GYPSUM TO GYPSUM

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

Protocol of action B2.2: Quality criteria for recycled gypsum, technical and toxicological parameters

Start date of the project: 2013/01/01 Duration: 36 months

LIFE PROGRAMME
LIFE11 ENV/BE/001039

GYPSUM TO GYPSUM

Identifier:	**DC2: Protocol of action B2.2: Quality criteria for recycled gypsum; technical and toxicological parameters**
Number of the associated action:	**B2**
Date:	**June 2015**
Class:	**Deliverable**
Responsible partner:	**Eurogypsum**
Distribution:	**PU: public**
Title:	**Protocol of action B2.2: Quality criteria for recycled gypsum; technical and toxicological parameters**

GYPSUM TO GYPSUM

Contact Information

Lead Contact	Eurogypsum – Mrs. Christine Marlet
Phone Number	+32 2 227 11 30
Email	info@eurogypsum.org

Document Contact	Christine Marlet, Eurogypsum
Deliverable	**Protocol of action B2.2: Quality criteria for recycled gypsum; technical and toxicological parameters**
Phone Number	+32 2 227 11 30
Email	info@eurogypsum.org
Participants	Knauf, S1, S2, SG1, SG2, LOEMCO, NWGR, GRI

GtoG Project Management Bureau

Name	Title	Phone	Email
Christine Marlet	Project Director	32 2 227 11 30	info@eurogypsum.org
Luigi Della Sala	Project Manager	32 2 227 11 62	project@eurogypsum.org
Thierry Pichon	ERMC Chair/President of the GtoG SC		Thierry.Pichon@siniat.com

GYPSUM TO GYPSUM

DOCUMENTS HISTORY

Version	Date	Author(s)
00	9 December 2014	Draft 1 Christine Marlet
01	12 January 2015	Christine Marlet-correction of 0.1.
02	13 April 2015	Christine Marlet-inclusion of test results Loemco
03	16 April 2015	Christine Marlet-minor corrections
04	22 April 2015	Anna Lang comments (Knauf)
05	9 June 2015	Christine Marlet-Reworked deliverable with conclusions of meetings and additional data
06	18 June 2015	Incorporation of Placo comments for parameters
07	27 July 2015	Answer Nickel issue based on the five producers responses
08	31 August 2015	Christine Marlet - Last version to all the partners
09	7 September 2015	Christine Marlet- Final version and executive summary
10	16 September 2015	Christine Marlet-final for peer review incorporating GRI comments and recycling WG comments-Knuaf and Saint Gobain Kallo comments
11	21 September 2015	Christine Marlet-insertion of comments Thierry Pichon and Saint-Gobain Placo FR
12	29 September 2015	Christine Marlet-Inclusion of comments from GRI and PlacoFR-Final version
13	2 October 2015	Peer review from UPM
14	6 October 2015	Luigi Della Sala - Final version after peer review

GYPSUM TO GYPSUM

Contents

I. Grant agreement

B2.2 Valorisation and qualification of deconstruction gypsum waste

In Action B2, the gypsum waste received from the four deconstruction sites (name the sites) will be qualified and re-assessed to ensure that the waste is suitable for reprocessing. The properties of the recycled gypsum will be agreed between the recyclers and the manufacturers.

COORDINATOR: GRI
Partners: NWGR, GRI, FGUPM-LOEMCO, L1, L2, SG1, SG2, KNAUFKG
Duration: M10 - M30

Processing removes the paper liner which is isolated for further processing elsewhere. Other than decontamination, separating the paper from the core is the most important step in processing and the main issue for proper incorporation into the manufacturing process (covered in Action B3).

The core gypsum itself is processed through a series of stages to render it to the manufacturer's specification. Great care is taken to ensure that physical impurities are removed from the material and the final product is stored in a dedicated location in order to avoid cross-contamination of gypsum powder and paper.

Incorporating processed gypsum into new gypsum plasterboards can have significant implications for fire resistance and fire rating of the product. If scrap boards are shredded, including the paper, before being incorporated into new boards, new boards will contain a higher quantity of paper in the core material. This could potentially reduce the fire resistance properties of boards. Amounts of recycled content must be carefully controlled and are currently kept to low levels to ensure fire safety properties are not compromised. Other stages reduce the paper content of processed gypsum by sieving.
The qualification of the waste must be done according to specific parameters received from the Gypsum manufacturers in order to obtain processed gypsum that can be more easily incorporated in the manufacturing process.

Methods employed:

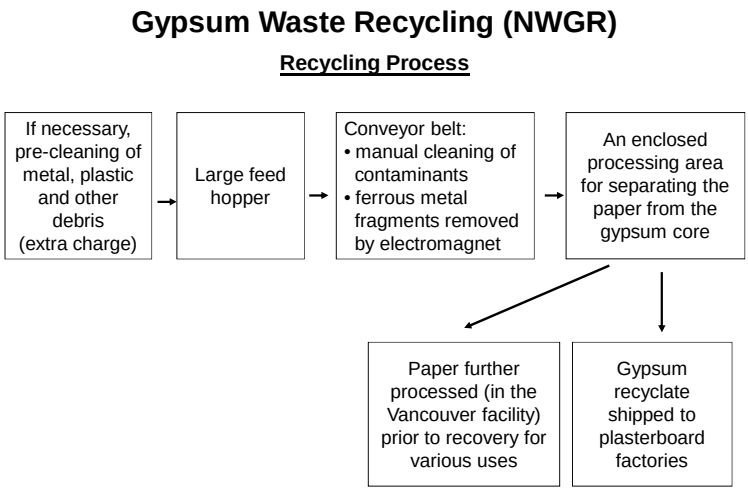

Figure 1. NWGR recycling process

The delivered waste is crushed by a bulldozer onto a pile and discontinuously fed to a hopper with a high strength chain. Some material like metal studs are sorted out manually (1 person) and magnets are installed to remove ferrous metals. The material is then directed to the sieving system.

The two step sieving system is shaken permanently (both sieves run with same frequency). Both underflow materials are put together on the conveyer belt with the gypsum material for processing. Visual analysis cannot detect any relevant amounts of plastics, laminates or tiles. In the raw paper fraction, these components could however be identified. The paper fraction is further submitted to an air separator, which cleans the paper from heavier components before processing it in the pulping installation.

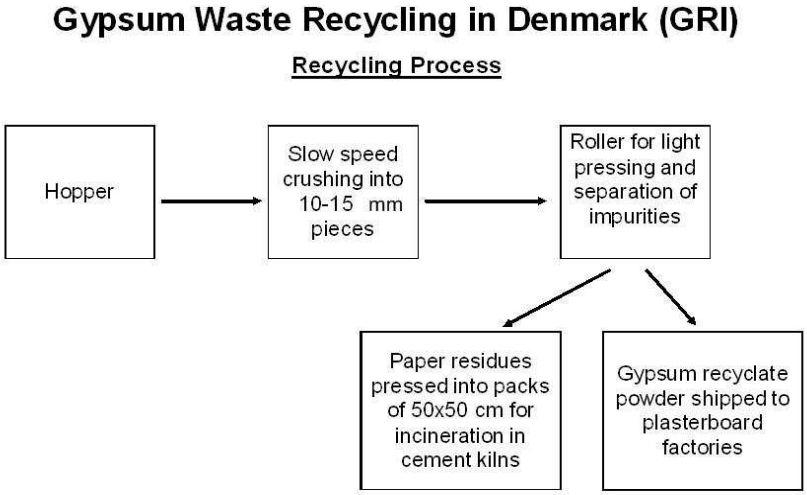

Figure 2. GRI recycling process

The plasterboard waste is conveyed via a hopper to a slow-speed crusher, where it is crushed into pieces of approx. 10-15 mm. Subsequently, the crushed material is conveyed on a screen belt provided with a magnet separator. It is then conveyed to a roller, where it is pressed lightly. Inside the roller the gypsum is separated and any impurities such as wall paper, tissue, etc. are removed. Impurities are then pressed into packs of 50 x 50 cm.

EXPECTED RESULTS

B2.2: **Gypsum waste specifications establishing the end-of-waste criteria (M28). See example[1] below: proposed in the grant agreement as a reference only**

Quality Parameters	Expressed as	Unit	Quality Criteria According Contract GFR/Gypsum Industry
Free moisture	H_2O	% by weight	< 10
Calcium sulphate dehydrate	$CaSO_4 \times 2H_2O$	% by weight	≥ 80
Chloride	Cl	% by weight	< 0,01
Magnesium salts, water soluble	MgO	% by weight	< 0,02
Sodium salts, water soluble	Na_2O	% by weight	< 0,02
Potassium salts, water soluble	K_20	% by weight	< 0,02
pH		---	5 – 9
Toxicity		---	non-toxic
			Guideline values
Organic carbon	TOC	% by weight	< 2

[1] The example is taken from a pilot project on recycling demolition waste carried by the German Gypsum Industry and GFR – (Part B)

Colour	Ry Lxaxbx	. /.	White
Smell		---	neutral

Table 1. Example of gypsum waste specifications included in the grant agreement

II. PART I - A1 Report on current practices for gypsum recycling

During the preparatory A1 action, the partners realised an inventory of existing specifications for recycled gypsum. We have the technical specifications that are needed for the re-incorporation of the recycled gypsum into the manufacturing process. In addition, we have the toxicological specifications related to the heavy metal trace elements in the recycled gypsum. Both parameters have been looked at during the development of the A1 report. Part I of this report takes over the content developed in the A1 report.

In summary, we have in 2013

1. The German draft quality criteria for the recycled gypsum from BVGips. The latter undergone a review in December 2013 (please see point IV for more details);
2. The UK quality criteria for the recycled gypsum developed by WRAP. The UK criteria cover open-loop recycling.
3. The GRI quality criteria;
4. A consolidation of the quality criteria used and developed by Eurogypsum member associations, covering point 1 and 2 plus Italy, The Netherlands, Belgium;
5. A consolidation of point 3 and 4;
6. A qualitative comparison between the technical and toxicological parameters.

This inventory of quality criteria are not harmonised and are country or company specific. During the pilot recycling projects, the recycled gypsum was tested by Loemco, the laboratory partner to the project. The results were compared with the current practices for qualifying the recycled gypsum. The aim is to reach harmonised voluntary guidelines to establish quality parameters for the recycled gypsum covering technical and toxicological criteria.

Recycled gypsum quality criteria in the gypsum industry (2012)

a. Gypsum draft quality criteria developed by BV Gips in April 2012

The German gypsum association recycling standard is a draft quality criteria for gypsum received from recycling plants. It was published in April 2012 and covers technical and toxicological parameters to qualify the recycled gypsum. The human health related parameters are based on earlier studies (Beckert, J, 1990) regarding the characteristics of natural and FGD gypsum.

Recycled Gypsum Draft Quality criteria developed by BV Gips				
	Technical Parameters	Expressed as	Values	
			Proposal BV Gips	Remarks BV Gips
1.	Particle Size		≤ 1 mm	Higher values are acceptable after plant specific agreement.
2.	Free moisture	H_2O	≤ 5 % by weight	
3.	Calcium sulphate dehydrate	$CaSO_4$ x $2H_2O$	> 85 % by weight	
4.	Total organic carbon TOC		< 0,5 % by weight	Deviation up to 1 % by weight is only possible after special agreement.
5.	Exclusion of visible contaminants		visual assessment	Residues of laminated boards or coating materials of sandwich panels count for impurities, too.
6.	Odour		neutral	
7.	Magnesium salts, water soluble	MgO	< 0,02 % by weight	Deviation up to 0.1 % by weight MgO is only possible after special agreement.
8.	Sodium salts, water soluble	Na_2O	< 0,02 % by weight	Deviation up to 0.06 % by weight Na_2O is only possible after special agreement.
9.	Potassium salts, water soluble	K_2O	< 0,02 % by weight	
10.	Chloride	Cl	< 0,01 % by weight	
11.	pH	---	5 – 9	
12.	Fluoride	F	< 0,02 % by weight	

13.	Radioactivity according to RP 112		Index < 0,5	
14.	The material has to be free of asbestos.			

Recycled Gypsum Draft Quality criteria developed by BV Gips				
	Toxicological Parameters	Expressed as	Values	
			Proposal BV Gips	Remarks BV Gips
15.	Trace element content according to Beckert Study[2]	As	< 4 mg/kg	Values can be adjusted to new human toxicological evaluations and threshold values
		Be	< 0,7 mg/kg	
		Pb	< 22 mg/kg	
		Cd	< 0,5 mg/kg	
		Cr	< 25 mg/kg	
		Co	< 4 mg/kg	
		Cu	< 14 mg/kg	
		Mn	< 200 mg/kg	
		Ni	< 13 mg/kg	
		Hg	< 1,3 mg/kg	
		Se	< 16 mg/kg	
		Te	< 0,3 mg/kg	

[2]BECKERT J., 1990. Comparison of natural gypsum and FGD gypsum: studies for a comparative assessment of the health impact of natural gypsum and FGD gypsum from coal-fired power plants with a view to their use in the manufacture of building materials. *VGB technical scientific reports "Thermal power plants",* 707.

		Tl	< 0,4 mg/kg	
		V	< 26 mg/kg	
		Zn	< 50 mg/kg	
		PAH (EPA)	< 0,2 mg/kg	
16.	Sulphur (elemental)	S	< 35 mg/kg	

Table 2. Gypsum Draft quality criteria developed by BV Gips in April 2012

b. Gypsum quality criteria developed by WRAP: UK PAS 2009

The Publicly Available Specification (PAS) has been developed by WRAP (Waste & Resources Action Programme) in collaboration with The British Standards Institution (BSI) in 2008.3

This PAS:

- Specifies minimum requirements for the production of recycled gypsum from plasterboard waste intended for a range of applications in existing and emerging end markets.
- Covers the selection, receipt and handling of input materials, the specifications of product grades, and the storage, labelling, dispatch and traceability of the products. It also specifies requirements for a quality management system for the production of grades of recycled gypsum to ensure they are consistently fit for their intended uses.
- Is for recycled gypsum produced from plasterboard waste that has been separately collected, or sorted and segregated from, other wastes, products or materials.
- Likely sources of plasterboard waste include:
    - Plasterboard manufacturing waste;
    - Over-ordering on construction sites;
    - Boards damaged during transportation, handling or storage;
    - Off-cuts during installation; and
    - Plasterboard stripped-out during refurbishment and demolition works.

The requirements for the recycled gypsum grades specify particle size distribution, residual paper content, purity, physical contamination and chemical composition limits, and acceptability of colour and smell.

The end markets to which this PAS applies include, but are not limited to, the following applications:

- Plasterboard manufacture;

[3]PAS 109:2008 Specification for the production of recycled gypsum from waste plasterboard-Wrap and BSI August 2008.

- Cement manufacture;
- Manufacture of construction products;
- Soil treatment in agriculture and horticulture;
- Manufacture of growing media;
- Soil stabilization and binding;
- Clarifying aquatic environments; and
- Absorbent for liquid spills.

In order to accommodate the widening range of end user requirements for recycled gypsum variations or additions to an end user specification may be required.
However, in all instances, the standard set by this PAS shall be the minimum requirement.

The recycler is responsible for consistently fulfilling any additional quality needs, such that the products are safe and consistently fit for their intended purposes.

Parameter	Specification					
Particle size distribution (% w/w retained on BS sieve individually)	**Fine grade**		**Coarse grade**		**Custom grade**	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
31.5 mm	0	0	0	0	As defined to suit intended end market (**8.1.1**)	
16 mm	0	0	40	80		
8 mm	0	0	20	60		
4 mm	0	0	0	40		
2 mm	0	0	0	20		
1 mm	0	10	0	10		
0.500 mm	0	20	0	5		
0.250 mm	0	40	0	2		
0.125 mm	20	60	0	2		
0.063 mm	40	80	0	2		
Residual paper / fibres						
Content	<1% w/w					
Size of paper pieces	Maximum 10 mm largest dimension					
Purity (content of $CaSO_4.2H_2O$)	>85% w/w					
Physical contaminants	Trace					
Chemical composition						
Soluble chloride (Cl)	<0.01% w/w					
Magnesium oxide (MgO)	<0.1% w/w					
Sodium oxide (Na_2O)	<0.06% w/w					
Colour	White, light grey or light beige, with no coloured particles					
Smell	Odourless / neutral					

Table 3. Gypsum quality criteria developed by WRAP: UK PAS 2009

Parameter	Test type	Minimum test frequency		Test method
		Validation	Business as usual	
Particle size distribution	Visual	Per waste batch input to process	Once per working day	Annex D
	Measured	Once, during stable operation in accordance with SOPs	Once per 1000 tonnes	BS EN 933-1:1997 (The test portion shall be dried at 45°C±2°C. Dry sieving shall be used and the procedure for washing specified in **7.1** of BS EN 933-1:1997 shall not be applied.)
Residual paper / fibres	Visual	Per waste batch input to process	Once per working day	Annex D
	Measured	Once, during stable operation in accordance with SOPs	Once per 1000 tonnes	Annex E
Purity	Measured	Once, during stable operation in accordance with SOPs	Once per 1000 tonnes	VGB-M 701e gravimetric (as calcium oxalate) method for determination of gypsum content (degree of purity, R°), or other comparable analysis method
Physical contaminants	Visual	Per waste batch input to process	Once per working day	Annex D
	Measured	Once, during stable operation in accordance with SOPs	Once per 1000 tonnes	Annex E
Chemical composition	Measured	Once, during stable operation in accordance with SOPs	Once per 1000 tonnes	VGB-M 701e photometric methods with atomic absorption spectroscopy (AAS), or other comparable analysis method
Colour	Visual	Per waste batch input to process	Once per working day	Annex D
Smell		Per waste batch input to process	Once per working day	Annex D

NOTE 5 When undertaking the procedure for determination of particle size distribution, the oven temperature has been reduced from that stated in BS EN 933-1:1997 to ensure it is significantly below the temperature at which calcination of the gypsum would occur.

Table 4. Explanation of the gypsum quality criteria developed by WRAP: UK PAS 2009

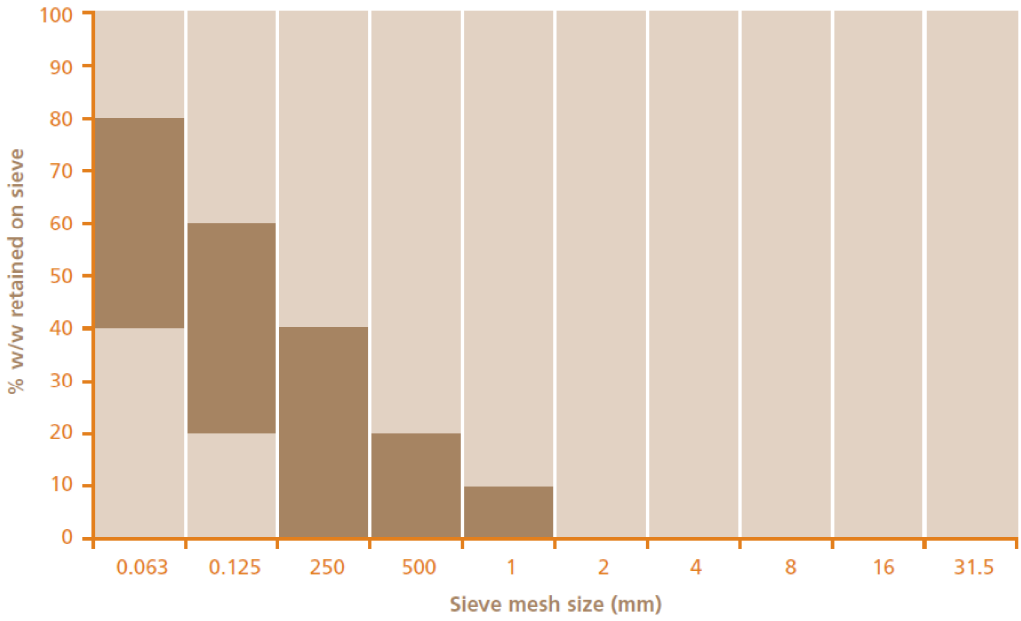

Figure 3. Limits of particle size distribution, Fine grade recycled gypsum.[4]

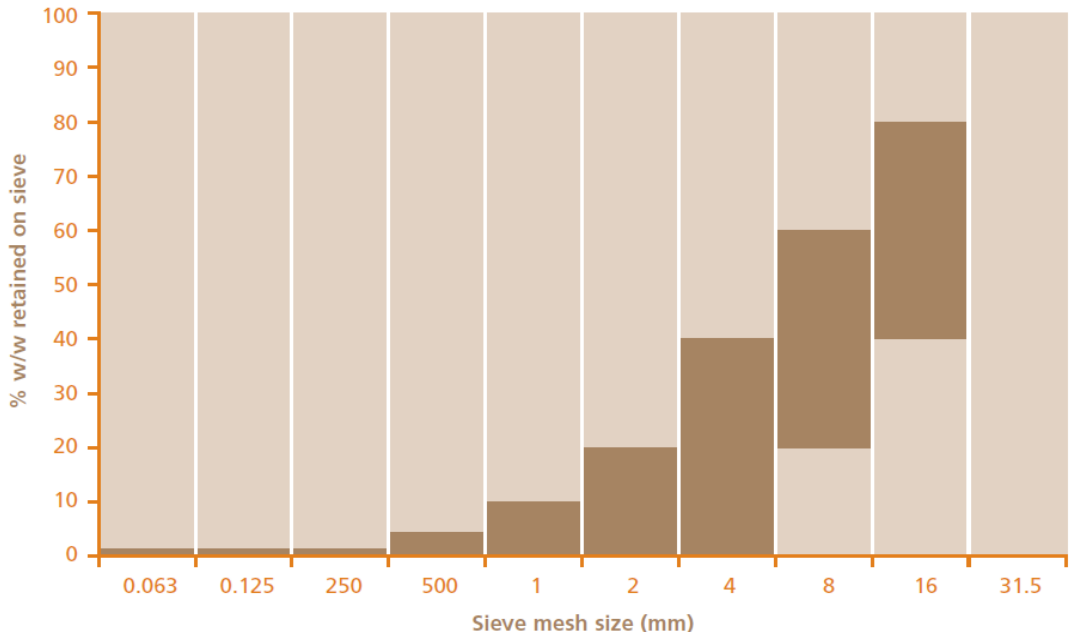

Figure 4. Limits of particle size distribution, Coarse grade recycled gypsum.[5]

[4]PAS 109:2008 Specification for the production of recycled gypsum from waste plasterboard-Wrap and BSI August 2008.

[5]PAS 109:2008 Specification for the production of recycled gypsum from waste plasterboard-Wrap and BSI August 2008.

c. Comparison of recycled gypsum criteria among Eurogypsum member associations.

In October 2012, Eurogypsum has carried out a survey among its member on the recycled gypsum quality criteria they were using in different countries. Results were made available to the GTOG project on January, 17th 2013 with the view to adopt the harmonised recycled gypsum guidelines stemming from the project provided the latter are fruit of a consensual approach between recyclers and producers. As we have several recyclers in France, Germany and the UK who are not partners to the GtoG project, it is intended to share the results with them after the project and reach thus a consensual quality criteria approach with all the actor of the gypsum recycling business.
The results of Eurogypsum survey can be found in the following tables.

Comparison of Recycled Gypsum Quality Criteria among EUROGYPSUM members Associations										
	Technical parameters	Expressed as			Values					
			NL	UK (PAS 109:2008)	Proposal BV Gips	Remarks BV Gips	NL	BE	UK (PAS 109:2008)	IT
1.	Particle Size		≤ 1 mm Sieve	Particle size distribution (% w/w retained on BS sieve individually)	≤ 1 mm	Higher values are acceptable after plant specific agreement.	≥ 13 mm, 5 % > 10 mm	Custom grade	Fine/ Coarse/ Custom grade: values see PAS 109	0-120 mm
2.	Free moisture	H_2O			≤ 5 % by weight			< 10 %	not defined	< 5 % by weight

3.	Calcium sulphate dihydrate	$CaSO_4$ x $2H_2O$		% w/w	> 85 % by weight			> 90 %	> 85 %	> 75 % by weight
4.	Total organic carbon TOC			% w/w	< 0,5 % by weight	Deviation up to 1 % by weight is only possible after special agreement.		< 1,5 %	< 1 %	< 1,0 % by weight
5.	Exclusion of visible contaminants			physical contaminants	visual assessment	Residues of laminated boards or coating materials of sandwich panels count for impurities, too.		Proposal OK	trace	
6.	Odour				neutral			Proposal OK	odourless/ neutral	
7.	Magnesium salts, water soluble	MgO		MgO	< 0,02 % by weight	Deviation up to 0.1 % by weight MgO is only possible after special agreement.		< 0,10 %	< 0,1 %	< 0,1 % by weight
8.	Sodium salts, water soluble	Na_2O		Na_2O	< 0,02 % by weight	Deviation up to 0.06 % by weight Na_2O is only possible after special agreement.		< 0,05 %	< 0,06 %	< 0,05 % by weight
9.	Potassium salts, water soluble	K_2O			< 0,02 % by weight			< 0,05 %	not defined	< 0,05 % by weight

10.	Chloride	Cl		Cl	< 0,01 % by weight			< 0,02 %	< 0,01 %	> 0,01 % by weight
11.	pH	---			5 – 9			Proposal OK	not defined	5<pH<9
12.	Fluoride	F			< 0,02 % by weight			Proposal OK	not defined	-
13.	Radioactivity according to RP 112				Index < 0,5			ACI Index < 0,5	not defined	index < 0,5
	Other Parameters?									
14.	The material has to be free of asbestos							proposal OK	not defined	yes

Table 5. Comparison of Recycled Gypsum Quality Criteria among EUROGYPSUM members Associations – Technical parameters

Comparison of Gypsum Waste Quality criteria among EUROGYPSUM members Associations			
	Toxicological	**Expressed as**	**Values**

	parameters							
			Proposal BV Gips	**Remarks BV Gips**	**NL**	**BE**	**UK (Quality Protocol)**	**IT**
15.	Trace element content according to "Beckert-Study"[6]	As	< 4 mg/kg	Values can be adjusted to new human toxicological evaluations and threshold values		to discuss	< 5.23 mg/kg	< 4 mg/kg
		Be	< 0.7 mg/kg			to discuss	not defined	< 0.7 mg/kg
		Pb	< 22 mg/kg			to discuss	< 31.9 mg/kg	< 22 mg/kg
		Cd	< 0.5 mg/kg			to discuss	< 0.3 mg/kg	< 0.5 mg/kg
		Cr	< 25 mg/kg			to discuss	< 17.9 mg/kg	< 25 mg/kg
		Co	< 4 mg/kg			to discuss	not defined	< 4 mg/kg
		Cu	< 14 mg/kg			to discuss	< 32.8 mg/kg	< 14 mg/kg
		Mn	< 200 mg/kg			to discuss	not defined	< 200 mg/kg
		Ni	< 13 mg/kg			to discuss	< 7.31 mg/kg	< 13 mg/kg
		Hg	< 1.3 mg/kg			to discuss	< 2 mg/kg	< 1.3 mg/kg
		Se	< 16 mg/kg			to discuss	< 7.37 mg/kg	< 16 mg/kg
		Te	< 0.3 mg/kg			to discuss	not defined	< 0.3 mg/kg

[6]BECKERT J., 1990. Comparison of natural gypsum and FGD gypsum: studies for a comparative assessment of the health impact of natural gypsum and FGD gypsum from coal-fired power plants with a view to their use in the manufacture of building materials. *VGB technical scientific reports "Thermal power plants",* 707.

		Tl	< 0.4 mg/kg			to discuss	not defined	< 0.4 mg/kg
		V	< 26 mg/kg			to discuss	not defined	< 26 mg/kg
		Zn	< 50 mg/kg			to discuss	< 40.3 mg/kg	< 50 mg/kg
		PAH (EPA)	< 0.2 mg/kg			PAH10< 0.50/PAH16< 0.8	not defined	< 0.2 mg/kg
16.	Magnesium[2]						< 2.412 mg/kg	
17.	Molybdenum						< 7.68 mg/kg	
18.	Phosphorous						< 87 mg/kg	
19.	Potassium[3]						< 1.992 mg/kg	
20.	Sulphur (elemental)	S	< 35 mg/kg			to discuss	< 209.200 mg/kg [4]	< 35 mg/kg

Table 6. Comparison of Recycled Gypsum Quality Criteria among EUROGYPSUM members Associations – Toxicological parameters

[2] Magnesium, to be proven
[3] Potassium, to be proven
[4] Value correct? < 209 g/kg in EA Quality Protocol Appendix B1

d. GRI quality criteria

GRI has developed specific requirements for the produced gypsum powder, which are depicted in the following table:

Criteria	Demand
Cl (chlorid content)	< 0,02% weight
pH	7 < pH < 9
Free moisture	< 10% weight
Purity (content of $CaSO_4$ x $2H_2O$)	Max. 5% points (weight) less than what the gypsum plants have supplied to the market during the last 20 years.
Rehydration	Max. 5% points (weight) less than what the gypsum plants have supplied to the market during the last 20 years.
Particle size	≤ 13 mm
Smell	Odourless/neutral
MgO	< 0,10% weight
Na2O	< 0,06% weight

Table 7. GRI quality criteria

The particle size of the powder is distributed in the following way (see picture). It has to be noted that rather the big standard particle size (50% of the particles are bigger than 0.5 mm) is chosen deliberately to make sure that the handling of the powder is possible at the receiving plasterboard plants, does not require any special handling equipment (like silo or blower trucks) and is not too dusty.

GRI has previously operated with a max particle size of 4 mm, but the receiving plasterboard plants requested a bigger particle size, as the small particle size made handling of the powder difficult as the handling of finer recycled gypsum powder was relatively dusty due to the fine particles.

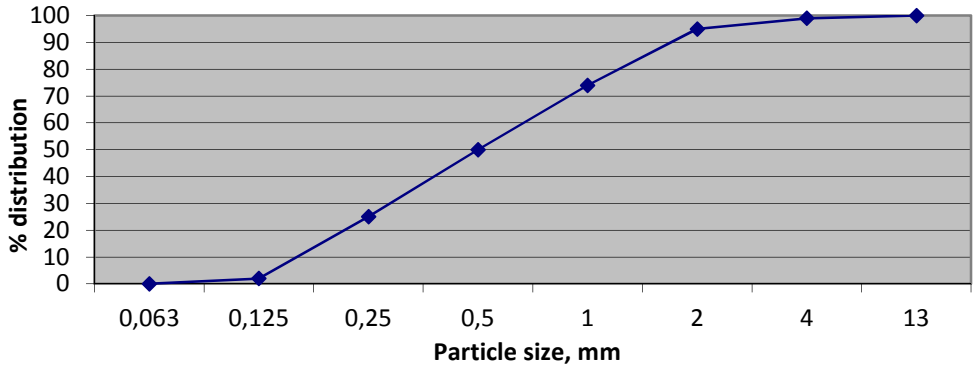

Figure 5. Standard particle size of recycled powder

e. Comparison between the quality criteria of the recycled gypsum in the above-mentioned tables

Technical parameters

- Particle size: BV Gips specifies lowest values, PAS 109 distinguished between fine and course grade and GRI deliberately choose to leave 50% of the particles bigger than 0.5 mm to make sure that the handling of the powder is possible at the receiving plasterboard plants, does not require any special handling equipment (like silo or blower trucks) and is not too dusty.
- Both BV Gips and the Italian Gypsum Association (Assogesso) limit the free moisture to 5% w/w.
- However, the Belgian Gypsum Association (ABLG) and GRI limit it to 10 % w/w.
- Purity of the recycled gypsum varies from 75% to 90%.
- Total organic carbon TOC is in all the cases under 1.5% w/w, being BV Gips more restrictive than the rest, limiting to 0.5% w/w.
- For the different salts (MgO, Na_2O, K_2O) the limit is similar and the biggest different is related to K_2O content. BV Gips limit it to 0.02 % w/w whereas the rest limit it to 0.05 % w/w.

Toxicological parameters

- BV Gips and IT Member Association follow the same criteria.
- PAS 109 differs from the above mentioned values, defining more restrictive values for Cd, Cr, Ni, Se and Zn and less restrictive for the rest of parameters.
- The following tables 2-29 and 2-30 summarizes the information collected in the previous sections about different technical and toxicological quality criteria.

TECHNICAL PARAMETERS	BV Gips	PAS 109	IT Eurogypsum Member Association	BE Eurogypsum Member Association	GRI
Particle size	≤ 1 mm higher values if agreement	fine grade ≤ 1 mm coarse grade ≤ 16 mm (see particle size distribution figure 2-29)	0-120 mm	Custom grade	≤ 13 mm 50% of the particles are bigger than 0.5 mm
Free moisture	≤ 5 % w/w	not defined	< 5 % w/w	< 10 % w/w	< 10 % w/w
Purity (content of calcium sulphate dihydrate)	> 85 % w/w	> 85 % w/w	> 75 % w/w	> 90 % w/w	Max. 5% points (weight) less than what the gypsum plants have supplied to the market during the last 20 years.
Total organic carbon TOC Content of residual paper / fibres	< 0.5 % w/w up to 1% if agreement	< 1% w/w	< 1 % w/w	< 1.5 % w/w	< 1 % w/w
Exclusion of visible contaminants	visual assessment	Trace	not defined	OK	not defined
Odour	Neutral	odourless / neutral	not defined	neutral	Odourless/neutral

Magnesium salts, water soluble (MgO)	< 0.02 % w/w up to 0.1% if agreement	< 0.1 % w/w	< 0.1 % w/w	< 0.1 % w/w	< 0.1 % w/w
Sodium salts, water soluble (Na2O)	< 0.02 % w/w up to 0.06 if agreement	< 0.06 % w/w	< 0.05 % w/w	< 0.05 % w/w	< 0.06 % w/w
Potassium salts, water soluble (K_2O)	< 0.02 % w/w	not defined	< 0.05 % w/w	< 0.05 % w/w	not defined
Chloride (Cl)	< 0.01 % w/w	< 0,01 % w/w	< 0,01 % w/w	< 0.02 % w/w	< 0.02 % w/w
pH	5 – 9	not defined	5 – 9	5 – 9	7 - 9
Fluoride (F)	< 0.02 % w/w	not defined	not defined	< 0.02 % w/w	not defined
Radioactivity according to RP 112	Index < 0.5	not defined	Index < 0.5	Index < 0.5	not defined
The material has to be free of asbestos.	OK	not defined	OK	OK	OK
Size of paper pieces	not defined	Max. 10 mm largest dimension	not defined	not defined	not defined
Colour	not defined	White, light grey or light beige, with no coloured particles	not defined	not defined	not defined

Rehydration	not defined	not defined	not defined	not defined	Max. 5% points (weight) less than what the gypsum plants have supplied to the market during the last 20 years.

Table 8. Comparison between the quality criteria of the recycled gypsum – Technical parameters

TOXICOLOGICAL PARAMETERS	BV Gips	PAS 109	IT Eurogypsum Member Association	BE Eurogypsum Member Association
As	< 4 mg/kg	< 5.23 mg/kg	< 4 mg/kg	to discuss
Be	< 0,7 mg/kg	not defined	< 0.7 mg/kg	to discuss
Pb	< 22 mg/kg	< 31.9 mg/kg	< 22 mg/kg	to discuss
Cd	< 0,5 mg/kg	< 0.3 mg/kg	< 0.5 mg/kg	to discuss
Cr	< 25 mg/kg	< 17.9 mg/kg	< 25 mg/kg	to discuss
Co	< 4 mg/kg	not defined	< 4 mg/kg	to discuss
Cu	< 14 mg/kg	< 32.8 mg/kg	< 14 mg/kg	to discuss
Mn	< 200 mg/kg	not defined	< 200 mg/kg	to discuss
Ni	< 13 mg/kg	< 7.31 mg/kg	< 13 mg/kg	to discuss
Hg	< 1,3 mg/kg	< 2 mg/kg	< 1.3 mg/kg	to discuss
Se	< 16 mg/kg	< 7.37 mg/kg	< 16 mg/kg	to discuss
Te	< 0,3 mg/kg	not defined	< 0.3 mg/kg	to discuss
Tl	< 0,4 mg/kg	not defined	< 0.4 mg/kg	to discuss
V	< 26 mg/kg	not defined	< 26 mg/kg	to discuss
Zn	< 50 mg/kg	< 40.3 mg/kg	< 50 mg/kg	to discuss
PAH (EPA)	< 0,2 mg/kg	not defined	< 0.2 mg/kg	PAH10< 0.50/PAH16< 0.8
Magnesium		< 2.412 mg/kg		
Molybdenum		< 7.68 mg/kg		
Phosphorous		< 87 mg/kg		
Potassium		< 1.992 mg/kg		
S	< 35 mg/kg	< 209.200 mg/kg	< 35 mg/kg	to discuss

Table 9. Comparison between the quality criteria of the recycled gypsum – Toxicological parameters

III. Part II - Parameters developed after the delivery of the A1 Report-09/2013

After consultation with recycling companies e. g. GRI and on the basis of current analytical results of recycled gypsum BV Gips modified the quality requirements with some specific tolerance ranges in terms of technical parameters. In December 2013, the German Gypsum association BV Gips developed the definitive quality requirements for the recycled gypsum with the corresponding analysis method including remarks for the use of the of the quality requirement always covering technical health and toxicological parameters.

a. Technical parameters

Quality parameters		Target value	Remark
Part 1 technical			
Particle size [mm]		≤ 1	Plant specific upward deviations permitted
Humidity [% w/w]	H_2O	≤ 5	< 10% w/w (when agreed particle size > 1mm (as bulk material))
Calcium sulfate dihydrate [% w/w]	$CaSO_4 \times 2H_2O$	≥ 85	Plant specific deviations down to 80 % w/w min. only after special agreement permitted
Org. carbon [% w/w]	TOC	≤ 1,0	Plant specific deviations up to 1,5 % w/w max. only after special agreement
Elimination Visible impurities		visual assess-ment	Residues of plasterboard lamination or wall board lamination also count as impurities
Odour		neutral	
Magnesium salts water soluble [% w/w]	MgO	< 0,02	Plant specific deviations up to 0,1 % w/w MgO max. only after special agreement[1)]
Sodium salts water soluble [% w/w]	Na_2O	< 0,02	Plant specific deviations up to 0,04 % w/w Na_2O max. only after special agreement[1)]

Potassium salts water soluble [% w/w]	K_2O	< 0,02	Plant specific deviations up to 0,06 % w/w max. only after special agreement permitted[1)]
Chloride [% w/w]	Cl^-	< 0,01	Plant specific deviations up to 0,02 % w/w only after special agreement permitted[1)]
pH value		5 - 9	
1) Observe interaction Cl with Na and Mg			

Table 10. Technical parameters developed after A1 report (September 2013)

b. Health parameters

Part 2 Health parameters			
Fluoride [% w/w]	F^-	< 0,02	
Radioactivity acc. to RP112 [index]		< 0,5	
Material must be asbestos-free			

Table 11. Health parameters developed after A1 report (September 2013)

c. Toxicological parameters

Quality parameters		Target value	Remark
Trace element contents acc. to maximum values „Beckert Study“ [mg/kg]	As	< 4	Values can be adjusted to new human-toxicological assessments and limits
	Sb	---	
	Be	< 0,7	
	Pb	< 22	
	Cd	< 0,5	
	Cr	< 25	
	Co	<4	

	Cu	< 14	
	Mn	< 200	
	Mo	---	
	Ni	< 13	
	Hg	< 1,3	
	Se	< 16	
	Te	< 0,3	
	Tl	< 0,4	
	V	< 26	
	Zn	< 50	
	PAK (EPA)	< 0,2	
Sulphur (primary)	S		Odour test

Table 12. Toxicological parameters developed after A1 report (September 2013)

d. Analysis method for the technical, health and toxicological parameters developed by BV Gips

Preliminary note

In order to determine the RC gypsum quality parameters further analysis methods can be used in order to provide results that are consistent with the results determined by the reference techniques.

Relevant parameters and corresponding analysis methods are defined in the delivery and taking delivery contracts for RC gypsum. When changing legal basic conditions, mentioned analysis methods can be adjusted to new requirements.

The following methods were discussed with the ad-hoc working group "analysis of recycled gypsum" of the *Wissenschaftlichen Beirates der Forschungsvereinigung der Gipsindustrie e.V.* (scientific advisory council of the research association of the German gypsum industry) in cooperation with the company *Dorfner Anzaplan GmbH*.

Participants: Dr. Thomas Bach (Dorfner Anzaplan GmbH), Helmut Günther (Hilliges Gipswerk GmbH), Prof. Dr. Hans-Ulrich Hummel (Knauf Gips KG), Dr. Hans-Jörg Kersten (Bundesverband der Gipsindustrie e.V.), Dr. Hans-Ulrich Kothe (Casea GmbH), Gundolf Krüger (Knauf Gips KG), Elmar Limley (Siniat GmbH), Sören Olejnik (VG Orth GmbH & Co. KG), Ralph Ostermann (Danogips GmbH), Heinrich Rohlfs (Fermacell GmbH), Dr. Winfried Spickermann (Saint-Gobain Rigips GmbH).

i. Analysis method for part 1 technical parameters

Parameters (unit)	Determination method(s)	Sample pre-treatment	Remark / References
Particle size (mm)	Granulometry		Eurogypsum-QA FGD gypsum
Humidity (% w/w)	VGB [1)] serial number 1 or VGB serial number	None	Gravimetry quick dryer, drying cabinet 40°C or TGA
$CaSO_4$ x 2 H_2O (% w/w)	VGB serial number 2.3 or VGB serial number 3	Pre-dried sample at 40-50°C to constant weight (odour determination at the same time)	Gravimetry (Sulfate determination) In sufficient quantity at 360°C in muffle kiln or quick test ultra-x at 360°C Methods to determine the calcium content are not recommended.
Organic carbon	Digit 3.1.3.2 DepV		DIN EN 13137 DepV
Elimination of visible impurities	DIN EN 933-11 (10 kg sample, indication optic, visible components in	Material > 1mm: Observe representative sample-taking	Method to classify components in coarsely recycled aggregates
Odour	VGB serial number 6	No odour at 40 - 50 °C (drying to constant weight)	Perception
Magnesium salts water soluble	VGB serial number 8.1.2 or 8.7	VGB serial number 0.3	AAS or ICP OES
Natrium salts water soluble (% w/w Na_2O)	VGB serial number 8.2.2 or 8.7	VGB serial number 0.3	AAS or ICP OES

Potassium salts water soluble (% w/w K_2O)	VGB serial number 8.3.2 or 8.7	VGB serial number 0.3 Stock solution A3	AAS or ICP OES
Chloride (% w/w Cl)	VGB serial number 8.8 (VGB serial number 8.8.1, 8.8.2 or 8.8.3 or A 8.8)	VGB serial number 0.3 Stock solution A3	Potentiometry, ion chromatography or titration or photometric determination

Parameters (unit)	Determination method(s)	Sample pre-treatment	Remark / Reference
pH value	VGB serial number 4	if need be, pre-dry sample at 40-45° C in drying cabinet (VGB serial number 1.1)	Following DIN EN ISO 787-9: 1995-04

Table 13. Analysis Method for technical parameters

ii. Analysis method Part 2 toxicological parameters

Parameters (unit)	Determination method(s)	Sample pre-treatment	Remark / Reference
		DIN EN 13657	Aqua regia dissolution (HNO3 + HCl 1:3) as DepV with fermentation tube or in microwave (compulsory for Hh)
As (mg/kg)	VGB serial number 9		

Be (mg/kg)	ICP OES (DIN EN ISO 11885)		DIN EN ISO 11885 Determination of selected elements ICP-OES (acc. to DepV)
Pb (mg/kg)			
Cd (mg/kg)			
Cr (mg/kg)			
Co (mg/kg)			
Cu (mg/kg)			
Mn (mg/kg)			
Ni (mg/kg)			
Se (mg/kg)			
Te (mg/kg)			
Tl (mg/kg)			
V (mg/kg)			
Zn (mg/kg)			
Hg (mg/kg)	Digit 3.1.11 DepV		DIN EN 1483 AAS DIN EN 12338 Mercury – Process after enrichment by amalgamation DIN EN ISO 17852, atomic fluorescence spectrometry (acc. to MantelVO)
S elementary	Declaration „no odour of sulphur“.		Recorded with odour test
PAK (mg/kg)	DIN ISO 18287		Gas-phase chromatograph process with confirmation by mass spectrometry (GC-MS) (acc. to DepV)

Table 14. Analysis Method for toxicological parameters

iii. Analysis method part 2 fluoride

Parameters (unit)	Determination method(s)	Sample pre-treatment	Remark / Reference
Fluoride (% w/w F)	Digit 3.2.16 DepV	VGB SERIAL NUMBER 0.3 Stock solution A3	DIN EN ISO 10304-1 (liquids ion chromatography) DIN 38405-4 anions (group D); determination g of fluoride (D 4)

Table 15. Analysis Method for fluoride

Abbreviations:

VGB: Information Sheet Analysis FGD gypsum M701 http://www.vgb.org (2. issue 2008)

DepV: Landfill Ordinance Annex 4 Guidelines on sampling (taking of samples, preparation of samples and analysis of wastes and landfill replacement construction materials)

AAS Atomic absorption spectrometry
ICP-MS Inductively coupled plasma mass spectrometry
ICP-OES Inductively coupled plasma – optical emission spectrometry

IV. Establishing and evaluating quality criteria for the recycled gypsum during the pilot projects

a. Introduction

In the Grant agreement, it was foreseen to establish the quality properties of the recycled gypsum and in parallel to assess the opportunity to establish the end-of-waste criteria for the recycled gypsum at EU level. The partners were aware about the necessary steps to obtain the end-of-waste status for recycled gypsum at EU level.

The end-of-waste status is appealing but in practice is today challenging to achieve at EU level for the recycled gypsum. Indeed, the GtoG project gave the recyclers and producers the opportunity to have together a round robin test on 20 recycled gypsum samples testing by a third party laboratory, partner to the project.

It is the first time that recyclers and producers have a collaborative approach for the establishment of quality criteria for the recycled gypsum on a scientific basis.

The gypsum recycling business is growing in France, the UK, Germany, Scandinavia, Belgium and the Netherlands. New recyclers businesses are emerging.

This will give the Gypsum sector the opportunity to establish further collaborations, also with other recyclers across Europe, taking advantage of the lessons learnt from the GtoG pilot tests.

In view of the above-mentioned, the partners decided to agree on guidelines for quality criteria for recycled gypsum, covering technical and toxicological parameters. These guidelines should be further optimized after the project, taking into account scientific developments mainly regarding the toxicological parameters.

b. Methodology

Quality criteria for recycled gypsum were evaluated in practice during the GtoG Pilot phase. The work methodology was as follows:

1. Recyclers:
   - Processed[7] the plasterboard waste received from the producers (business as usual)-Trial 1
   - Processed plasterboard waste from production, construction and demolition waste, including the plasterboard waste stemming from the demolishers partners to the project-Trial 2.
2. Producers:
   - Standard production as implemented by each manufacturer – including different raw material streams and a standard percentage of production recycled gypsum – Trial 1
   - Maximized the percentage of C&D waste (post-consumer recycled gypsum) from various jobsites, keeping the same percentage of production recycled gypsum as in the first round (*Note: the aim was to maximize C&W waste – not production waste*).
3. Producers, recyclers and the laboratory Loemco:
   - Analysed the technical and toxicological parameters for the recycled gypsum. The partners decided to use the technical and toxicological criteria as developed by BV Gips as a benchmark, as well as the analysis methods defined by BV Gips.
4. Laboratory Loemco:
   - Carried out the testing.
   - As Loemco was not equipped to carry out the radioactivity tests according to the Gamma-ray Spectrometry, Saint-Gobain Gyproc Belgium offered to cover the costs of the radioactivity tests with SCK-CEN Laboratory for Gamma-ray Spectrometry in Belgium. Similarly, Loemco was not equipped to carry out the Hg-test with atomic fluorescence spectrometry. Therefore, these have been carried out by SGS, Institut Frenesius in Germany. Costs were borne by Eurogypsum. Also, TOC tests in accordance to DIN EN 13137 were

[7] production of recycled gypsum from waste plasterboard, incorporating the removal of contamination and the paper lining

performed by Intemac, Instituto tecnico de materiales y construccciones in Spain. Costs were borne by Eurogypsum.

5. Producers, recyclers and laboratory Loemco:
   - Discussed the test results.
   - Agreed on final guidelines to be further improved after the project

c. Re-incorporation trials and test of the recycled gypsum powder

One of the aims of the GtoG project is to re-incorporate up to 30% of the recycled gypsum in the plasterboard (please see B3 report for more details on the re-incorporation technical feasibility). The tonnages received via the demolishers were not sufficient to reach the 30% so that waste stemming from other construction and demolition sites were also included in the pilot projects.

In a B3 meeting of the producers, the latter decided to perform two trial rounds:

- 1st round: Standard production as implemented by each manufacturer – it will include all the different raw material streams and the standard percentage of production recycled gypsum.

- 2nd round: Maximize percentage of C&D waste (post-consumer recycled gypsum) from various jobsites and keep the same percentage of production recycled gypsum as in first round (*Note: aim is to maximize C&W waste – not production waste*). It was decided to use as many as necessary job sites to collect the postconsumer recycled gypsum. It was agreed that everybody receives 100 tons of post-consumer recycled gypsum.

In practice, the following was achieved:

Manufacturer	**Gypsum waste source**		**Incorporation**
	Trial 1	**Trial 2**	**Rate (second trial)**
Knauf	Production waste	Production and Demolition waste from KSE -36.64 tons plasterboard waste	17%
Placoplatre	Production, Construction and Demolition waste	Demolition waste from PIN-140.32 tons plasterboard waste	25 - 30%
Saint Gobain Belgium	Production waste	Production and Demolition waste From Recass (demo waste 2/3)-240 tons plasterboard waste	30%

Siniat UK	Production, Construction and Demolition waste	Demolition waste from Cantillon-20 tons plasterboard waste	23%
Siniat France	Production, Construction and Demolition waste	Production, Construction and Demolition waste-67.52 tons plasterboard waste	22%

Table 16. Re-incorporation trials and test of the recycled gypsum powder

d. Testing the recycled gypsum

1. Introduction

Each producer sent to Loemco:

- Samples of conventional gypsum: natural gypsum and/or FGD Gypsum
- Samples of recycled gypsum for the first re-incorporation trials (business as usual),
  - Production waste only,
  - Production, construction and demolition waste
- Samples of recycled gypsum second re-incorporation trials (optimisation of the percentage up to 30%)
  - Production, construction and demolition waste stemming from the job site,
  - Production and demolition waste stemming from the job site.

2. Number of samples received and samples tested

Material		Samples received		Samples tested	
		1st trial	2nd trial	1st trial	2nd trial
Recycled gypsum	RG	5	10	3	10
Plasterboard	PB	6	7	6	7
Conventional gypsum	GY-M	3	2	3	2
	GY-F	1	1	1	1
	GY-R	4	0	3	0
Waste paper	WP	5	6	5	0
Stucco		2	1	2	0
Total		26	27	23	20

Table 17. Summary of gypsum samples received and tested

Not all the samples were tested for several reasons:

For the 1st trial, 2 of the 5 samples received as recycled gypsum from C&D waste finally were not processed material by a recycler. The material of both seems to come from raw demolition material.

One of the samples received as internal production gypsum waste (GY-R) was finally other type of recycled material with high content of impurities like fibres and paper. The sample was initially prepared and tested in the laboratory but final tests according the BV Gips testing protocol were not performed since the material was not pure enough.
During the 1st trial it was decided not to test waste paper samples for the 2nd trial but in spite of it 5 more samples were received.

Stucco samples were not included in the testing protocol. Even though LOEMCO tested the 2 samples of this material received during the 1st trial in order to provide more data. For the 2nd trial it was decided to fix the tests to the protocol and the stucco sample received afterwards was not tested.

Explanation of symbols

GY-F	FGD Gypsum
GY-M	Mined gypsum
GY-R	Production waste
RG	Recycled gypsum (production, construction and demolition waste)

Table 18. Explanation of symbols included in table 23

3. Samples received first trials

The samples below originate from production waste

Figure 5-6. Samples received for first trials

The samples below originate from construction and demolition waste

Figure 7-8. Samples received for first trials

4. Samples received second trials

The below samples originate from construction and demolition waste

Figure 9-12. Samples received for second trials

Figure 13-14. Samples received for second trials

GYPSUM TO GYPSUM

e. Laboratory Analysis Results - 10 April 2015

Technical Parameters

Guideline for the establishment of Quality citeria for recycled Gypsum at European level -anonimised ALL

Technical parameters

10 April 2015

Parameter	Test Method	Powder spec	FIRST TRIAL								SECOND TRIAL											
			Conventional gypsum				Recycled gypsum (internal and C&D waste)				Conventional gypsum			Recycled gypsum (internal and C&D waste)								
			GY-F-01	GY-F-02	GY-M-01	GY-M-02	GY-R-01	RG-01	RG-02	RG-03	GY-F-03	GY-M-03	GY-M-04	RG-04	RG-05	RG-06	RG-07	RG-08	RG-09	RG-10	RG-11	RG-12	RG-13
Particle size	Granulometry	0 - 15 mm																					
Free moisture	VGB serial number 1	< 10%	0,05	6,64	4,89	0,08	1,00	0,51	2,50	9,94	6,85	4,52	0,12	1,92	0,27	9,47	9,40	10,46	11,74	17,14	4,14	4,50	7,84
Purity (Calcium Sulphate CaSO4 2H2O)	VGB serial number 2.3	> 80%	96,41	93,89	89,59	89,01	89,85	86,95	87,70	88,78	93,40	90,67	91,42	79,83	82,97	90,22	90,64	90,20	88,72	89,78	83,06	89,26	88,25
TOC	Gigt 3.1.3.2 DepV DIN EN 13137	< 1.5% w/w	0,01	0,16	0,04	0,03	0,83	3,13	0,75	0,44	0,22	0,03	0,04	0,63	0,82	0,79	0,75	0,83	0,84	0,84	0,78	0,30	0,19
Magnesium salts, walter sol.	VGB serial number 8.1.2	< 0.1% w/w	0,006	0,012	0,009	0,004	0,012	0,010	0,029	0,012	0,012	0,008	0,005	0,038	0,013	0,013	0,013	0,012	0,012	0,033	0,019	0,009	0,008
Sodium salts, walter sol.	VGB serial number 8.2.2	< 0.06% w/w	0,004	0,007	0,004	0,002	0,019	0,066	0,019	0,023	0,008	0,004	0,003	0,026	0,023	0,019	0,019	0,019	0,018	0,017	0,028	0,021	0,019
Potassium salts	VGB serial number 8.3.2	< 0.05% w/w	0,001	0,003	0,003	0,001	0,006	0,034	0,012	0,011	0,003	0,003	0,004	0,021	0,024	0,007	0,007	0,007	0,006	0,007	0,020	0,036	0,007
Sol. Chloride	VGB serial number 8,8,3	< 0.02% w/w	0,002	0,005	0,006	0,001	0,011	0,124	0,013	0,008	0,004	0,006	0,003	0,009	0,009	0,009	0,012	0,010	0,012	0,014	0,019	0,007	0,009
Ph	VGB serial number 4		6,50	7,03	8,10	7,42	8,51	8,35	8,22	7,87	7,28	8,05	7,45	8,91	8,82	7,78	7,62	7,56	7,53	8,42	8,43	8,34	7,80
Fluoride		< 0.02% w/w																					
^{40}K	Radioactivity Lab specific method (Bq/kg)										10	13	24	71	47	9	< 10	16	< 18	13	67	< 31	< 31
^{137}Cs											< 0,6	< 1,4	< 0,9	< 2,1	< 4,0	< 0,9	< 0,5	< 1,2	< 1,1	< 0,7	< 1,3	< 1,8	< 1,8
$^{226}Ra*$											2,8	5,9	12,5	20,1	19,8	8,4	6,7	7,1	6,2	8,1	9,7	3,5	6,2
$^{232}Th*$											< 2,1	< 5	< 3,4	< 9	< 17	2,1	< 2,4	< 5	< 5	1,6	< 6	< 8	< 7

Table 19. Guidelines for the establishment of quality criteria for recycled gypsum at European level

GYPSUM TO GYPSUM

Toxicological Parameters-see point F conclusions for further analysis

Guideline for the establishment of Quality citeria for recycled Gypsum at European level-LOEMCO TABLE																										
Chemical parameters																										
Values can be adjusted to new human-toxicological assessments and limits																										
10 April 2015																										
					FIRST TRIAL								**SECOND TRIAL**													
Quality parameters	**Element**	**Test method**	**Target value-Bvgips (mg/kg)**	**Quality Protocol - UK**	Conventional gypsum				Recycled gypsum (production and C&D waste)				Conventional Gypsum			Recycled gypsum (production and C&D waste)										
Trace element contents [mg/kg]		DIN EN ISO 11885 Determination of selected elements ICP-OES (acc to DepV)			GY-F-01	GY-F-02	GY-M-01	GY-M-02	GY-R-01	RG-01	RG-02	RG-03	GY-F-03	GY-M-03	GY-M-04	RG-04	RG-05	RG-06	RG-07	RG-08	RG-09	RG-10	RG-11	RG-12	RG-13	
	As		< 4	5,23	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21	<0,21
	Be		< 0,7	-	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
	Pb		< 22	31,9	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	187,76	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18	<0,18
	Cd		< 0,5	0,3	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
	Cr		< 25	17,9	<0,01	1,42	<0,01	0,85	1,39	<0,02	5,97	1,37	<0,01	<0,01	0,78	4,85	3,47	2,06	1,10	2,03	1,79	2,34	5,94	1,22	<0,02	
	Co		<4	-	<0,01	<0,01	<0,01	<0,01	<0,02	<0,02	<0,01	<0,02	<0,01	<0,02	<0,01	<0,02	2,61	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	
	Cu		< 14	32,8	<0,01	<0,01	<0,01	<0,01	<0,01	<0,02	<0,02	<0,01	<0,01	<0,01	<0,01	4,59	<0,01	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	4,13	<0,02	
	Mn		< 200	2,412	16,10	53,40	18,80	43,80	25,23	52,83	33,90	14,82	52,80	17,40	62,20	56,10	50,60	26,20	21,10	25,40	24,00	26,08	52,80	10,24	20,40	
	Mo		-	7,68	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
	Ni		< 13	7,31	<0,01	<0,01	<0,01	<0,01	5,02	17,12	16,63	8,60	<0,01	<0,01	<0,01	23,90	26,00	10,20	<0,05	9,87	6,92	10,05	28,08	13,14	7,42	
	P		-	87	45,50	24,60	27,60	42,00	112,00	58,00	66,90	52,30	29,30	26,40	69,50	158,00	142,00	131,00	103,00	110,00	105,00	96,20	72,20	58,20	31,00	
	Se		< 16	7,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	<0,37	
	Te		< 0,3	-	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	
	Tl		< 0,4	-	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	
	V		< 26	-	4,11	2,74	2,96	3,11	4,37	5,99	7,36	6,07	1,03	4,03	5,44	4,58	4,61	4,50	3,54	3,99	4,32	5,09	7,42	3,70	5,29	
	Zn		< 50	40,3	4,30	15,30	4,19	4,31	15,50	6,39	29,54	39,52	16,90	3,94	5,32	52,90	31,29	18,41	18,31	13,96	17,24	16,67	43,11	16,02	13,68	
	Hg		< 1,3	<2	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	<0,13	
	PAK	Gas-phase chromatograph process with confirmation by mass spectrmetry (GC-MS (acc to DEpV)	< 0,2	-																						
	(EPA)																									
	S			209,2																						

Table 20. Guidelines for the establishment of quality criteria for recycled gypsum at European level

f. Discussion of the test results

Overall, the proposed specification limits for recycled gypsum seem to be appropriate since only a few reference values are exceeded for some recycled gypsum samples.

For example, sample RG-01 exceeds the proposed limits for TOC, water soluble sodium salts and soluble chloride. These higher values in the RG-01 sample could most probably be explained by the fact that this is internally recycled material from the production process, with a relatively high paper content. The texture and density of the sample, compared to other similar samples, point in this direction. The content is thus not linked to the external recycled gypsum used to produce the plasterboards of the second trial. In the specific case of the trial one, Plcao wish to highlight that there was a low fraction of plaster board waste in the recycle material (mostly gypsum blocs), and this is definitely not representative of the standard external scrap received in the plant. One can expect higher content of residual paper and larger impact on the process.

Free moisture of samples RG-06, RG-07, RG-08, RG-09 and RG-10 are slightly above or near the 10% proposed limit. Some producers prefer not to use recycled gypsum with higher water content, because this influences the energy demand (and therefore the cost) of the drying step in the production process. PLACO wishes to highlight that high humidity creates also some handling issue for transporting, conveying, discharging from silo and dosing in the calciner. Loss of yield and maintenance related to these issues are significant and negatively impact the overall benefit of using the recycle material. Some calcination equipment are more tolerant to high free moisture content, then the possibility to lower the specification at <5% should allowed depending on plant configuration.

On the other hand, the water content of gypsum based waste is largely depending on the weather conditions during demolition activities and transport, and recyclers usually have the opportunity to regulate moisture content by mixing up wetter and dryer gypsum based waste from different sources, depending on the required specifications of the manufacturer.

Regarding the toxicological parameters almost all results are below the proposed reference values. Only the Ni content is higher for some samples and for sample RG-04, the Pb-content is exceptionally high. The samples were re-tested and the new values confirmed the initial ones.

A radiation analysis has been performed to the samples of 2nd trial (conventional and recycled material). Radioactivity indices are all far below the limit of 0,5 indicated in the European Commission document 'Radiation Protection 112'.

g. Conclusions

The partners agreed that the BV Gips toxicological values will be taken as the reference table. The UK Pas cover open-loop and is thus less relevant for close-loop recycling.

The technical requirements as specified in the table are accepted by the partners with the addition of a remark table to leave open negotiations between the recycler and the manufacturer at plant level.

The test results on Nickel will be redone to see why we have the result discrepancy between the test results and the adopted value by BV Gips. The radioactivity results will be declined in one value. The test on Hg will be carried out via AAS.

h. Eurogypsum recycling Working Group 29 April 2015

The Eurogypsum recycling WG suggested to redo the test on mercury as the latter were not carried out in accordance with the specified analytical methods. The Laboratory SGS in Germany realized the test and costs were borne by Eurogypsum.

Next to the value table of the technical parameters, a remark table should be included as follows:

Parameter	Test Method	GtoG Powder spec	Eurogypsum Comments
Particle size	Granulometry	0 - 15 mm	Particle size ok, depending on plant specifics In some plants less than 20% below 0.1mm
Free moisture	VGB serial number 1	< 10%	≤ 5% (up to < 10%) [2)]
Purity (Calcium Sulphate CaSO4 2H2O)	VGB serial number 2.3	> 80%	> 85% (at least 80%) [3)]
TOC	Gigt 3.1.3.2 DepV DIN EN 13137	< 1.5% w/w	≤ 1,0% (≤ 1,5%) We must be sure that the TOC only measures the paper content
Magnesium salts, walter sol.	VGB serial number 8.1.2	< 0.1% w/w	≤ 0,02% (≤ 0,1%) [4)]
Sodium salts, walter sol.	VGB serial number 8.2.2	< 0.06% w/w	≤ 0,02% (≤ 0,04%) [4)]
Potassium salts	VGB serial number 8.3.2	< 0.05% w/w	< 0,02% (< 0,06%); water sol.

Sol. Chloride	VGB serial number 8,8,3	< 0.02% w/w	< 0,01% (< 0,02%) [5)]
Ph	VGB serial number 4		pH, 5-9 [4)]
Fluoride		< 0.02% w/w	
Radioactivity	Radioactivity Lab specific method (Bq/kg)		

Table 21. Guidelines for the establishment of quality criteria for recycled gypsum at European level – Comments from Eurogypsum recycling Working Group (29 April 2015)

1) Values in (): Plant specific deviations after special agreement permitted.
2) The 10 % comes from wet flue gas desulphurisation and is inherent in the system. In contrast it is possible without any technical or logistical problems to meet at least the 5%. Increased moisture contents incur costs for the gypsum industry.
3) Low purity compared with FGD gypsum (≥ 95%) considers the lower purity of natural gypsum.
4) According to EUROGYPSUM/ECOBA/VGB Quality Requirements on FGD gypsum.
5) Depending on water quality in plasterboard production.
The Eurogypsum recycling WG considers that the frequency of testing should be left at the plant level decision.

It was decided at the B2.2 meeting held the 24th June 2015 that Eurogypsum's comments will be added as a guideline to the specification that the B2.2 group provides.

i. Readjusted Toxicological Table as of 29 May 2015

- The value of mercury with the test in accordance with the analysis method have been added
- There is now one value for radioactivity calculated by the Belgian Laboratory
- The test on nickel has been redone but results are the same.

Samples analysed again are marked in blue in the table below.

GYPSUM TO GYPSUM

Element [mg/kg]	Test method	Proposed limits		1st TRIAL								2nd TRIAL										
		BV Gips DE	Quality Protocol UK	Conventional gypsum				Recycled gypsum (production and C&D waste)				Conventional Gypsum			Recycled gypsum (production and C&D waste)							
				GY-F-01	GY-F-02	GY-M-01	GY-M-02	GY-R-01	RG-01	RG-02	RG-03	GY-F-03	GY-M-03	GY-M-04	RG-04	RG-05	RG-06	RG-07	RG-08	RG-09	RG-10	RG-11	RG-12	RG-13
As	DIN EN ISO 11885 Determination of selected elements ICP-OES (acc to DepV)	< 4	5,23	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21	< 0,21
Be		< 0,7	-	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Pb		< 22	31,9	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	130,40	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18	< 0,18
Cd		< 0,5	0,3	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Cr		< 25	17,9	< 0,01	1,42	< 0,01	0,85	1,39	< 0,02	5,97	1,37	< 0,01	< 0,01	0,78	4,85	3,47	2,06	1,10	2,03	1,79	2,34	5,94	1,22	< 0,02
Co		< 4	-	< 0,01	< 0,01	< 0,01	< 0,01	< 0,02	< 0,02	< 0,01	< 0,02	< 0,01	< 0,02	< 0,01	< 0,02	2,61	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Cu		< 14	32,8	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,02	< 0,02	< 0,01	< 0,01	< 0,01	< 0,01	4,59	< 0,01	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	4,13	< 0,02
Mn		< 200	2,412	16,10	53,40	18,80	43,80	25,23	52,83	33,90	14,82	52,80	17,40	62,20	56,10	50,60	26,20	21,10	25,40	24,00	26,08	52,80	10,24	20,40
Ni		< 13	7,31	< 0,01	< 0,01	< 0,01	< 0,01	7,52	40,50	12,30	7,64	< 0,01	< 0,01	< 0,01	30,70	31,40	7,91	8,51	10,40	8,60	2,88	31,60	11,30	11,10
Se		< 16	7,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37	< 0,37
Te		< 0,3	-	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05
Tl		< 0,4	-	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12	< 0,12
V		< 26	-	4,11	2,74	2,96	3,11	4,37	5,99	7,36	6,07	1,03	4,03	5,44	4,58	4,61	4,50	3,54	3,99	4,32	5,09	7,42	3,70	5,29
Zn		< 50	40,3	4,30	15,30	4,19	4,31	15,50	6,39	29,54	39,52	16,90	3,94	5,32	52,90	31,29	18,41	18,31	13,96	17,24	16,67	43,11	16,02	13,68
Hg	DINEN 1483 AAS-DINEN 12338-Merury process after enrichment by amalgation. DIN ISO 1785 atomic fluorescnce spectrometry (acc to MatelVO)	< 1,3	< 2	0,20	0,43	<0,05	<0,05	0,30	0,08	0,23	<0,05	0,39	<0,05	<0,05	0,21	0,21	0,28	0,29	0,29	0,31	0,29	0,21	<0,05	<0,05
Asbestos content	X-ray diffraction	Free of asbestos (YES / NO)		YES	YES	YES	YES	YES	YES	YES	----	YES	----	----	YES	YES	YES	YES	YES	YES	YES	----	----	----
Radioactivity Index	RP 112 Document (EC)	< 0,5		----	----	----	----	----	----	----	----	< 0,02	< 0,05	< 0,07	< 0,14	< 0,17	< 0,04	< 0,04	< 0,05	< 0,05	< 0,04	< 0,08	< 0,06	< 0,07

Table 22. Readjusted toxicological table (29 May 2015)

j. Other developments and modifications

Refinement of the Granulometry results

Loemco provided more specified results (e.g. x% < 3 mm) to increase the informative value of the Standard Powder Specification. It was agreed to use the measure of 4mm.

Parameter	Test method	Powder spec	1st TRIAL								2nd TRIAL											
			Conventional gypsum				Recycled gypsum (internal and C&D waste)				Conventional gypsum			Recycled gypsum (internal and C&D waste)								
			GY-F-01	GY-F-02	GY-M-01	GY-M-02	GY-R-01	RG-01	RG-02	RG-03	GY-F-03	GY-M-03	GY-M-04	RG-04	RG-05	RG-06	RG-07	RG-08	RG-09	RG-10	RG-11	RG-12	RG-13
Max. size measured (mm)	UNE-EN 933-1	----	<0,1	0,1	20	----	4	2	4	14	0,1	20	----	4	8	8	4	14	8	14	8	8	8
Particles < 4 mm (%)	UNE-EN 933-1	----	100	100	67	----	99	100	96	91	100	61	----	89	92	95	96	92	97	92	83	95	90

Table 23. LOEMCO's explanation of granulometry results

Chloride

Loemco specified the link between the presence of paper in recycled gypsum and the level of chloride in the powder. Loemco checked if the sample that shows the remarkable high value for TOC of 3,13, originates from a manufacturer that does not remove paper in the recycling process.

The response of Loemco is as follows: The manufacturer uses internal material with variable content of chloride and paper, which explains the higher content of both in the sample received.

The content is not linked to the recycled gypsum waste used to produce the plasterboards of the second trial.

Asbestos

Element [mg/kg]	Test method	Proposed limits		1st TRIAL								2nd TRIAL											
		BV Gips DE	Quality Protocol UK	Conventional gypsum				Recycled gypsum (production and C&D waste)				Conventional Gypsum			Recycled gypsum (production and C&D waste)								
				GY-F-01	GY-F-02	GY-M-01	GY-M-02	GY-R-01	RG-01	RG-02	RG-03	GY-F-03	GY-M-03	GY-M-04	RG-04	RG-05	RG-06	RG-07	RG-08	RG-09	RG-10	RG-11	RG-12	RG-13
Asbestos content	X-ray diffraction	Free of asbestos (YES / NO)		YES	YES	YES	YES	YES	YES	YES	----	YES	----	----	YES	YES	YES	YES	YES	YES	YES	----	----	----

Table 24. Asbestos results

Asbestos content were analyzed to the powder samples with an X-Ray diffractometer and the Rietveld method to quantify the content, taking into account it is a semi-quantitative method. Through the interpretation of the X-Ray diffract grams provided by the diffractometer software, none of the 6 types of asbestos minerals were found in the samples tested.

After discussion during the meeting, the partners recommends to use the atomic absorbance method and if asbestos is found, then to use PLM to confirm the type of asbestos. This method will be recorded in the final guidelines setting the quality criteria (technical and toxicological) for the recycled gypsum.

Toxicological parameters-Nickel issue

Nickel has higher values than foreseen in the toxicological parameters of BV Gips and by the UK and derived from the reference values for heavy metals concentration in gypsum of the Beckert study[8]. We do not know the causes of the discrepancies.

i. The discussion

We observed a discrepancy on the nickel test results but not on the other heavy metals elements. Nickel is a carcinogenic parameter. The reason for the Ni-results is not clear, as is the real health risk related to the measured Ni-concentrations, which are for some samples above 13 mg/kg. .

A concentration of 13 mg/kg in the plasterboard core would, according to Beckert (1990), correspond to a concentration of 0,078 µg/m³ air in a production and processing environment, whereas, also according to the Beckert-study, maximum allowable concentrations for Nickel, from a health risk perspective, would be 500 µg/m³ air. A worst case scenario, for the application environment, showed that the maximum intake for a worker during extreme dust formation due to sawing was 2,6 µg over a period of 10 years, always supposing the Nickel-concentration in the plasterboard is 13 mg/kg. For comparison: the maximum allowable intake for a worker in a production environment would be $1{,}13 \times 10^7$ µg in 10 years, and the Ni-intake in "clean-air" regions is estimated at 600 µg over the same period.

Although the values from the Beckert study are widely recognized as reference values for heavy metal concentrations in FGD and natural gypsum, these values do not represent the concentrations above which a human health risk occurs. Exceeding these toxicological quality criteria does not necessarily mean there is a clear and definite health risk. However, for the time being, the sole scientific analysis regarding gypsum toxicology we can rely upon is the Beckert study, and it is wise to keep the Beckert-value as a first guidance. A new survey is currently being carried out by the Gypsum Industry in relation to the toxicological parameters of FGD Gypsum but is not yet finalized.

The test results therefore show that the consortium should continue to work towards a definitive solution for all toxicological parameters which are for the time being reference values and not risk-based threshold values

[8] BECKERT J., 1990. Comparison of natural gypsum and FGD gypsum: studies for a comparative assessment of the health impact of natural gypsum and FGD gypsum from coal-fired power plants with a view to their use in the manufacture of building materials. *VGB technical scientific reports "Thermal power plants",* 707.

ii. The Solution

Since there were no reasonable explanation for the elevated Nickel-content, Saint-Gobain Belgium (SG Kallo) asked an independent laboratory to analyse (with the same methodology) the gypsum samples of SG Kallo that were sent to LOEMCO for the GtoG-project.

Ni (mg/kg)	SGS Analysis
Recy - 1st trial	1,80
Recy - 2nd trial	1,80
Recy - 2nd trial	1,80
Recy - 2nd trial	1,12
Recy - 2nd trial	1,90
Recy - 2nd trial	2,00
FGD - 1st trial	1,50
FGD - 2nd trial	1,70

Table 25. Nickel results

The LOEMCO results for Ni in SG Belgium samples varied between <0.01 and >10 mg/kg, and are not correlated to the SGS-values. The SG Belgium results suggest that the Ni-concentrations are most probably below the Beckert-value (13 mg/kg)

However, establishing meaningful toxicological threshold values for recycled gypsum remains however a working item for the future as well as the source of the discrepancies between the laboratory test results.

V. Agreed guidelines for the quality criteria of the recycled gypsum (technical and toxicological parameters)

Introduction

The quality criteria of the recycle gypsum covers:

- **Technical parameters**, i.e., particle size distribution, residual paper content, purity, physical contamination.

- **Toxicological parameters**, i.e., reference values for metal and metalloids: elements that are potentially harmful for human risk. The values for the toxicological parameters in the Quality Criteria Guidelines for the Recycled Gypsum should **not be considered as absolute limit values but as reference or warning levels** since they were derived from one study on natural and synthetic gypsum that was established by Beckert et al. in 1990. The main objective of this study was to look at the health impact of FGD gypsum, used in the gypsum industry, compared to natural gypsum. The study was based on a dataset containing 12 natural gypsum samples and 15 FGD gypsum samples. All samples were collected in German mines or German coal fired power plants.

  For the risk assessment, Beckert et al. took the maximum concentrations from this dataset. The study focused on human health risks related to dust formation. The Beckert study concluded that there was no respiratory risk related to these maximal heavy metal concentrations in the gypsum samples. So, we know that under normal circumstances of installation and use, the examined (maximum) concentrations in FGD and natural gypsum do not pose a health risk. However, those values shall be redefined for the recycled gypsum with the results of a toxicological survey being carried out by the Gypsum Industry on FGD gypsum due to be released early 2016.

The five manufacturers did not observe any chemical or toxicological issues when re-incorporating the recycled gypsum. On the other hand some issues with production equipment have been reported; e.g. the need to invest in broader conveyor belts to cope with the input of a higher volume of recycled powder than the plants are used to. As noticed above, fine grinding of the recycle powder, as a consequence of the paper separation process, Placoplatre thinks that this can create handling issues and potentially maintenance and machine stops in conveyors, silos, discharges and metering systems. This issue is even more dramatic at high free moisture levels which are frequently encountered with the scrap material. This wgy why limiting the fraction of the fine fraction or, alternatively controlling the apparent density of the powder, is an important criteria for the incorporation of high fraction of recycle in the plasterboard process.

Placoplatre reminds that the second trials have been performed with high quality recycle material, i.e. with a low content of paper liner (because of the low fraction of plaster board). This was clearly a positive factor enabling high addition rate without dramatic effect on the calcination and board forming process. But it is representative of the everyday external scrap quality and even exceeds to some extend the proposed specifications below. In particular the risk of disturbances of the calcination process and the need for recipe adjustment at the board forming area (such as adding more water, which is the biggest cost centre in the process) are

slightly underestimated. Establishing the overall economical balance of recycling addition should assess these aspect more accurately.

Technical parameters

Parameter	Powder spec	Test method
Particle size	0 - 15 mm	UNE-EN 933-1
Free moisture	< 10%	VGB serial number 1
Purity ($CaSO_4$ $2H_2O$)	> 80%	VGB serial number 2.3
TOC	<1.5%	Gigt 3.1.3.2 DepV DIN EN 13137
Magnesium salts, walter sol.	< 0.1%	VGB serial number 8.1.2
Sodium salts, walter sol.	< 0.06%	VGB serial number 8.2.2
Potassium salts, water sol.	< 0.05%	VGB serial number 8.3.2
Sol. Chloride	<0.02%	VGB serial number 8.8.3
pH	6-9	VGB serial number 4

Table 26. Agreed technical parameters

Toxicological parameters

Important note: the values of all the toxicological parameters are reference values (not limit values-minimum or maximum values).

Element [mg/kg]	Powder spec	Test method
As	< 4	DIN EN ISO 11885 Determination of selected elements ICP-OES (acc to DepV)
Be	< 0,7	
Pb	< 22	
Cd	< 0,5	
Cr	< 25	
Co	< 4	
Cu	< 14	
Mn	< 200	
Ni	< 13	
Se	< 16	
Te	< 0,3	
Tl	< 0,4	
V	< 26	
Zn	< 50	
Hg	< 1,3	DINEN 1483 AAS-DINEN 12338-Mercury process after enrichment by amalgamation. DIN ISO 1785 atomic fluorescence spectrometry (acc to MatelVO)
Radioactivity	< 0,5	RP 112 Document (EC)

Index		
Asbestos	none	atomic absorbance-method and PLM **

*** see guideline below*

Table 27. Agreed toxicological parameters

“Ni (Nickel):

For Nickel, the maximum concentration in the Beckert dataset was 13 mg/kg. The values from the Beckert-study are widely recognized as reference values for heavy metal concentrations in FGD and natural gypsum. However, these values do not represent the concentrations above which a human health risk occurs. These "risk-based threshold values" have not been defined. Further study in relation to the toxicological parameter of FGD Gypsum is currently being carried out by the Gypsum Industry. After the Life-project, the results of the study can be analyzed for the recycled gypsum. The quality criteria would then be revised in 2017.

Guidance on the quality criteria of the recycled gypsum

Purity

From a manufacturing point of view, it is preferable to work with a purity level as high as possible.

The purity of recycled powder is mainly influenced by the market where the boards were originally produced, i.e. the type of gypsum that has been used to produce these boards. For markets where FGD has been used many years, a purity of 85% or more can be reached and the target value may be increased accordingly.

Test frequency

The frequency of testing needs to be agreed between the recycler and the manufacturer. In general, toxicological parameters are recommended to be tested monthly or quarterly, depending on volume of recycled powder that is supplied.

Technical parameters are recommended to be tested either weekly or monthly. Some parameters may have to be tested daily, depending on location, e.g. moisture and chloride.

Asbestos testing method

It is recommended to use the atomic absorbance-method and if asbestos is found, then to use PLM to confirm the type of asbestos.

Sampling

Outcomes of testing can be uncertain as powder composition varies. It is important that samples are taken correctly; i.e that the samples are homogenized and prepared in the laboratory using a riffle splitter (VGB M-701). In the recycling environment one sample is not representative; the sample that is forwarded for testing should consist of min. 10 individual samples that have been homogenized into one that is sent to the laboratory.

Comments by the Eurogypsum Recycling Working Group

The Eurogypsum recycling Working Group is a committee created by Eurogypsum formed by several members taken from the following bodies:

- national gypsum associations experts;
- company experts representing the national association;
- direct experts from companies as long as the company is a member of the national association.

The group has the following objectives:

- Regulatory monitoring of the subject dealt with by the WG;
- Analysis of legislation impacting the subjects dealt with by the WG;
- Advocacy for the subject dealt with by the WG;
- Drafting briefing note and position papers on the subjects dealt with by the WG;
- Attendance to commission meetings and other for a meeting:
- an internal report must be drafted by the expert attending after the meeting;
- Organisation of WG meetings (agenda, minutes, implementation of actions).

This group added the following comments to the technical parameters which were decided in the GtoG-project:

Parameter	Test Method	GtoG Powder spec	Recycling Group Comments
Particle size	Granulometry	0 - 15 mm	Particle size ok, depending on plant specifics
Free moisture	VGB serial number 1	< 10%	≤ 5% (up to < 10%) [2)]
Purity (Calcium Sulphate CaSO4 2H2O)	VGB serial number 2.3	> 80%	> 85% (at least 80%) 3)
TOC	Gigt 3.1.3.2 DepV DIN EN 13137	< 1.5% w/w	≤ 1,0% (≤ 1,5%)
Magnesium salts, walter sol.	VGB serial number 8.1.2	< 0.1% w/w	≤ 0,02% (≤ 0,1%) [4)]
Sodium salts, walter sol.	VGB serial number 8.2.2	< 0.06% w/w	≤ 0,02% (≤ 0,04%) [4)]
Potassium salts	VGB serial number 8.3.2	< 0.05% w/w	< 0,02% (< 0,06%); water sol.
Sol. Chloride	VGB serial number 8.8.3	< 0.02% w/w	< 0,01% (< 0,02%) 5)
Ph	VGB serial number 4		pH, 5-9 4)
Fluoride		< 0.02% w/w	
Radioactivity	Radioactivity Lab specific method (Bq/kg)		

Table 28. Eurogypsum recycling Working Group comments on parameters agreed

1) Values in ( ): Plant specific deviations after special agreement permitted.
2) The 10 % comes from wet flue gas desulphurisation and is inherent in the system. In contrast it is possible without any technical or logistical problems to meet at least the 5%. Increased moisture contents incur costs for the gypsum industry.
3) Low purity compared with FGD gypsum (≥ 95%) considers the lower purity of natural gypsum.
4) According to EUROGYPSUM/ECOBA/VGB Quality Requirements on FGD gypsum.
5) Depending on water quality in plasterboard production.

The Eurogypsum recycling WG considers that the frequency of testing should be left at the plant level decision.

Conclusions

The purpose of this document is to provide guidance on specifications to increase the usage of recycled gypsum. This attempt represents the first example of data collection and analysis on current practices for recycling and reincorporating recycled gypsum. By detailing and comparing the specifications of different stakeholders (not only recyclers and manufacturers, but also experts in this field), the GtoG guidelines specifications can be truly considered best practices in recycling gypsum waste, and they are at disposal of all the interested stakeholders for being further analysed and strengthened. By actually contributing to the general aim of the GtoG project, namely to improve the way in which gypsum wastes are treated, these guidelines fit perfectly to the GtoG project's main interest and way of working, which has always been to analyse the current situation and create examples that can guide all stakeholders to further improve it.

ANNEX I-Granulometry results

Explanation of symbols for granulometry results - 10 April 2015

GY-F	FGD Gypsum
GY-M	Mined gypsum
GY-R	Production waste
RG	Recycled gypsum (production-construction and demolition waste
Second trials	Except for one trials, all trials have been done using production and demolition waste

Table 29. Explanation of symbols for granulometry results - 10 April 2015

Granulometry

Test- GY-F-01

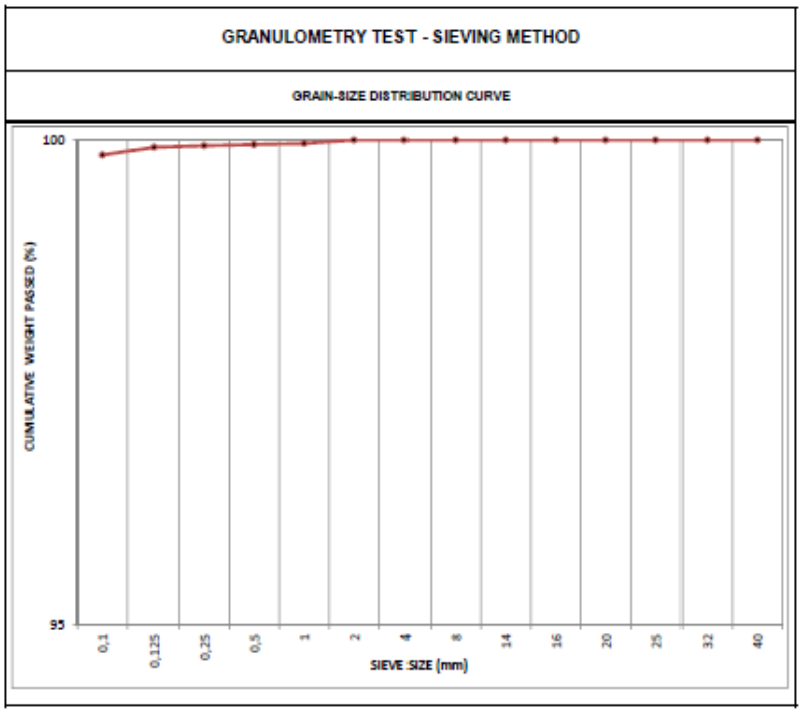

Figure 15. Explanation of granulometry results for GY-F-01

Test GY-F-02

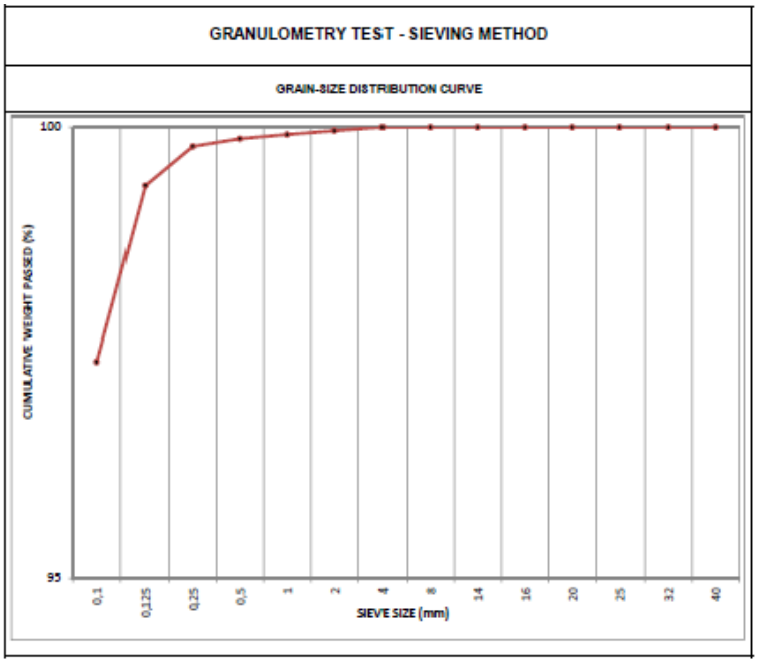

Figure 16. Explanation of granulometry results for GY-F-02

Test GY-F-03

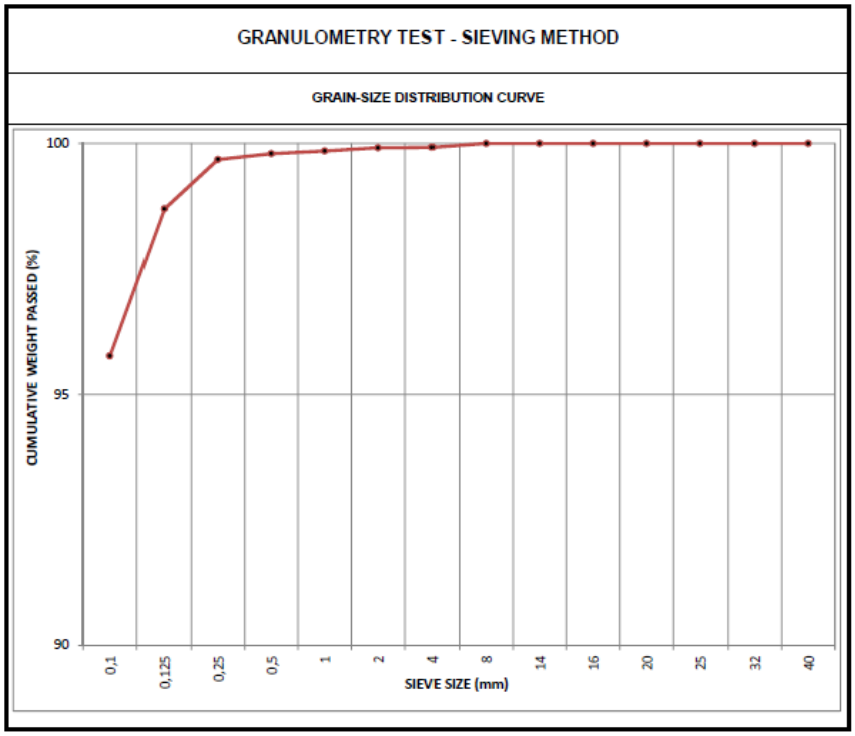

Figure 17. Explanation of granulometry results for GY-F-03

Test GY-M-01

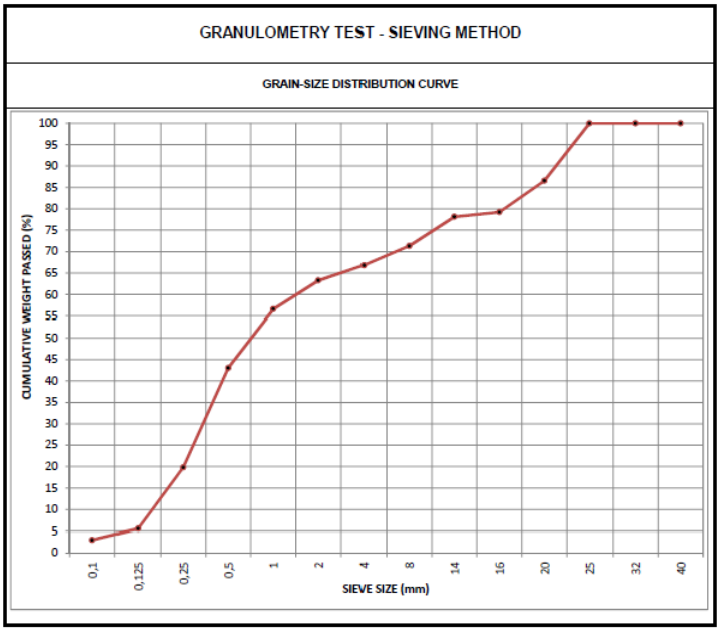

Figure 18. Explanation of granulometry results for GY-M-02

TEST GY-M-03

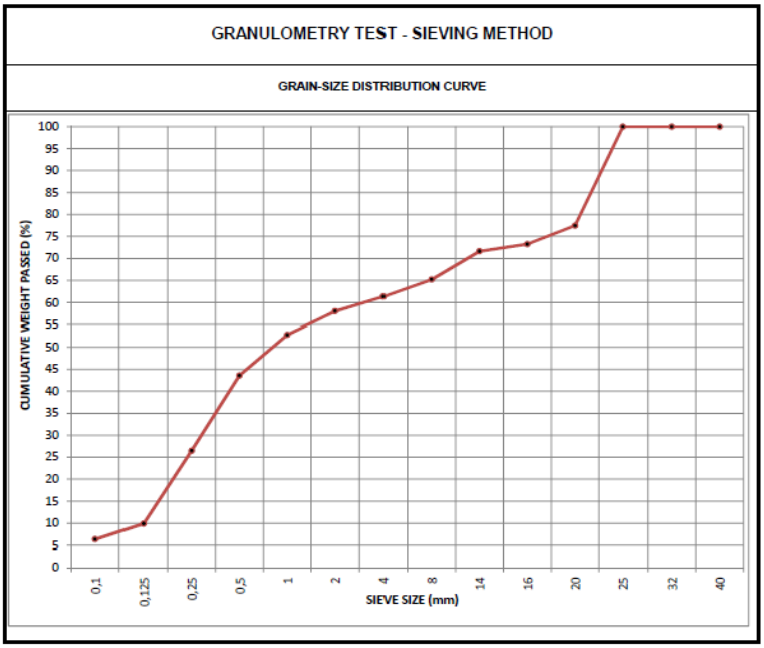

Figure 19. Explanation of granulometry results for GY-M-03

TEST GY-R-01

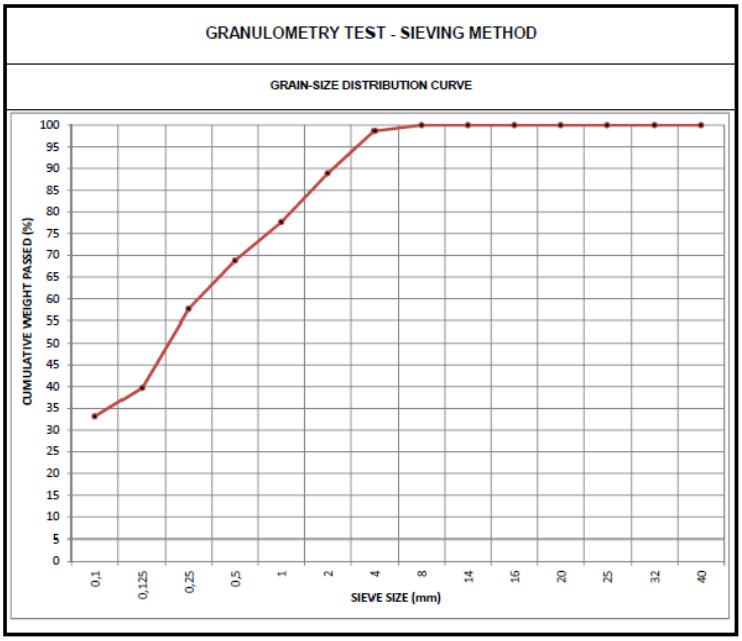

Figure 20. Explanation of granulometry results for GY-R-01

TEST RG-01

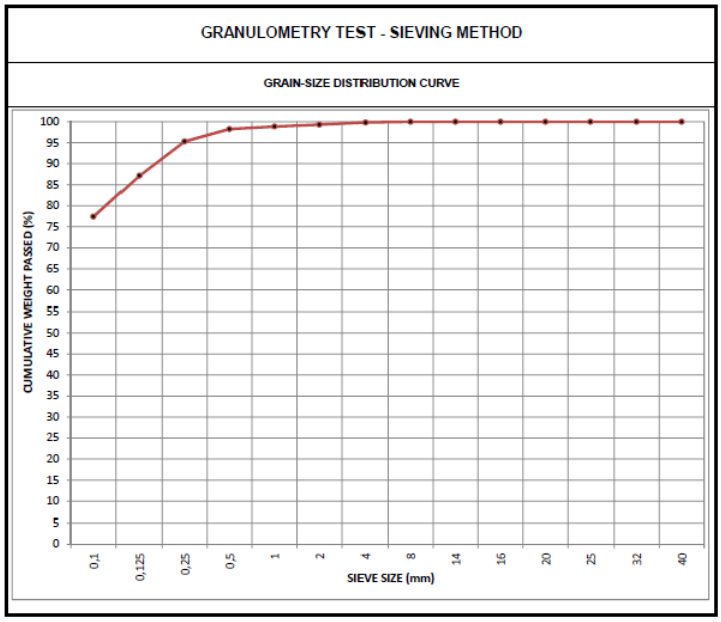

Figure 21. Explanation of granulometry results for RG-01

TEST RG-02

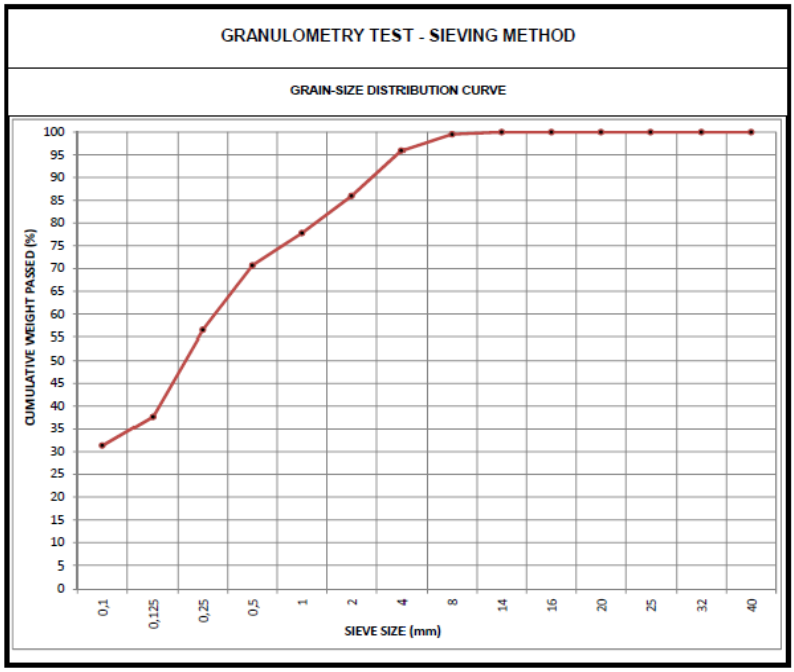

Figure 22. Explanation of granulometry results for RG-02

TEST RG-03

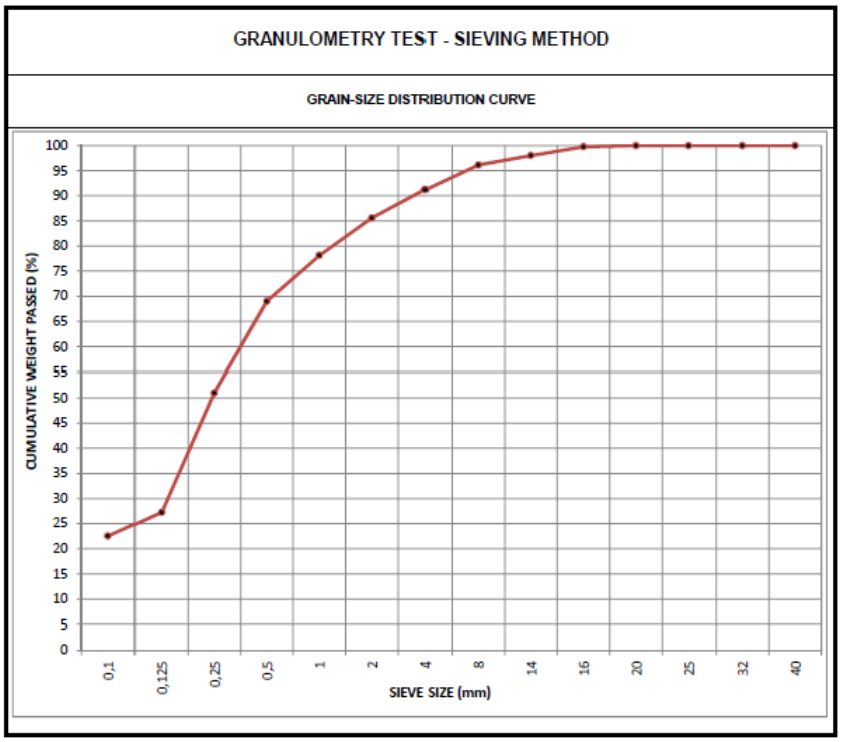

Figure 23. Explanation of granulometry results for RG-03

TEST RG-04

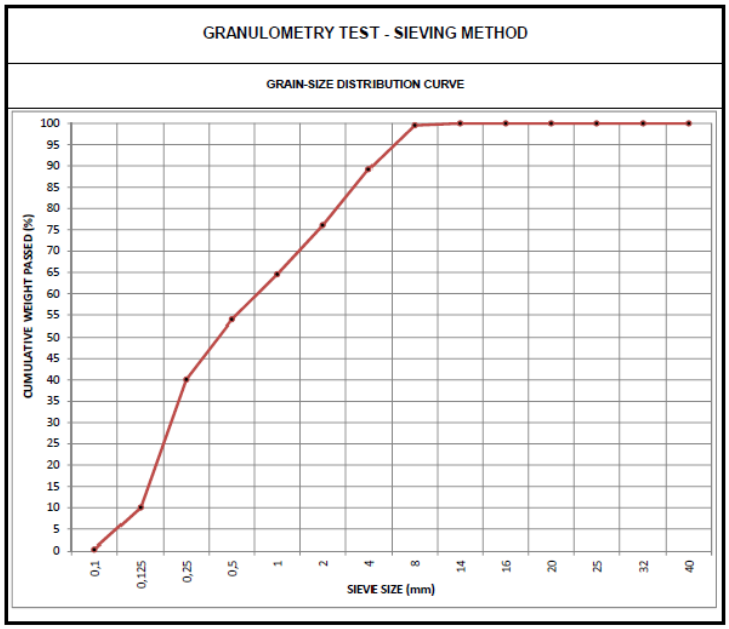

Figure 24. Explanation of granulometry results for RG-04

TEST RG-05

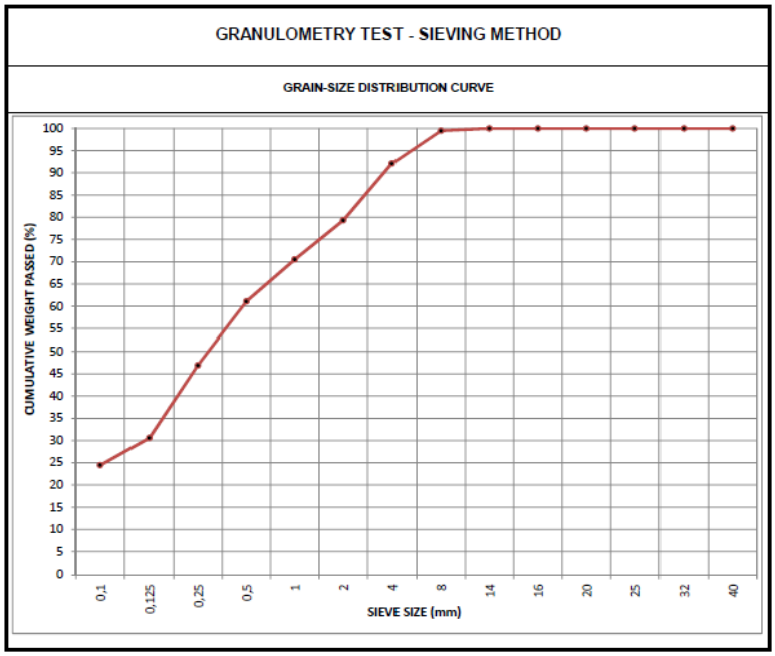

Figure 25. Explanation of granulometry results for RG-05

TEST RG-06

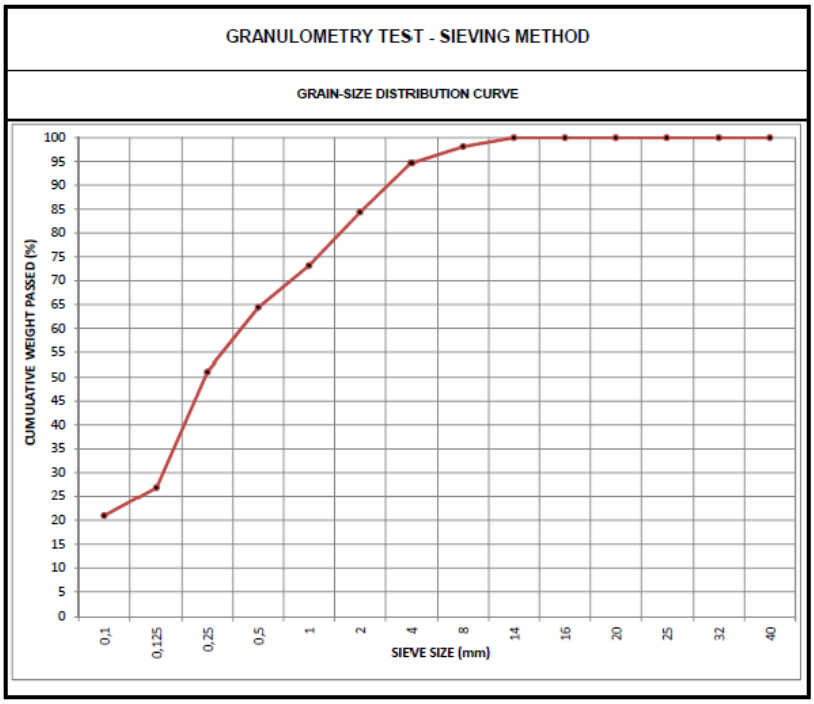

Figure 26. Explanation of granulometry results for RG-06

TEST RG-07

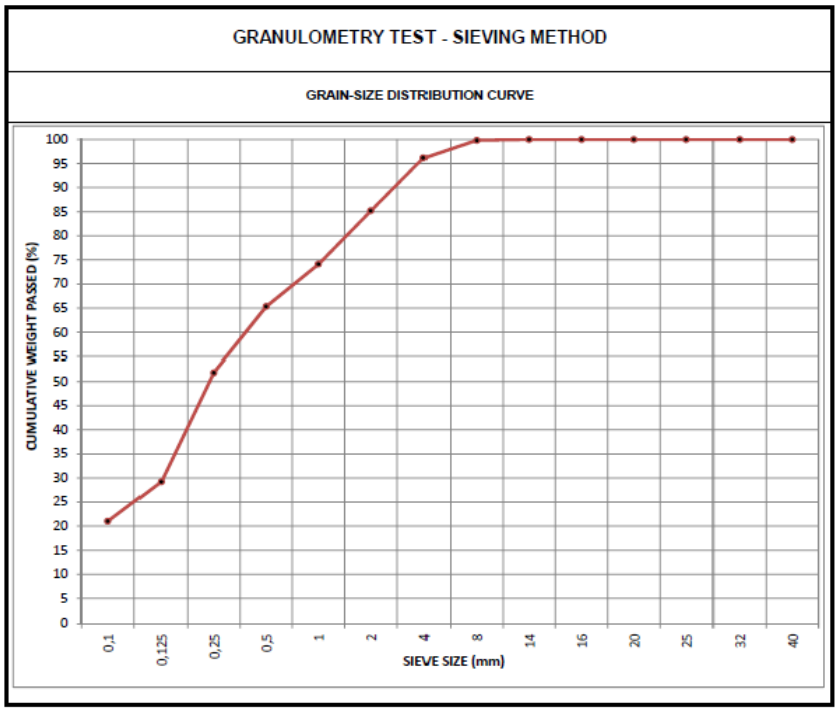

Figure 27. Explanation of granulometry results for RG-07

TEST RG-08

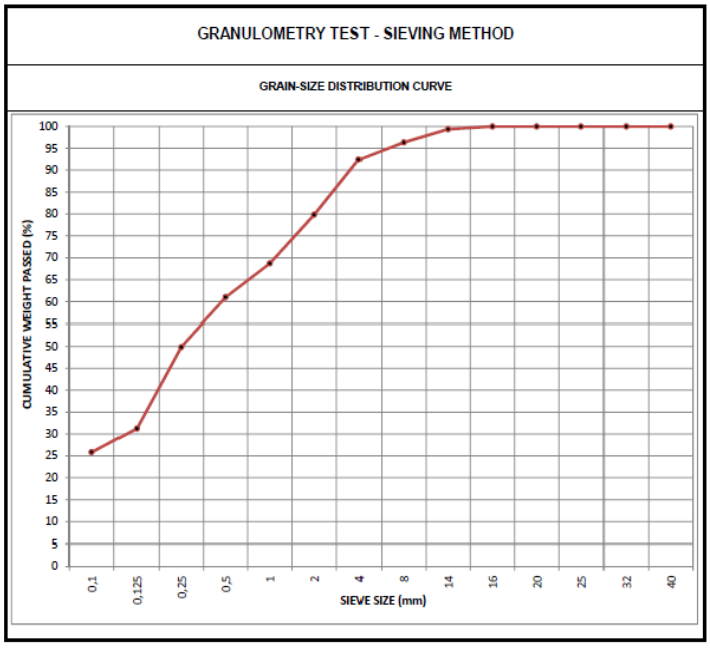

Figure 28. Explanation of granulometry results for RG-08

TEST RG-09

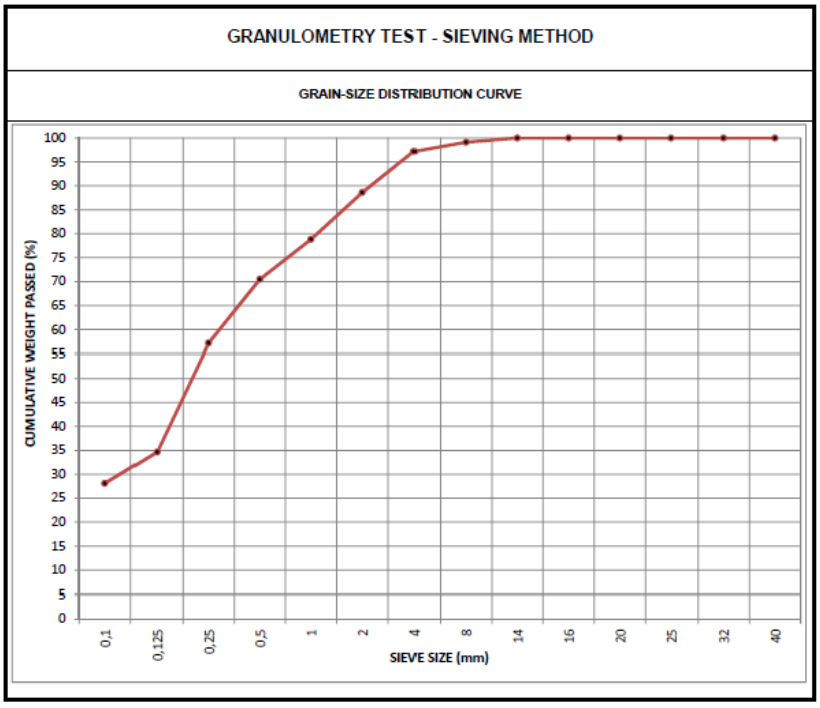

Figure 29. Explanation of granulometry results for RG-09

TEST RG 10

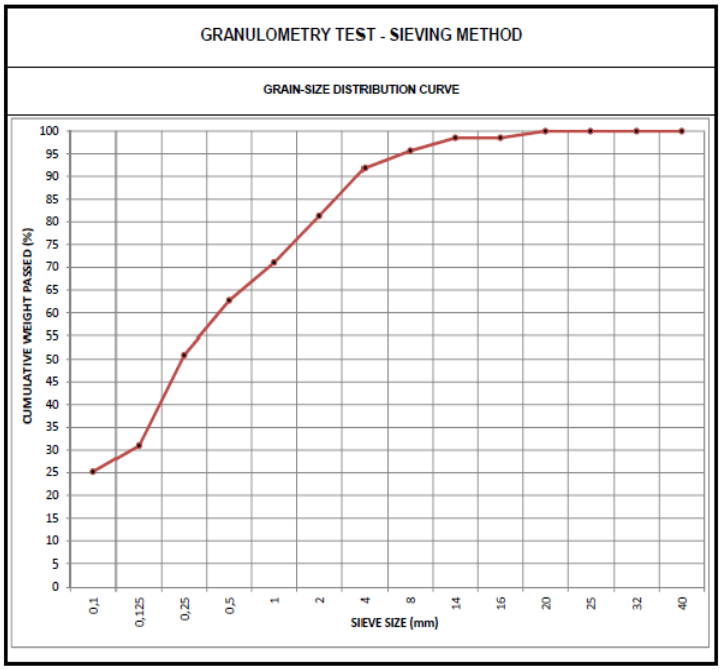

Figure 30. Explanation of granulometry results for RG-10

TEST RG-11

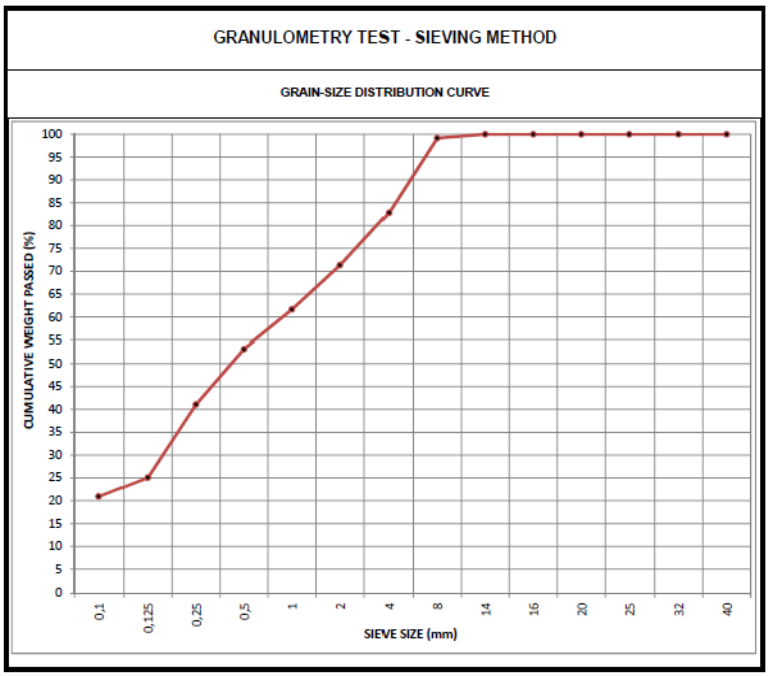

Figure 31. Explanation of granulometry results for RG-11

TEST RG-12

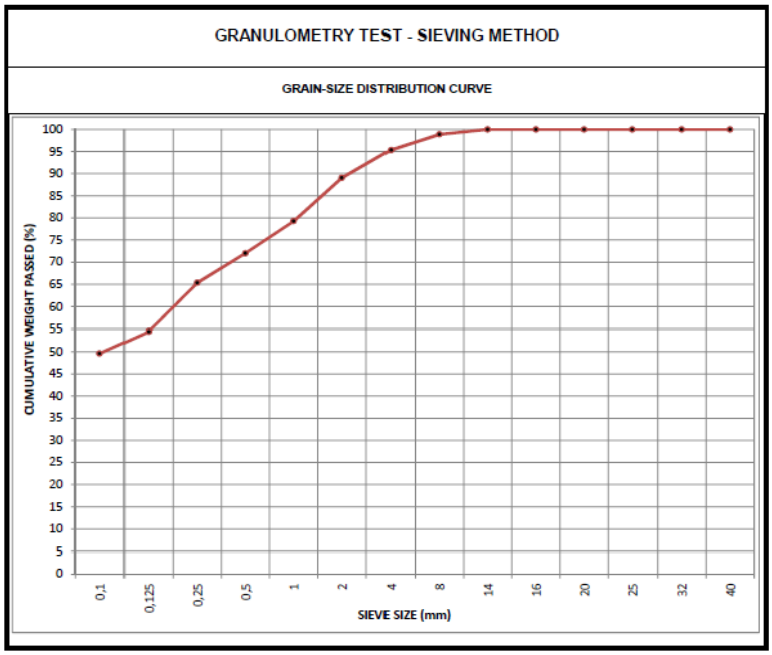

Figure 32. Explanation of granulometry results for RG-12

TEST RG-13

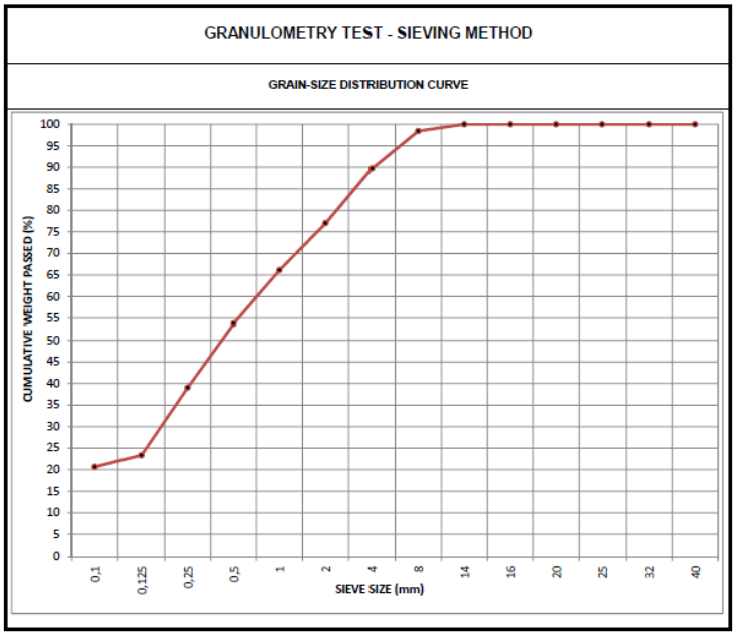

Figure 33. Explanation of granulometry results for RG-13