiling, the following steps can be followed:

- Step 1: removal of the eventual wooden boards using a crowbar and by hand
- Step 2: removal of the plasterboards using a crowbar and by hand
- Step 3: removal of the mineral wool by hand



Figures 37 to 39: manual deconstruction of a plasterboard system for ceiling with mineral wool nailed on a wooden framework – Source: KS Engineering (Germany)

Remark: plasterboard systems for ceiling and flooring screwed or nailed on a metallic or a wooden framework are rare. They could be deconstructed from top to bottom or using the same type of technique that described above.

2.1.2.4. Deconstruction techniques for systems arranged with a channel

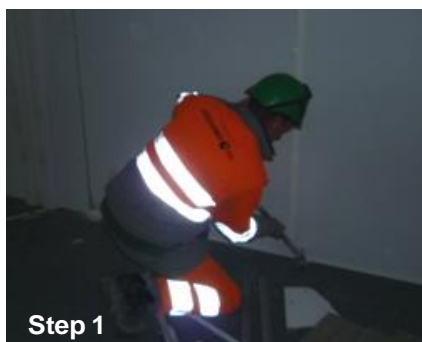
When a system is simply arranged with a channel, the plasterboards are not attached by nails or screws. Thus the deconstruction technique consists of removing the channel using a manual tool like a shovel, a screwdriver, a crowbar... and removing the different materials that constitute the system manually. This technique allows collecting the plasterboards in one piece and to sort and order in the skips the different materials easily.

The effectiveness of the tool used to remove the channel is equivalent from a tool to another and will mainly depend on the habit of the worker.

The technique described below concerns plasterboard systems made of simple or double plasterboards with or without insulator attached by a channel and a metallic framework.

The detailed steps of deconstruction of a simple plasterboard partition with mineral wool arranged with a metallic channel are described and illustrated below. The steps can slightly differ according to the presence of some materials or not and in the case of simple or double plasterboard partition.

- Step 1: removal of the channel using a manual tool as a shovel (a sledgehammer is used on the picture) and manually
- Step 2: removal of the plasterboard by hand
- Step 3: removal of the insulator by hand
- Step 4: the last plasterboard is removed entirely by hand





Figures 40 to 45: manual deconstruction of a simple plasterboard partition with mineral wool arranged with a metallic channel – Source: Occamat (France)

A small machine can also be used to deconstruct mechanically the partition. But it presents the same disadvantages that listed in the part 2.1.2.3. of this document.

2.1.2.5. Deconstruction techniques for system for ceiling attached with ceiling hangers

In the case of plaster tiles systems for ceiling hanged with ceiling hangers, the usual technique that consists in making the frame and the panels fall with a shovel must be avoided so as to avoid the breaking of the tiles and a time-consuming loading the wastes in the skips.

As a result, it is recommended to follow the method described below:

- Step 1: a staff member takes off the plasterboards one by one from a scaffolding or an individual platform on castors and removes the metallic frames that are not fixed with ceiling hangers. The staff member gives it to a staff member on the ground.
- Step 2: the metallic frames that are fixed by ceiling hangers are removed. The frames are grouped together for a later loading.
- Step 3: once the plasterboards have been completely removed, the ceiling hangers are unscrewed with an automatic screwdriver.

2.2. ECONOMICS OF DECONSTRUCTION

2.2.1. Methodology to analyse the costs of deconstruction

Before the beginning of the works, it is necessary to have access to decision and evaluation tools regarding deconstruction process versus demolition process of gypsum-based systems.

The project manager or the demolition company has to decide the methodology which will be adopted to remove the recyclable gypsum-based products from the other materials that constitute the system so as to deliver the maximum retrieval rate.

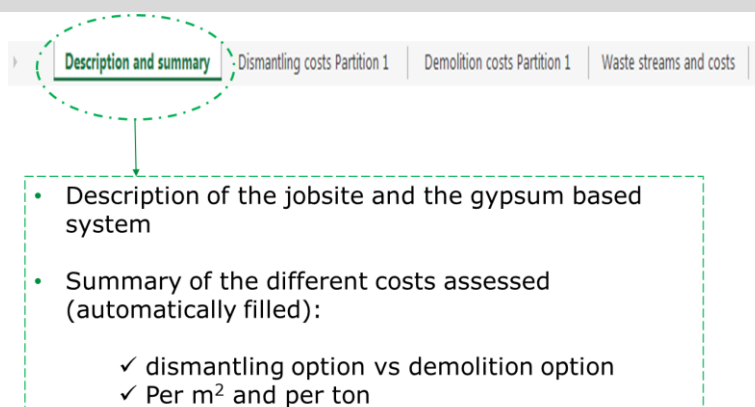
In order to assess the economic feasibility of deconstruction of the gypsum-based system, a methodology has been developed to calculate a cost range or an average cost of deconstruction per square meter and per ton for a given gypsum-based system and a given deconstruction or demolition technique in a given country.

This tool is intended to:

- Project owners or project managers who can include it in the specifications and use it in the decision process,
- Engineering offices and demolition companies to assess the savings using one methodology or another, one route or another, one outlet or another.

This tool is developed in an excel file made up of 5 sheets for a given type of gypsum-based system:

1st sheet:



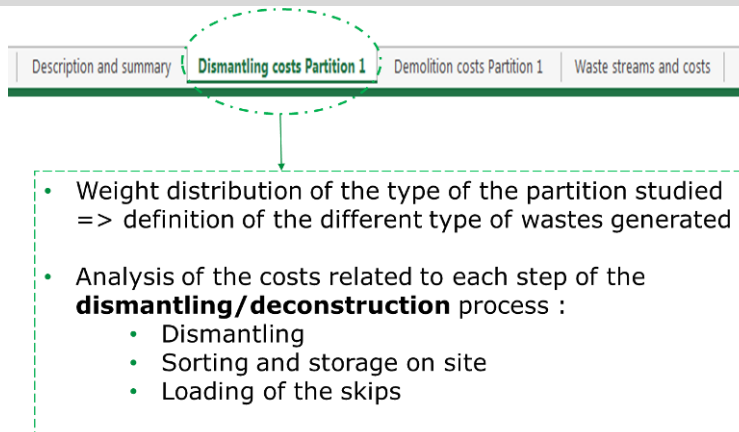
The costs assessed are summarized in the following tables:

	Dismantling option		Demolition option	
	Per m ²	Per ton	Per m ²	Per ton
<i>Cost of dismantling/demolition</i>				
<i>Cost of storage and transportation</i>				
<i>Cost of the outlets</i>				
<i>Total</i>				

	Dismantling option		Demolition option	
	Total (m ² calculation)	Total (ton calculation)	Total (m ² calculation)	Total (ton calculation)
<i>Cost of dismantling/demolition</i>				
<i>Cost of storage and transportation</i>				
<i>Cost of the outlets</i>				
<i>Total</i>				

Figure 46: tables of the costs assessed with the tool developed in the scope of the GtoG project

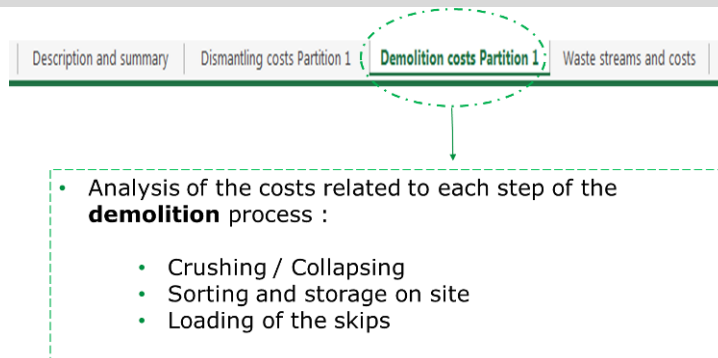
2nd sheet:



The costs to deconstruct the partition are assessed in this file.

The technical description of the various materials the partition is made up and the way these materials are dismantled, sorted, stored and loaded assess total costs per square meter and per ton to deconstruct the gypsum-based system studied.

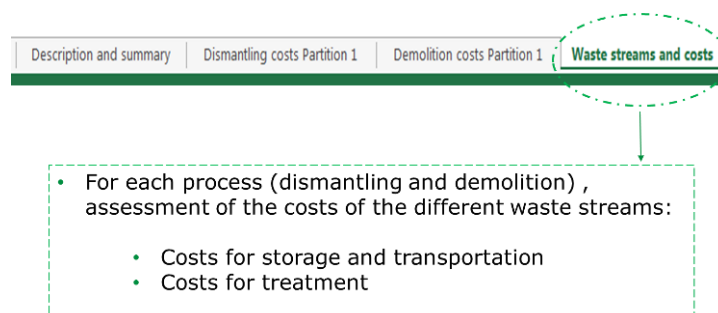
3rd sheet:



The costs to demolish the gypsum-based system are assessed in this file.

The way the entire gypsum-based system is dismantled, sorted, stored and loaded assess total costs per square meter and per ton for demolishing the partition studied.

4th sheet:



The detailed tables are enclosed to this document (Appendix 2).

2.2.2. Presentation of the 5 jobsites tested

5 pilot projects from 5 demolition companies in 4 countries have been studied in the scope of the GtoG project so as to test the methodology presented there before.





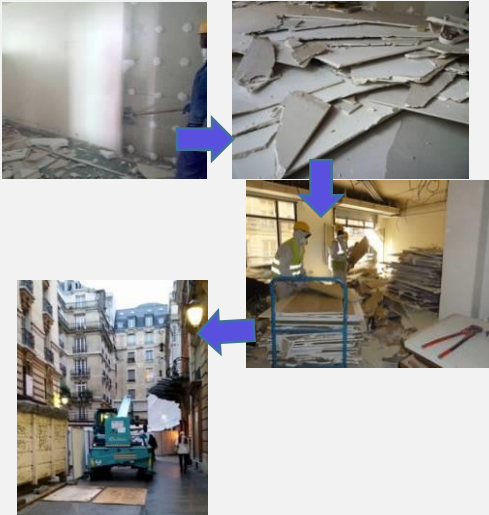

DEMOLITION COMPANY	COUNTRY
OCCAMAT	France
PINAULT & GAPAIX	France
KSE Engineering GmbH	Germany
CANTILLON Ltd	England
RECYCLING Assistance	Belgium

The information about the jobsite, the gypsum based system, the methodology of deconstruction and the gypsum wastes recycled are presented in the 5 datasheets below.








PILOT PROJECT DESCRIPTION – 1/5

DEMOLITION COMPANY :		OCCAMAT
COUNTRY :		FRANCE
	JOBSITE LOCATION	Levallois Perret close to Paris
	TYPE OF BUILDING	Construction : 1968 Refurbishment : during the last 10 years in some of the floors 9 floors building ⇔ 32 000 m ² to deconstruct
	TYPE OF GYPSUM BASED SYSTEM STUDIED	Partition between desks made of wallpaper on 1 BA13 plasterboard fixed on metal frame with metallic junction + glass wool+ 1BA13 plasterboard fixed on metal frame with metallic junction and covered by wallpaper Brand : KNAUF, SINIAT, PLACOPLATRE – Year unknown
PERIOD OF WORKS		January 2014 to April 2014
	REMOVAL DESCRIPTION	Manual deconstruction → Sorting and segregation of the different materials → Storage in the floors → Removal to the ground floor through a hopper → Loading of the skip with a mechanical machine (bobcat)
	GYPSUM RECYCLING	13 x 10m ³ skips of gypsum plasterboard deconstructed transported by truck to SINIAT Plant in Auneuil – France, 86 km far from the jobsite Tracking by follow-up notes 67,52 tons of gypsum plasterboard recycled

PILOT PROJECT DESCRIPTION – 2/5

DEMOLITION COMPANY :		PINAULT&GAPIAX
COUNTRY :		FRANCE
	JOBSITE LOCATION	Paris, district 8
	TYPE OF BUILDING	<p>Year of construction : 1876</p> <p>Big works campaign in 1955 (inside and on the front of the building, in the courtyard). From this date, the building became entirely a commercial building.</p> <p>3 floors building. 1 000 m² to deconstruct</p> <p>Current Type of using: offices</p>
  	TYPE OF GYPSUM BASED SYSTEM STUDIED	<ul style="list-style-type: none"> - Plaster blocks partitions - Insulation system made of plasterboard and expanded polystyrene (EPS) glued together and glue to the bearing wall - Simple and double BA13 plasterboard partitions screwed on a metallic framework - Hanging ceiling <p>Identified brands (branded plasterboards): PLACOPLATRE → BA13 plasterboards from 1988 and from 1998 + plaster tiles</p>
PERIOD OF WORKS		June 2014
	REMOVAL DESCRIPTION	<p>Manual deconstruction → Sorting and segregation of the different materials → Storage in the floors → Loading of a wheeled trolley by hand → Loading of the skip with a telescopic rotating forklift</p>
	GYPSUM RECYCLING	<p>1 skip of 15 m³ has been sent to the NWGR recycling unit in Vaujours (France) – 35 Km distance from the jobsite.</p> <p>Tracking by follow-up notes</p> <p>9,38 tons of plaster blocks and BA13 plasterboards recycled.</p>





PILOT PROJECT DESCRIPTION – 3/5

DEMOLITION COMPANY :		CANTILLON LTD
COUNTRY :		ENGLAND
	JOB SITE LOCATION	66 Chiltern Street, London, England
	TYPE OF BUILDING	2 X 12 Storey Tower Block - Concrete and metal frame with block work and PB partitioning, and refurbished in the 1980's Use of the building: Shared office facility between several different companies
	TYPE OF GYPSUM BASED SYSTEM STUDIED	Simple plasterboard partition – fixed to metal channeling interspersed with glass partition, occasional wall (usually outer) with glass/rock wool insulation. PB was either painted or painted wallpaper. No laminated PB Brand and year of the plasterboards in the information in known: Possibly Gyproc - year unknown ...
PERIOD OF WORKS		5 months from July to December 2014
    	REMOVAL DESCRIPTION	All PB was removed by hand, using sledgehammers, crowbars, and other hand tools. The PB was kept separate from other materials and kept under cover and dry. The PB was then dropped down a chute/hopper by hand to ground level where it was mechanically loaded in to a roll on roll off skip or directly in to the back of a tipper.
	GYPSUM RECYCLING	4 X 10tonne plus skip transported to NWGR in Avonmouth, Bristol for onward movement to Siniat UK in Avonmouth, Bristol. Approximately 35tonne was reprocessed by Siniat UK.
		

PILOT PROJECT DESCRIPTION – 4/5

DEMOLITION COMPANY :		KS ENGINEERING GMBH
COUNTRY :		GERMANY
	JOBSITE LOCATION	Graben (nearby Munich), Germany
	TYPE OF BUILDING	Five identical buildings of the army, one floor, without basement
 	TYPE OF GYPSUM BASED SYSTEM STUDIED	<p>- Ceiling: plasterboard (partly acoustic panel), wooden frame, mineral wool</p> <p>-partitions:</p> <p>plasterboard (partly acoustic panel), wooden frame, mineral wool</p> <p>plasterboard, metallic frame, no insulation</p> <p>plasterboard, wooden frame, wood wool insulation (Heraklith)</p> <p>Brand of the plasterboards: Rigips, Knauff</p>
PERIOD OF WORKS		February and March 2014
 	REMOVAL DESCRIPTION	Manual deconstruction → Sorting and segregation of the different materials → carrying out from the building using a wheelbarrow → loading of the skips
	GYPSUM RECYCLING	<p>Gypsum-based waste stored in 4 covered skips of 40 m³.</p> <p>36,64 tons of plasterboards sent to GRI recycling plant in the Netherlands from the 24 of February to the 6 of March 2014.</p>

PILOT PROJECT DESCRIPTION – 5/5

DEMOLITION COMPANY :		RECYCLING ASSISTANCE	
COUNTRY :		BELGIUM	
		JOBSITE LOCATION	Brussels, Belgium
		TYPE OF BUILDING	Offices building 54217 m ²
 		TYPE OF GYPSUM BASED SYSTEM STUDIED	Partitions of: - Plaster blocks - Plasterboards screwed on a metallic framework, with mineral wool Brand of the plasterboards: Gyproc
PERIOD OF WORKS		June 2014 to November 2014	
		REMOVAL DESCRIPTION	Mechanical deconstruction → Storage of the sorted wastes on the different floors → Loading with the help of a bobcat machines of skips lifted by a lift
		GYPSUM RECYCLING	~ 43 tons of plasterboards and plaster blocks sent to NWGR in Kallo until the end of November 2014

2.2.3. Economics data coming from the pilot projects

The figures mentioned below are coming from the 5 jobsites presented in the previous chapter.

2 types of partition have been studied through the 5 jobsites:

- Partitions made of plaster blocks
- Partitions with plasterboards

On the basis of the methodology employed, the location of the jobsite, the amount and the outlets considered, the costs assessed are summarised in the board below:

Type of gypsum based system	type of Costs	Dismantling option Per m ²	Demolition option Per m ²
Plaster blocks	Cost of dismantling/demolition	0,22 €	0,22 €
	Cost of storage and transportation	0,02 €	0,02 €
	Cost of the outlets	0,06 €	0,11 €
	Total	0,30 €	0,35 €
Plasterboard	Cost of dismantling/demolition	2,30 € to 4,61 €	2,34 € to 5,58 €
	Cost of storage and transportation	0,01 € to 0,54 €	0,14 € to 4,19 €
	Cost of the outlets	0,01 € to 0,16 €	0,88 € to 13,25 €
	Total	2,32 € to 5 €	7 € to 19 €

• PLASTER BLOCKS:

For **plaster blocks** the costs are only influenced by the costs of the outlets since, as explained previously (see part 2), there is no significant difference regarding techniques to deconstruct plaster blocks and demolition techniques. As a result for plaster blocks, the costs of dismantling are assessed to be the same that the costs of demolition and the costs of storage and transportation are assessed to be the same from a technique to another too.

• PLASTERBOARDS:

For **plasterboards** the costs using dismantling or demolishing are really closed. The total costs for this kind of partition are influenced by the transportation and the costs of the outlets.

Nevertheless, the jobsites studied show that savings are made using deconstruction techniques.

Costs per ton have also been assessed on the different pilot projects. Those costs are function of the different materials the partitions are made up. Weights of those different materials are variable from one partition to another and the costs calculated can't be considered as a replicate.

The costs per square meter assessed and summarised above can be a basis to assess the total costs on any jobsite.

The accurate calculation of the costs have to be assessed using the entire methodology.

2.2.4. The variable data and limits

To choose the way to deconstruct a gypsum-based system, the analysis must not only focus on economics but take also into account other parameters, in particular:

- Safety requirements (working at heights for example)
- Technical constraints to remove the unwanted materials/ products/ contaminants so as the gypsum wastes respect the specifications of the recyclers
- Environmental aspects such as :
 - Mode of transport
 - Distance from the jobsite to the transfer station and the recycling unit
 - Savings of raw materials
- Deadline for the works achievement

Besides the works have to be followed and monitored during the different phases (deconstruction, sorting, loading the skips).

It is also advised to communicate during the preparation phase to make the operators aware of the specifications the gypsum-based waste have to respect and the way adopted to deconstruct and remove the gypsum waste system. The communication can focus on errors to be avoided as shown on the example below coming from a French demolition jobsite.

WASTE QUALITY

The wastes sent must only contain plaster-based material. If other types of wastes are mixed with the gypsum-based waste, the skips will not be accepted and they will be sent in landfill: Waste treatment costs multiplied per 5 !!!

Examples of mistakes that must be avoided:



Fire switch left



Metallic framework left
between 2 plasterboards



Pieces of false ceiling

LOADS OF GYPSUM-BASED WASTE MUST NOT CONTAIN ANY OTHER TYPE OF WASTE!
IF SOME DOUBTS ARE REMAINING PLEASE ASK TO THE PERSON IN CHARGE OF THE WASTE MANAGEMENT

Figure 47: example of communication on OCCAMAT GtoG pilot project in Levallois Perret, France

3. Recommendations for an improvement of recyclability

The recommendations expressed below concern not only the end-of-life of the gypsum-based systems but also the conception and installation of the systems. The aim of these recommendations is to improve the practices at each step in order to improve the recyclability¹ of the gypsum-based systems at the end.

3.1. RECOMMENDATIONS LINKED TO ECO-DESIGN AND CONSTRUCTION OF THE GYPSUM-BASED SYSTEMS AND MATERIALS

Eco-design of buildings and systems constitutes the basis of the following steps aiming to improve the recyclability of gypsum-based materials.

3.1.1. Recommendations towards the manufacturers

The manufacturers have a responsibility regarding the products they are putting on the market. Within a circular economy approach, the future end-of-life of the systems they are manufacturing should always been taken into account. Thus eco-design should be highly included regarding two approaches:

- Regarding the chemical composition more especially in terms of additives, or the materials itself used to design the systems: some of them do not enter in the waste acceptance criteria of the recyclers (plastic foils stuck to the plasterboards for instance)
- Regarding the way the materials are designed to be arranged together to constitute the system: at the end of life of the system, if it necessitates too much time, too many workers or techniques too specific to deconstruct the system, the demolition company could choose to demolish it instead of deconstruct it properly. During the GtoG project it appeared that according to the deconstruction technique chosen, systems arranged together with glue, screws or nails necessitate more time to be deconstructed than systems arranged with seals for instance. According to the type of system, the type of jobsite and the waste market in a given country, the economic balance will not necessarily be in favour of deconstruction of the system. The systems that can be easily separated drive the demolition companies to deconstruct instead of demolish. Consequently it is recommended to the manufacturers to work on eco-design of systems that will encourage the demolishers to opt for deconstruction.

3.1.2. Recommendations towards the project owner and project manager for the construction phase

As purchasing advisors, project owners and project managers, including architects, have a key role to play. It is very important that they take into account the lifecycle of the building and integrate considerations regarding the “design for deconstruction” approach.

¹ Recyclability must be considered in the light of physical and chemical properties of a material or systems that facilitate or impede the possibility to recover the material(s).

First of all it is recommended when choosing between two different types of systems to include an end-of-life approach and thus choose a system which has a proven recovery route existing locally.

Plus when choosing a gypsum-based system, it is recommended to the project owners and project managers to take note of the recyclers' specifications in order to avoid as much as possible to prescribe:

- the use of gypsum-based materials that will not enter in the waste acceptance criteria of the recyclers. As highlighted before, the gypsum-based products manufactured currently do not all enter in the recyclers specifications;
- the assembling of materials that will not be easy to remove at the end-of-life of the systems or the building and will make the entire system non-recyclable. Indeed in some cases, a gypsum-based material that could have been recycled can't anymore because of its assembling with non-recyclable and non-separable (within acceptable technical and economic conditions) materials. It is the case of plaster blocks or plasterboard partitions coated with earthenware for instance.

3.1.3.Recommendations towards the construction companies

The way the gypsum-based systems are implemented by the construction company is decisive to allow its recycling. As previously recommended to the other stakeholders that play a role upstream from a construction project, the construction companies should keep in mind that the system they are installing will be deconstructed one day. They should systematically wonder if the different materials that constitute the gypsum-based system will be technically and economically severable at the end-of-life of the system.

A constructive system that would not allow the proper deconstruction of a gypsum-based system for technical and economic reasons at the end-of-life of the system must be preferred to another systems that facilitate selective demolition.

For example, the opposite pictures show a system constituted by plasterboards nailed on beams, metallic wires tangled around the nails and the whole coated with a plaster coating that made impossible the segregation of the plasterboards from the wires. The system, found on a deconstruction jobsite of a teaching hospital in France in 2013, has been deconstructed using a sledgehammer and the wastes have been eliminated in a non-hazardous waste landfill.



Figures 48 and 49: example of a gypsum-based system non-recyclable because of the way it has been installed – Source: Occamat (France)

To avoid this type of scenario, it is advised to follow the construction steps planned by the plasterboard manufacturers that are generally available on their respective Internet websites. As much as possible it should be avoided to make “permanently” interdependent the recyclable gypsum-based products with other materials. For instance, wires and switch should not be attached permanently to the recyclable gypsum-based materials or it risks to be forgotten on the products during the deconstruction and the load would not match some recyclers' specifications. The choice of a coating that would not enter in the waste acceptance criteria of the recyclers and thus make the plaster blocks non-recyclable has to be avoided also.

Regarding the choice of the gypsum-based system or the gypsum-based material that will constitute the system, it is recommended to choose a system for whom the different constituting materials have an existing recovering route locally.

3.2. RECOMMENDATIONS LINKED TO THE DECONSTRUCTION OF THE GYPSUM-BASED SYSTEMS AND TO THE GYPSUM-BASED WASTE MANAGEMENT UNTIL THEIR FINAL OUTLET

At the end-of-life of the gypsum-based system, the different steps from the deconstruction jobsite to the recycling unit with possible waste management company(ies) as a third party, are decisive to allow the gypsum-based system recovering.

3.2.1.Recommendations towards the project owner for the deconstruction phase

Historically asbestos was widely used for different applications because of its desirable physical properties before to be finally recognized as a hazardous material in the countries of the projects. Lead paint in another example of material that has been historically used but is nowadays forbidden in the countries of the project².

The presence of any hazardous material, as asbestos and lead paint, is strictly forbidden in the waste acceptance criteria of the recyclers.

Prior to the beginning of the works, the project owner has to carry out the diagnoses of the hazardous materials especially the asbestos and lead paint diagnoses if their building are concerned by their possible presence (building built prior the ban of use of these products).

The results of these diagnoses must be especially passed on the deconstruction company.

3.2.2.Recommendations towards demolition companies

During the deconstruction phase, the aim is that the demolition company implements deconstruction techniques and process that will allow to segregate the recyclable gypsum-based materials from the other materials they are arranged with and that do not enter in the waste acceptance criteria of the recyclers. The best deconstruction techniques that have been observed in the scope of the GtoG pilot projects have been described in the second part of this handbook. It is recommended to implement these techniques. Plus during the temporary storage of the waste onsite, their loading in the skips and until the removal of the skips from the jobsites, measures must be taken as much as possible in order to avoid the contamination of the sorted recyclable gypsum-based materials with other materials.

3.2.3.Recommendations towards transfer stations and waste sorting companies

When the recyclable gypsum-based waste are sent to a transfer station or a waste sorting company, measures must be taken to guaranty that the loads will not be contaminated by other wastes that would not comply with the waste acceptance criteria of the recyclers. The sorted loads must be carefully stored on the transfer station in covered skips whenever it is possible if requested by weather conditions.

² Remark: to the GtoG partners' knowledge, no gypsum-based product integrating asbestos has been manufactured in the past. Nevertheless, the risk to find asbestos in gypsum-based products or systems manufactured before the ban of importation and using of asbestos remains.

Moreover, prior to send the loads of sorted recyclable gypsum-based waste to the recycling unit, it is highly recommended to proceed to visual checking, inspection of the loads in order to be sure that it comply with the waste acceptance criteria of the recyclers.

4. Conclusions

The statement concerning the recyclable and non-recyclable gypsum-based systems shows that in some cases the setting of the system will impede the recycling route. Regarding the demolition phase, two types of barriers are identified:

- the endogenous factors are those related to the design itself. For instance the choice of the chemical substance to obtain waterproof effect may have an adverse effect on the conformity of the production when contained in some recycled gypsum. Wax should be preferred to silicon as this effect will not exist. Another example is the plastic foil glued to the plasterboard that cannot be properly separated with current available technology. It was exactly the case with thermal insulation plasterboard but some recent set-up facility can treat this type of product at ease.
- the exogenous factors are those related to the way the systems are put in place and afterwards deconstructed and collected to the recycling facility through a transfer station or not.

The pilot projects carried out by the demolishers in the scope of the GtoG project have shown in most cases that the demolishers can properly deconstruct the gypsum-based systems and segregate the materials in compliance with the waste acceptance criteria of the recyclers. Some systems initially recyclable were in fact not anymore due to the way construction companies put the system in place.

Regarding the choice of deconstruction versus demolition techniques, it is mainly proved selective demolition that facilitate the recycling route will induce savings. According to the demolishers, we may assume that the operation costs for both demolition and deconstruction practices are similar. The savings are in fact made on the route: landfilling is much more expensive more especially in the countries with a high landfill tax. Regarding the practices in terms of deconstruction, it is not relevant to conclude at this stage of the study that one practice is better than another. Demolishers have their habits with high skilled employees mastering a type of practices. Being good at using a certain practice doesn't mean being good for all. The conclusion that can be made from the study is that, beyond the environmental benefits, the choice of deconstruction can lead to important cost-savings on big jobsites, especially thanks to the recovering of the gypsum-based wastes that generally cost less than their landfilling. This is the main driver that leads demolishers to adopt selective demolition approach.

Although that the deconstruction companies can adapt their deconstruction techniques to the systems they meet, the design and installation of systems less complex could be a driver towards the spread out of deconstruction practices. The manufacturers, project owners, project managers including architects, and the construction companies must integrate eco-design of the systems and eco-construction of the buildings at each step in order to build buildings and systems that will be easier to deconstruct and recover, preferably recycle at the end of life.

Appendix: detailed sheets of the economic approach of deconstruction versus demolition

Tab “Description and summary”

JOBSITE				
Owner				
Demolition company				
Localisation of the jobsite				
Brief description of the building				
Description of the GB products and the expected GBW quantity				
Duration for the dismantling, sorting, storage and transportation of wastes (months)				
	Dismantling option		Demolition option	
	Per m2	Per ton	Per m2	Per ton
Cost of dismantling/demolition	4,00 €	165,29 €	6,08 €	251,29 €
Cost of storage and transportation	0,00 €	13,88 €	0,36 €	8,60 €
Cost of the outlets	0,01 €	36,86 €	4,55 €	110,00 €
Total	4 €	216 €	11 €	369,9 €
	Dismantling option		Demolition option	
	Total (m2 calculation)	Total (ton calculation)	Total (m2 calculation)	Total (ton calculation)
Cost of dismantling/demolition	20 000,00 €	20 000,00 €	30 406,00 €	30 406,00 €
Cost of storage and transportation	1 680,00 €	1 680,00 €	1 040,00 €	1 040,00 €
Cost of the outlets	4 460,00 €	4 460,00 €	13 310,00 €	13 310,00 €
Total	26 140 €	26 140 €	44 756 €	44 756,0 €

Tab "Dismantling costs Partition 1"

DISMANTLING COSTS FOR PARTITION TYPE 1							
number of square meters of partition type 1	5000						
Weight per square meter of partition type 1	Kg	% of weight	First evaluation of tonnages	Type of skip (m3)	Density of waste with coefficient of expansion	tonnage per skip	Square meter of partition (equivalent) per skip
Metal frames	1,8	7%	9,00	20	0,08	1,6	889
Wooden frames	0	0%	0,00	10	0,15	1,5	0
Plasterboard BA 13	20,4	84%	102,00	20	0,3	6	294
Insulation (mineral wool)	2	8%	10,00	20	0,1	2	1000
Partition	24,2	100%	121,00				
Cost of the dismantling phase (Partition type 1)	Description of the task per m2 of partition	Wage rate of a worker	Number of hours needed per square meter	Cost per m2 of partition	Cost per ton of partition		
Step 1: Dismantling with a shovel	number of hours needed to dismantle one square meter	20 €	0,05	1,00 €	41,32 €		
Step 2: Sorting and storage operation on site	number of hours needed to properly isolate each type of waste and store temporarily	25 €	0,12	3,00 €	123,97 €		
Cost of the loading phase	Description of the task per ton of partition	Hourly cost of a worker or equipment	Number of hours needed per ton of waste	Cost per m2 of partition	Cost per ton of partition		
Step 3: Loading of the skips for each type of waste							
Plasterboard (manual labour)	number of hours needed to load a skip with plasterboards	0 €	0	0,00 €	0,00 €		
Equipment	number of hours of mechanical equipment to load a skip with plasterboards	0 €	0	0,00 €	0,00 €		
Metal Frame (manual labour)	number of hours needed to load a skip with metal frames	0 €	0	0,00 €	0,00 €		
Equipment	number of hours of mechanical equipment to load a skip with metal frames	0 €	0	0,00 €	0,00 €		
Insulation(manual labour)	number of hours needed to load a skip with insulation	0 €	0	0,00 €	0,00 €		
Equipment	number of hours of mechanical equipment to load a skip with insulation	0 €	0	0,00 €	0,00 €		
Wooden frames (manuel labour)	number of hours of mechanical equipment to load a skip with wooden frames	0 €	0	0,00 €	0,00 €		
Equipment	number of hours of mechanical equipment to load a skip with wooden frames	0 €	0	0,00 €	0,00 €		
Total Step 3				0,00 €	0,00 €		
TOTAL (step1 +step2 +step 3)				4,00 €	165,29 €		

Tab “Demolition costs Partition 1”

DEMOLITION COSTS FOR PARTITION TYPE 1							
number of square meters of partition type 1	5000						
Weight per square meter of partition type 1	Kg	% of weight	First evaluation of tonnages	Type of skip (m3)	Density of waste with coefficient of expansion	tonnage per skip	Square meter of partition per skip
Partition	24,2	100%	121,00	20	0,250	5	207
Cost of the demolition phase (Partition type 1)	Description of the task per m2 of partition	Wage rate of a worker	Number of hours needed per square meter	Cost per m2 of partition	Cost per ton of partition		
Step 1: crushing, collapsing	number of hours needed to demolish one square meter	20 €	0,05	1,00 €	41,32 €		
Step 2: Sorting and storage operation on site	number of hours needed to store temporarily the waste	25 €	0,12	3,00 €	123,97 €		
Cost of the loading phase	Description of the task per ton of partition	Hourly cost of a worker or equipment	Number of hours needed to load the skip	Cost per m2 of partition	Cost per ton of partition		
Step 3: Loading of the skip							
Mixed waste (manual labour)	number of hours needed to load a skip with mixed waste	20 €	8	0,77 €	32,00 €		
Equipment	number of hours of mechanical equipment to load a skip with mixed waste	30 €	9	1,31 €	54,00 €		
Total Step 3				2,08 €	86,00 €		
TOTAL (step1 +step2 +step 3)				6,08 €	251,29 €		

Tab “Waste streams and costs”

WASTE STREAMS FOLLOWING A <u>DISMANTLING</u> PROCESS					Cost for storage and transportation									Cost for treatment				Total Costs	
GYPSUM BASED WASTE																			
Recyclable GBW	Tonnages	Density of material	Density of wastes (with coefficient of expansion)	Volume m3	Storage (type of skips m3)	Cost for rental per month	number of skips	Total cost	Number of skips per roundtrip	number of roundtrips	Distance to the recycling unit (in hour)	Cost of the haulier per hour	Hauling cost	Destination (transfert station)	Final Route (recovering, recycling, landfilling)	Cost per ton	Treatment cost		
Plasterboards type 1	102	1	0,3	340															
Plasterboards type 2	0	1	0,3	0															
Sandwich panels	0	1	0,3	0															
Laminates (10 cm EPS)	0	0,1	0,045	0															
Laminates (10 cm Mineral wool)	0	0,17	0,075	0															
Plaster Ceilings	0	0,8	0,25	0															
Plasterblocks	0	1	0,6	0															
TOTAL	102			340	20	50	2	0	2	9	2	80	1440	Transfert station	Recycling	55	5610	7050	
Non recyclable GBW																			
Laminates (EPS)	0	0,1	0,045	0															
Laminates (Mineral wool)	0	0,17	0,075	0															
Others	0	0,5	0,3	0															
TOTAL	0			0	20	50	1	0	2	0	0,5	80	0	Transfert station	Landfilling mono cell	110	0	0	
METAL																			
Recyclable metal frames	9	1,7	0,08	113	20	50	2	0	2	3	0,5	80	120	Transfert station	Recycling	-250	-2250	-2130	
INSULATION																			
EPS	0	0,015	0,007	0	0	0	0	0	2	0	0,5	80	0	Transfert station	Recycling	0	0	0	
Mineral wool	10	0,05	0,1	100	20	50	1	0	2	3	0,5	80	120	Transfert station	Landfilling	110	1100	1220	
WOOD																			
Wooden frames	0	0,2	0,15	0	10	40	2	0	2	0	1	80	0	Transfert station	Recovering	30	0	0	
REMAINING MIXED WASTES	0		0,25	0	10	40	2	0	2	0	1	80	0	Transfert station	Landfilling	110	0	0	
TOTALS	121			553				0					1680				4460	6140	

WASTE STREAMS FOLLOWING A <u>DEMOLITION</u> PROCESS					Cost for storage and transportation									Cost for treatment				Total Costs
Mixed wastes	Tonnages	Density of material	Density of wastes (with coefficient of expansion)	Volume m3	Storage (type of skips m3)	Cost for rental per month	number of skips	Total cost	Number of skips per roundtrip	number of roundtrips	Distance to the recycling unit (in hour)	Cost of the haulier per hour	Hauling cost	Destination (transfert station)	Final Route (recovering, recycling, landfilling)	Cost per ton	Treatment cost	
Mixed wastes	121,00	N/A	0,25	484	20	50	2	0	2	13	1	80	1040	Transfert station	Landfilling	110	13310	14350
TOTALS	121,00			484				0					1040				13310	14350