Fly ash for forest road rehabilitation

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Background

Lack of utilization of ash

- Total annual production of ash is 1.5 million tons in Finland
  - 600.000 tons wood and peat based fly ash (FA)
  - 52 power plants around the Finland
- Use of FA is divided roughly evenly between
  - Earthwork
  - Landfill
  - Fertilizer and other use
- Land fill charge 55 €/tn!

Poor condition of forest roads

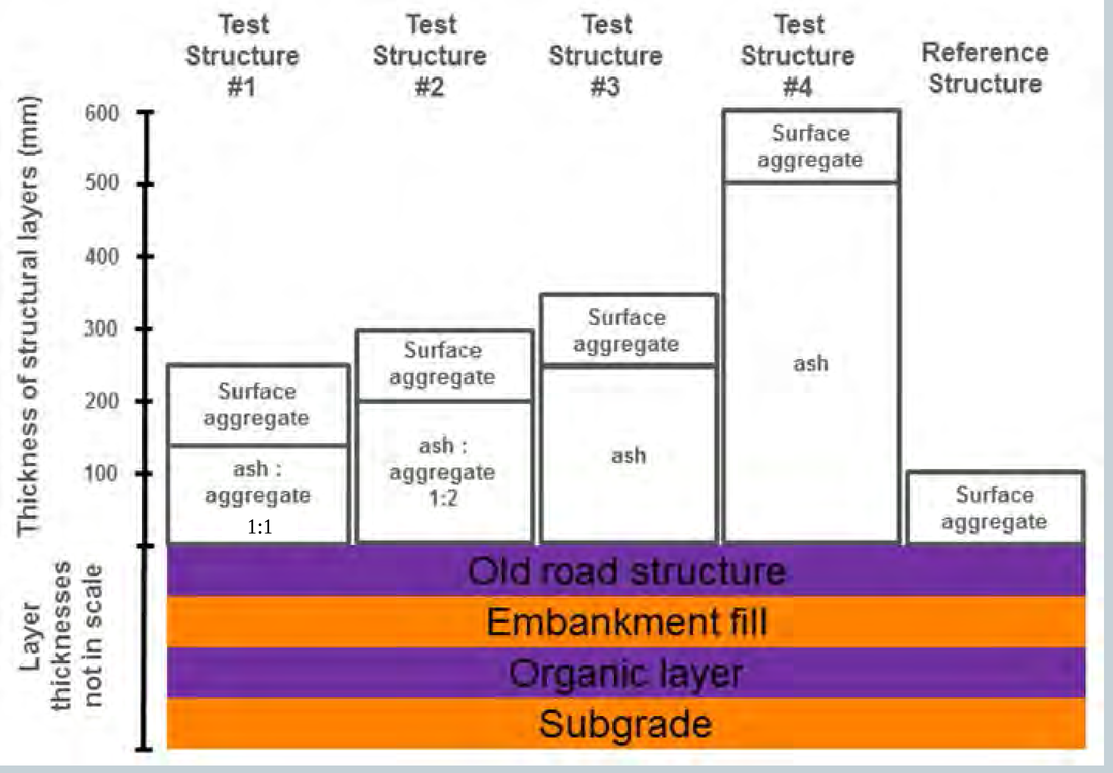
- 3000-4000 km are rehabilitated annually
  - Costs about 10.000 €/km
- Transportation restriction during spring thawing season and fall
- Improvement material and its delivery are biggest costs on rehabilitation.
- *Which is right technique to renovate with bio FA ?*

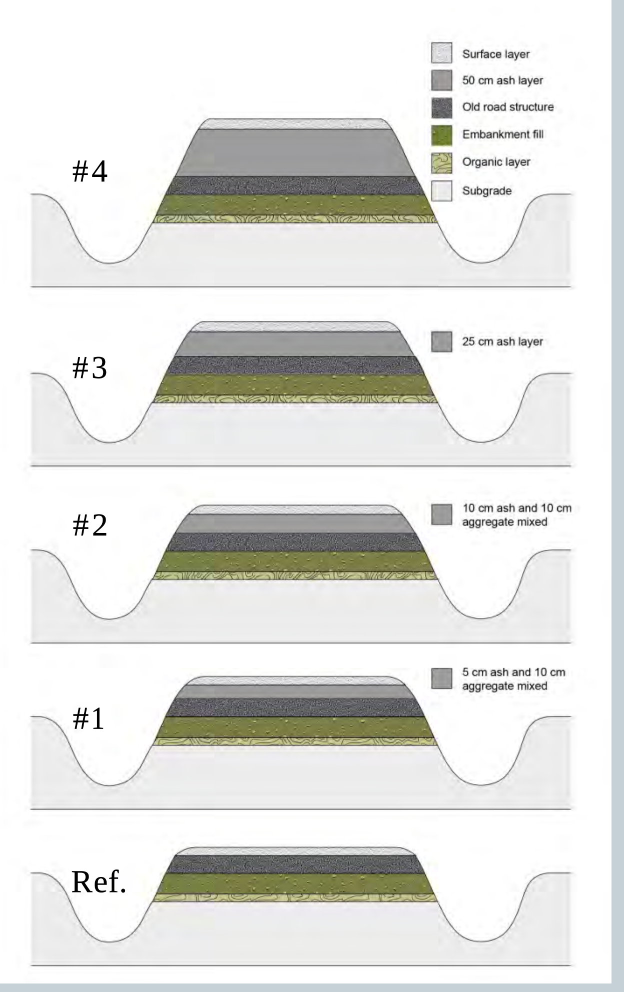
Fly ash is suitable for road construction

- Calcium oxide react with water > higher stiffness of structure
- Several positive impacts
  - Reducing quantity of waste in land fill
  - Reducing need of natural stone material
  - (Higher bearing capacity of road?)

Test structures

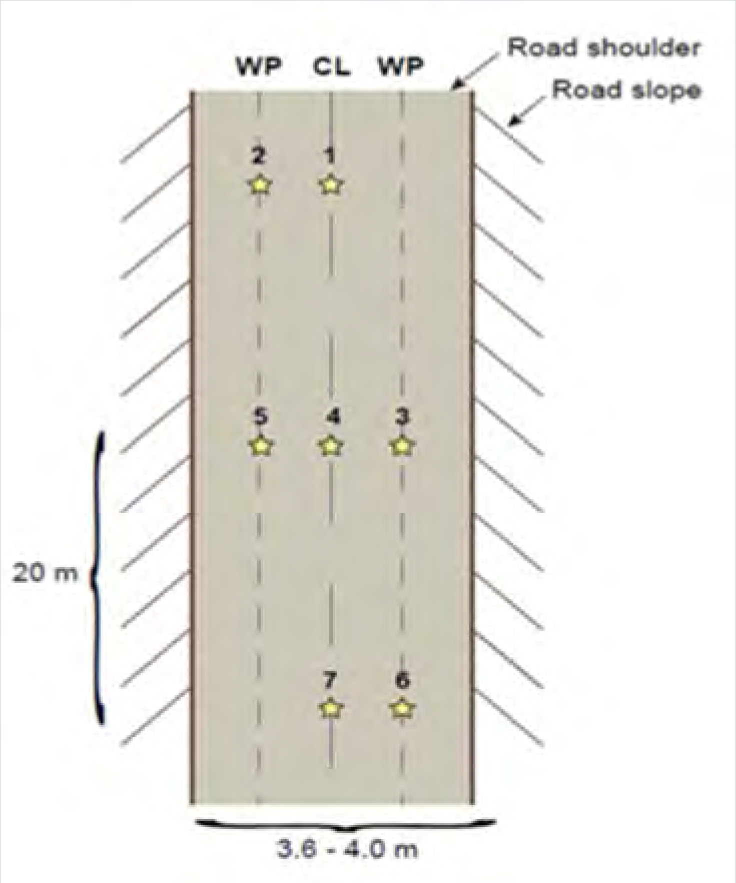
- Two uniform FA structure and two mixed FA / aggregate structure and reference structure



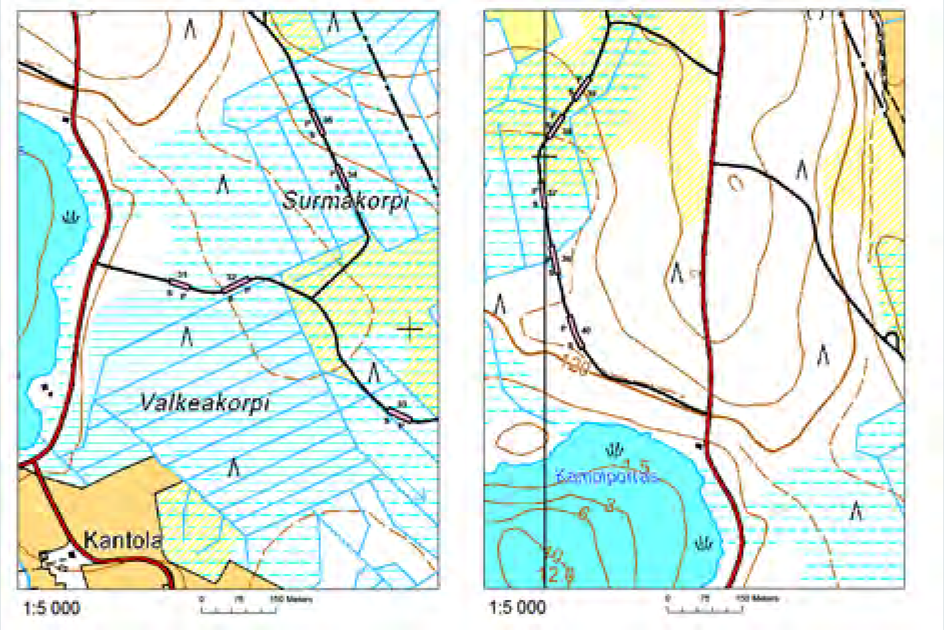


Road cross section

Measuring points and test road sections



- Three measuring point on centre line (CL) and four measuring point on wheel path (WP)
- Two test road sections for each test structure



Bearing capacity measurements

- Dynamic Cone Penetrometer (DCP),
- Light Falling Weight Deflectometer (LFWD),
- Falling Weight Deflectometer (FWD).

<table>
<tr><th></th><th>2011 Summer</th><th>2011 Autumn</th><th>2012 Spring</th><th>2012 Summer</th><th>2013 Spring</th><th>2014 Spring</th></tr>
<tr><td>DCP</td><td>x</td><td rowspan="3">Rehabilitation</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>LFWD</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>FWD</td><td></td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
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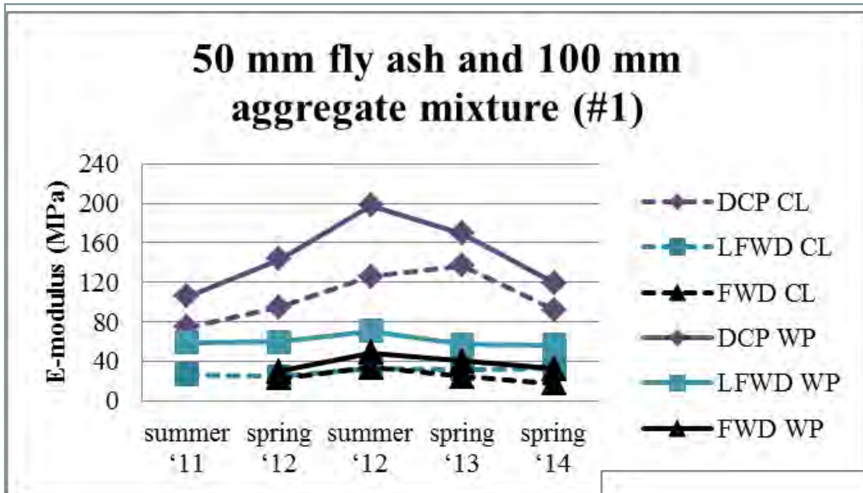
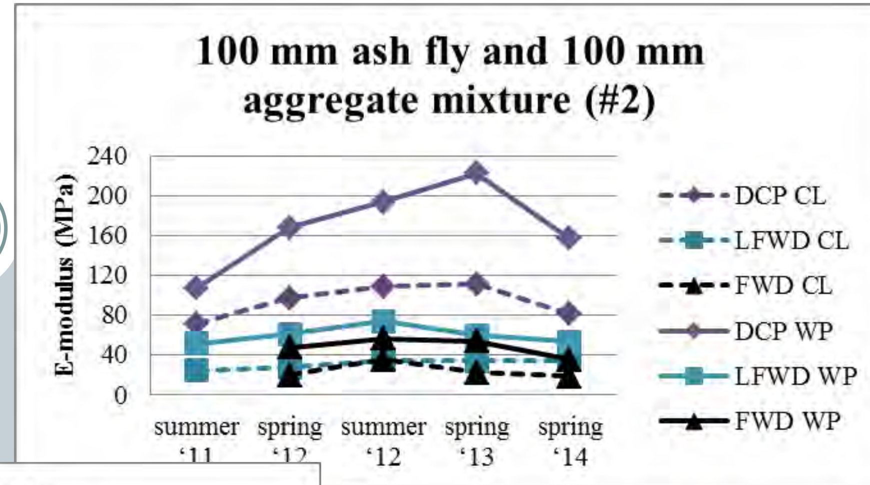
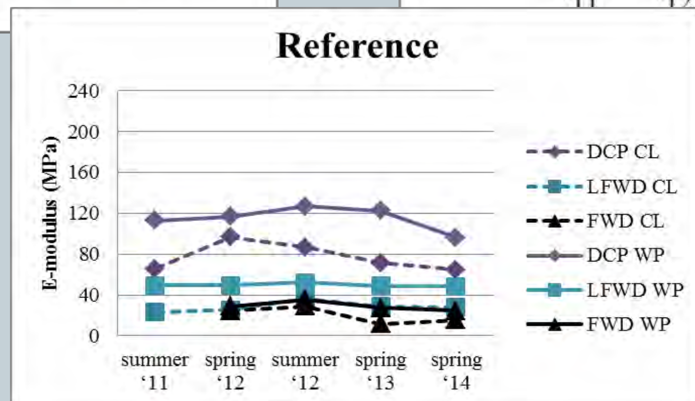
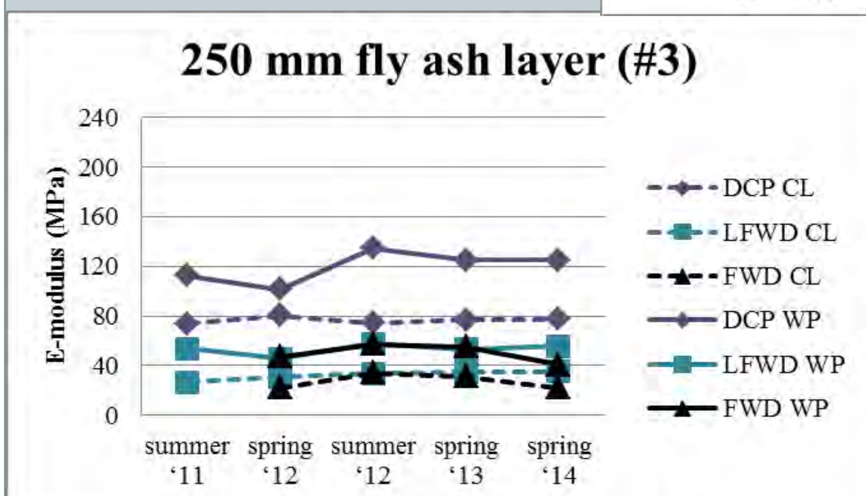
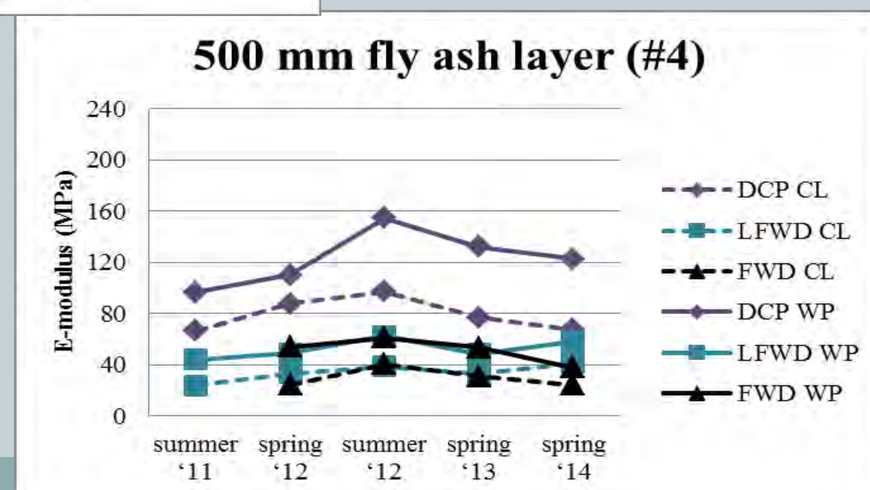
Measurement results











Paired sample t-test

	Device	Class	Test structure	Summer'11 MPa	Spring'12 MPa	Summer'12 MPa	Spring'13 MPa	Spring'14 MPa
Mean *St.Dev.*	DCP	WP	#1	106	37 *27*	92 *78*	64 *41*	
Mean *St.Dev.*	DCP	WP	#2	107	61 *37*	87 *17*	115 *56*	50 *30*
Mean *St.Dev.*	DCP	WP	#3	112	-11 *12*		13 *15*	
Mean *St.Dev.*	DCP	WP	#4	97		58 *64*	36 *28*	
Mean *St.Dev.*	LFWD	WP	#1	59		12 *7*		
Mean *St.Dev.*	LFWD	WP	#2	52		22 *15*		
Mean *St.Dev.*	LFWD	WP	#3	54	-9 *8*			
Mean *St.Dev.*	LFWD	WP	#4	44		19 *14*		15 *9*
Mean *St.Dev.*	DCP	CL	#1	74	21 *18*		62 *42*	
Mean *St.Dev.*	DCP	CL	#2	71		38 *28*	40 *12*	
Mean *St.Dev.*	DCP	CL	Ref.	66	31 *24*			
Mean *St.Dev.*	LFWD	CL	#1	27		7 *5*		6 *4*
Mean *St.Dev.*	LFWD	CL	#2	24		10 *6*	10 *3*	10 *5*
Mean *St.Dev.*	LFWD	CL	Ref.	23	9 *6*	15 *7*	9 *6*	18 *8*

- *Every test structure type were compared separately between initial bearing capacity result and result of each measurement round after rehabilitation - A negative value indicated a decline in bearing capacity and a positive value strengthening of it ($p<0.05$)*
- The number of observations was highest in the column where comparisons were made between measurement rounds of the same season
- The observations were almost double in the case of #1 and #2 test structures compared to uniform FA structures
- The same numbers of observations were made with DCP and LWFD devices. The E_{LFWD} values of bearing capacity did not improve as much as E_{DCP} values

Independent sample t-test

	Device	Class	Round	Reference MPa	#1 Mpa	#2 Mpa	#3 MPa	#4 MPa
Mean *St.Dev.*	DCP	WP	Spring 2012	116 *36*		52 *24*		
Mean *St.Dev.*	DCP	WP	Summer 2012	127 *32*		67 *24*		
Mean *St.Dev.*	DCP	WP	Spring 2013	122 *26*	47 *40*	+100 *42*		
Mean *St.Dev.*	DCP	WP	Spring 2014	96 *25*		60 *16*		
Mean *St.Dev.*	Loadman	WP	Summer 2012	52 *7*	18 *12*	21 *12*		
Mean *St.Dev.*	DCP	CL	Spring 2013	71 *30*	65 *55*			
Mean *St.Dev.*	Loadman	CL	Spring 2014	28 *8*				13 *5*

- *The results of rehabilitated test structures are compared to results for reference structures of the same measurement round ($p<0.05$)*
- The bearing capacities were quite often statistically significant between the #1 test structure and the reference structure, and between the #2 test structure and the reference structure
- The number of DCP observations were more than double that with the LFWD
- E_{FWD} results were also analysed, but statistically significant results were not found
- Two statistically significant differences were observed on the centre line
- No observations were made during the first measurement round before rehabilitation

Discussion & Conclusion

- **The initial summer bearing capacity was reached already the next spring after rehabilitation**
  - better trafficability during the most crucial time for haulage
- **The means of bearing capacity were clearly higher on the wheel path than the centre line**
  - compaction of test structures had taken place
- **Improvement of bearing capacity seems to be bigger with the #1 and #2 test structures**
  - consequence of adding aggregate?

How to do things better?

Inadequate compaction during construction work, unequal storage times of FA and the lack of a better mixing technique

Time for chit-chat

- More information from article:

Kaakkurivaara, T., Kolisoja P., Uusitalo, J. & Vuorimies N. (2015) Fly ash in forest road rehabilitation. Croatian Journal of Forest Engineering Vol. 36, Issue 2, 2015 (’Formec special issue’)

- Questions?