GEOPOLYMER CAMP

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AN OVERVIEW OF NATURAL FIBRES REINFORCED GEOPOLYMER COMPOSITES

KINGA KORNIEJENKO

ERANet LAC

PK

SEVENTH FRAMEWORK PROGRAMME
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Outline

- Introduction
- Natural fibers reinforced geopolymers
- Project: *Development of ecofriendly composite materials based on geopolymer matrix and reinforced with waste fibers*
- Results: research results
- Cocnlusions: potential application, further research

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- Growing environmental awareness and importance of development of sustainable construction materials for decreasing environmental impact of construction industry are main motivators to research works on new, innovative materials' solutions.
- In the environmental point of view, the addition of renewable fibres will be especially beneficial. The replacement of the synthetic fibres with their natural counterparts reduces significantly the environmental impact (closing important life cycles, including CO2).
- The natural fibres have also other features such as: low cost of production, low density, they are renewable in short time, non-toxic, and easy to process.

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- **The cotton (Gossypium)** is the primary raw material used in textile industry. A lot of research work connected with geopolymers reinforced by cotton fibres has been conducted in years 2013 -2014. The cotton was introduced to geopolymer matrix based on fly ashes as a short fibre addition as well as research with cotton fabric layers was made.
- The results show that the content of short cotton fibres (up to 0.5 wt%) increases the compressive and flexural strength, flexural modulus and fracture toughness of the composites.
- They show optimum value of fibre addition 2.1 wt% according to mechanical properties of the composition.

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- **Abaca (Manila hemp)** fibre is extracted from a banana species.The research was connected with the utilization of scrap abaca fiber as reinforcement (long fibre ca. 25 cm) in fly ash-based geopolymer matrix. The results show that abaca fibre-reinforced geopolymer has better flexural strength in comparison with geopolymer without reinforcement.
- Pineapple leaf fibres are a waste product of pineapple cultivation. The metakaolin based matrix was reinforced by 3 wt%- long fibres. The results showed that mechanical properties of the material can be considerable improved by using pineapple leaf fibres.
- The other research was made on geopolymer matrix based on fly ash class-C reinforced by short fibre. The result show that fibers improve the mechanical properties (compressive and flexural strength) of the composites and did not change the nature of geopolymers as a fire or acid resistance material.

Natural fibres - overview

- **Sisal fibers (Agave sisalana)** are stiff fibers used to manufacture various products. The research was made on two types of geopolymers based on metakaolin and fly ash.
- The metakaolin based matrix was reinforced by 3 wt%. 25 mm sisal fibres. The results shows considerable improvement the mechanical properties comparison with matrix without fibre addition.
- The other research have been performed based on geopolymer based on fly ash. The best results for mechanical properties were obtained to 2 wt% short sizal fibres.

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- **Flax** (Linum usitatissimum) is one of the oldest and the most widely used cellulosic fibres. It is one of the most popular fibres as an addition to geopolymer matrix. The research was made on different raw materials such as: dehydroxylated kaolinite-type, low calcium fly-ash.The research results pointed improving mechanical properties by fibre addition, especially flexural strength.
- **Hemp (Cannabis sativa) -** the investigation based on foamed matrix. The results show that this composite can be interesting in building applications, because of good bonding between matrix and reinforcement in the composites, good stability to the thermal variation and improvement of mechanical properties.

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- **Coir** - the investigation for short coir was conducted for geopolymers based on fly ash with 1 wt% fibre addition. The result show that fibres admixture improves mechanical properties comparison with geopolymers without fibre addition. Additionally, a coir improves the crack resisting capacity.
- **Jute -** the test results present that the incorporation of juta fibers in geopolymers appears a viable solution to overcome its initial brittle behaviour.
- **Raffia -** the research for short raffia fibres was conducted for geopolymers based on fly ash. The results show that the composites has worse properties than synthetic fibre. However they still have reasonable mechanical properties for some construction purposes.

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- **Sweet sorghum** - to the composite (geopolymer matrix based on Class F fly ash) it was implemented as waste – bagasse as a fine fibre (below 10 mm) . The results show that the compressive strength slightly decrease and the tensile and flexural strengths both increase with the content of sweet sorghum fibres up to 2 % and then decrease to be lower than that of the geopolymer without fibres addition. There is also change the behaviour during failure from the brittle to “ductile”.
- **Luffa** is a kind of tropical and subtropical vines in the cucumber family. The composite includes about 10 vol% fibres.The results show that the compressive and flexural strengths of the end geopolymeric products respectively increase and the composites are durable (no significant deterioration in mechanical performance over a duration of 20 months)
- **Bamboo** - the results show that the proper bamboo preparation allow gain the flexural tests results comparable with synthetic fibres such as PP.

Natural fibres - overview

- **Wood and sawdust -** different fraction of wood waste was added to the geopolymers based on fly ash and metakaolin. The research result shows that the shape and size of wood aggregates affect the properties of the geopolymer composites. The 5% of sawdust addition is optimal taking under consideration all mechanical properties.
- The other possibilities of reinforcement geopolymers composites are offered by some plant waste such as corn husk, rice husk and coffee grounds. Other possibilities are offered by animal fibres such as wool and related mammalian fibres and mineral fibres such as basalt and diatomite.

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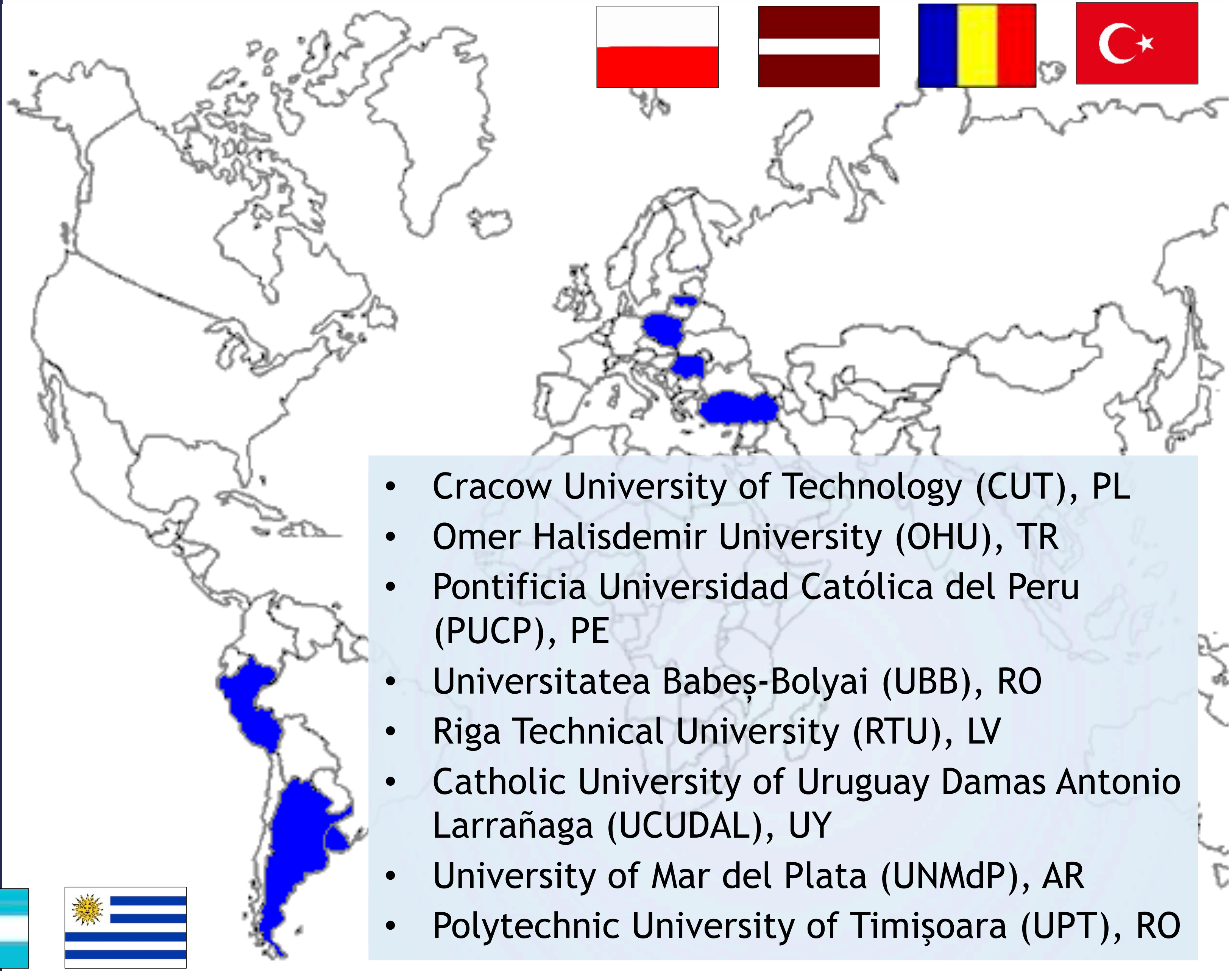

- Cracow University of Technology (CUT), PL
- Omer Halisdemir University (OHU), TR
- Pontificia Universidad Católica del Peru (PUCP), PE
- Universitatea Babeş-Bolyai (UBB), RO
- Riga Technical University (RTU), LV
- Catholic University of Uruguay Damas Antonio Larrañaga (UCUDAL), UY
- University of Mar del Plata (UNMdP), AR
- Polytechnic University of Timişoara (UPT), RO

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Laboratory works:

- Cracow University of Technology (CUT), PL
  - Flax, Hemp, Raffia, Coir
- Omer Halisdemir University (OHU), TR
  - Waste fibres (also inorganic)
- Pontificia Universidad Católica del Peru (PUCP), PE
  - Sizal, Flax
- Universitatea Babeș-Bolyai (UBB), RO
  - Hemp, Waste form wood industry
- Catholic University of Uruguay Damas Antonio Larrañaga (UCUDAL), UY
  - Celulose

Computer modeling:

- University of Mar del Plata (UNMdP), AR
- Polytechnic University of Timișoara (UPT), RO
- Riga Technical University (RTU), LV

FIBRE project - chosen results

Figure 1. Flax tow after dew retting process.

Figure 2. Flax hurds.

Figure 3. Green tow flax fibre.

Figure 4. Hemp hurds.

Figure 5. Decorticated hemp fibre

Figure 6. Hemp microfibres.

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FIBRE project - chosen results

- Compressive strength test after 28 days

Sample	MPa	standard deviation
Geopolymer without fibre	42.70	3.38
Geopolymer with tow flax fibres after dew retting process (1%)	31.92	1.80
Geopolymer with flax hurds (1%)	30.72	3.36
Geopolymer with green tow flax fibres (1%)	33.46	3.12
Geopolymer with hemp hurds (1%)	35.90	2.00
Geopolymer with decorticated hemp fibres (1%)	42.65	4.17
Geopolymer with hemp microfibres (1%)	35.20	7.03

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FIBRE project - chosen results

- Flexural strength test after 28 days

Sample	MPa	standard deviation
Geopolymer without fibre	5.22	0.25
Geopolymer with tow flax fibres after dew retting process (1%)	4.67	0.06
Geopolymer with flax hurds (1%)	5.83	0.80
Geopolymer with green tow flax fibres (1%)	5.12	0.37
Geopolymer with hemp hurds (1%)	5.28	0.27
Geopolymer with decorticated hemp fibres (1%)	6.09	0.13
Geopolymer with hemp microfibres (1%)	6.01	0.63

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- The composites with hemp fibres have better mechanical properties – compressive strength as well as flexural strength.
- The differences between fibres have an influence for mechanical properties. The best results were achieved for fine fibres such as decorticated hemp fibres and microfibres.
- However the fibres admixtures do not improve the mechanical properties significantly, it has some additional benefits such as change the character of failure mechanism (from brittle to ductile) and, in case of natural fibres, reduction environmental influence.
- This composites are environmentally friendly material for application in different areas such as construction industry.

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Contact:

Kinga Korniejenko
CUT | Faculty of Mechanical Engineering
Jana Pawła II 37 street
mob. + 48 (0) 609 97 49 88
Email: kinga@mech.pk.edu.pl
kkorniej@gmail.com

Thank you for attention