DEFEAT

Development of an Innovative Insulation
Fire Resistant Facade from the
Construction and D**e**molition W**a**s**t**e.

Newsletter

4th issue: December 2023

DEFEAT Highlights

The DEFEAT project is due to be completed at the end of 2023 having achieved all its scientific and technical goals. Upon completion, it will have substantially contributed to research and innovation in critical sectors of the Cypriot economy and society, such as the management of CDW and the improvement of the buildings energy efficiency and passive fire protection.

DEFEAT project progress

Due to the Covid-19 pandemic difficulties and limitations occurred in the first two years of the project, the project Coordination, on behalf of the project Consortium, requested and granted a 6-months extension form RIF.

This extension was deemed necessary for the successful completion of all the contractual obligations and deliverables of the project.

The project will be completed at the end of 2023 (31/12/2023), having achieved all its scientific and technical objectives delivered and successfully and on time all its Deliverables.

The most significant achievements of DEFEAT project in the last 12 months:

- ***Separation of the Construction and Demolition Waste in real conditions*** / Demonstration of the Automated CDW Sorting Prototype System in pilot-scale (FRC, UCY, Netiatis).
- ***Pilot-scale production of the DEFEAT final product, the Geopolymer Composite Facade,*** using the production techniques of casting and 3D-printing (FRC, UCY, Netiatis, RECS, Pharmakas).
- ***Feasibility Study*** (techno-economic evaluation) and ***Life Cycle Assessment*** (LCA) of the DEFEAT products (RECS, Pharmakas, UCY).
- ***Business Plan***: market study and scenarios for the penetration of the DEFEAT products (STRATAGEM, RECS, Pharmakas).
- ***Design and Costing of a large-scale Manufacturing Plan*** for the DEFEAT final product (RECS, Pharmakas, FRC).

The scientific achievements and research results of DEFEAT project were disseminated through the following events:

- ✓ Workshop "**An Innovative Robotic Separation Method of the Construction and Demolition Waste (CDW)**"
- ✓ Demonstration Event "**Demonstration of the Applicability and Performance of Fire Resistance Façades developed from Construction and Demolition Waste (CDW)**"
- ✓ Symposium "**A Day of Scientific Insight and Innovation**"

DEFEAT Workshop

DEFEAT Symposium

Demonstration Event

DEFEAT

Implementation of an Automated Construction and Demolition Waste Sorting Prototype

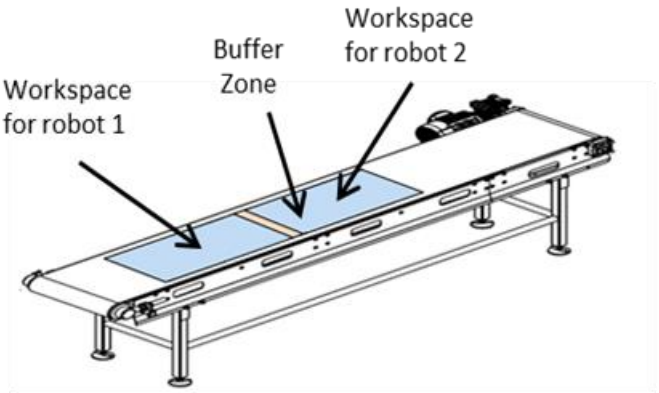
CDW Robotic Separation System

A pilot-scale Automated CDW Sorting prototype system is developed and evaluated. The system utilizes a supervised deep learning image processing approach in conjunction with robotic arm manipulators to achieve precise separation of rubbles into their respective types.

The YOLO (You Only Look Once) deep learning object detection architecture emerged as the pivotal choice for this task, demonstrating exceptional capabilities in real-time object location and classification.

YOLO detection & classification process

The developed YOLO models were seamlessly integrated with a robotic system, resulting in a prototype CDW separation system. This system comprises an industrial camera, a conveyor belt, two robotic manipulators, and a dedicated local PC. The conveyor belt, driven by a stepper motor for higher precision, is divided into three notional sectors: the camera capture area and the two robot working spaces. The camera captures CDW objects in the first sector, and the deep learning model processes the information, identifying material type, location coordinates, and size of each rubble. This data is then passed to the two robotic manipulators, which efficiently separate the rubble into two groups based on location on the conveyor.



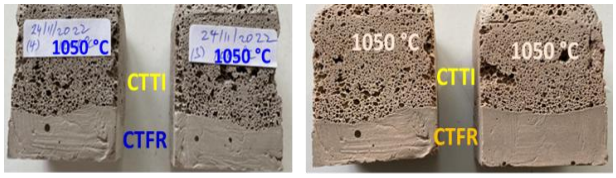
Prototype CDW Separation System

The **Prototype Automated CDW Separation System** demonstrates an excellent physical environment for implementing and testing the performance and accuracy of the deep learning process in real-time applications. The small-scale hardware prototype proves the concept of a fully automated CDW sorting system, showcasing the capabilities of data communication, analysis, and feedback between the vision system, conveyor belt, and robotic manipulators. The **innovative system** developed in the DEFEAT project not only represents a significant leap forward in the waste management technology but also underlines the potential for automation in addressing environmental challenges. Moving towards a more sustainable future, this system stands as a testament to the power of technology in revolutionizing traditional processes and paving the way for efficient, eco-friendly solutions. ***The project Partners FRC, UCY and Netiatis were cooperating for this achievement.***

The research results of the Automated CDW Sorting Prototype System development and up-scaling are included in two papers submitted and accepted for publication in peer-reviewed journals.

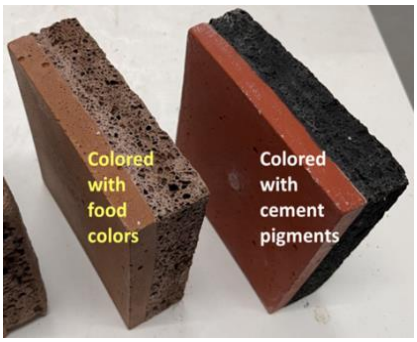
Prototype of the DEFEAT Composite Material: Lab-scale testing and Pilot-scale validation

The innovative **DEFEAT Composite Material** (DEFEAT-CM) developed in the frame of DEFEAT project to be used for the heat and fire resistance of buildings was successfully tested in lab-scale for mechanical and thermal properties. The innovative material consists of two geopolymer layers, compact and foamed, which were bonded together during the production. The DEFEAT-CM showed compressive strength approximately three times higher than that of common materials used for the fire resistance and thermal insulation of buildings (i.e. gypsum boards). The bulk density of the geopolymer composite was lower than 900 kg/m^3, which is comparable to that of the gypsum boards (600 - 1000 kg/m^3), while it was thermally stable at temperatures up to 1050 °C, showing mass loss less than 8 %wt. and low dry linear shrinkage. Finally, good adhesion bonding was also noted between the two layers of geopolymers.



before exposure to 1000 °C after exposure to 1000 °C

Lab-scale CTFR-CTTI prototype



Large-scale colored CTFR-CTTI prototype

The DEFEAT Composite Material was also validated in pilot-scale, using samples of dimensions 40x40x5 cm^3. No significant deviation was observed in the properties of DEFEAT-CM between the lab- and pilot-scale. Besides, cement pigments and food colors were successfully used for its coloring. The production process followed for the new material was proved reliable and repeatable. By the project completion, the DEFEAT-CM achieved a TRL 4-5, which is an excellent bridge to pass from the scientific lab-scale research to the innovative building facade engineering. ***The project Partners FRC, UCY, Netiatis, RECS and Pharmakas were cooperating for this achievement***.

Pilot-scale production of the DEFEAT Composite Material with the 3D printing technique

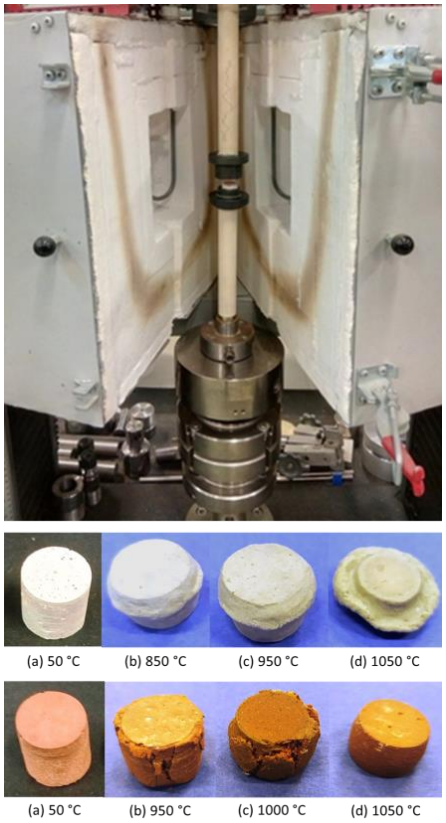
The Additive Manufacturing (AM) technology was applied in pilot-scale for the 3D printing of the DEFEAT-CM. For this activity, the 3D Printing machine *DELTA WASP 3MT 4.0 LMD* with manual concrete extruder, which is established in the laboratory of FRC, was used. A 3D-printing pattern of 60% infilling was selected for the up-scaling of the process, using the mix designs of the optimum fire-resistant geopolymers. The formation of voids in the selected pattern was advantageous to achieve a lightweight and fire-resistant geopolymer with low thermal conductivity and sufficient mechanical strength. The rheological properties of used mixtures and the selected 3D printing pattern were proved crucial for the process and the properties of the final materials. Moreover, the filament height and width and the printed layer thickness were proved to affect the porosity developed in the interlayer of the final materials. The up-scaled 3D printed DEFEAT Composite Material reached comparable mechanical strength and density to those of the corresponding material produced by the casting process. ***The up-scaling of the 3D-printing process for the DEFEAT-CM production was carried out by FRC***.

3D printing of BW-based geopolymer

Fire resistance testing of DEFEAT Composite Material

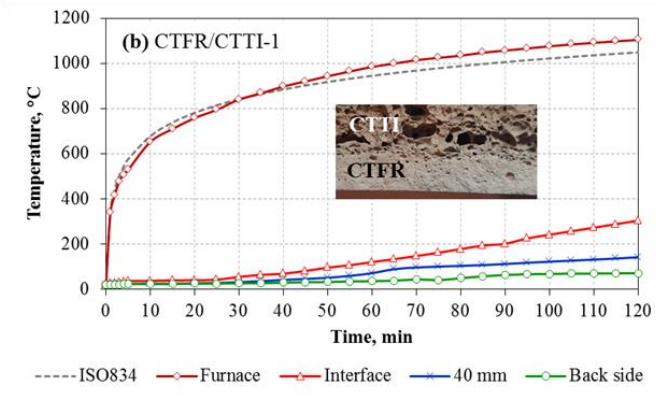
The performance of the optimum fire-resistant geopolymers composing the DEFEAT-CM was evaluated, during and after their exposure to fire.

The compressive deformation testing at high temperatures with simultaneous load bearing revealed a linear elastic behavior for the brick waste-based fire-resistant geopolymer (BFR) up to 950 °C, a plastic deformation at 1000 °C and a pseudo-plastic behavior at the end of the test (1050 °C), which resulted in the plastic deformation of sample, without its breaking. Under the same test, the ceramic tile waste-based fire-resistant geopolymer (CTFR) exhibited plastic deformation at 850 °C, which became permanent with intensive signs of melting by the end of the test, at 1050 °C. After exposure at high temperatures, the BFR geopolymer lost ~20% of its initial compressive strength at 600 °C, which was recovered after exposure to 800 °C and increased at 1050 °C. Accordantly, the initial compressive strength of CTFR decreased of about 50% after its exposure to 600 °C and of an additional 10%, after exposure to 800 °C, while after being exposed at 1050 °C, it exceeded the initial compressive strength by almost 10%. The variations observed in the mechanical behavior of geopolymers were attributed to microstructural transformations occurred in the formed geopolymeric alkali-aluminosilicate hydrate gel phase.



On-fire testing of optimized fire-resistant geopolymers

The fire resistance of DEFEAT products was also evaluated according to the ISO834 standard. Although both the BFR-CTTI and CTFR-CTTI geopolymer composites failed the fire resistance testing according to the ISO834 standard, they achieved to meet the requirement to keep the temperature at the concrete-geopolymer interface below the critical value of 180 °C, for more than one hour. Besides, both the DEFEAT products succeeded to maintain the temperature at the interface with the concrete at 300-360 °C, after two hours exposure to fire, which is below the critical temperature for concrete exfoliation and explosive spalling phenomena starting to occur (~380 °C). These achievements are of great importance for the efficient passive fire protection of a building.

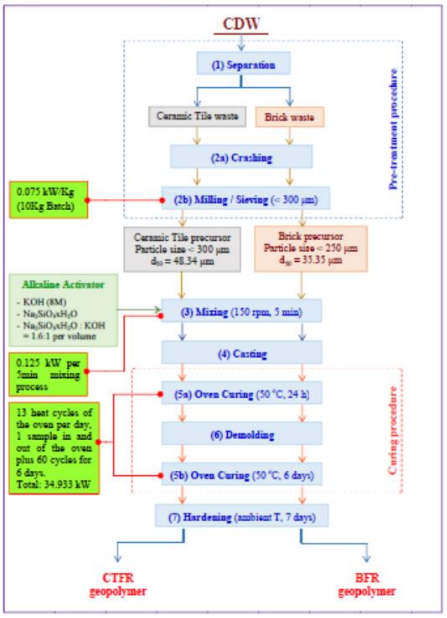


Testing of DEFEAT products according to the ISO834 time-temperature standard

The research results of the fire resistance testing are included in two scientific papers submitted and accepted for publication in peer-reviewed journals.

Flow sheets of the DEFEAT Composite Material production processes

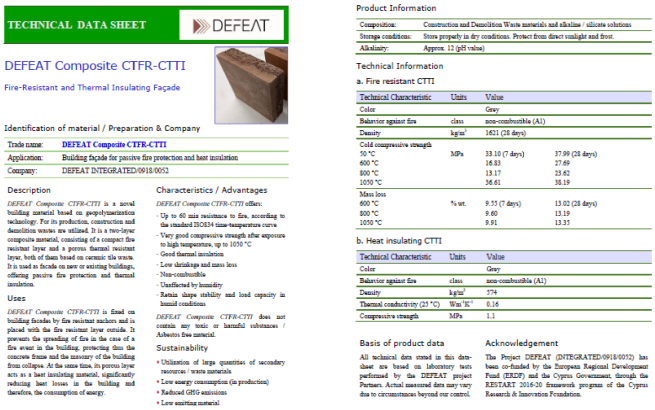
The flowsheets of the casting and 3D printing processes investigated for the production of the innovative DEFEAT Composite Material (DEFEAT-CM) were finalized, including also data of energy consumption for the most critical stages. Casting process was assessed as suitable for on-site and off-site production of the new material. According to this production route, the fire-resistant and the thermal insulation geopolymers are separately produced and then, they are combined into the DEFEAT-CM either, by fixing with fireproofing anchors or by pouring the fresh foam geopolymer layer onto the surface of the compact one, which could be fresh or hardened. The 3D printing process takes advantage of the printing pattern that form voids in their structures, so as to achieve a lightweight and fire-resistant geopolymer with low thermal conductivity and sufficient mechanical strength. From technical point of view, both manufacturing processes can be used for the production of the DEFEAT Composite material. ***The project Partners FRC and RECS were cooperated for this achievemen***t.



Flow sheet of casting process

Technical data sheets of the DEFEAT Composite Material

The Technical Data Sheets of the main products of DEFEAT project (geopolymer composite facades), the CTFR-CTTI and the BFR-CTTI, were successfully developed. Each Technical Data Sheet includes a brief description of the corresponding product, its origin and structural design, as well as brief information on the product uses, its technical characteristics and advantages and the related environmental impact and sustainability. Moreover, the Technical Data Sheet summarizes the values of the main properties, as they obtained from products testing against heating and fire. ***The Technical Data Sheets of the DEFEAT main products were composed by the project Partner FRC***.


TECHNICAL DATA SHEET

DEFEAT Composite CTFR-CTTI

Fire-Resistant and Thermal Insulating Façade

Identification of material / Preparation & Company

Trade name:	DEFEAT Composite CTFR-CTTI
Application:	Building façade for passive fire protection and heat insulation
Company:	DEFEAT INTEGRATED/0918/0052

Description

DEFEAT Composite CTFR-CTTI is a novel building material based on geopolymerization technology. For its production, construction and demolition wastes are utilized. It is a two-layer composite material, consisting of a compact fire resistant layer and a porous thermal resistant layer, both of them based on ceramic tile waste. It is used as facade on new or existing buildings, offering passive fire protection and thermal insulation.

Uses

DEFEAT Composite CTFR-CTTI is fixed on building facades by fire resistant anchors and is placed with the fire resistant layer outside. It prevents the spreading of fire in the case of a fire event in the building, protecting thus the concrete frame and the masonry of the building from collapse. At the same time, its porous layer acts as a heat insulating material, significantly reducing heat losses in the building and therefore, the consumption of energy.

Characteristics / Advantages

DEFEAT Composite CTFR-CTTI offers:

- Up to 60 min resistance to fire, according to the standard ISO834 time-temperature curve
- Very good compressive strength after exposure to high temperature, up to 1050 °C
- Good thermal insulation
- Low shrinkage and mass loss
- Non-combustible
- Unaffected by humidity
- Retain shape stability and load capacity in humid conditions

DEFEAT Composite CTFR-CTTI does not contain any toxic or harmful substances / Asbestos free material.

Sustainability

- Utilization of large quantities of secondary resources / waste materials
- Low energy consumption (in production)
- Reduced GHG emissions
- Low emitting material

Product Information

Composition:	Construction and Demolition Waste materials and alkaline / silicate solutions
Storage conditions:	Store properly in dry conditions. Protect from direct sunlight and frost.
Alkalinity:	Approx. 12 (pH value)

Technical Information

a. Fire resistant CTTI

Technical Characteristic	Units	Value	
Color		Grey	
Behavior against fire	class	non-combustible (A1)	
Density	kg/m³	1621 (28 days)	
Cold compressive strength			
50 °C	MPa	33.10 (7 days)	37.99 (28 days)
600 °C		16.83	27.69
800 °C		13.17	23.62
1050 °C		36.61	38.19
Mass loss			
600 °C	% wt.	9.55 (7 days)	13.02 (28 days)
800 °C		9.60	13.19
1050 °C		9.91	13.35

b. Heat insulating CTTI

Technical Characteristic	Units	Value
Color		Grey
Behavior against fire	class	non-combustible (A1)
Density	kg/m³	374
Thermal conductivity (25 °C)	W/m·K	0.16
Compressive strength	MPa	1.1

Basis of product data

All technical data stated in this data-sheet are based on laboratory tests performed by the DEFEAT project Partners. Actual measured data may vary due to circumstances beyond our control.

Acknowledgement

The Project DEFEAT (INTEGRATED/0918/0052) has been co-funded by the European Regional Development Fund (ERDF) and the Cyprus Government, through the RESTART 2016-20 framework program of the Cyprus Research & Innovation Foundation.

Technical Data Sheet of DEFEAT product CTFR-CTTI

Up-scaling of the lightweight fire-resistant and insulating geopolymer panel at KU Leuven

The optimum brick and ceramic tile waste-based foamed inorganic polymers (IPs) developed at KUL showed density below 600 kg/m^3, compressive strength of about 2 MPa and thermal conductivity of 0.13 – 0.14 W/(K·m). As a proof of concept, the mix-design developed for this material was up-scaled and a porous lightweight panel of dimensions 1x1x0.04 m^3 was produced. The up-scaling process was completed in 2 steps: from lab- to medium-scale with

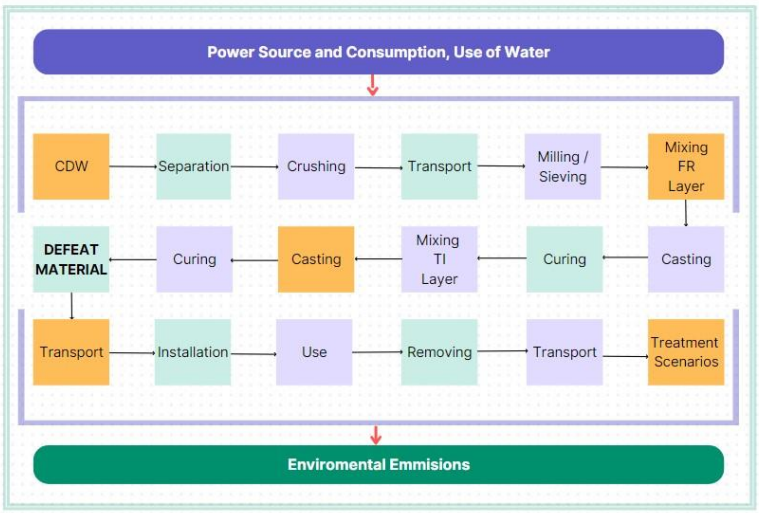
Up-scaled of lightweight panel

the production of a 40x40x5 cm^3 panel and from medium- to pilot- scale with the production of a 100x100x4 cm^3 one. During the upscaling process, two main points were in focus: the feasibility / smoothness of the production process and the effect on final foam properties.

The fire resistance of the optimized brick waste-based porous IP was also evaluated according to the ISO834 fire curve. The tested IP succeeded the ISO384 standard curve requirements and limits without undergoing any damage, yielding or spalling phenomena. The temperature at the concrete-IP interface was below 120 °C and the back side temperature below 50 °C, for the whole duration of the test. Moreover, the concrete slab protected by the fire resistant porous IP material did not appear any sign of spalling or other mechanical damage and remained as it was initially, before the fire test.

Life Cycle Assessment of the DEFEAT Composite Material

A comprehensive Environmental Evaluation and Life Cycle Assessment (LCA) was undertaken to examine the DEFEAT Composite Material based on CDW. The study aimed to assess the environmental impacts of the DEFEAT product throughout its entire life cycle and against equivalent conventional alternatives used in construction. Employing a standardized approach, the analysis covered raw materials acquisition, manufacturing, usage, and end-of-life management stages. Focusing on the mass of DEFEAT Composite Material boards (1 x 1 x 0.05 m^3) required for covering 100 m^2 of façade walls, both "cradle to gate" and "cradle to grave" analyses were conducted using SimaPro software, consistently revealing DEFEAT's superior sustainability, particularly in preventing harmful emissions. A positive environmental impact of DEFEAT's manufacturing process was demonstrated, emphasizing the benefits of using secondary raw materials (CDW). In comparison, the Market Model, consisting of extruded polystyrene (XPS) and gypsum fibreboard, (GF) was designed to have equivalent fire-resistant and thermal insulation properties. The Market Model exhibited non-sustainability, primarily due to increased quantities of GF required for similar fire-resistance performance as well as the significant negative environmental impact associated with the manufacturing of polystyrene. While DEFEAT's positive influence slightly diminishes in a 100% landfill disposal scenario, it is noteworthy that, even with this decrease, the overall environmental impact remains favourable. This underscores the importance of responsible End-of-Life (EoL) practices, emphasizing DEFEAT's continued contribution to a more sustainable construction industry. ***The project Partners UCY and RECS were cooperating for this achievement.***



DEFEAT product LCA study Boundary Conditions

Submission of Patent application for the DEFEAT Composite Material

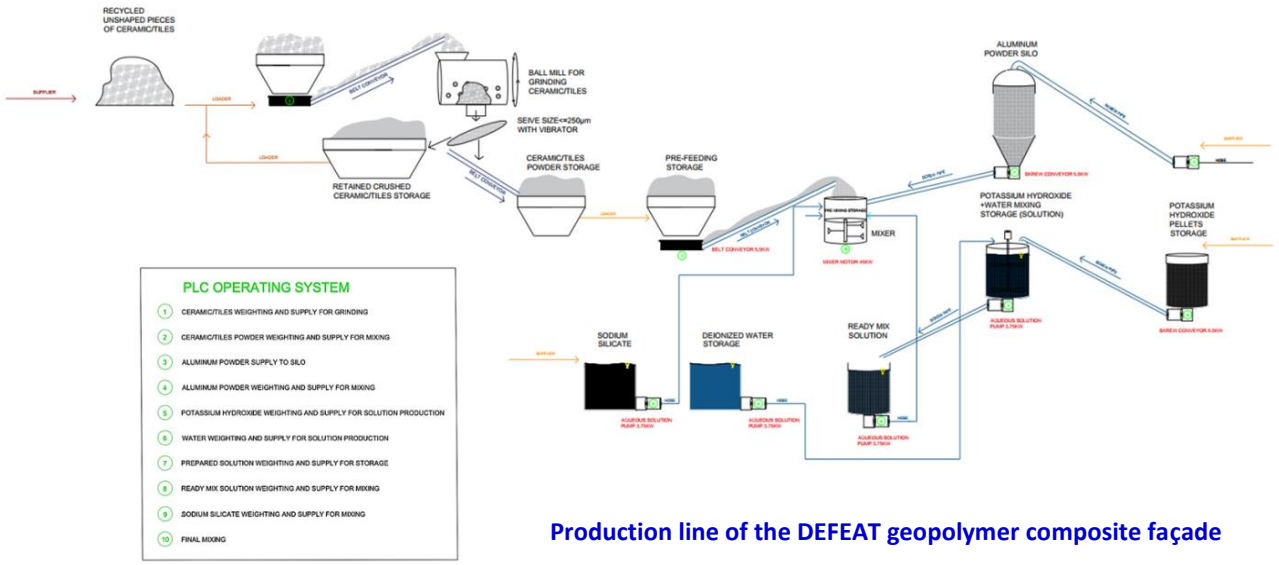
The project Partner Pharmakas undertook all the necessary activities for preparing the information required and submitting a patent application for the final product developed in the DEFEAT, along with the support of an external specialist consultant who has been recruited for this reason. The patent application

process consisted of two major phases: first, the patent application assessment (Phase A), and second, the patent application preparation and submission (Phase B).

Design and Costing of a large-scale Manufacturing Plant for the DEFEAT Composite Material

Based on the successful development of the DEFEAT Composite material prototypes, BFR-CTTI and CTFR-CTTI, the industrial production of the DEFEAT geopolymer composite façade was designed. The prototypes with dimensions of 42 x 50 x 5 cm^3 provided guidance for the individual production process steps of the raw materials storage, mix design, products manufacturing, and curing to produce geopolymer composite boards of 100 x 100 x 5 cm^3. These dimensions align with the specified requirements for the industrial production of the DEFEAT final product (geopolymer composite façade).

The production line of the DEFEAT final product breaks down into 11 sections, covering all the production stages from the raw material grinding to the heating of curing chamber. The associated equipment costs for each stage amount to a total investment of €108,000. **The project Partners RECS, Pharmakas and FRC were involved in this task.**



Production line of the DEFEAT geopolymer composite façade

Business Plan: towards the commercialization of the DEFEAT Composite Material

The development of this Business Plan represents a significant milestone in DEFEAT Project towards establishing a successful and sustainable business. Through meticulous research, strategic analysis, and thoughtful planning, a robust roadmap has been created that will drive DEFEAT's product growth.

The developed Business Plan outlines a clear vision, highlighting the unique value proposition, target market, and competitive advantage. The market has been identified and thoroughly analyzed, understanding the needs and preferences of potential customers, as well as the dynamics of such industry. This knowledge enables to tailor the DEFEAT product and services to meet the demands of the target audience effectively.

Moreover, the financial projections made, demonstrate a solid understanding of the financial aspects of this business. Revenue streams, cost structure, and investment requirements, have been considered, ensuring a realistic and attainable financial forecast. The comprehensive financial analysis has provided us with a clear understanding of the break-even point and profitability targets. **The Business Plan was implemented by the project Partner STRATAGEM with the support of the Partner RECS.**

DEFEAT Meetings and Events

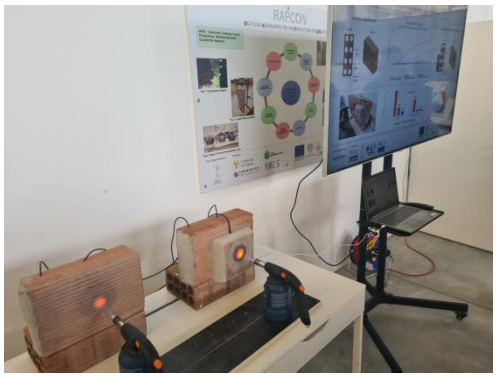
"An Innovative Robotic Separation Method of the Construction and Demolition Waste (CDW)"

The workshop "***An Innovative Robotic Separation Method of the Construction and Demolition Waste (CDW)***" was successfully implemented on the 17th of February 2023. ***The Workshop was organized by the project's Partners FRC and STRATAGEM*** and took place at the laboratories of the Frederick University, School of Engineering. The scope of the event was to present the methodological approach applied for the design and implementation of the Automated Robotic Separation Prototype System of the Construction and Demolition Waste (CDW) and demonstrate the operation of the system on a pilot-scale and in real conditions.

An invitation with the program of the Workshop and a summary of the DEFEAT project was sent to more than 60 persons via e-mail, covering different professional sectors that could be interesting for the results of the DEFEAT project, like as academia, R&D organizations, SMEs, business, industry, NGOs, public organizations, governmental bodies and other stakeholders. Finally, more than 40 people attended the Workshop. The "gallery" section of the project website - http://defeat.frederick.ac.cy/index.php/defeat-media/gallery - includes photos from the event.

"Demonstration of the Applicability and Performance of Fire Resistance Façades developed from Construction and Demolition Waste (CDW)"

A demonstration event with the title "***Demonstration of the Applicability and Performance of the Fire Resistance Façades developed from the Construction and Demolition Waste (CDW)***" was successfully implemented on March 29, 2023 to present in a pilot-scale the application of the innovative DEFEAT Composite Material and demonstrate its fire resistance properties. ***The demonstration event was organized by project Partners RECS, FRC and Pharmakas*** on Wednesday, 29 March 2023 and hosted at the premises of RECS. About 25 people from different professional sectors with interest for the results of DEFEAT project attended the demonstration event. The "gallery" section of the project website (http://defeat.frederick.ac.cy/index.php/defeat-media/gallery) includes photos from this event.



"A Day of Scientific Insight and Innovation"

A specific event aimed at promoting the innovations and the scientific and technological results achieved in the DEFEAT project was organized and implemented under the title "***A Day of Scientific Insight and***

DEFEAT

Innovation". The Scientific Information Day was organized by the FRC (the Host Organization of DEFEAT project) with the support of all the other Partners and took place on November 23, 2023, at the Frederick University with the participation of people from the local academic and research community, enterprises, public organizations, governmental bodies, SMEs and other stakeholders. The main achievements of the DEFEAT project, as well as the new products and systems developed in the frame of the project, were presented in details by the involved Partners. The event also allowed for various discussions on the current situation of CDW management in Cyprus and their valorization in the production of low-cost and environmental-friendly materials for buildings, the relevant legislation and the barriers existing for its implementation. The "gallery" section of the project website includes photos from this event (http://defeat.frederick.ac.cy/index.php/defeat-media/gallery).

2nd General Assembly Meeting

The DEFEAT Project convened its 2nd General Assembly Meeting on the 21st of June 2023, adopting a hybrid format. During the meeting, the participants reviewed the most recent advancements and progress made in the project, along with the upcoming actions scheduled until its completion. The Project's Coordinator commenced the session by providing an overview of the project's current status and addressing pertinent matters. Subsequently, each Work Package presented their respective work within their designated package. The meeting concluded with a presentation on Financial Management and comprehensive discussions regarding other significant tasks.

Join our network !

Project's Partners

The Project DEFEAT (INTEGRATED/0918/0052) has been co-funded by the European Regional Development Fund (ERDF) and the Cyprus Government, through the RESTART 2016-20 framework program of the Cyprus Research & Innovation Foundation"

European Union
European Regional Development Fund
Republic of Cyprus
Structural Funds of the European Union in Cyprus