

Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **SMART (INTELLIGENT) MATERIALS USED IN ARCHITECTURE**

Yuriy Fedkovych Chernivtsi National University, Ukraine

Prof. Igor Fodchuk, Prof. Mariana Borcha















## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# YURIY FEDKOVYCH CHERNIVTSI NATIONAL UNIVERSITY











The University was founded on 1875 by decree of Austro-Hungarian emperor Franz Joseph

The main building of the University – the previous Residence of the Orthodox Metropolitans of Bukovyna and Dalmatia designed by the prominent Czech architect Josef Hlavka.







## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024







# 28.06.2011

6

The main University buildings - former Bukovynian and Dalmatian Metropolitans Residence was included to the UNESCO Heritage List







Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **CHERNIVTSI UNIVERSITY TODAY**











Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024







## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

## Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **BACHELOR AND MASTER STUDIES**

## **FIELDS OF EDUCATION**

## Education

- TEACHER TRAINING (BIOLOGY AND HUMAN HEALTH)
- TEACHER TRAINING (TECHNOLOGIES)
- TEACHER TRAINING (GEOGRAPHY)
- TEACHER TRAINING (ENGLISH)
- TEACHER TRAINING (GERMAN)
- TEACHER TRAINING (FRENCH)
- TEACHER TRAINING (HISTORY)
- TEACHER TRAINING (UKRAINIAN)
- TEACHER TRAINING (MATHEMATICS)
- ...

# Arts and humanities

- PRINTING AND PUBLISHING
- FINE ARTS, DECORATIVE ARTS AND RESTORATION
- PHILOLOGY (GERMANIC LANGUAGES AND LITERATURES)
- PHILOLOGY (ROMANCE LANGUAGES AND LITERATURES)
- PHILOLOGY (UKRAINIAN LANGUAGE AND LITERATURE)
- HISTORY AND ARCHEOLOGY
- MUSIC ART

### Social sciences, journalism and information

- ECONOMICS
- INTERNATIONAL ECONOMIC RELATIONS
- POLITICAL SCIENCE
- INTERNATIONAL RELATIONS
- PSYCHOLOGY
- CULTURAL STUDIES
- JOURNALISM







**SPECIALTIES** 



### Business, administration and law

- SOCIAL WORK
- PHYSICAL THERAPY AND ERGOTHERAPY
- SOCIAL WELFARE

### Natural sciences, mathematics and statistics

- BIOLOGY
- ECOLOGY
- CHEMISTRY
- BIOTECHNOLOGIES AND BIOENGINEERING
- GEODESY
- PHYSICS AND ASTRONOMY
- APPLIED PHYSICS AND NANOMATERIALS
- EARTH SCIENCES
- GEOGRAPHY
- MATHEMATICS
- APPLIED MATHEMATICS







## Erasmus+ <u>Programme</u> Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

## Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **BACHELOR AND MASTER STUDIES**

## **FIELDS OF EDUCATION**

### Information Technologies (IT)

- SOFTWARE DEVELOPMENT
- COMPUTER SCIENCES
- COMPUTER ENGINEERING
- CYBERSECURITY
- SYSTEM ANALYSIS
- INFORMATION SYSTEMS AND TECHNOLOGIES

### Engineering, manufacturing and construction

- FOOD PROCESSING
- ELECTRICAL ENGINEERING AND ELECTROMECHANICS
- METROLOGY AND INFORMATION-MEASURING TECHNOLOGY
- MICRO- AND NANOSYSTEM ENGINEERING
- TELECOMMUNICATIONS AND RADIO ENGINEERING
- ARCHITECTURE AND URBAN PLANNING
- CONSTRUCTION AND CIVIL
  ENGINEERING

### Agriculture, forestry, fisheries and veterinary

• AGRONOMY











# Health and welfare

- MANAGEMENT
- ACCOUNTING AND TAXATION
- FINANCE, BANKING AND INSURANCE
- MANAGEMENT
- MARKETING
- ENTREPRENEURSHIP, TRADE AND EXCHANGE ACTIVITY
- PUBLIC MANAGEMENT AND ADMINISTRATION
- LAW
- INTERNATIONAL LAW

## Services

- TOURISM
- PHYSICAL EDUCATION AND SPORT







Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **INTERNATIONAL UNIVERSITY RANKINGS**











# Yuriy Fedkovych Chernivtsi National University **RANKED 1201+**









Erasmus+ <u>Programme</u> Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# ChNU AND ERASMUS+ KA107 and KA2

















Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **AMAZE** team from YURIY FEDKOVYCH CHERNIVTSI NATIONAL UNIVERSITY



## **Prof. IHOR FODCHUK**

Dean of Faculty Architecture, Construction and **Applied Arts** 



### **YURIY SOBKO**

Associate prof.

Department of Construction



## **MARIANA BORCHA**

Head of Department Information **Technologies and Computer Physics** 





### **TETIANA ANTOSHCHUK**

Associate prof.

Department of Architecture







### **VOLODYMYR ROMANKEVYCH**

Assistant of prof.

Department of Construction



### NATALIA VATAMANYUK

Associate prof.

Department of Architecture







Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **Students** from Yuriy Fedkovych **Chernivtsi National University**

# **Specialities:**

# ARCHITECTURE AND URBAN PLANNING

- CONSTRUCTION AND CIVIL ENGINEERING
- INFORMATION SYSTEMS AND TECHNOLOGIES

# **AMAZE Summer School**

















### Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## **ARCHITECTURE AND URBAN PLANNING**



## **CONSTRUCTION AND CIVIL ENGINEERING**



# Anastasia Aurite Sofia Kolodrivska

**3th year of Bachelor program** 

## **3th year of Bachelor program**

Vita Buzyniak

First year of Master program

**3th year of Bachelor program** 









## **INFORMATION SYSTEMS AND TECHNOLOGIES**



# **Angelina Auziak**

# Natalia Panivnyk

**3th year of Bachelor program** 







Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

**Project objectives IO1 - AMAZE e-book for developing of complex design industrial** IO2 - AMAZE e-toolkit manual for digital learning in producing complex design industrial parts

module course 2 – Smart (Intelligent) Materials

## «Ultra-high strength composites»





Principles of structural strength and density, modified composites with a complex of finely dispersed additives of microsilica and metakaolin









## module course 3 – CAD/CAM/CAE design

## Drawings in the Revit software package using BIM technologies

Our team developed a project for the reconstruction of a brewery in Chernivtsi using Revit software and printed it on a 3D printer.





Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## module course 2 **Smart (Intelligent) Materials**

## «Ultra-high strength composites»



**New materials and properties** used in architectural design «Ultra-high strength composites»

Principles of structural strength and density, modified composites with a complex of finely dispersed additives of microsilica and metakaolin









# Module course 2 in IO1 - AMAZE e-book for developing of complex design industrial:







## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024



Ultra-high strength composites are a material of high structural strength and density. They are made in the form of a special dispersed product with a compressive strength of 150 N/mm<sup>2</sup> Ultra-strength concretes, especially those with advanced additives and reinforcement, exhibit exceptional properties such as high strength, durability, and sometimes even self-healing capabilities. While they may not fit the traditional definition of "smart materials" like shape memory alloys or piezoelectric materials, they do possess certain characteristics that could be considered "smart" in the context of civil engineering and construction.

For instance, some ultra-strength concretes incorporate self-healing mechanisms, where cracks that form due to stress or other factors can be automatically repaired over time through chemical reactions within the material. This self-healing ability mimics some aspects of smart materials, which can autonomously respond to changes in their environment.

Furthermore, ultra-strength concretes can be engineered to have specific responses to external stimuli such as temperature variations, moisture levels, or mechanical stress. While these responses might not be as dynamic or sophisticated as those of traditional smart materials, they still demonstrate a degree of adaptability and functionality that aligns with the concept of smart materials







**000155412** Ukrainian Context harest, Romania, 8-17 Julv 2024









### **Results of strength testing of concrete mixtures**















## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## **Results of strength testing of concrete mixtures**













Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## **Research methods:**

**1.Scanning electron microscopy (SEM)** 

2. Energy dispersive X-ray spectroscopy, Hitach SU-70

## **3. High-resolution X-ray diffractometry**

X'Pert PRO MRD diffractometer in a multicrystal diffraction scheme for CuKal radiation.





4. Determination of water resistance by the wet spot method in accordance with EN 12390-8 18

**5.** Determination of compressive strength on a hydraulic press in accordance with EN 12390-4







Zeiss EVO-50 scanning electron microscope with CCD detector











Co-funded by the

**European Union** 

## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

## Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# **Development of cement composite formulation**

	Recipe No. 1 kg/m3	Recipe No. 2 kg/m3
Cement PC-I 500 (EN 197-1:2011)	600	600
Quartz powder 50 microns.	-	30
Quartz sand, fraction 0.4-0.63 mm	584	520
Crushed stone diorite fraction 2/5 mm	315	315
Crushed stone diorite fraction 5/10 mm	315	315
Crushed stone diorite fraction 10/20 mm	660	660
Microsilica 0.1-0.3 microns.	-	60
Metakaolin 1-40 microns	-	30
Distilled water	160	160
Fiber	1%	1%
Plasticizer	5%	5%













## Compressive strength in kN







## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

**European Union** Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024





Co-funded by the





The phase composition of cement containing various clinker minerals

from analysis of experimental X-ray diffractograms (by the Rietveld method)







## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## X-ray studies were performed at the collective use center in the Lashkarev Institute of Semiconductor Physics (Kyiv)



Analysis of theoretical (by the Rietveld method) and experimental diffractograms of hydration compounds

















## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

## Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024





<i>d</i> / <i>a</i>	Name of the		
<i>a/n</i>	compound		
0.974, 0.563, 0.388,	Ettringitis		
0.278, 0.303, 0.191	Calcite		
0.491, 0.262, 0.192	Portlandite		
0.278, 0.335, 0.181	Hydrosilicate calcium		
1.049, 0.262, 0.278	Janite		
0.308, 0.297, 0.351	Tobermoryt 1.1-nm		
0.552, 0.310, 0.301	Tobermorite 1.4 nm		
0.307, 0.301, 0.279	Wedge tobermorite		
0.287, 0.269, 0.260	HSC		
0.303, 0.277, 0.256	GSK		
0.305, 0.275, 0.268	CHS		
0.263, 0.262	CHAS		
0.276, 0.309	СНА		





## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## **SEM** images of the fracture surface of the cement matrix

To understand the formation of hydration phases in high-strength concrete composites and the effect of ultrafine modifiers, the microstructure of the fracture surface and their phase composition were obtained by scanning electron microscopy using energy dispersive x-ray spectroscopy





# Influence of ultrafine modifiers on the processes of cement stone structure formation

Experiments were carried out at the State University of Stefan cel Mare (Suceava, Romania)















# Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

24

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## **SEM** image of the fracture surface of the cement matrix with the modified mixture

## Enlarged SEM image of zone A of the fracture surface of the cement matrix of the modified mixture

















### Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

Co-funded by the **European Union** 

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024



Elemental composition of
mixture according to the
results of energy dispers
on maps



<sup>15</sup> The list of elements in the table and their percentage content indicate the presence of the vast majority of calcite CaCO3 in concrete matrix No. 1. In the presence of moisture, as a result of the reaction of calcium oxide with atmospheric carbon dioxide, a layered structure with low adhesion and cohesion is usually formed. According to the EDX analysis, the fracture of concrete composite No. 1 mainly occurs in areas with high concentrations of calcite.

Element	Apparent Concentration	Wt%	Standard Label
С	108.28	19.27	С
0	285.15	44.50	SiO2
Na	5.13	0.45	Albite
Mg	2.27	0.21	MgO
Al	10.60	0.82	A12O3
Si	55.79	3.86	SiO2
K	19.90	1.07	KBr
Ca	495.17	29.03	Wollastonite
Fe	10.54	0.79	Fe









f concrete samples of the initial results of EDX analysis, and the sive X-wave analysis, respectively,









### ius+ Programme Key Action 2 Cooperation Partnerships Co-funded by the for Higher Education (KA220-HED) Erasmus+ Programme of the European Union aent number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context and the results of energy dispersive X-ray analysis, respectively

Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024 Elemental composition of concrete samples with the mixture modified by a complex based on microsilica and metakaolin EDX analysis





 

 Fe
 12.70
 0.94
 Fe

 The phase structure of the cement composite of formulation No. 2 is characterized by a large number of phases and their heterogeneity. The phase composition is dominated by

compounds of low and high basicity HSCs, as well as unreacted microsilica particles. Probably, the significantly higher compressive strength of formulation No. 2 is associated with a more developed specific surface area of pozzolanic particles, which are able to react faster with Ca(OH)2, forming a dense microstructure.

26













## Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

## SEM images of the cement surface microstructure of the initial mixture

Experiments were carried out at the Bakul Institute of Superhard Materials, Kyiv. Ukraine

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$									-	-	
N₀    N₀      5    6      1    2.52      40,30    0,57      1,74    39,23	All a charge of the			С	0	Mg	Al	Si	K	Fe	Ca
1  2.52  40,30  0,57  1,78  13,38  0,49  1,74  39,23			Nº Region	%							
1 2.52 40,30 0,57 1,78 <b>13,38</b> 0,49 1,74 <b>39,2</b> 3	6										
			1	2.52	40,30	0,57	1,78	13,38	0,49	1,74	39,23
2 6,54 36,56 0,59 0,43 <b>12,34</b> - <b>43,5</b> 4		3	2	6,54	36,56	0,59	0,43	12,34	-	-	43,54
<b>4</b> 3 20,32 42,05 37,18 - 0,45	4		3	20,32	42,05	-	-	37,18	-	-	0,45
4 18,40 40,61 40,19 - 0,34 0,46			4	18,40	40,61	-	-	40,19	-	0,34	0,46
<b>1</b> 5 21,33 37,56 0,70 1,8 <b>17,81</b> 0,8 1,30 <b>18,69</b>			5	21,33	37,56	0,70	1,8	17,81	0,8	1,30	18,69
6 21,66 38,90 0,71 2,15 <b>18,44</b> 0,92 1,01 <b>16,20</b>		b	6	21,66	38,90	0,71	2,15	18,44	0,92	1,01	16,20
7 19,06 40,28 0,54 1,37 23,64 0,58 0,8 13,74			7	19,06	40,28	0,54	1,37	23,64	0,58	0,8	13,74

Intergranular zones 1 and 2 have a significantly lower carbon content (two times) and a higher calcium content than the corresponding zones 5 and 6, while the calcium to silicon ratio is almost the same.















### Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024



500мкт

## **Fragments of SEM images of the microstructure of cement matrix surface with modified formulation**

SEM images of the microstructure for formulation No. 2, are more developed and dense. This may be due to the fact that the modified samples are characterized by a higher content of hydration products, and the densified structure in this form gives a significant increase in strength.

Region №	C (%)	O (%)	Mg (%)	Al (%)	Si (%)	Fe (%)	Ca (%)
1	11,51	46,05	_	-	42,24	-	0,20
2	12,12	45,50	-	-	41,95	-	0,43
3	17,15	42,85	-	0,18	38,98	_	0,55
4	14,06	41,09	1,24	1,92	17,09	0,94	22,95
5	9,37	45,89	1,00	2,92	21,94	1,13	17,09
6	8,02	45,23	1,10	2,86	23,41	1,01	17,80
7	20,28	40,69	0,40	1,53	26,38	0,80	9,34











### Erasmus+ Programme Key Action 2 Cooperation Partnerships Co-funded by the for Higher Education (KA220-HED) **European Union**

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024











a) - experimental (dark line) and calculated (red) diffractograms for more than a year of hydration of the compounds of the modified composite;

b) - on the 28th day of hydration of the composite.







To design concrete with a certain minimum durability, an understanding of the micro- and nanostructurallevel processes that cause deterioration, including the rates at which these processes occur under the conditions in which the concrete will be exposed, is required. In the latter respect, a wide range of climatic, chemical and physical factors must be considered, which are the subject of further research.

- Modification of the cement matrix with a complex of finely dispersed silica and aluminosilicate compounds at a certain ratio leads mainly to the formation of low-base calcium hydrosilicates and such C-S-H structural models as jenite (d/n, nm: 1.049; 0.262; 0.278) and tobermorite (d/n, nm: 0.552; 0.310; 0.301; 0.308; 0.297; 0.351), which have a layered structure and are essentially nanomaterials. These phases were formed from Ca(OH)2 and active silica components with a Ca/Si ratio of 1.1-1.2.
- The adding of metakaolin cause the formation of stable calcium silicate hydroaluminates with crystalline structure which indicated by maxima on the X-ray diffractogram corresponding to d/n = 0.305; 0.275; 0.268; 0.263; 0.262 (nm) and hydroaluminates d/n=0,276; 0.309 (nm).















# Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412 European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School - National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

- It was found that in X-ray diffractograms, the main intensity maxima of hydration products are located in the same angular positions as the intensity maxima for clinker minerals, in particular, for alite (C3S) and belite (C2S). This indicates their crucial role in the formation of the cement matrix structure.
- The presence of compounds that include AI and Fe at the later stages of hydration (over 1 year) is a sign of the formation of secondary phases of hydroaluminates and calcium hydroferrites. The increase in strength by 36% is explained by the optimal use of free calcium hydroxide and amorphous silica, which is a sign of a progressive pozzolanic reaction in the cement matrix during one year of hydration
- During the year of hydration with the introduction of silica and aluminosilicate modifiers, a significant decrease in the content of Ca(OH)2 and high-base calcium hydrosilicates CSH-II is observed with a simultaneous increase in the content of jenite and tobermorite, which are likely to have been transformed from CSH, which is the reason for the increase in strength















Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

# Module course 2 in IO2 - AMAZE e-toolkit manual for digital learning in producing complex design industrial parts. Ultra-high strength composites

module course 2 **Smart (Intelligent) Materials** 

«Ultra-high strength composites»



Laboratory work #1

Laboratory work #2

Principles of structural strength and density, modified composites with a complex of finely dispersed additives of microsilica and metakaolin









- Production and storage of cement prisms

  - Bending and compressive strength testing of cement prisms
    - Laboratory work #3
    - Preparation of a concrete sample
      - Laboratory work #4.
      - Class of concrete according to strength
        - Laboratory work #5 X-ray studies of cement
          - Laboratory work #6
          - Scanning electron microscopy of concrete





Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED) Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Summer School – National University of Science and Technology POLITEHNICA Bucharest, Romania, 8-17 July 2024

THANK YOU ! MULŢUMESC ! DZIĘKUJĘ !

**GRACIAS** !









# ДЯКУЮ !

