MINRESCUE

From Mining Waste to Valuable Resource:
New Concepts for a Circular Economy
(RFCS GA 899518)

Edition 2
Feb. 2022

MINRESCUE aims to address one of the major challenges of coal mining industry in Europe:

Developing innovative concepts for managing, recycling and upcycling waste geomaterials generated by coal mining activities across Europe.

CORE OBJECTIVES

Money saving and environmental footprint reduction

Upgrade CMWGs to a sustainable construction materials

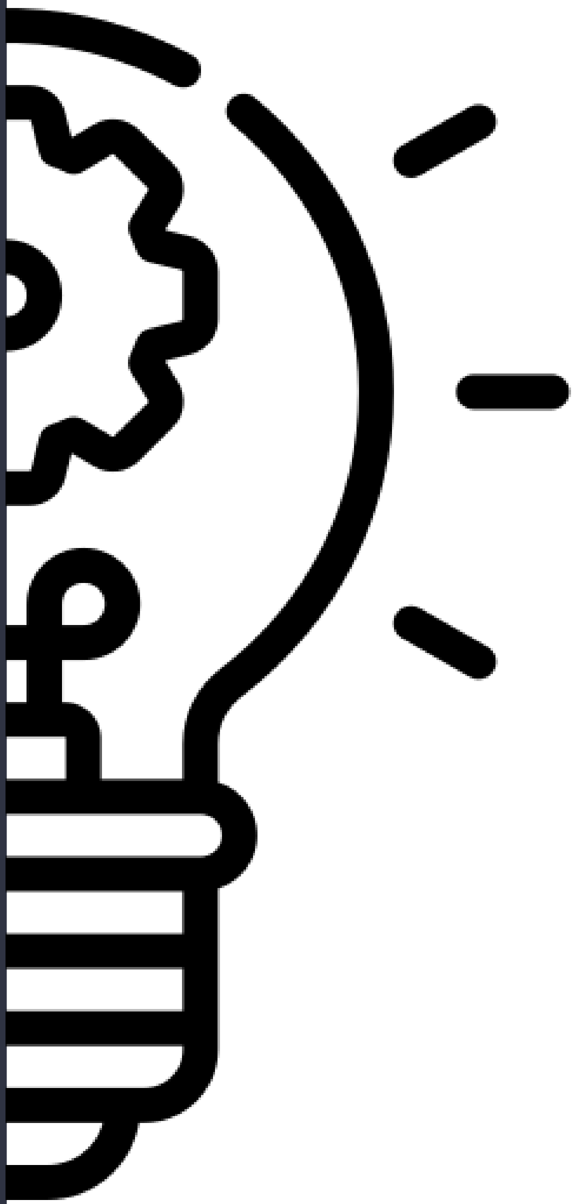
Circular economy in coal mining areas

INNOVATIONS

Explore the effects of site location, climatic conditions, treatment strategy, and material properties on the performance of upgraded and/or treated CMWGs.

Durability of the upgraded and/or treated CMWGs' performance

Technical guidelines to upgrade any type of CMWGs



ADDED VALUES

The specific added value of MINRESCUE can be found in the six areas of the proposed research

- Specialized physical and chemical characterisation of CMWGs
- Treatment protocols for CMWGs
- Transport (hydro-chemo) properties of treated CMWGs
- Mechanical and geotechnical behaviour of treated CMWGs
- Advanced constitutive modelling of CMWGs
- Upcycling of CMWGs for new products

KEY RESEARCH ACTIVITIES & OBJECTIVES

- The mechanical and chemical characterisation of the mining waste materials
- Numerical modelling to predict behaviour of treated CMWGs
- Assessment and demonstration of the durability of materials and (geo)-structures made by CMWGs under realistic conditions
- Providing guidelines for the design of construction materials and (geo)-structures with the treated

- Providing guidelines for the design of construction materials and (geo)-structures with the treated
- Developing concepts for recovering upgraded components
- Substantiation of the reduction of environmental impacts through well thought-out life cycle assessment (LCA)
- Paving the way for market uptake of CMWGs treatment upgrading and upcycling technologies

WORK PACKAGES

1. Physical and chemical characterisation of CMWGs and their treatment
2. Mechanical experiments and numerical modelling
3. Closing the cycle of CMWGs application in construction
4. Reporting and coordination
5. Project dissemination and outreach

ISSUES THAT MINRESCUE ADDRESSES

CMGW-induced pollutions

Large areas occupied by CMWG dumps

Large demand for raw geomaterials

Waste dump failure

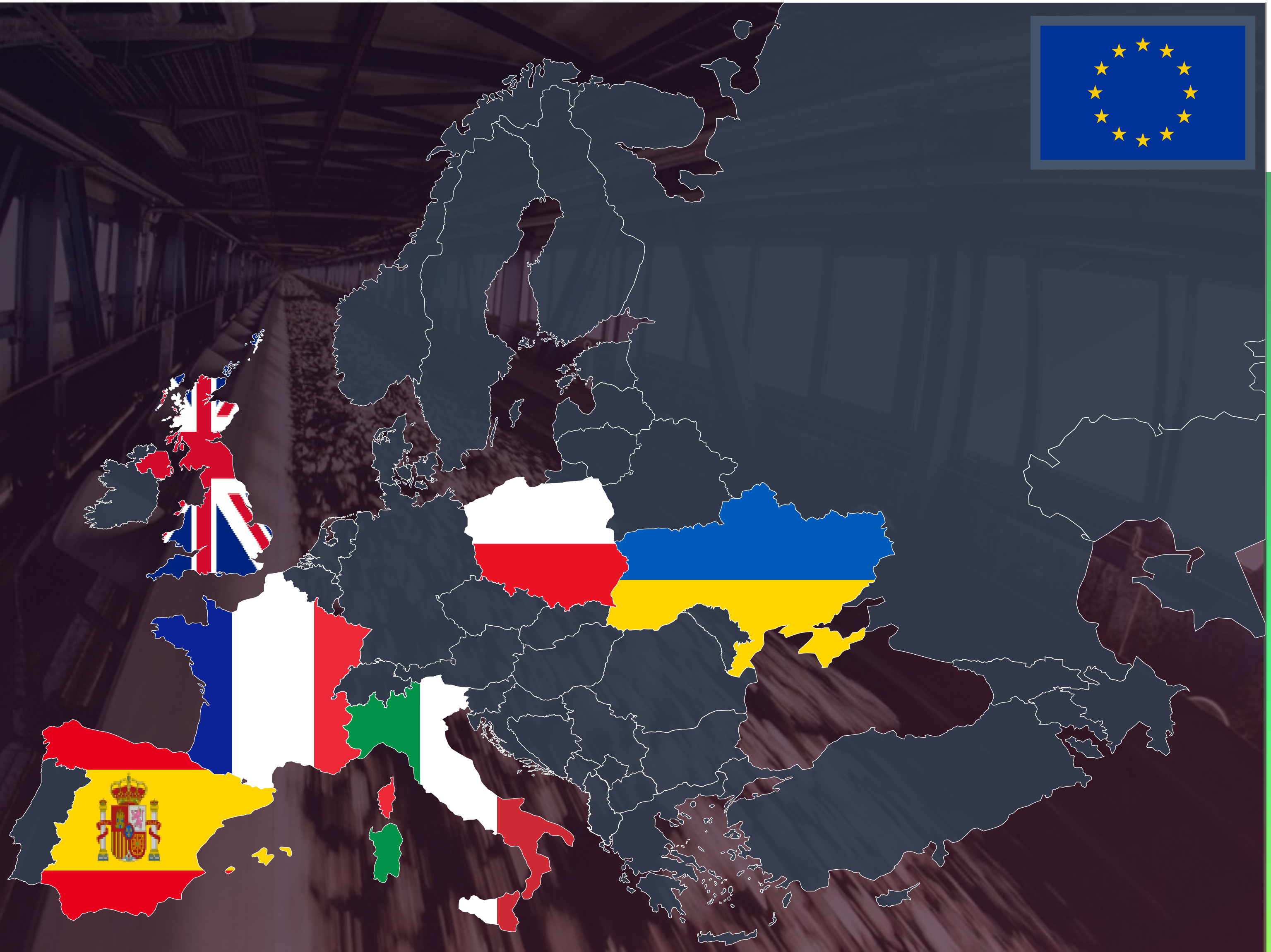
Countries

6

Organizations

12

12 pioneering organizations from 6 European countries are participated in MINRESCUE



MINRESCUE

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UNIVERSITY OF EXETER

GIG

POLITECNICO
MILANO 1863

CERGY PARIS
UNIVERSITÉ

Géosciences pour une Terre durable
brgm

Subterra

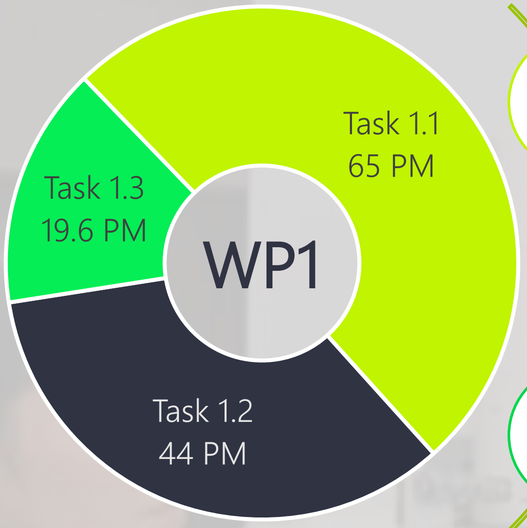
poltegor – instytut
INSTYTUT GÓRNICTWA ODKRYWKOWEGO

TesiSystem
Soluzioni prefabbricate

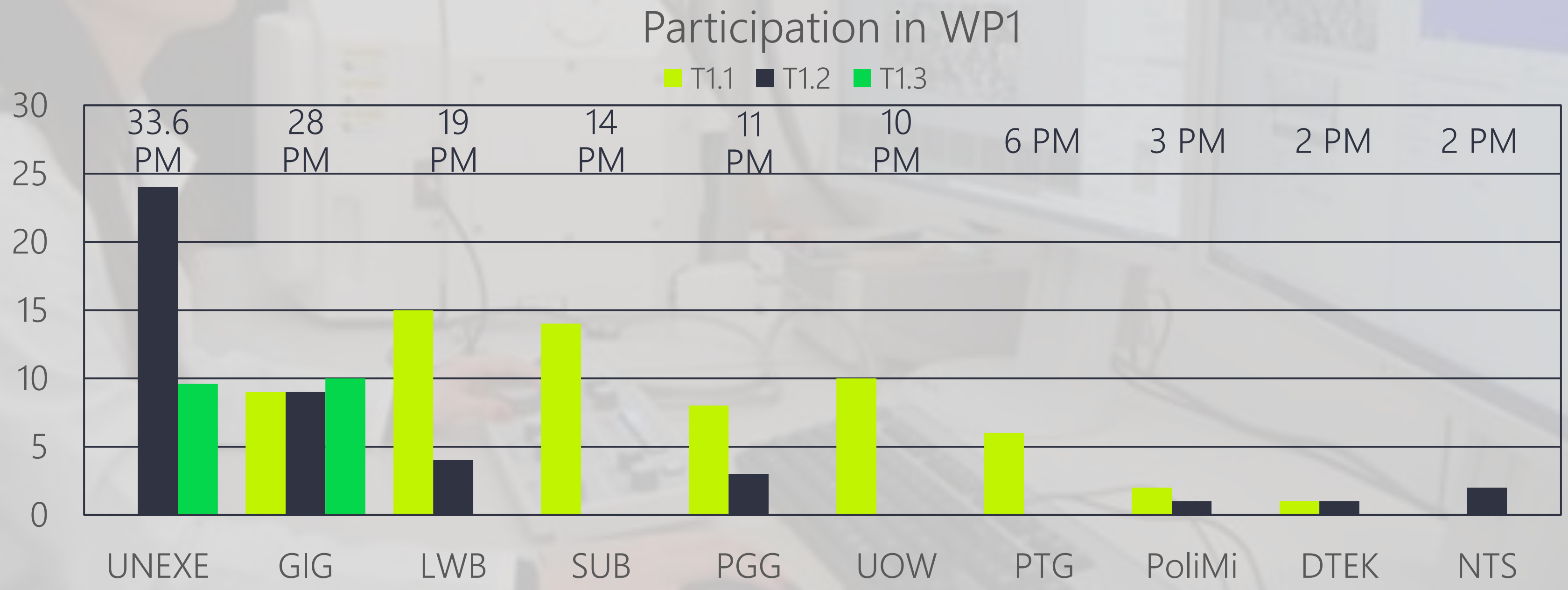
D.TEK

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT



- **1.1** Collection of detailed data-sets on CMWSs, experimental integration and data-base creation
- **1.2** Physical and chemical characterisation of CMWGs
- **1.3** Treatment of CMWGs for upcycling them in construction industry



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WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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TASK 1.1

COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

Create a publicly available database on “itemised” coal mining waste classification in order to pave the way for their rational use as secondary raw materials

1 Classification of CMWGs according to their origin, formation, and storage/dumping conditions

GIG WARWICK THE UNIVERSITY OF WARWICK

2 Performing geotechnical campaign on the selected spoils and analysing the treatments and behaviour

Subterra

3 Providing access to new and existing data from mines in Poland and Ukraine

DTEK

4 Feed-back and forth information with reference to the information needed on the CMWGs properties for their upcycled use as constituents in concrete materials and products

POLITECNICO MILANO 1863

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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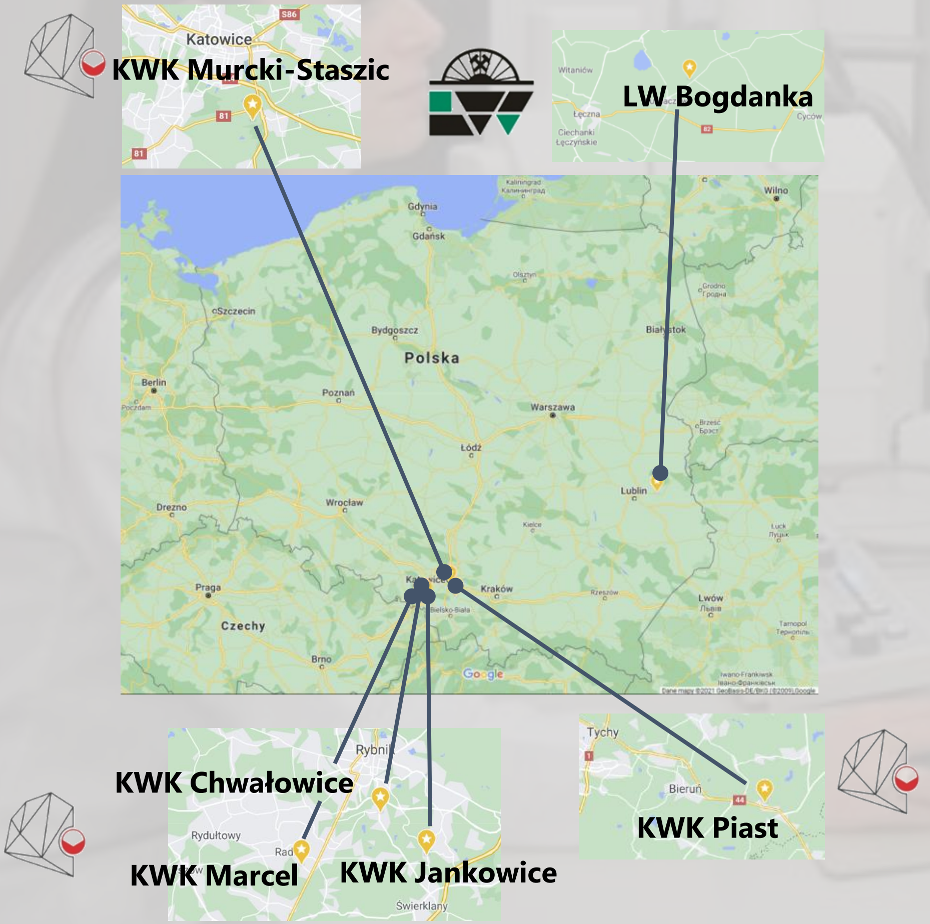
TASK 1.1

COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

GIG, in cooperation with PGG and LWB, have collected CMWGs from 6 underground hard coal mines.



LW Bogdanka

Staszic

Piast

Marcel

Chwałowice

Jankowice

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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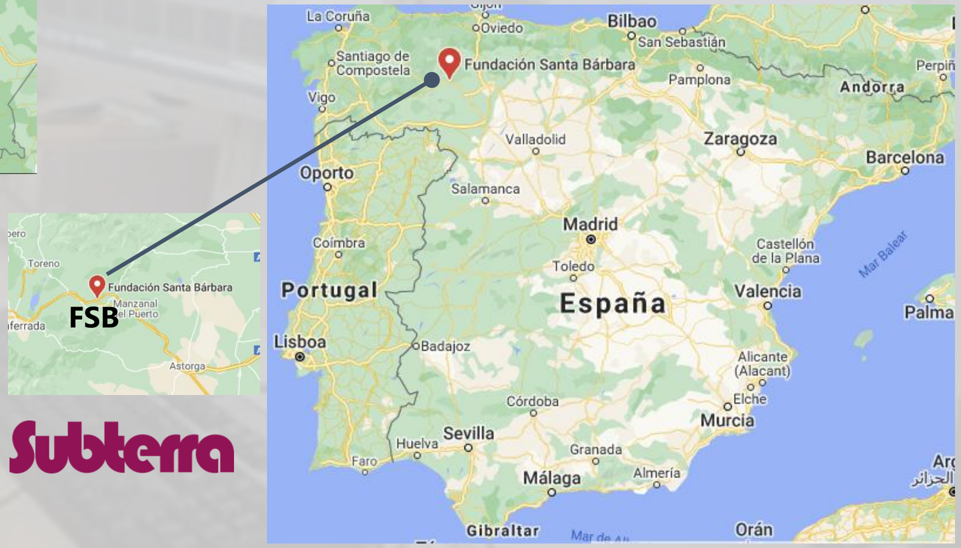
TASK 1.1

COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

SUB has collected CMWGs from a 2 years-old spoil heap that belonged to the Santa Bárbara Foundation School (FSB) mine in the Ponferrada region, Spain



PTG has also collected CMWGs from the Wałbrzych hard coal mining region, Poland.

TASK 1.1

COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

Post-mining waste is being tested in the GIG laboratory e.g. different fractal diameters D10, D50, D90, specific gravity, plasticity indices, initial water content, optimum water content, dry and bulk densities, petrographic composition, ash content, sulfur content, caloric, moisture, coal content.

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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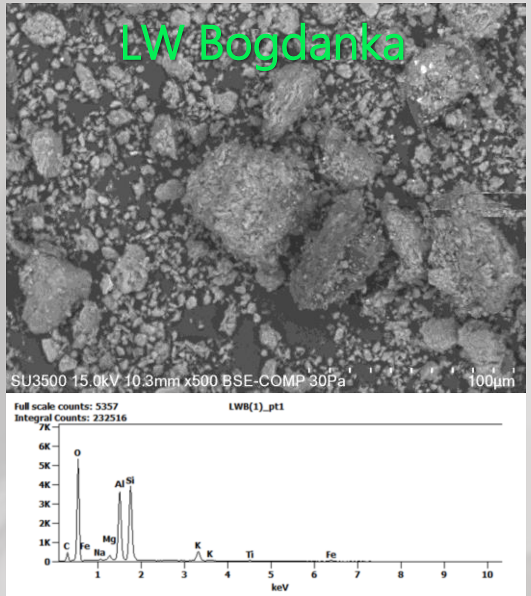
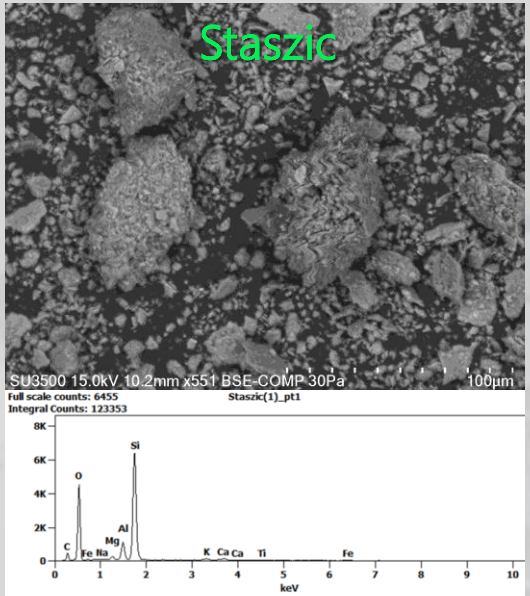
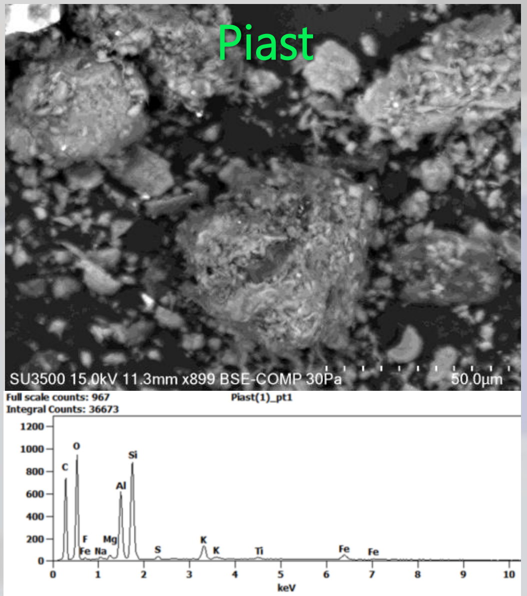
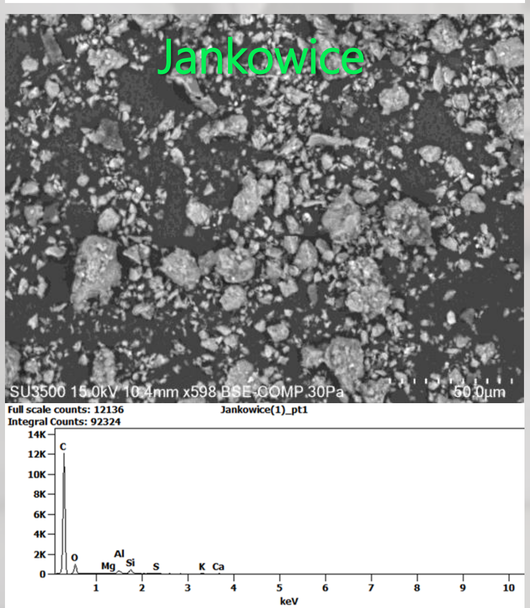
TASK 1.1

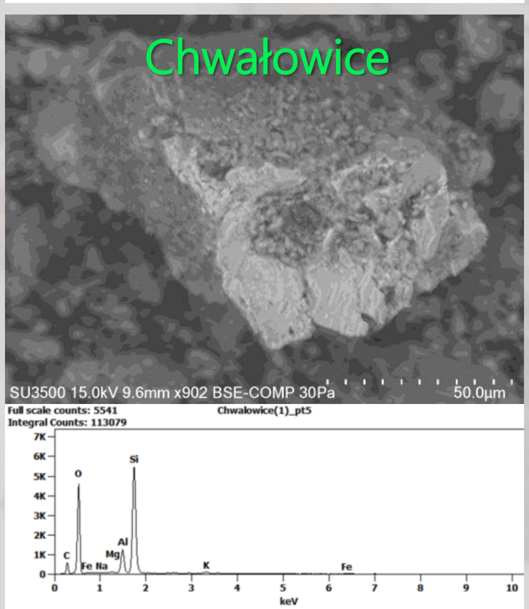
COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

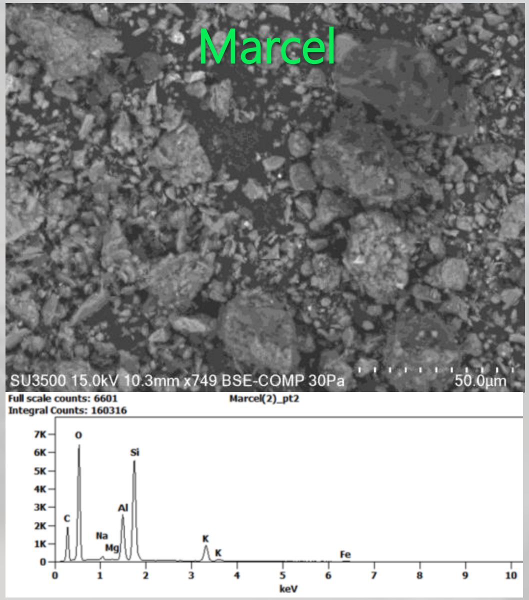












WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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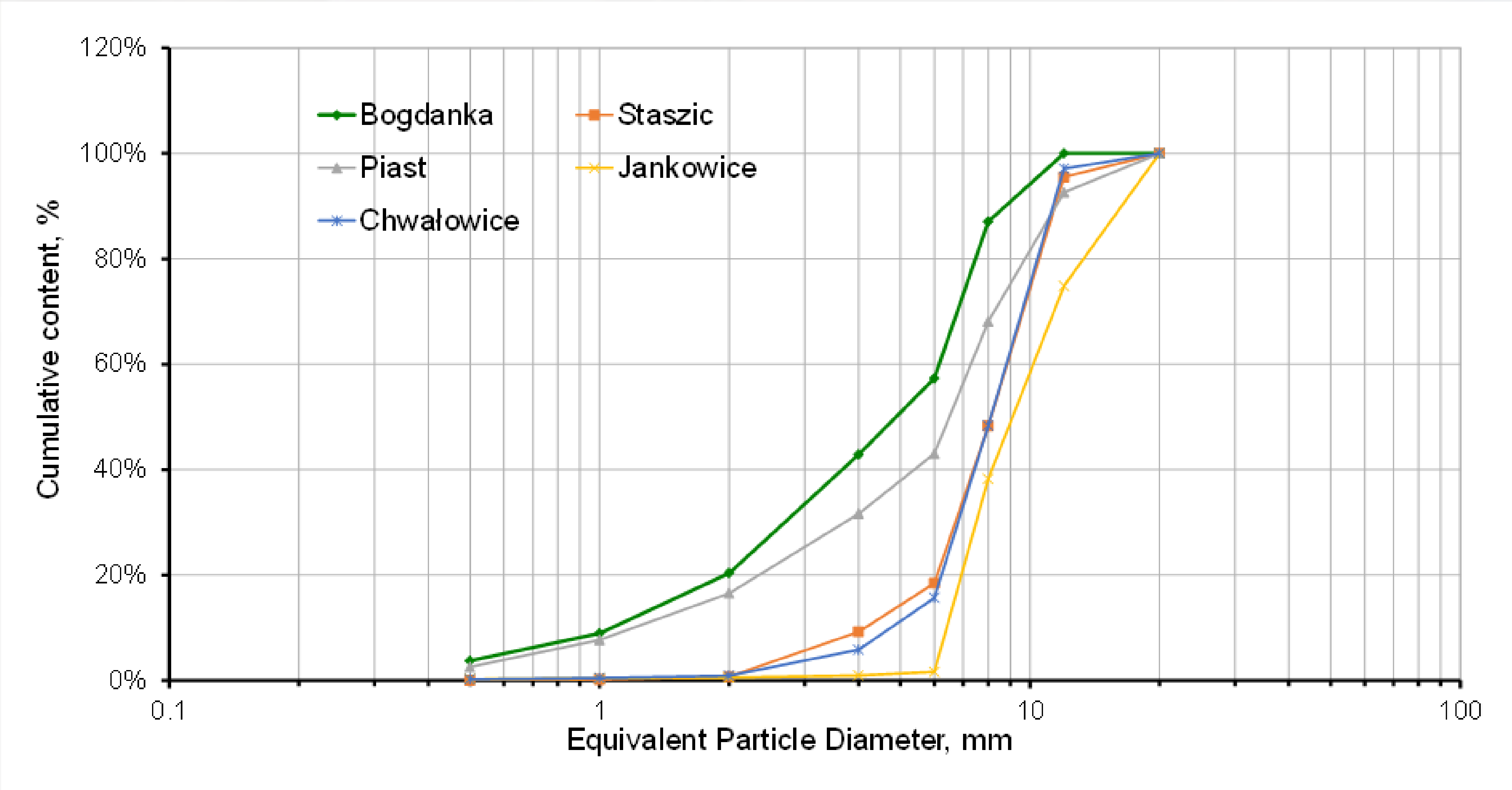
TASK 1.1

COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

The grain size distributions of the collected CMGWs



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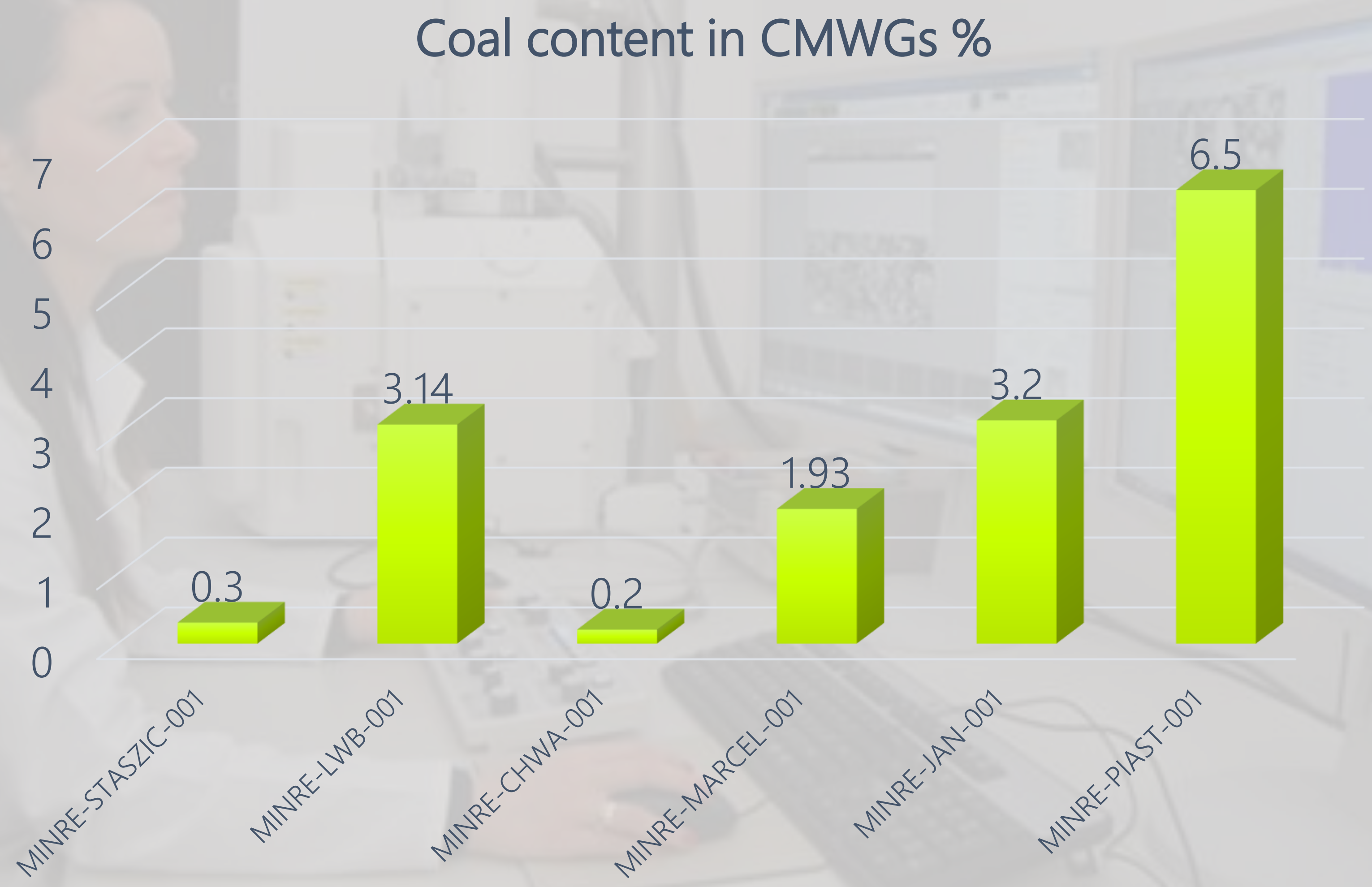
COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

WORK PACKAGE 1
ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT



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TASK 1.1
COLLECTION OF DETAILED DATASETS AND DATA-BASE CREATION

CMWGs	MINRE-PIAST-001/3		MINRE-JAN-001/3		MINRE-STASZIC-001/3		MINRE-LWB-001/3		MINRE-LWB-001/3		MINRE-MARCEL-001/3	
Parameter	Determined value		Determined value		Determined value		Determined value		Determined value		Determined value	
	as received	dry	as received	dry	as received	dry	as received	dry	as received	dry	as received	dry
Unit	[%m/m]		[%m/m]		[%m/m]		[%m/m]		[%m/m]		[%m/m]	
water	1.69	-	2.01	-	1.07	-	1.49	-	1.03	-	0.85	-
ash	80.58	81.97	83.38	85.09	90.67	91.65	81.27	82.5	84.83	85.71	78.8	79.48
carbon	8.69	8.84	8.17	8.34	2.02	2.04	7.67	7.79	5.89	5.95	12.27	12.38
hydrogen	0.77	0.78	0.53	0.54	0.19	0.19	<0.11	<0.11	0.22	0.23	0.54	0.55
sulphur	1.87	1.9	0.1	0.1	0.16	0.16	1.85	1.88	0.35	0.35	0.29	0.29
organic carbon TOC	8.69	8.84	8.17	8.34	2.02	2.04	7.67	7.79	5.89	5.95	11.94	12.04
Unit	[J/g (kJ/ka)]		[J/g (kJ/ka)]		[J/g (kJ/ka)]		[J/g (kJ/ka)]		[J/g (kJ/ka)]		[J/g (kJ/ka)]	
gross calorific	2980	3030	2640	2690	370	370	2810	2850	1400	1410	4050	4080
net calorific	2770	2860	2470	2570	290	320	2760	2850	1320	1360	3920	3970
specific density	2.46 [g/cm^3]	-	2.46 [g/cm^3]	-	2.64 [g/cm^3]	-	2.48 [g/cm^3]	-	2.64 [g/cm^3]	-	2.38 [g/cm^3]	-

WORK PACKAGE 1
ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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TASK 1.2
PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

Determine physical and chemical characterisation of CMWGs for their upcycling in construction applications

1. Radioactivity analysis (GIG)

2. Full physical and chemical characterisation (not geotechnical; not radioactive). Innovative techniques (focussing on in situ and hydrometallurgy) to recover critical metals and upcycle CMWG (University of Exeter)

3. Granting the accesses to representative samples (DTEK)

4. Feed-back and forth information with reference to the information needed on the CMWGs properties for their upcycled use as constituents in concrete materials and products (Politecnico Milano 1863)

WORK PACKAGE 1
ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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TASK 1.2

PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

- SEM/EDX (LOADING)
- XRD
- ICP-MS
- XRF (LOADING)
- TOC
- XPS
- BET (LOADING)

UNEXE has undertaken comprehensive physical and chemical characterisation of the received samples.

TASK 1.2

PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

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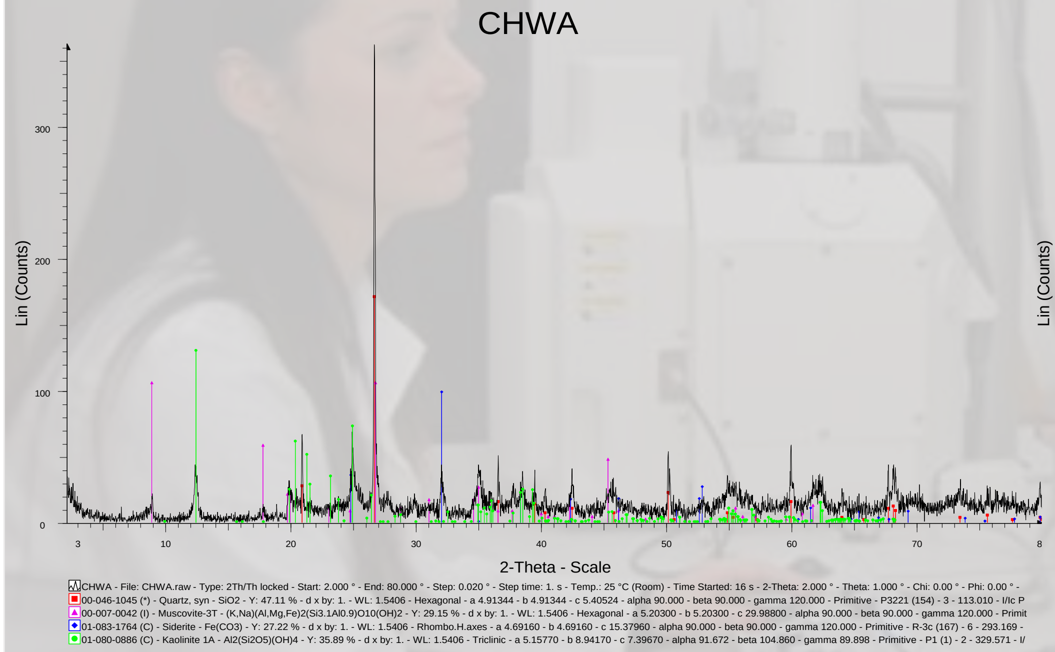
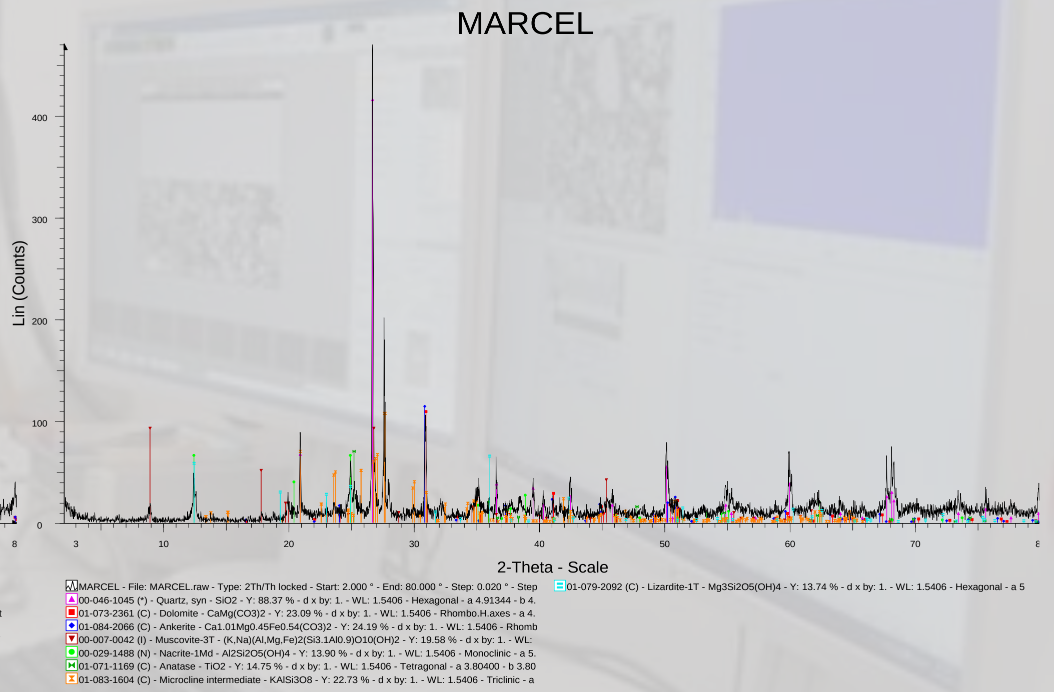
XRD pattern





XRD patterns for the 2 samples (Chwałowice and Marcel) indicating their primary mineralogy. Both XRD patterns confirm the presence of quartz and muscovite, and various clay minerals (kaolinite in Chwałowice, nacrite and lizardite in Marcel).

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ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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TASK 1.2

PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

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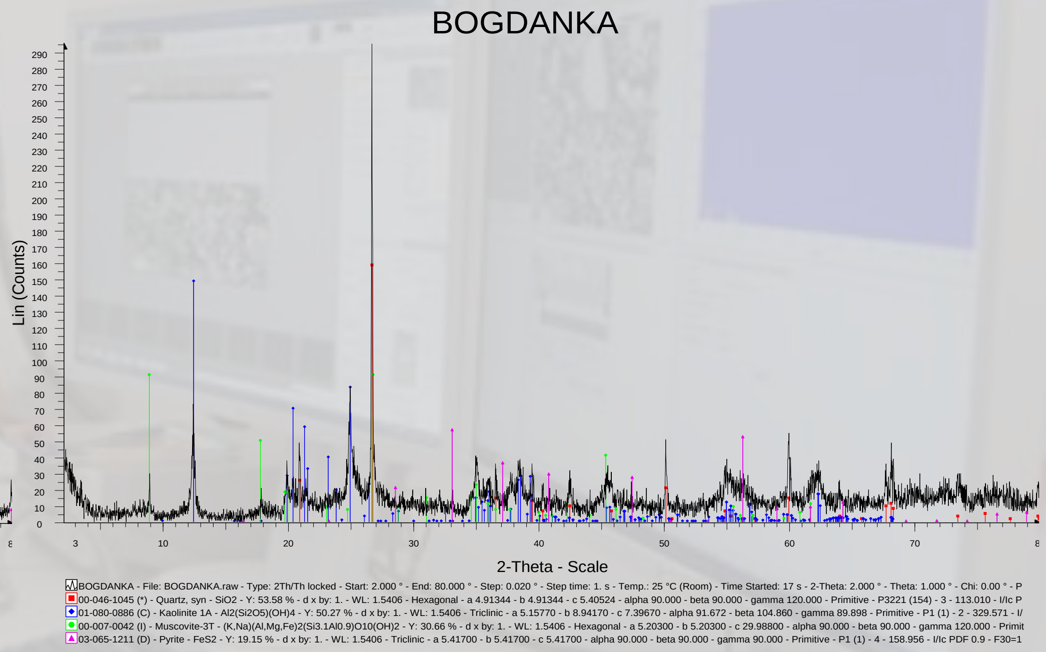
XRD pattern



XRD patterns for the 2 samples (Staszic and Bogdanka) indicating their primary mineralogy. Both XRD patterns confirm the presence of quartz and muscovite and kaolinite, plus accessories such as phengite, illite, and (at very low concentrations) pyrite.

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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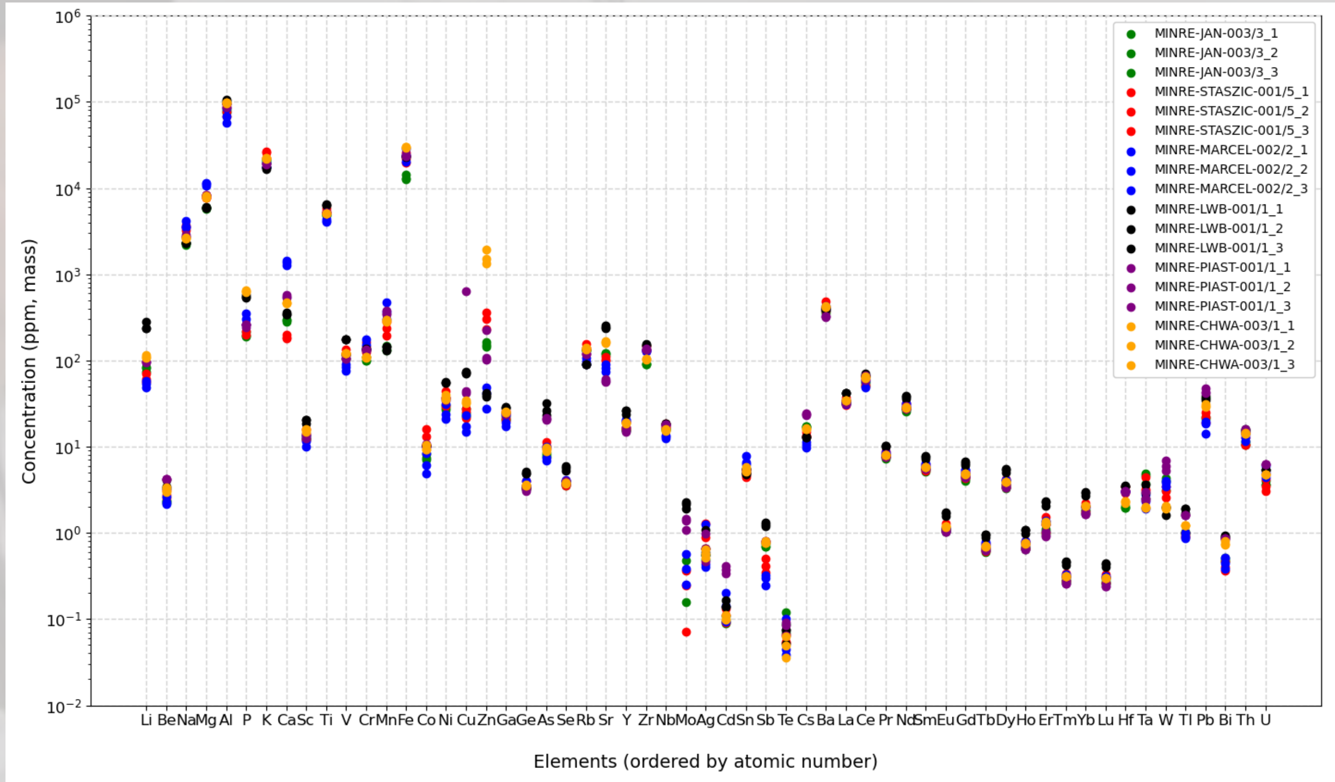
TASK 1.2
PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

WORK PACKAGE 1
ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

ICP-MS



Whole-sample metal concentrations for trace (and some major) metals, determined by ICP-MS of powdered, acid-digested samples.

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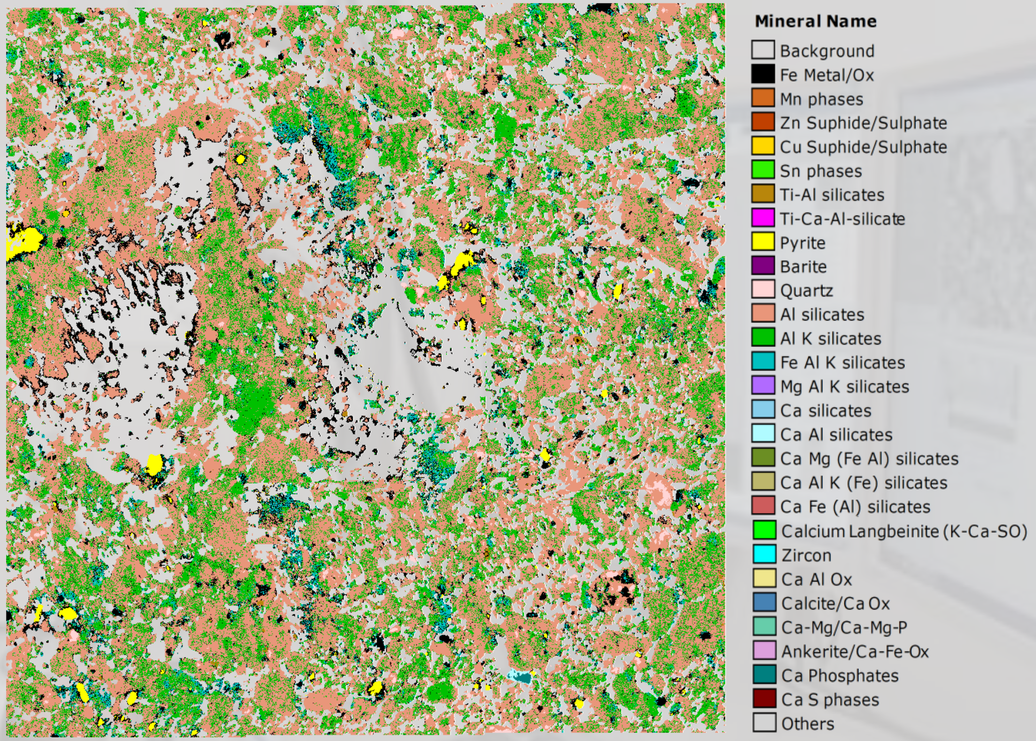
TASK 1.2
PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

QEMSCAN map



QEMSCAN maps of a powdered split from sample Bogdanka. The predominance of lilac and olive indicate the predominance of aluminosilicates, some potassium-rich. These are overwhelmingly clays, micas and feldspars.

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TASK 1.2

PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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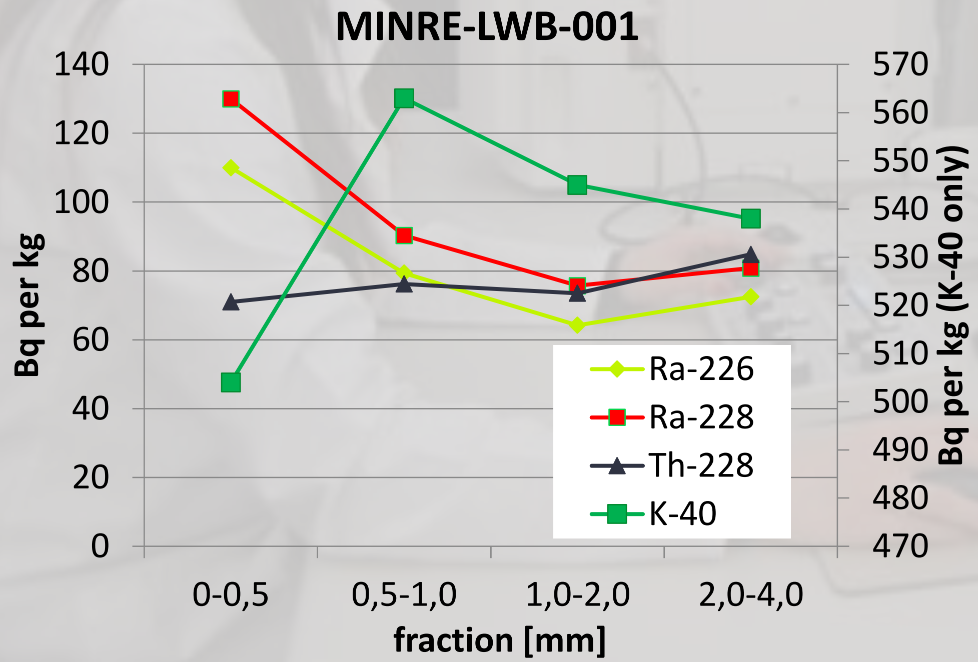
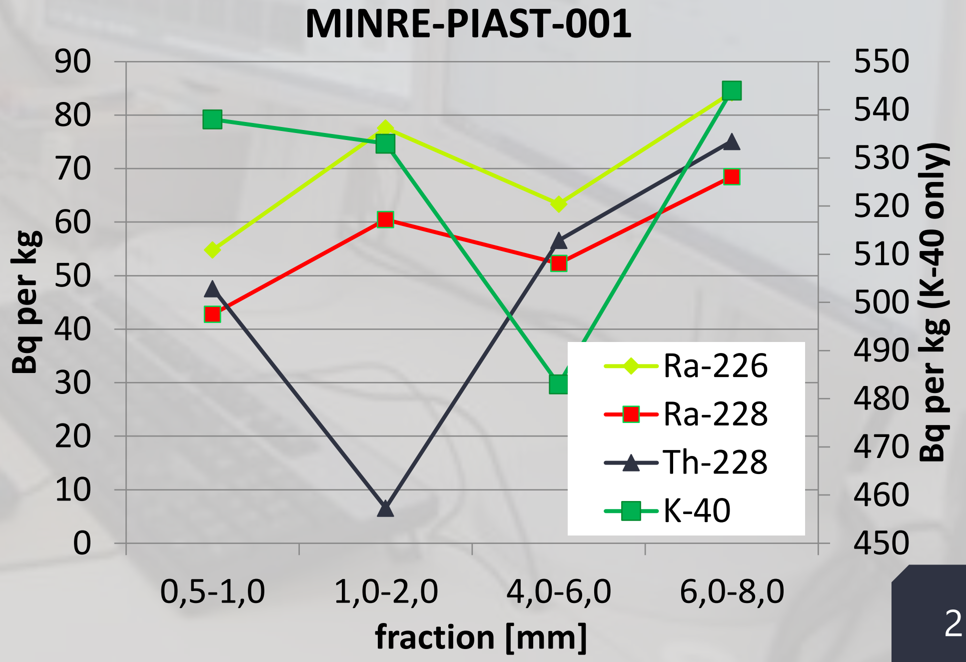
The activity concentration of the following radionuclides ^{226}Ra, ^{228}Ra, ^{228}Th, ^{210}Pb and ^{40}K was determined using a gamma-ray spectrometry equipped with a hyper pure germanium detector with relative efficiency of 35%, cooled by liquid nitrogen.

Fast, reliable, non-destructive method of radionuclides concentration determination.





TASK 1.2
PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS

WORK PACKAGE 1
ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

EURATOM 2013/59 Directive

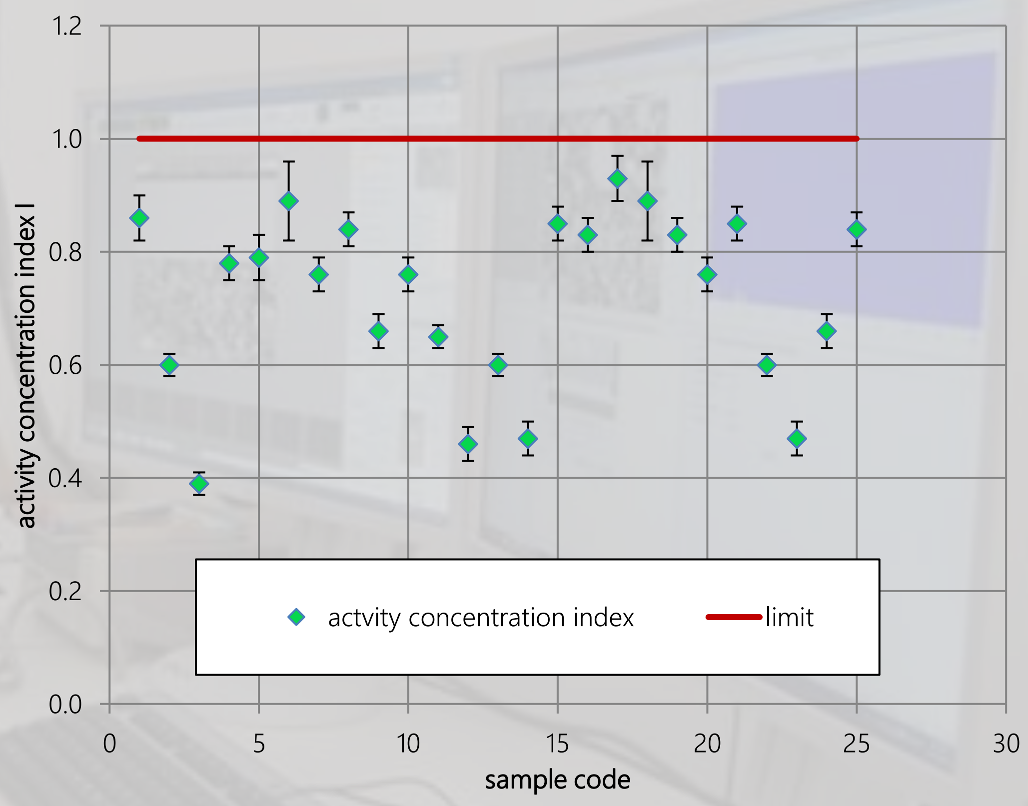
The maximum concentration of radium ^{226}Ra, thorium ^{232}Th and potassium ^{40}K is determined by the following formula:

$$\frac{C_{Ra}}{300\ Bq \cdot kg^{-1}} + \frac{C_{Th}}{200\ Bq \cdot kg^{-1}} + \frac{C_K}{3000\ Bq \cdot kg^{-1}} \leq 1$$

where C_{Ra}, C_{Th} and C_K mean the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively (expressed in $Bq \cdot kg^{-1}$).

The results of conducted measurements are as following:

^{226}Ra	41.4 – 170 $Bq \cdot kg^{-1}$
^{228}Ra	35.1 – 130 $Bq \cdot kg^{-1}$
^{232}Th	38.7 – 84.8 $Bq \cdot kg^{-1}$
^{210}Pb	38.7 – 166 $Bq \cdot kg^{-1}$
^{40}K	383 – 914 $Bq \cdot kg^{-1}$



Calculated activity concentration indices of 25 tested samples compared to limit

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WORK PACKAGE 1

ADVANCED PHYSICAL AND CHEMICAL CHARACTERISATION OF CMWGS AND THEIR TREATMENT

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TASK 1.3

TREATMENT OF CMWGS FOR UPCYCLING THEM IN CONSTRUCTION INDUSTRY

Develop novel methods to remediate CMWGs in order to make them suitable for large scale upcycling applications in construction industry.

1

Providing the practical treatment protocols to enhance the quality and characteristics of mining waste in terms of elevated natural radioactivity, which can obstruct rational waste management.

GIG

2

Conducting bioavailability experiments using simulated lung and intestinal fluids in order to determine the impact of "as-received" and "treated" CMWGs on human health.

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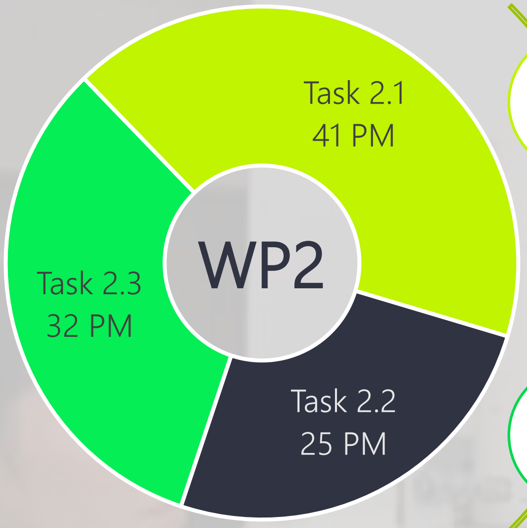
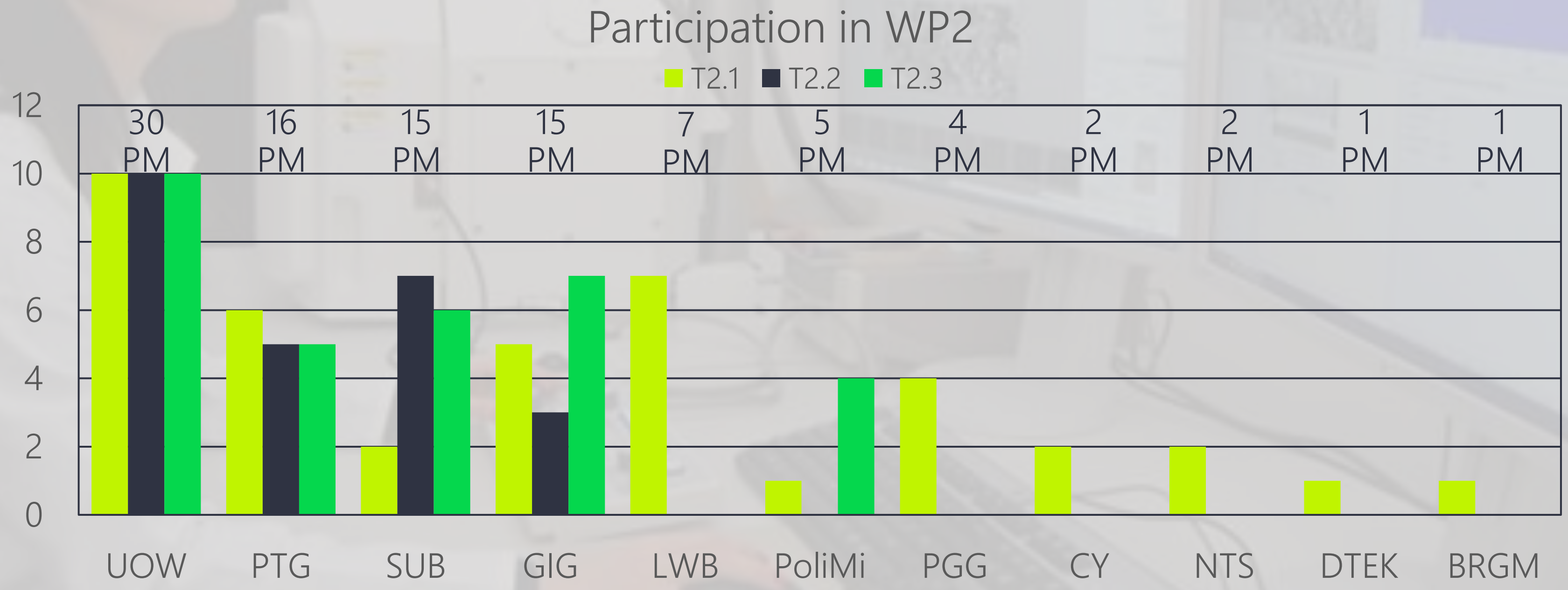
WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS



- **2.1** Geotechnical and mechanical characterisation of CMWGs
- **2.2** Transport properties of treated CMWGs
- **2.3** Constitutive and numerical modelling



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WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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TASK 2.1

GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

To achieve a better understanding of how influencing factors affect the behaviour and geotechnical characteristics of CMWGs

1. Conducting standard element-level and creep-based tests
2. Providing access to the required testing materials with their basic in situ characteristics information that will be used for the subsequent thorough geotechnical identification of samples from proposed mines
3. Extension of the work undertaken as part of this task and Tasks 1.2 and Task 1.3 by developing a complementary laboratory testing plan
4. Conducting a thorough probabilistic analysis of the existing as well as newly obtained geotechnical data
5. Testing uniaxial compressive and shear strengths of CMWGs at different weathering states
6. Working on characterisation of the cyclic response of treated CMWGs and their crushability
7. Collection of data to be fed-forth to life cycle assessment task in WP3 (Task 3.4)
8. Feed-back and forth information

WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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TASK 2.1

GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

Task 2.1

- CMWGs

  - Critical state characterisation
  - Chemical treatment of CMWGs' impact on behaviours

- Cemented aggregates

  - Mix design's impact on mechanical behaviours
  - Grain/pore sizes' impact on mechanical behaviours

- Foam concretes

  - Stress and volume change during hydration process
  - Stress and volume change during drying and wetting cycles

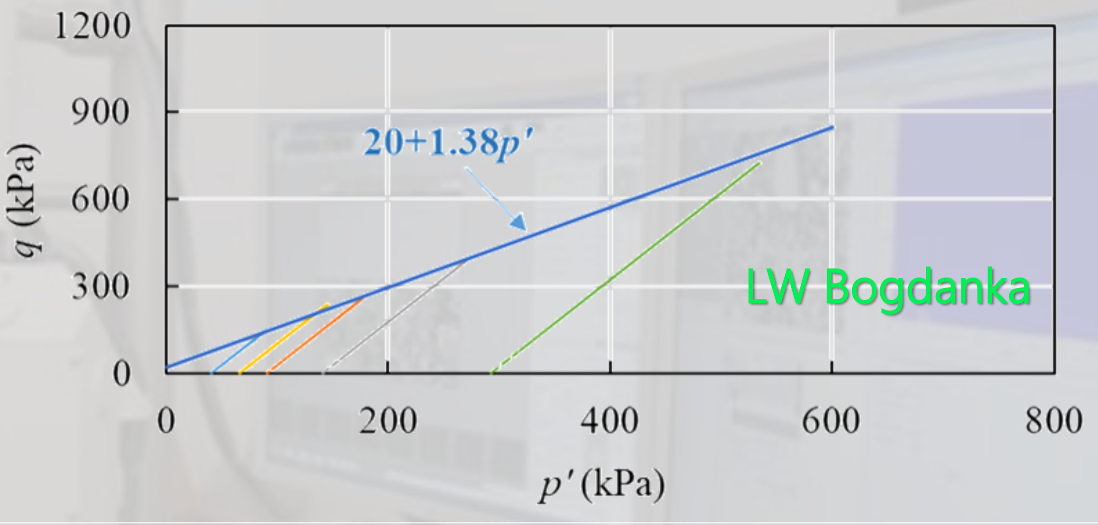
TASK 2.1

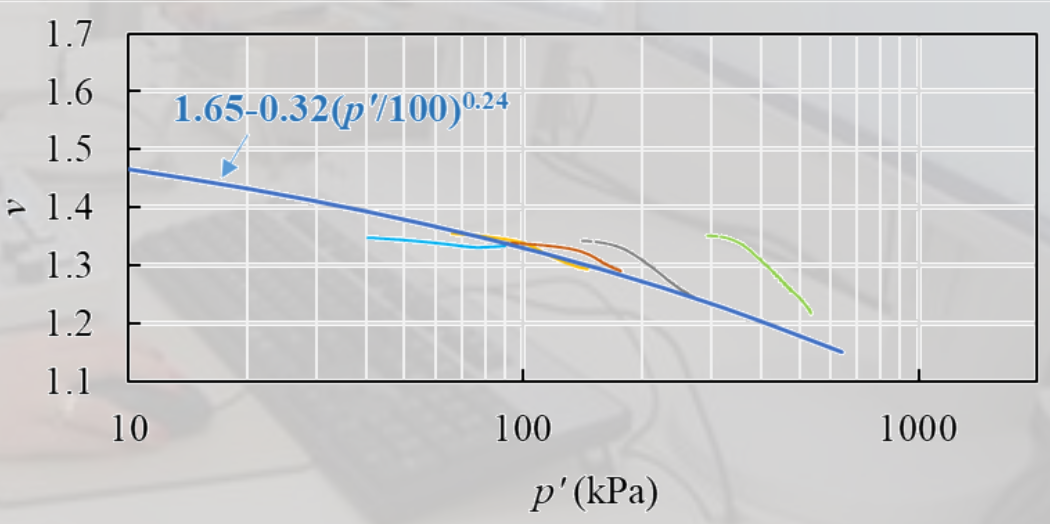
GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

A critical state characterisation was carried out in consolidated drained triaxial compression and isotropic consolidation tests.





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WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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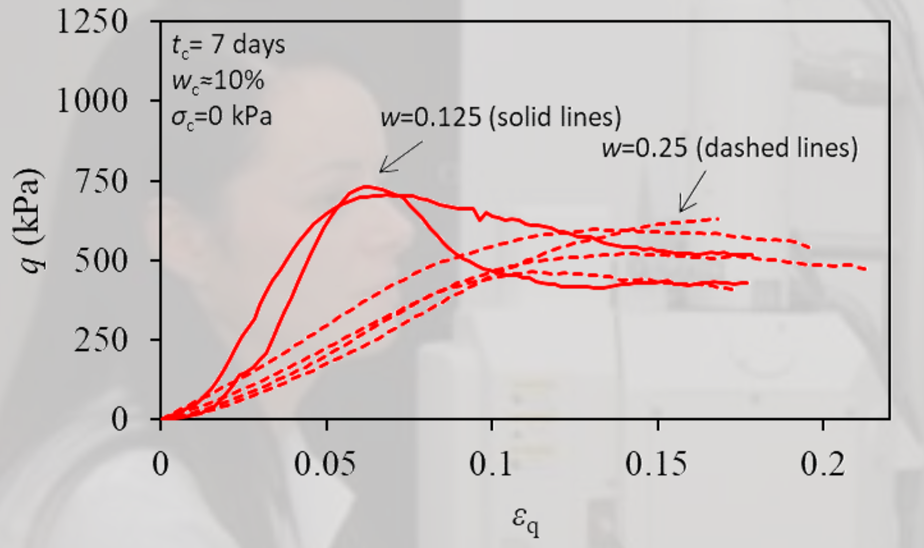
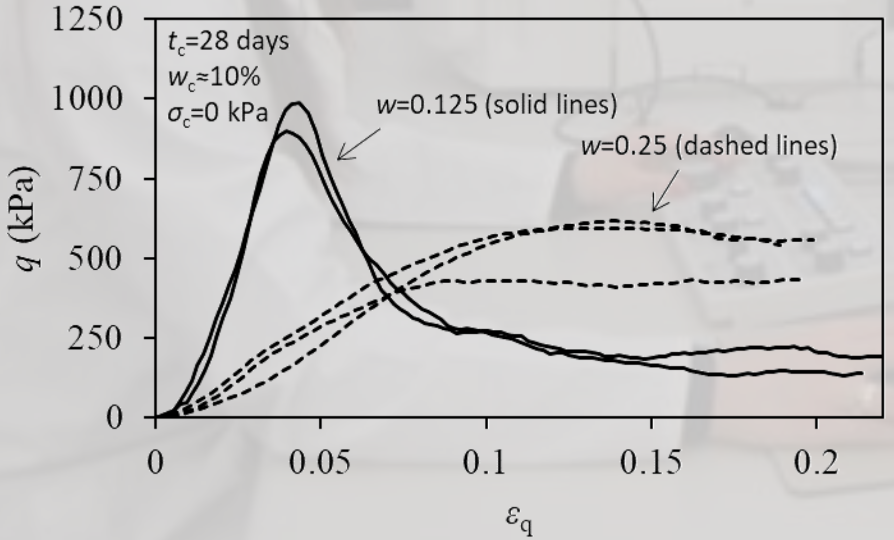
TASK 2.1

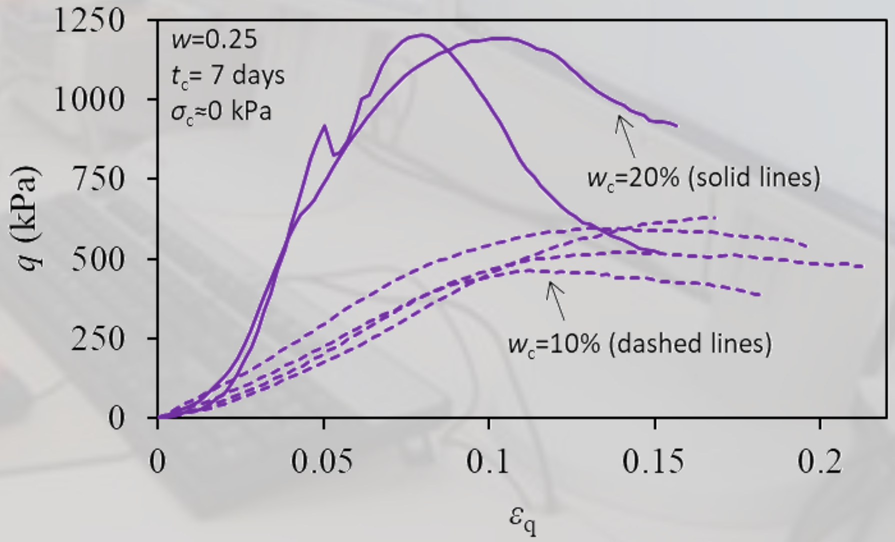
GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS



An investigation into the influence of mix designs (water content, binder to filler ratio, curing duration) was carried out using unconsolidated undrained triaxial tests.

Influence of water content (w), cement content (w_c) and curing duration (t_c) on unconsolidated undrained strength





TASK 2.1

GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

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WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

Time-dependant hydration process, chemical shrinkage and water retention behaviour of CMWG-bearing foam concrete.

1. Design and fabrication of a purpose-built foam generator and 2 modified unsaturated oedometers

2. Designing, testing and fine-tuning a chemical shrinkage and a hydration testing procedure for CMWG-bearing foam concrete

3. Setting-up a soil water characteristic testing system and testing the water retention behaviours of treated CMWGs

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TASK 2.1

GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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Water absorption test result

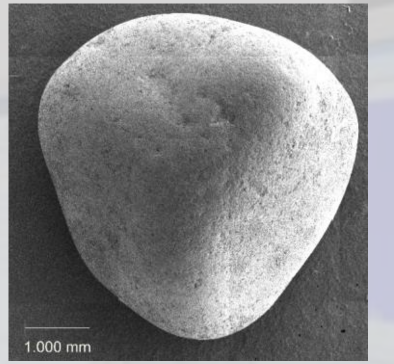
CMWG	Name/ID	WA_{24h}	WA_{24h} max recommended by NF EN 18-545
MINRE-CHWA-002/3	S WC-2/6	2.14	2.5(±2)
MINRE-CHWA-002/4	S1 WC-2/6	1.6	2.5(±2)
MINRE-WALB-004	S2 WC-0.63/4	2.6	2.5(±2)
MINRE-CHWA-002/5	G1 WC-4.5/8	5.15	5-6 (±2)
MINRE-CHWA-002/6	G2 WC-6.3/16	5.96	5-6 (±2)
MINRE-CHWA-002/7	G3 WC-7/16	4.446	5-6 (±2)
MINRE-CHWA-002/8	G4 WC-18/30	4.05	5-6 (±2)
MINRE-WALB-004	G5 WC-4/10	7.2	5-6 (±2)
MINRE-WALB-004	G6 WC-10/20	7.2	(±2)

TASK 2.1

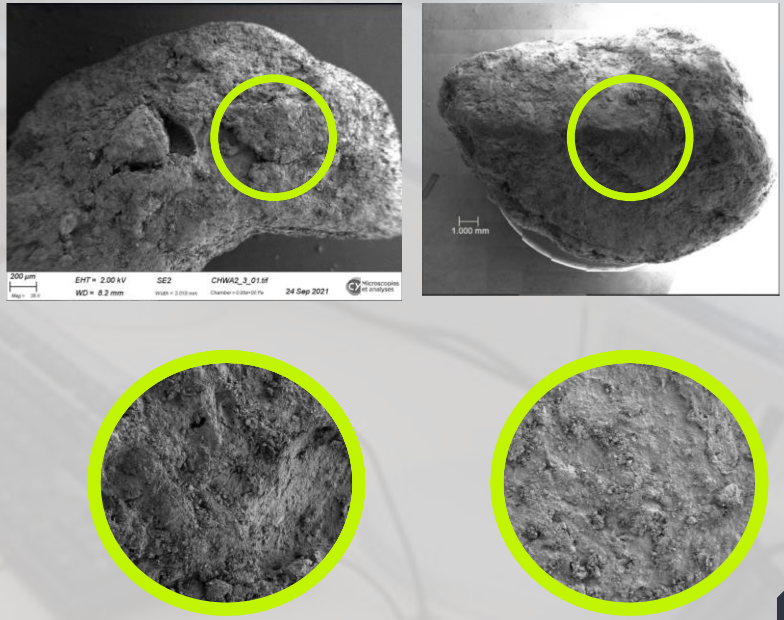
GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

SEM/EDX was used to determine the morphology and elementary composition of Chwałowice samples.

It shows that the surfaces of most aggregates are somewhat rough and contain elongated features, significantly more so than the surface of a natural sand typically used in concrete production.



A natural sand particle



CMWGs

WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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TASK 2.1

GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

DTA/ATG were performed on 7 CMWG samples at a heating rate of 10°C / min up to approximately 1000°C.

Mass loss results from DTA/ATG

CMWG	Name/ID	Mass loss (%)		
		50-200°C	200-410°C	410-1000°C
MINRE-JAN-003/4	JAN 3/4	0.959	2.445	10.625
MINRE-CHWA-002/3	S WC-2/6	0.633	0.997	10.42
MINRE-CHWA-002/4	S1 WC-2/6	0.633	0.997	8.085
MINRE-CHWA-002/5	G1 WC-4.5/8	0.690	0.687	9.82
MINRE-CHWA-002/6	G2 WC-6.3/16	0.589	0.767	14.35
MINRE-CHWA-002/7	G3 WC-7/6	0.387	2.219	16.18
MINRE-CHWA-002/8	G4 WC-18/30	1.099	1.959	12.968

These mass losses are smaller than the mass loss of a natural sand (typically used in concrete production) at 19.87% when heated to about 1000°C.

TASK 2.1

GEOTECHNICAL AND MECHANICAL CHARACTERISATION OF CMWGS

polteqor – instytut
INSTYTUT GÓRNICTWA ODKRYWKOWEGO

WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

PTG has also conducted cyclic freeze-thaw resistance measurements on Walbrzych in accordance with NF EN 1367-1.

0 to -1 °C

210 ± 90 min

– 17,5 ± 2,5 °C

240 min

Freeze-thaw cycle (24 hrs)
10 cycles

Thawing the cans

at 20 °C

Holding the cans at

20 ± 3 °C

10 h

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MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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TASK 2.2

TRANSPORT PROPERTIES OF TREATED CMWGS

To identify the key parameters that control aging and deterioration of treated waste geomaterials

1 Measurements and observations of the physical characteristics of the treated CMWGs including porosity, permeability, and transmissivity under various environmental conditions using a purpose-built instrumentation system

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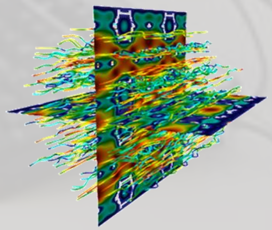

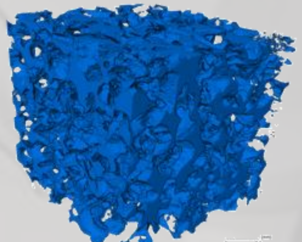

2 Conducting experiments on samples before and after erosimeter tests

GIG

3 Conducting experiments to evaluate the evolution of hydraulic properties within CMWG samples with different particle grading

WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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TASK 2.3

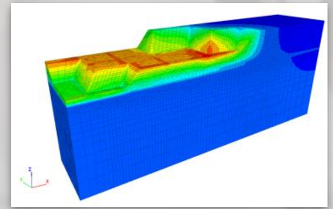
CONSTITUTIVE AND NUMERICAL MODELLING

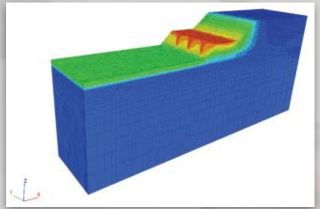
To identify the key parameters that control aging and deterioration of treated waste geomaterials

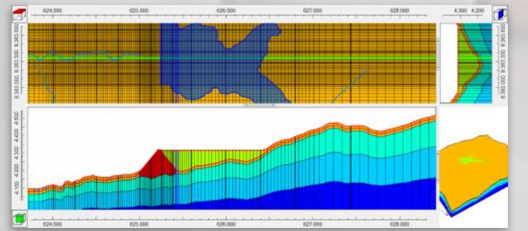
2

Creating numerical models with FLAC (2D and 3D) and ROCSCIENCE (RS3)

Subterra GIG







1

Development and validation of advanced constitutive models

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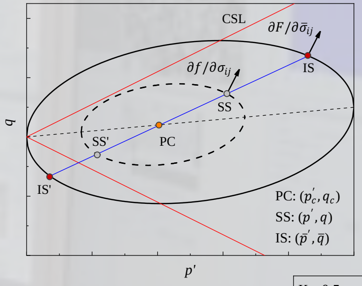
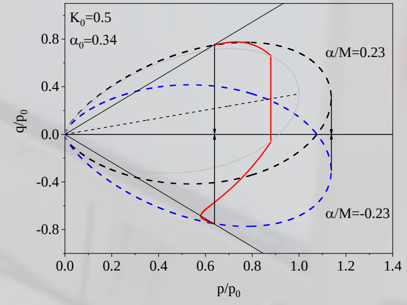
BS-CLAY1



AA1-CLAY



3

Feed-back and forth information with reference to the information needed on the CMWGs properties for their upcycled use as constituents in concrete materials and products

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WORK PACKAGE 2

MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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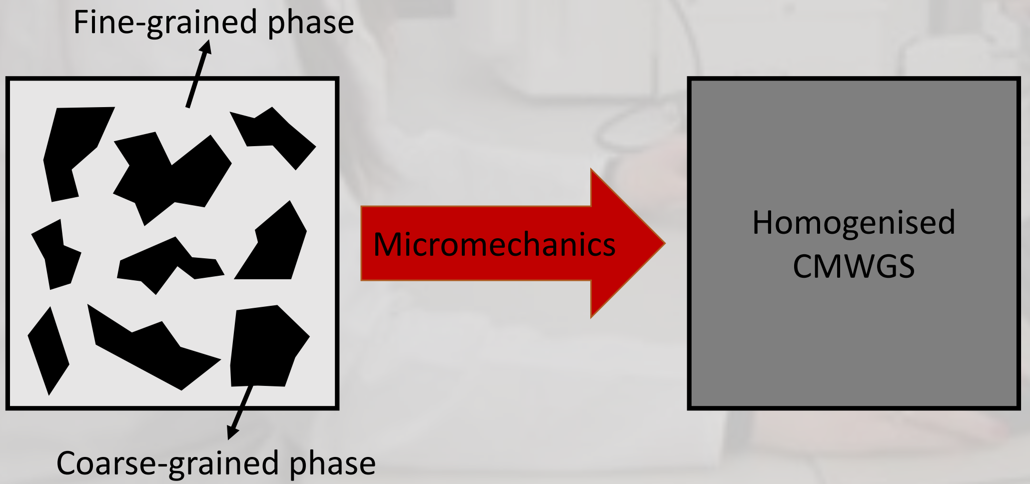
TASK 2.3

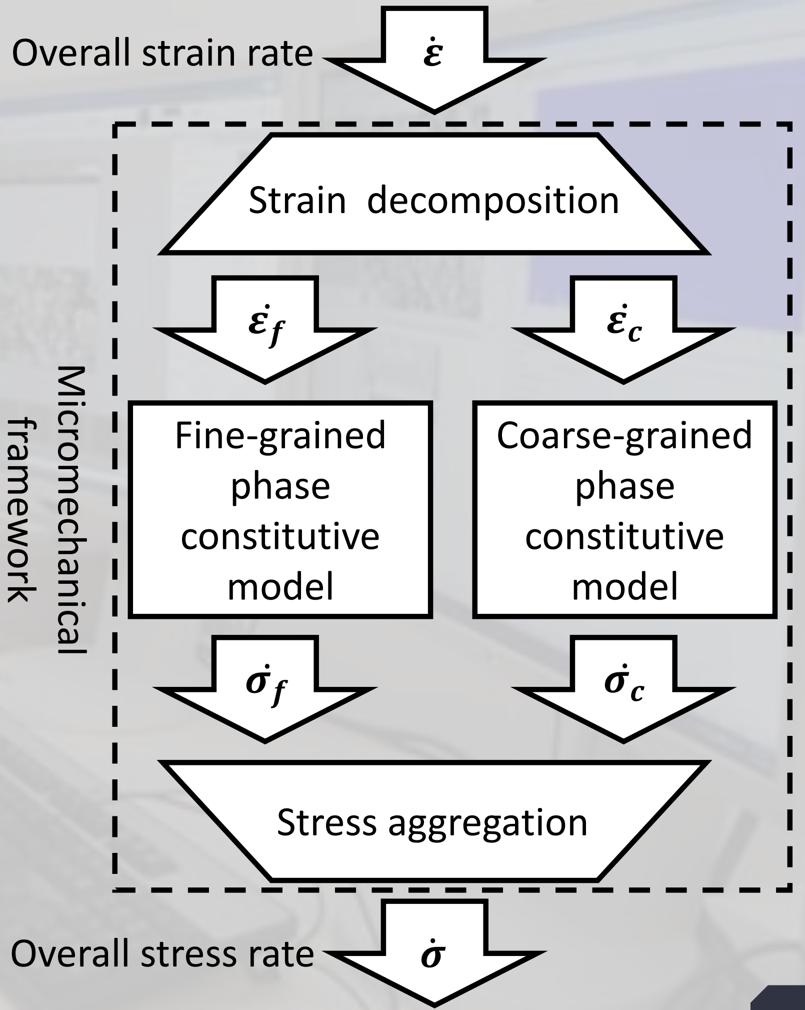
CONSTITUTIVE AND NUMERICAL MODELLING

From the constitutive modelling point of view, CMWGs can be considered as composite materials that are made of different components with various physical and mechanical properties.

The adopted micromechanical theory turns two-phased composite CMWGs into the homogenous ones that exhibit the overall behaviour of original material.



Model structure



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MECHANICAL EXPERIMENTS AND ADVANCED MODELLING OF THE SHORT- AND LONG-TERM BEHAVIOUR OF TREATED CMWGS

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TASK 2.3

CONSTITUTIVE AND NUMERICAL MODELLING

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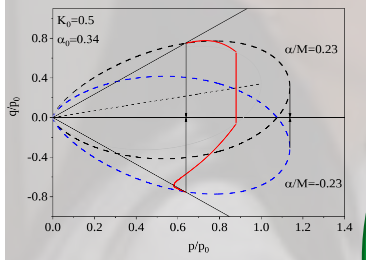
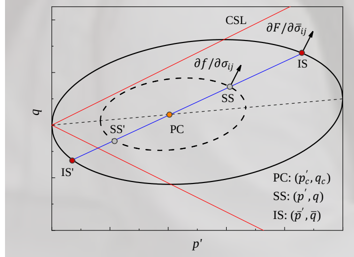
Two versatile constitutive models (namely, AA1-CLAY and BS-CLAY1) have been developed at UOW for the fine-grained part of the CMWGs.

Studies have begun at UOW to develop a constitutive model for granular soils





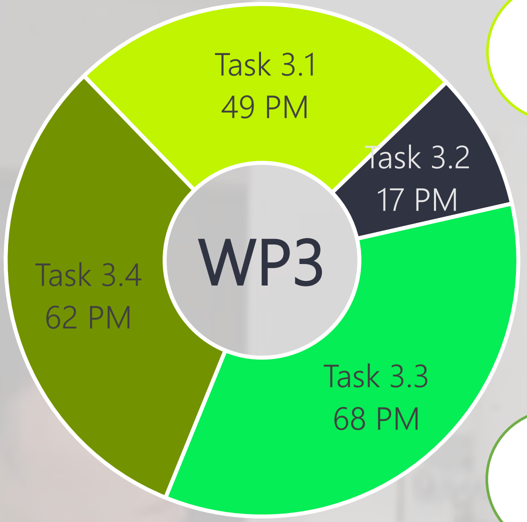
Fine-grained constitutive model

+

Coarse-grained constitutive model

Micromechanical framework
(Dejaloud and Jafarian, 2017)

WORK PACKAGE 3
CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

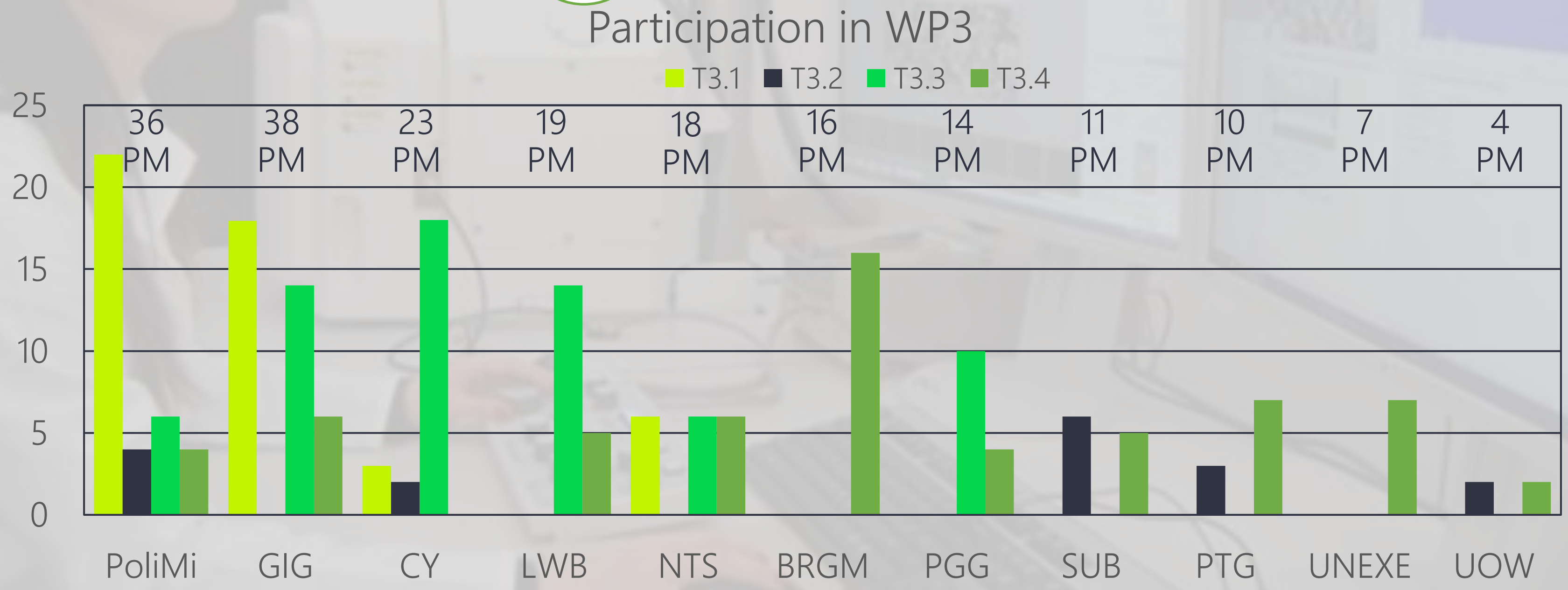


3.1 Geotechnical and mechanical characterisation of CMWGs

3.2 Transport properties of treated CMWGs

3.2 Transport properties of treated CMWGs

3.4 Constitutive and numerical modelling



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WORK PACKAGE 3
CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

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TASK 3.1
UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

Producing ordinary Portland cement and polymer concrete products with CMWGs used as aggregates in substitution of ordinary stone aggregates.

1. Taking care of the development and testing of ordinary Portland cement concrete with CMWGs and also working on adaptation of the achieved mix-design formulations to different application technologies: direct pouring of self-compacting mixes, spraying or shotcrete, even including disperse fibre reinforcement employing fibres made with different materials (steel, polymer).

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2. Conducting scalability of the production to real scale applications.

3. Producing polymer concrete mixes, following same testing protocol as in item 1, and focusing on applications in different parts of mining activities as a part of circular economy approach.

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WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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The feasibility study of using the selected CMWGs as replacement of natural aggregates in concrete has started at PoliMi.

Investigated mixes with different replacement volume percentages of CMWGs

Specimen	CMWG	Natural fine	CMWG < 10mm	Natural coarse	CMWG > 10mm
Reference 1	-	100%	-	100%	-
Reference 2	-	100%	-	100%	-
Coarse replacing	MINRE-MARCEL-001	100%	-	75%	25%
Fine replacing 1	MINRE-MARCEL-001	75%	25%	100%	-
Fine replacing 2	MINRE-MARCEL-001	75%	25%	100%	-
Coarse and fine replacing	MINRE-MARCEL-001	87%	13%	87%	13%
Coarse replacing	MINRE-WALB-003	100%	-	75%	25%
Coarse replacing**	MINRE- WALB-003	100%	-	75%	25%

Reference mix

Material	[kg/m^3]
Cement	330
Sand	964
Gravel	896
Filler	77
Superplasticiser	1.98
Water/Cement	0.48
Water [l/m^3]	158

TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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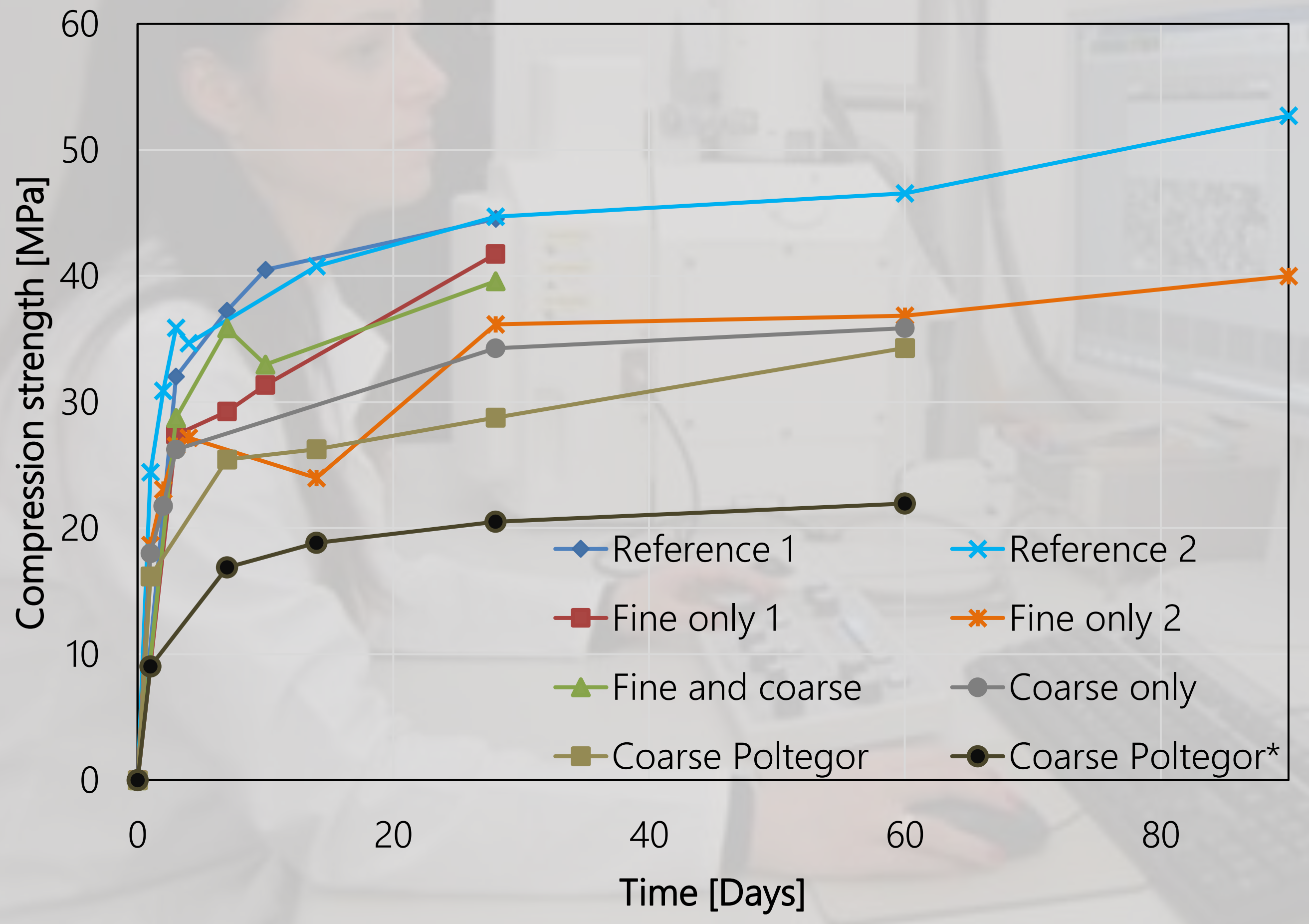
WORK PACKAGE 3
CLOSING THE CYCLE OF CMWGS
APPLICATION IN CONSTRUCTION

Evolution of cubic compressive strength for the different investigate mixes



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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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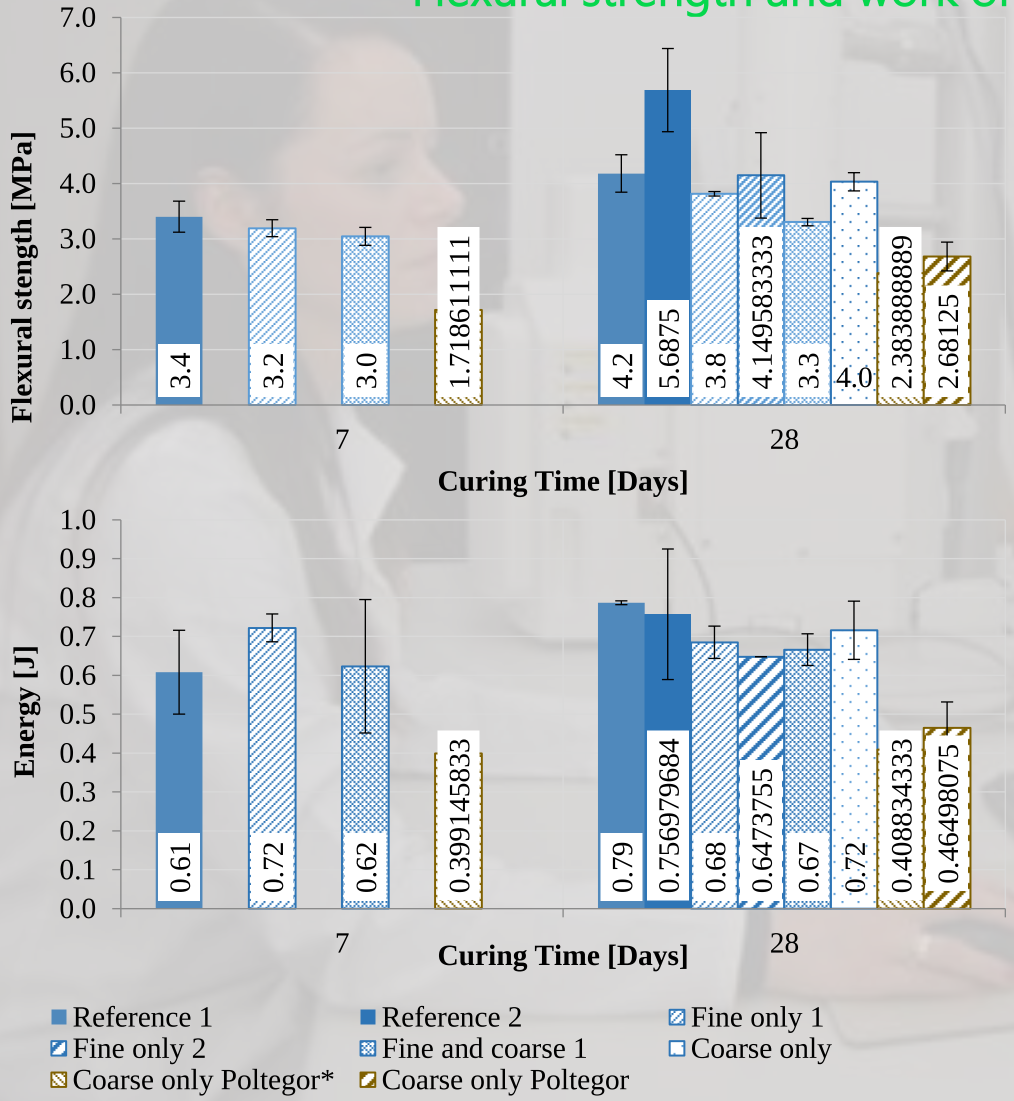
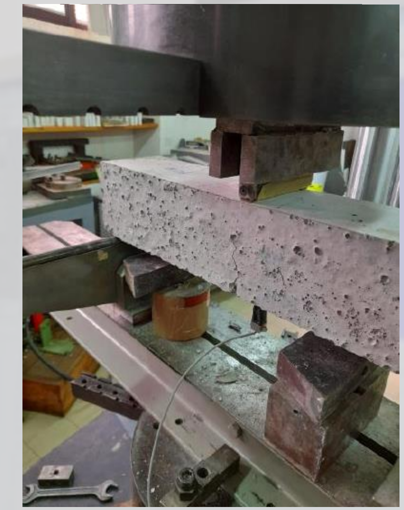
CLOSING THE CYCLE OF CMWGS
APPLICATION IN CONSTRUCTION

Flexural strength and work of fracture for investigated mixes





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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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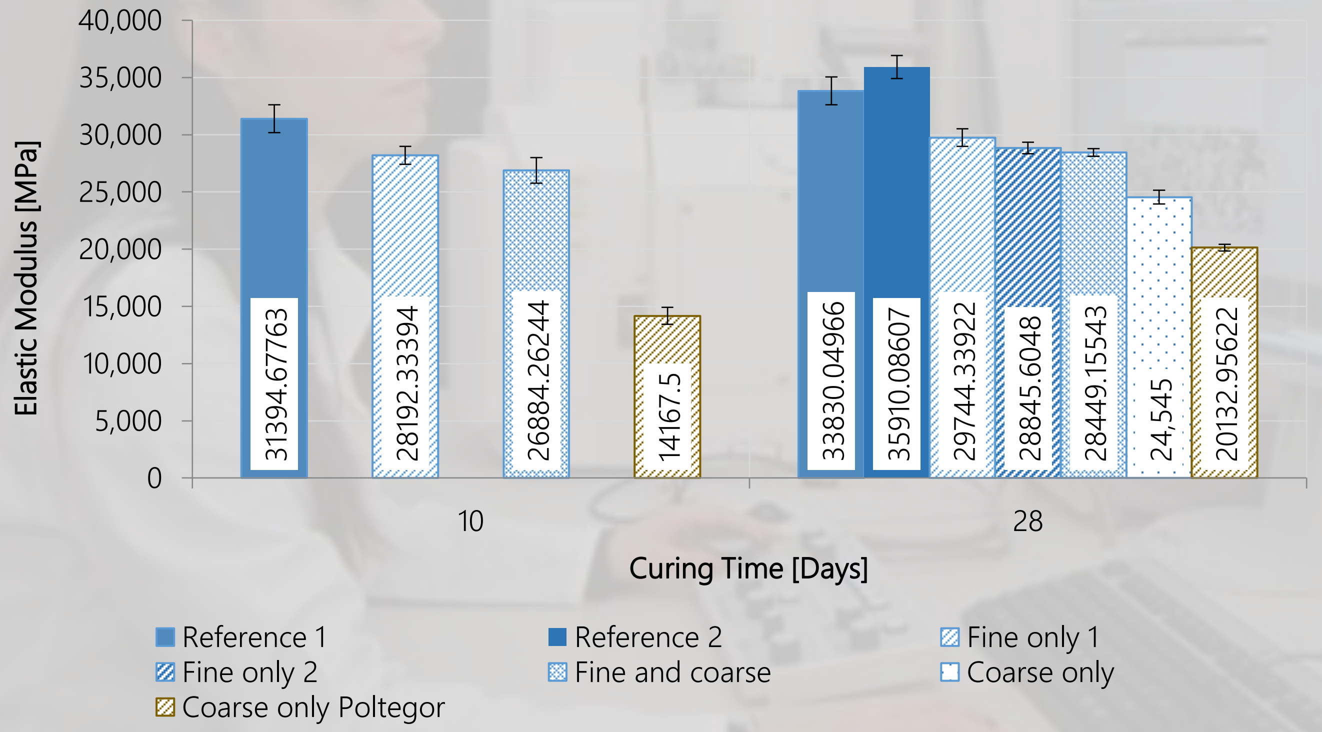
CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

Elastic modulus of investigated mixes



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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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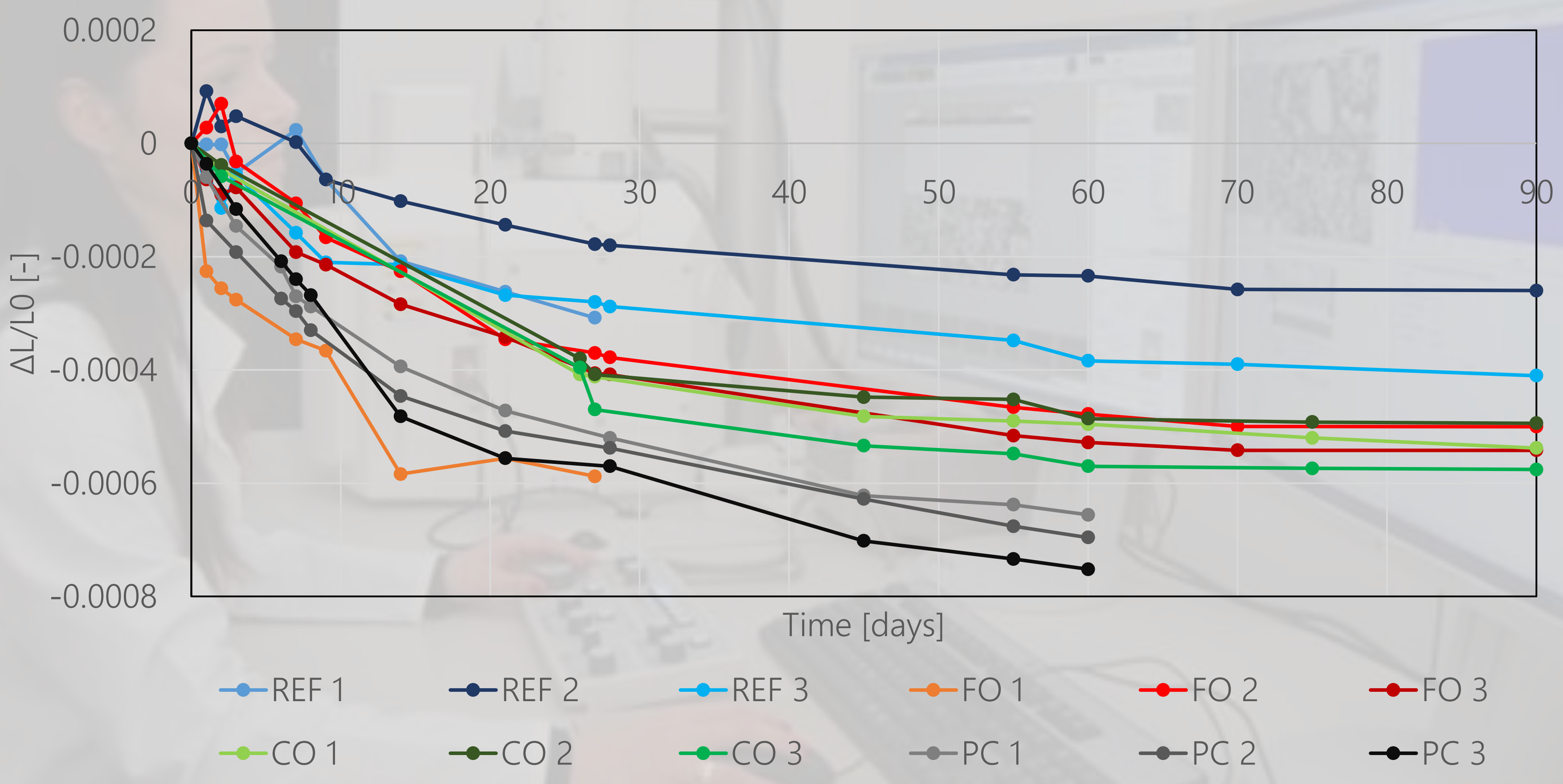
Shrinkage tests



TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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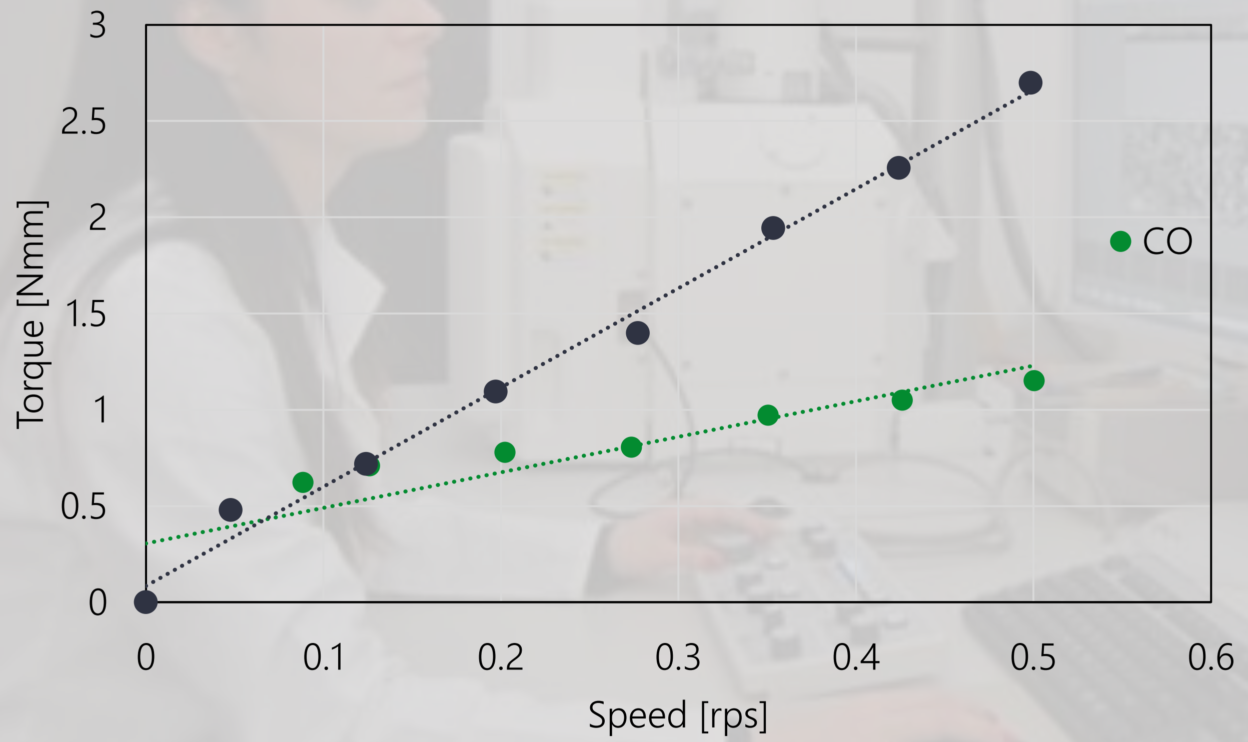
Rheological tests



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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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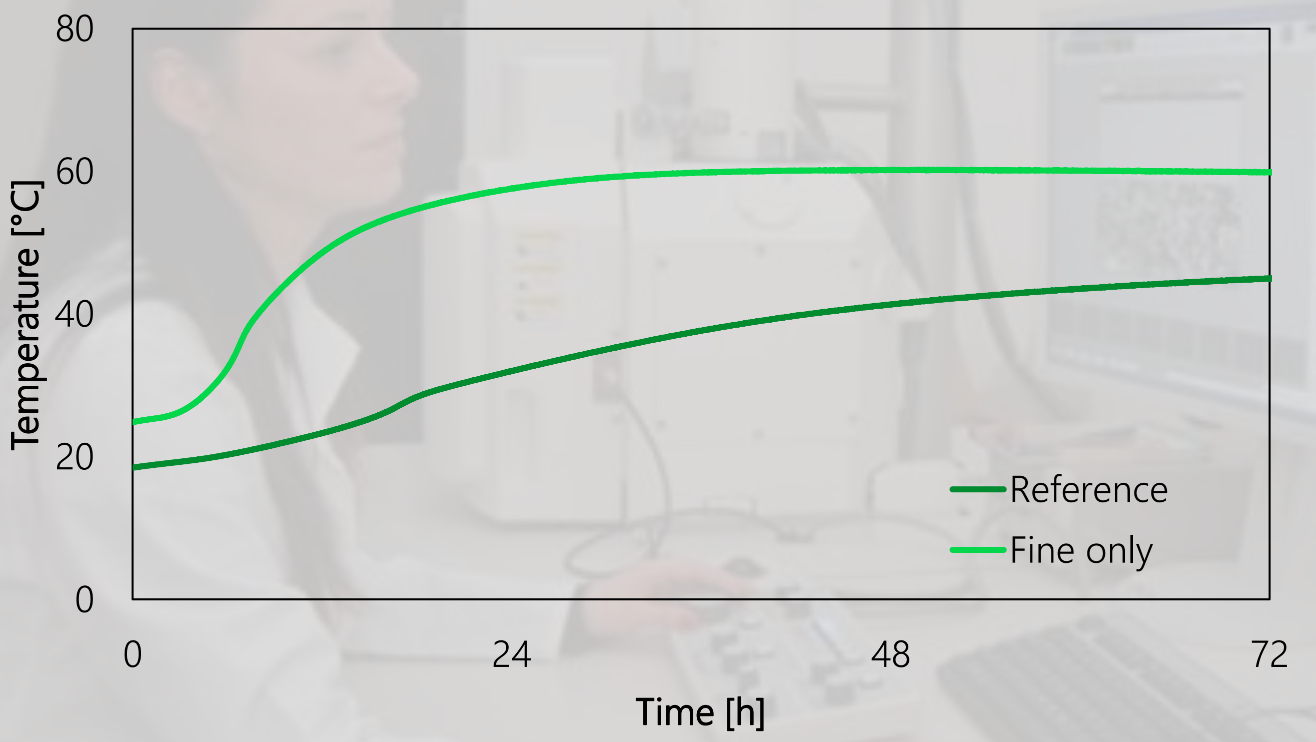
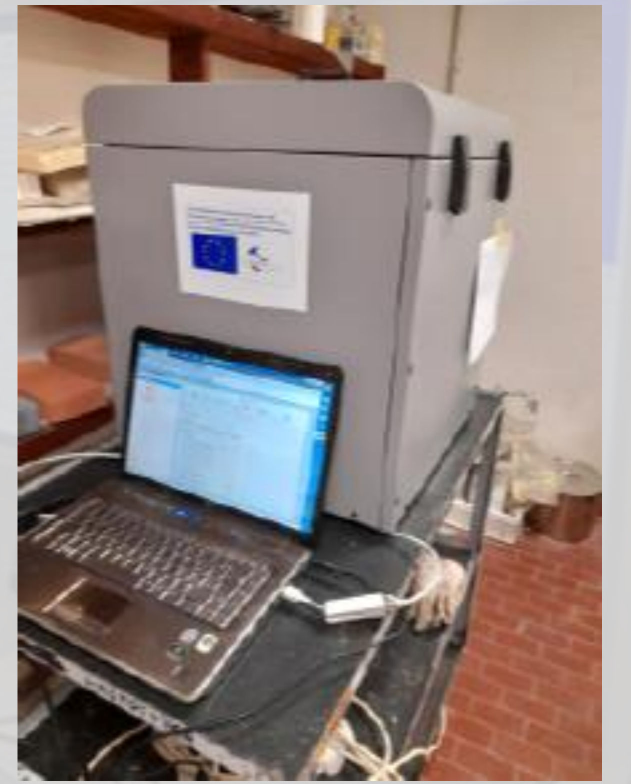
Calorimeter tests





TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

With respect to task 3.1, GIG worked on development of polymer concrete mixture with CMWGs. The aim of the research was to check the feasibility of making polymer concrete mixtures and to evaluate the mechanical properties as an input data for design and modelling work in task 3.3.

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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

The bending strength test was carried out based on the PN-EN 196-1: 2016-07 standard. The air-conditioning and testing of samples was carried out in accordance with the PN-EN ISO 291: 2010 standard in the following ambient conditions: temperature 23 ± 2°C, relative air humidity 50 ± 10%.

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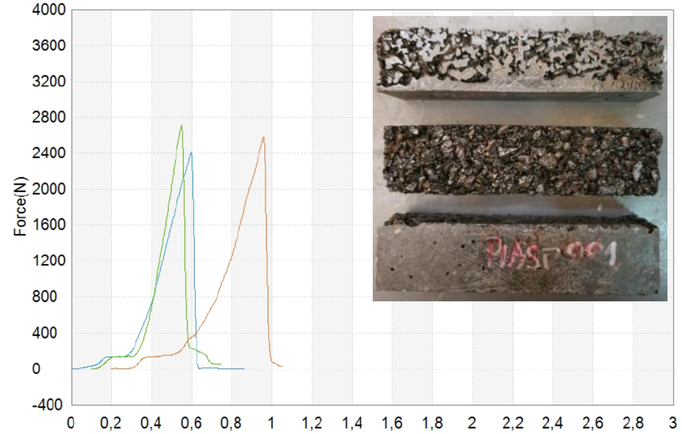
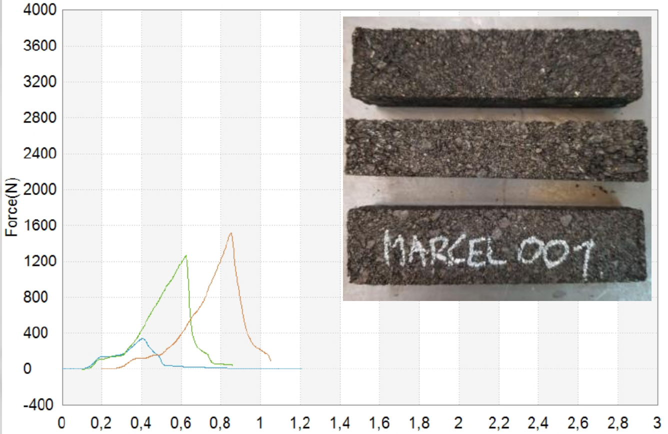
TASK 3.1

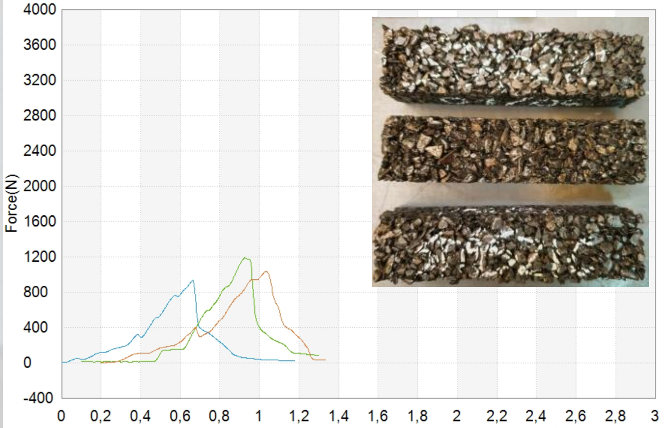
UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

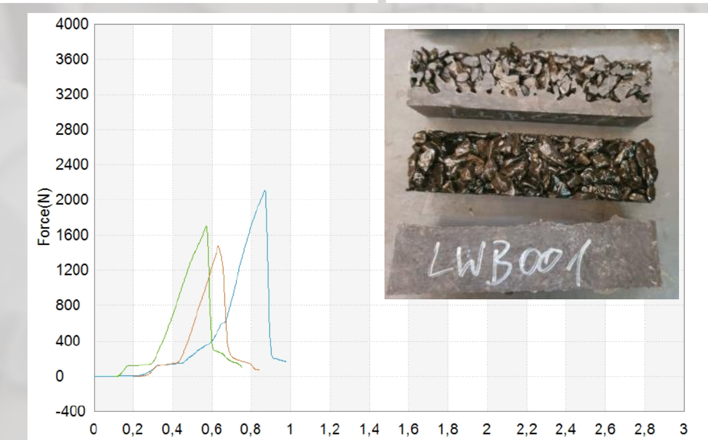
WORK PACKAGE 3
CLOSING THE CYCLE OF CMWGS
APPLICATION IN CONSTRUCTION

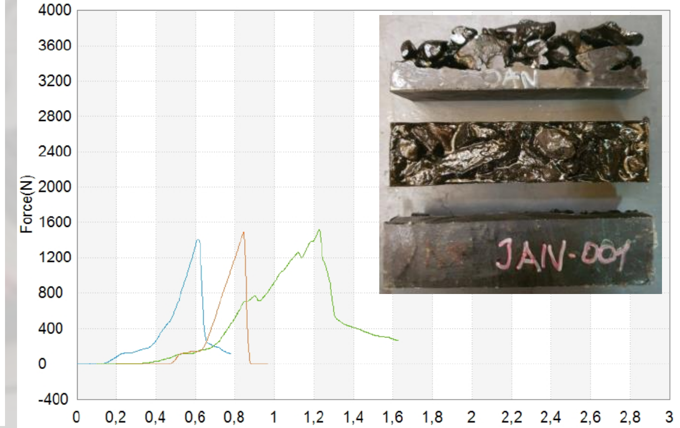
Bending strengths of polymer concretes made with CMWGs











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TASK 3.1

UPCYCLING OF CMWGS AS CONSTITUENTS IN CONSTRUCTION MATERIALS AND ADAPTION TO DIFFERENT APPLICATION TECHNOLOGIES

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WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

Bending strengths of polymer concreter made with fine-grained wastes

Sample	Bottom ash	Fly ash	Limestone 2-6 mm	Resin	Average Stress
	wt. %				[MPa]
GS1	81	4	0	15	23.4
GS2	81	4	0	15	25.1
GS3	85	0	0	15	25.7
GS4	61	4	20	15	25.1
GS5	65	0	20	15	24.8
GS6	81	4	0	15	2.31
GS7	85	0	0	15	1.76
GS8	61	4	20	15	20.1
GS9	65	0	20	15	24.0
GS10	81	4	0	15	12.1
GS11	85	0	0	15	11.6
GS12	61	4	20	15	24.4
GS13	65	0	20	15	20.8
GS14	61	4	20	15	23.9

Bending strengths of polymer concretes made with CMWGs

Sample	Mining waste	Resin	Fraction	Average Force	Averag e Stress
	[wt. %]		[mm]	[N]	[MPa]
MINRE-LWB-001	80	20	0-20	1760	4.45
MINRE-JAN-001	80	20	0-20	1466	3.23
MINRE-MARCEL-001	80	20	0-20	1036	3.16
MINRE-PIAST-001	80	20	0-10	2565	6.67
MINRE-STASZIC-001	80	20	0-20	1050	2.43

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WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

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TASK 3.2

DURABILITY PERFORMANCE OF PORTLAND CEMENT CONCRETE CONTAINING TREATED CMWGS

Investigating the long-term behaviour of formulated concrete-like mixtures in laboratory simulated environments intended to replicate target real-site exposure conditions and combining mechanical and environmental actions.

1. Evaluation of the interaction of aggressive environments with concrete

2. Evaluation of the cover degradation and thickness loss, mass loss due to degradation of concrete as consequence of water, acid and chloride attack and in simulated environments in monolithic concrete samples

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3. Evaluation of the corrosion resistance of the material by itself as well as onset of active corrosion of "covered" reinforcement bars analysed through electrochemical techniques, corrosion potential and corrosion rate through polarisation resistance

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4. Evaluation of freeze/thaw resistance in aggressive waters, through measurement of scaling and capillary suction using neutron radiography in cracked and un cracked states

5. Providing feedback from the results of mechanical experiments and the effects of strength parameters' variabilities on their expected performance when used as aggregates in the new products.

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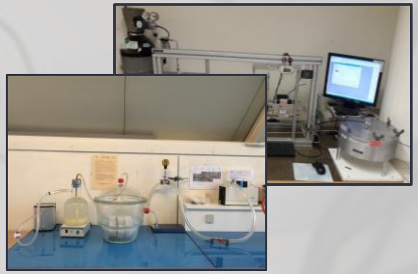

WORK PACKAGE 3
CLOSING THE CYCLE OF CMWGS
APPLICATION IN CONSTRUCTION

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TASK 3.3

PROTOTYPING AND DURABILITY PERFORMANCE VALIDATION OF NEW (PRECAST) PRODUCTS EMPLOYING ADVANCED CONCRETE-LIKE MATERIALS WITH CMWGS

Design of new products made of new ordinary Portland cement and polymer concrete mixtures with CMWGs.




1
Designing, producing and installing precast concrete elements and samples using a set of mix designed within the frame of the Task 3.1

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2
Parametric investigation in the sight of commercial implementation of precast element production to validate and optimise the behaviour of the newly developed products, including the viability assessment of their future application.

GIG



3
Testing the new polymer concrete products in underground conditions

GIG

TASK 3.3

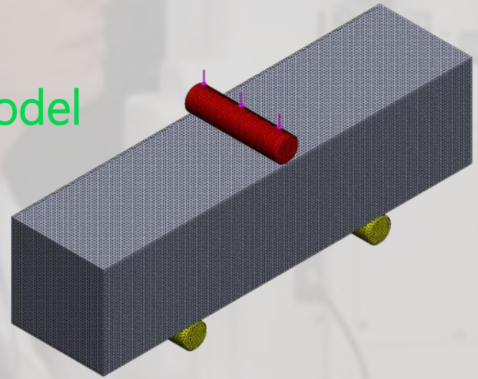
PROTOTYPING AND DURABILITY PERFORMANCE VALIDATION OF NEW (PRECAST) PRODUCTS EMPLOYING ADVANCED CONCRETE-LIKE MATERIALS WITH CMWGS

WORK PACKAGE 3
CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

GIG

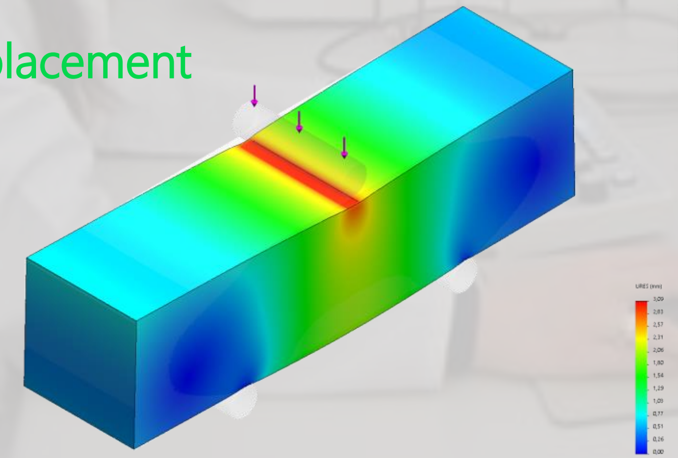
With respect to task 3.3, in sight of commercial implementation of precast element production, a parametric investigation is underway by GIG using SolidWorks® to validate and optimise the behaviour of the newly developed polymer concrete.

FEM model

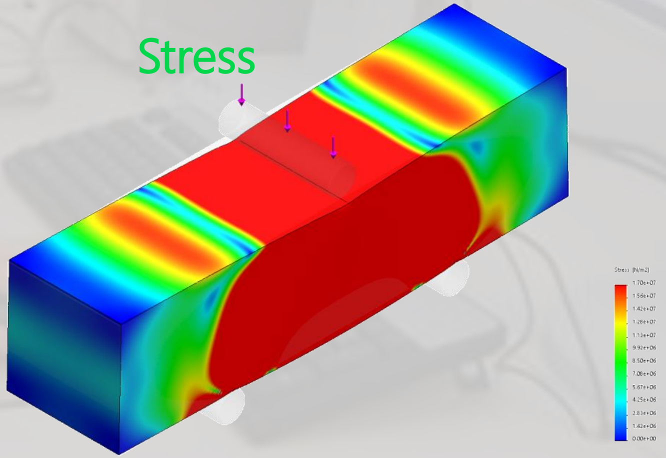


Young modulus	Poisson's ratio	Density	Tensile strength
[MPa]	[-]	[kg/m^3]	[MPa]
4000	0.23	2250	10.5

Displacement



Stress



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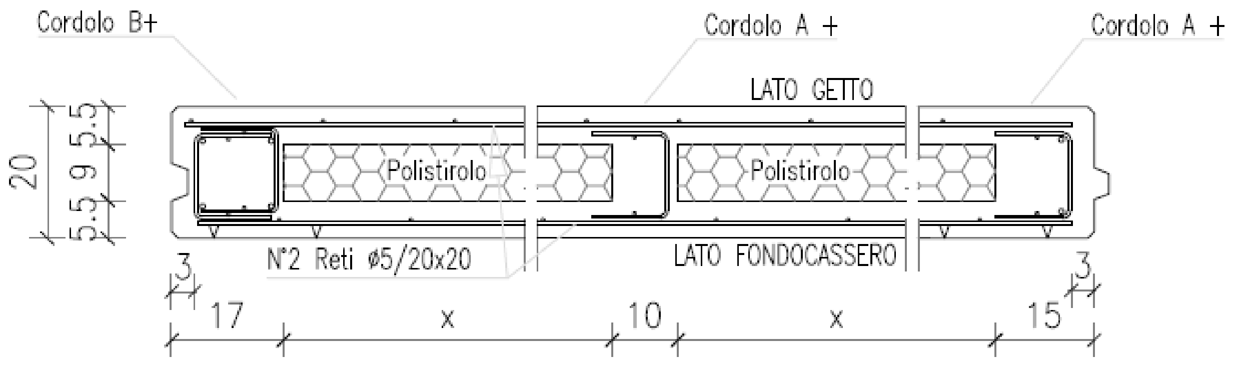
TASK 3.3

PROTOTYPING AND DURABILITY PERFORMANCE VALIDATION OF NEW (PRECAST) PRODUCTS EMPLOYING ADVANCED CONCRETE-LIKE MATERIALS WITH CMWGS

TesiSystem

In this task, NTS (in collaboration with PoliMi) has started developing the structural design of the demonstrator, which has been identified as a cladding panel for precast reinforced concrete industrial buildings.

Specimen	ID	Natural fine	CMWG<10 mm	Natural coarse	CMWG>10 mm
Reference	REF	100%	-	100%	-
Fine and Coarse	FC	87%	13%	87%	13%



WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

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WORK PACKAGE 3

CLOSING THE CYCLE OF CMWGS APPLICATION IN CONSTRUCTION

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TASK 3.4

DURABILITY PERFORMANCE OF PORTLAND CEMENT CONCRETE CONTAINING TREATED CMWGS

Environmental and technico-economic assessments of the treatment routes developed in the MINRESCUE project and the upcycling of the CMWGs in the construction products.

1. The inventory of current practices in coal mines for the management of wastes, and the assessment of the costs associated to health and environmental damages.

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2. The inventory of current practices in construction sector and the identification of scenarios for the use of CMWGs or new products designed in Task 3.1, 3.2 and 3.4

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3. The modelling of the unit process operations required for the metallurgical pre-treatment and the upcycling of CMWGs (developed in Tasks 1.2 and 3.1, 3.2 and 3.3), using USIM PAC software.

   GIG, UNIVERSITY OF EXETER, POLITECNICO MILANO 1863

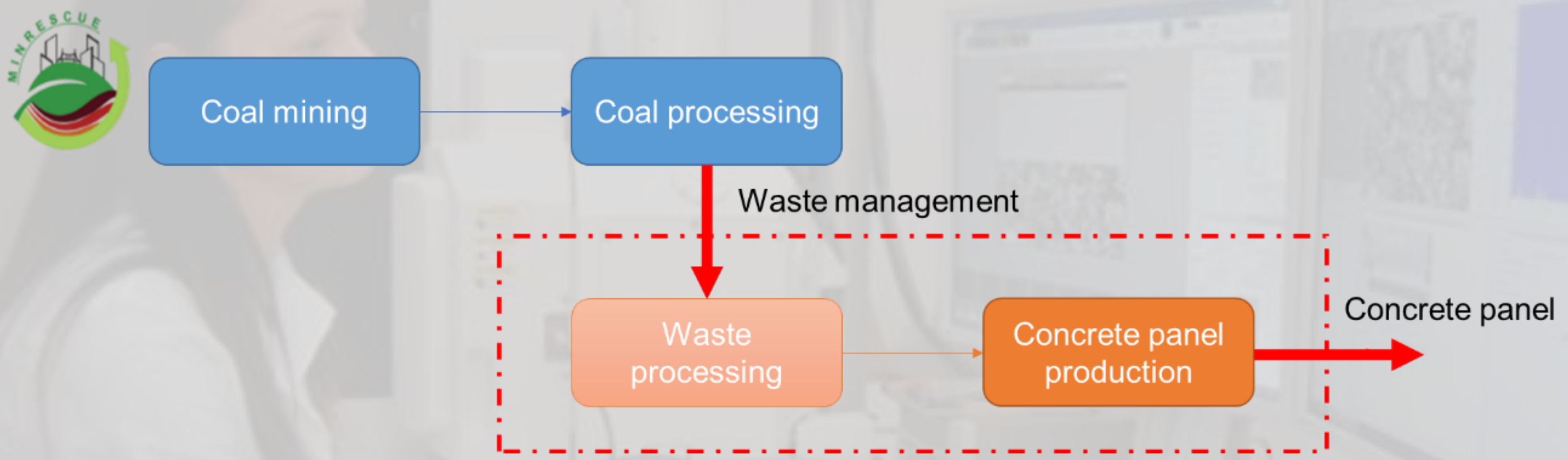
4. Life cycle assessment in order to assess environmental performances of MINERESCUE concept

5. The economic evaluation of the scenarios identified previously.

TASK 3.4

DURABILITY PERFORMANCE OF PORTLAND CEMENT CONCRETE CONTAINING TREATED CMWGS

MINRESCUE SCENARIO



BUSINESS AS USUAL SCENARIO

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MILESTONES

WP1

- M1.1: Development of characterisation and pre-treatment strategy for upcycling of CMWGs (M24)

WP2

- M2.1: Validation of constitutive models for CMWGs and calibration of model parameters with the available experimental results (M36)
- M2.2: Numerical implementation of developed models to provide suitable modelling tool and guideline for construction industry (M36)

WP3

- M3.1: A holistic approach to the production of cementitious composites containing CMWGs: mechanical & durability property assessment (evaluation: completion of D 3.1, D 3.3). (M36)
- M3.2: Realisation of prototype with concrete containing CMWGs. (M30)
- M3.3: Technical and economic feasibility of upcycling CMWGs in construction materials and products (assessment completion of D 3.5). (M36)

DELIVERABLES

WP1

- D1.1: Database rationale of characteristics of existing CMWGs (M18)
- D1.2: Characterisation of physical and chemical properties of CMWGs for their upcycling in construction materials (M24)
- D1.3: Treatment protocols of mining waste (M24)

WP2

- D2.1: Results of characterisation of mechanical and geotechnical properties related to CMWGs, and evolution of their properties in the long-term (M24)
- D2.2: Report on durability of CMWGs' transport properties (M24)
- D2.3: Results of numerical modelling of CMWGs (M36)

WP3

- D3.1: Guidelines to performance based mix-design formulation of ordinary Portland cement containing CMWGs and adaption to different technologies (M24)
- D3.2: Guidelines to performance based proportioning polymer concrete containing CMWGs (M24)
- D3.3.1: Durability properties of cement based construction materials and products employing CMWGs (M36)
- D3.3.2: Durability performance of polymer concrete products employing CMWGs (M36)
- D3.4: LCA of upcycling CMWGs in construction materials and products (M36)

DELIVERABLES

00

1 Dec 2020

Deliverables
D5.1 (All partners)
D5.2 (GIG)
D5.3 (All partners)

1 Mar 2021

Deliverables
D4.2 (UOW)

12

1 Sep 2021

Deliverables
D4.1.1 (UOW)
D5.3 (All partners)

1 Mar 2022

Deliverables
D1.1 (GIG)
D5.3 (All partners)

24

1 Sep 2022

Deliverables
D1.2 (UNEXE)
D1.3 (GIG)
D2.1 (UOW)
D2.2 (UOW)
D3.1 (PoliMi)
D3.2 (GIG)
D4.1.2 (UOW)
D4.2 (UOW)
D5.1 (All partners)
D5.3 (All partners)

1 Mar 2023

Deliverables
D4.2 (UOW)

36

31 Aug 2023

Deliverables
D2.3 (SUB)
D3.3.1 (CY)
D3.3.2 (GIG)
D3.4 (BRGM)
D4.1.3 (UOW)
D5.1 (All partners)
D5.3 (All partners)
D5.4 (GIG)

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