Wood ash utilization as a binder in soil stabilization for road construction – first results of large-scale tests

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SUSTAINABLE ENERGY BIOMASS P Mg K Ca ASH ECONOMY

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Background

- **Wood ashes contain significant amounts of CaO**
  - wood ashes have soil binding properties (binding of water due to hydration of CaO, coagulation of soil particles caused by Ca cations) similar to burnt lime
  - the substitution of burnt lime as a binder for stabilisation of silt and clay soils seems to be a reasonable way of wood ash utilisation.
- **The results of R&D projects especially from Finland and Sweden show that wood ashes are suitable for soil stabilisation of road bases.**
- **Since the framework conditions in Finland and Sweden are different to those in Austria due to the climatic conditions and the composition of the ashes (co-combustion with peat and other organic matter), a comprehensive investigation of this utilisation strategy under Austrian framework conditions is necessary.**

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Goals

- Evaluation of the suitability of wood ashes as a binder for soil stabilisation.
- Development and evaluation of a process for soil stabilisation with wood ashes in practice.
- Technical, economic and ecological evaluation of the whole process.
- Preparation of guidelines for the proper utilisation of wood ashes as a binder in soil stabilisation.

Methodology
Laboratory tests

- **Selection of wood ash samples**
  - Bottom ash, coarse fly ash (mixture of economiser, air pre-heater and cyclone fly ash) and filter fly ash (ESP) from a grate furnace (GF)
  - Boiler fly ash, filter fly ash (baghouse filter) and mixture of boiler and filter fly ash form a bubbling fluidised bed boiler (BFBB)
- **Wet chemical analysis of wood ash samples**
- **Basic pressure resistance tests**
  - Comparison of the pressure resistance of test blocks made with different wood ash fractions to test blocks made with burnt lime as a binder 7, 21 and 28 days after preparation
- **Selection of most suitable ashes based on laboratory test results and permit obligations**
- **Determination of the optimum mixing rate by performing additional pressure resistance tests with different ash/soil mixing ratios**

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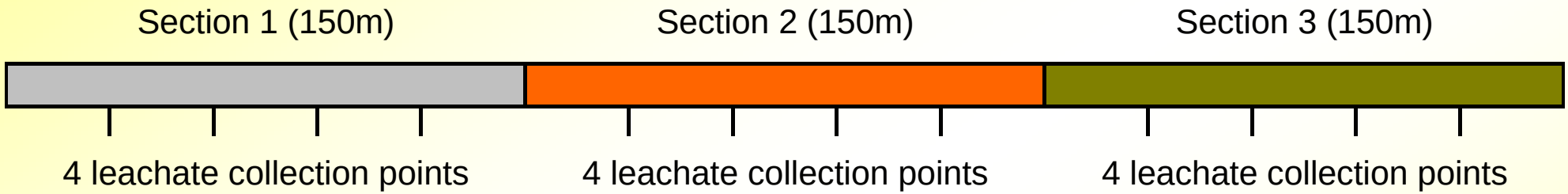
Methodology
Large-scale field test (I)

➢ Test layout



Section 1 Binder: burnt lime

Section 2 Binder: ash from a bubbling fluidised bed boiler

Section 3 Binder: ash from a grate furnace

➢ Sampling and wet chemical analysis

- Sampling of soil from each section, burnt lime, wood ash as well as the lime/soil and wood ash/soil mixtures

➢ Installation of leachate collection points

- 4 collection points per section
- Sampling and analysis over a period of 3 years (until autumn 2013)

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Methodology
Large-scale field test (II)

➢ Soil stabilisation

- Application of the binding material by a spreader (burnt lime and fly ashes from a bubbling fluidised bed boiler) or a shovel excavator (mixture of bottom and coarse fly ash from a grate furnace)
- Mixing of the binding material with the soil of the road base with a rotary hoe
- Compaction with a roller compactor

➢ Measurement of the bearing capacity of the base layer

- Measurements on top of the base layer before as well as 7 and 28 days after soil stabilisation, using a light falling deflectometer

Results
Laboratory tests (I)

➢ Content of CaO & relevant heavy metals of the ash samples selected

Sample	Ca [mg/kg] d.b.	free CaO [mg/kg] d.b.	Ca as CaO [wt. %] d.b.	Cd [mg/kg] d.b.	Zn [mg/kg] d.b.
GF bottom ash	278,000	359,000	92%	0.5	59
GF coarse fly ash	351,000	381,000	78%	15.8	2,280
GF filter fly ash	313,000	261,000	60%	27.0	5,360
BFB boiler fly ash	226,000	160,000	51%	4.7	240
BFB filter fly ash	259,000	125,000	34%	8.3	387
BFB mixture of boiler and filter fly ash	252,000	111,000	31%	6.9	331
Average values Austrian soil				0.3	140
Limiting values ash/soil mixture				1.1	450

- The free CaO content and the share of Ca bound as free CaO are higher for the ash fractions from the grate furnace, since
  - → CaO is preferably formed at temperatures above 900°C and
  - → the combustion temperature in grate furnaces is usually between 900 and 1050°C, while the combustion temperature in a BFB boiler is usually between 800 and 900°C.
- High contents of Cd and Zn in fly ashes from grate furnaces in comparison to average values for Austrian soils and Austrian limiting values for stabilised soil
  - → Fly ashes from GF are not suitable for soil stabilisation under Austrian conditions but mixtures of bottom ash and coarse fly ash can be utilized

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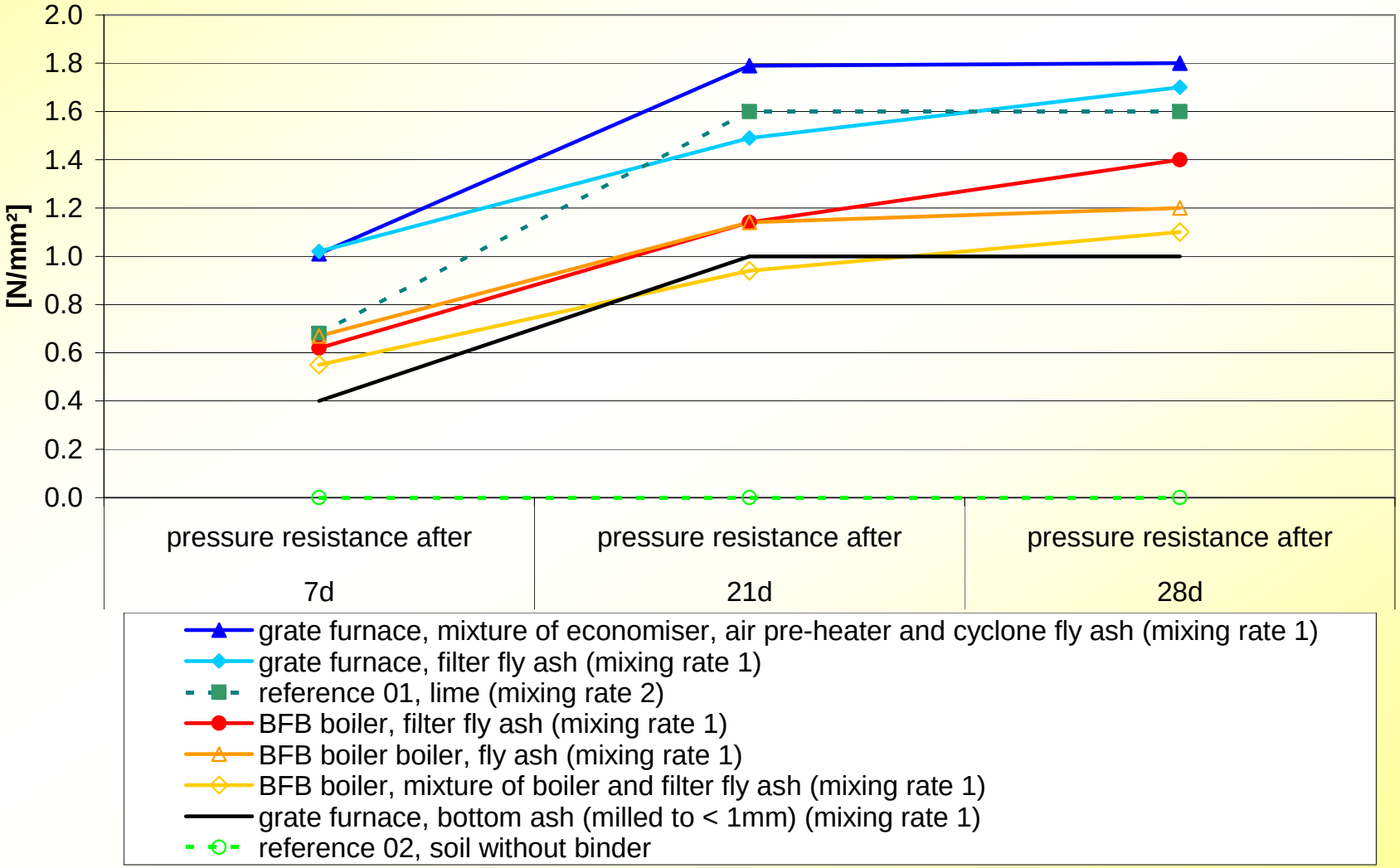
Results
Laboratory tests (II)

➢ Pressure resistance tests performed for selected ash fractions



Results
Laboratory tests (III)

Pressure resistance tests (continued)

- Wood ash can be used as a binding material for soil stabilisation.
- The binding properties, however, depend on the particle size as well as on the content of CaO in the ash.
  - The particle size (a smaller particle size leads to better results) has a bigger influence than the CaO content (a higher CaO content leads to better results).
- So based on the binding properties, fly ashes are favoured over bottom ashes.
- Based on the results of the pressure resistance tests and the limiting values for the ash/soil mixture according to permit obligations a mixture of bottom and coarse fly ash from a GF and a mixture of boiler and filter fly ash from a BFBB were selected for the field test.

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Results - application process - field test

Burnt lime



BFBB fly ash


Mixture of bottom and coarse fly ash (GF)



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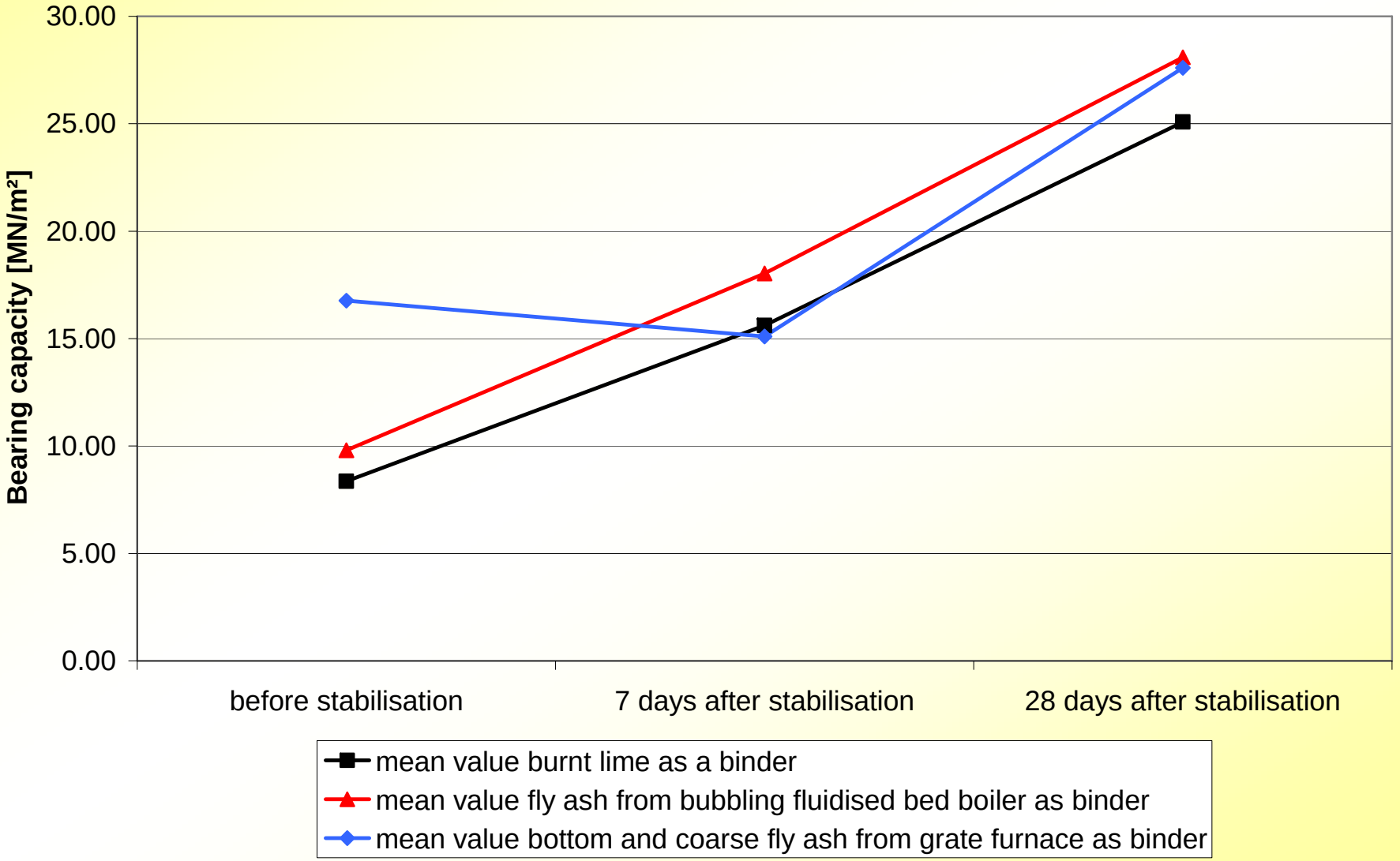
Results - bearing capacity - field test



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First Results - ecological evaluation

- All limiting values were met by all samples from all three sections regarding the contents in the solid matter as well as in the leachate of the soil/ash and soil/lime mixture.
- Additionally, leachates collected at the leachate collection points will also be analyzed and evaluated.
- The analysis of the first batch of leachate samples (7 sampling dates in the first year) shows for most of the parameters values below the limiting values for drinking water. However, more data is needed and the sampling and analysis will continue until autumn 2013.
  → then a comprehensive ecological evaluation will be possible

First Results - economic evaluation

- The longer processing time required for the application and mixing of wood ash compared to burnt lime will be considered in the ongoing detailed evaluation of the economic feasibility of wood ash utilization as a binding material in road construction.
- First results show that, considering the whole process chain from biomass combustion plant to soil stabilization, utilization costs below the current disposal costs for wood ash (currently between 60 and 100 €/t for bottom and coarse fly ash) can be expected.
  → However, further investigations are still needed and final results are expected for late 2012.

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Conclusions

- With the proper admixing rate applied, wood ash can substitute burnt lime as a binding material for soil stabilisation.
- Fly ashes from GF are not suitable under Austrian conditions due to their high contents of volatile heavy metals → concentrations in the stabilised soil would exceed the limiting values defined by the Austrian authorities (especially for Cd and Zn). A mixture of bottom and coarse fly ash from GF can be utilised.
- Fly ashes from FBB feature comparably lower heavy metal contents due to the dilution with bed material and are therefore suitable for soil stabilisation.
- Pro's and Con's (so far):

  Pro's: results comparable to soil stabilised with burnt lime; lower raw material costs

  Con's: longer processing time for wood ash in comparison with burnt lime → an optimisation of the logistics and the pre-processing of ashes is necessary

Outlook

- A detailed evaluation of the economic feasibility of the utilisation of wood ash as a binding material is currently underway. Further research will focus on possibilities to optimize the process of ash collection and pre-processing.
- The ecological evaluation of soil stabilization with wood ashes will focus on the analysis of the leachate samples collected regularly over a period of 3 years from the ongoing field test.
- **The results of these investigations shall provide the basis for a successful implementation of wood ash utilisation as a binder for soil stabilization in practice in the future in Austria.**

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