SOIL TREATMENT WITH NON TRADITIONAL ADDITIVES IN EARTHWORKS

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Earthworks challenges:

- use all of extracted materials
- reduction of water consumption
- reduction of greenhouse gases emissions
- ...

One technical solution, the soil treatment:

- traditional additives: lime, hydraulic binders
- non traditional additives

Non traditional treatments = improvement of environmental balance of earthworks?
Objectives

1. Experimental investigations
   - Mechanical behaviour
   - Physical properties
   - Microstructure

2. Environmental assessment
   - Life cycle assessment

Definition of the uses
   - Technical benefit?

Environmental impact
   - Environmental benefit?

1 + 2: Decision of use of the non traditional additive with regard to technical and environmental benefits
Non traditional additives

Elaborated with by products of the transformation of:

- Citrus
- Sugar beets
- Wood

Secondary additives:
- Water, Acid, Surfactants

Industrial by products

Non traditional additives

- Acid solution: ISS, dosage 0.01%
- Enzymatic solution: Permazyme, dosage 0.002%
- Calcium lignosulfonate, dosage 0.5 – 5%

Treatment of a silty soil (PI = 14) with the enzymatic solution
Experimental results

Mechanical behaviour of treated soil

Compaction at standard Proctor effort (0.6MJ/m³)

- Maximum dry density
- Optimal water content
- Zero air voids Ga = 2.69

Dry density (Mg/m³) vs. Water content (%)

- Untreated
Experimental results

Mechanical behaviour of treated soil

Proctor compaction

- Maximum dry density
- Optimal water content
- untreated
- 0.002% Permazyme

Modification of the compaction optimum
Experimental results

Mechanical behaviour of treated soil

Proctor compaction

- Increase of the density on the dry side of the compaction curve

UCS at OWC

- Increase of UCS
- No evolution with the time

Graph showing:
- Dry density (Mg/m³) vs. Water content (%)
- USC (MPa) at 7 and 28 days
- Comparison between untreated and 0.002% Permazyme

Legend:
- untreated
- 0.002% Permazyme
- 0.6MJ/m³
- Zer air voids Ga = 2.88

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Experimental results

Index properties

<table>
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<th></th>
<th>0</th>
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<th>20</th>
<th>30</th>
<th>40</th>
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<td></td>
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<td>PI = 14</td>
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<tr>
<td>0.002% Permazyme</td>
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No modification of the plasticity and microstructure of the soil
Experimental results

Main points

Modification of the compaction properties, improvement of the dry density for water content between 8 and 15%

Small improvement of the UCS

No modification of the microstructure of the soil

Definition of the uses of the treatment
**Objective:** reach a minimal dry density independently of the water content

**In the field:** target density > 98.5% of the maximum dry density
### Definition of the uses

**Objective:** reach a minimal dry density independently of the water content

**Situation 1:** compaction at the same energy, $w_i = 9\%$

<table>
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<th>Dry density (Mg/m$^3$)</th>
<th>Water content (%)</th>
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<tr>
<td>untreated</td>
<td>0.002% Permazyme</td>
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The treatment reduces the water consumption at constant compaction energy.
Definition of the uses

Objective: reach a minimal dry density independently of the water content

Situation 2: compaction at the same water content, $w_i = 9\%$

The treatment reduces the required compaction energy for the same water consumption
Environmental assessment

Experimental results

Expected water and energy savings

Global reduction of the environmental impact of the system?

**Methodology:** Life Cycle Assessment (LCA), ISO 14040 & 14044 (2006)

**Objective:** characterise in different situations whether the treatment improves or not the environmental balance of the project

Comparative study
Functional unit: 1000 m³ of dry soil
Results of the environmental assessment: **Situation 1**

**LCIA method:** French standard NF P 01-010 partially based on CML 2001 (Guinée et al. 2002)

Values calculated for 1000 m³ of compacted soil
Environmental assessment

Results of the environmental assessment: **Situation 1**

LCIA method: French standard NF P 01-010 partially based on CML 2001 (Guinée et al. 2002)

Values calculated for 1000 m³ of compacted soil

Reduction of the environmental impact for the treatment
Environmental assessment

Results of the environmental assessment: **Situation 2**

LCIA method: French standard NF P 01-010 partially based on CML 2001 (Guinée et al. 2002)

Values calculated for 1000 m³ of compacted soil

Similar environmental impact for treated and untreated alternatives
Concluding remarks

Technical and environmental results

Modification of the compaction properties without altering intrinsic characteristics

Reduction of the environmental impact depending on environmental and technical construction choices

Prospects

In situ tests

Test the method for various situations
(soils / additives / initial conditions)
Acknowledgments

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Thank you for your attention!