Increased fly ash utilization — value addition through forest road reconstruction

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Background

- Reconstruction annually occurs on 3000–4000 km of forest roads in Finland, while the total length of forest roads is approximately 135 000 km. The total costs of forest road construction and reconstruction were approximately 45.8 million euros in Finland, or equivalent to 12 400 euros per (built or reconstructed) kilometer in 2013.
- Increased fly ash utilization has potential benefits from an economic point of view. Dumping charges have risen lately in Europe, especially in Finland to €70 per ton. As a result of rising dumping charges, new applications or methods for utilizing fly ash have become more relevant.

Background

- The quantity of ash is generally increasing, as a result of growing bioenergy use. Increased fly ash (FA) utilization (e.g., in forest roads) could achieve notable financial savings.
- No ready-made cost calculation models were available for FA construction on forest road systems. The special characteristics of FA complicate this research topic, as FA requires certain types of treatment and construction techniques.
- Many previous forest road cost studies have focused on the cost minimization of new forest road network planning and construction. These studies focused more on the effects of forest road location in relation to construction costs, but different road materials were not compared.

Objectives

- The aim of our study was to develop a cost calculation model for reconstruction and estimate the economic aspect for utilizing fly ash (FA) on forest road circumstances.
- The target of our study was to compare economic efficiency between test structure types to regular reconstruction and seek an opportunity for minimizing costs at landfills.

Methodology

- A description of the construction work was divided into work phases, and suitable earthmoving machines were attached to them.
- Total cost calculation formulas were created for uniform, mixed, and regular test structures, which included machines and construction materials. Construction costs for every test structure type were calculated per kilometer based on these values.
- Our study used regular reconstruction as reference, containing only aggregate for increasing bearing capacity.

Methodology

- The FA and aggregate (Agg.) were used on four different test structures (tons per kilometer)

Test structure	FA	Agg. For mixing	Surface Agg.	Total
#1	200	550	550	1 300
#2	400	550	550	1 500
#3	1 000	-	550	1 550
#4	2 000	-	550	2 550
Regular	-	-	1100	1 100

Methodology

- The FA and aggregate described based on used material thicknesses and volumes

Test structure	Thickness, m			Volume, m^3/km		
	FA	Agg. for mixing	Surface Agg.	FA	Agg.	Total
#1	0.05	0.1	0.1	180	720	900
#2	0.1	0.1	0.1	360	720	1 080
#3	0.25	-	0.1	900	360	1 260
#4	0.5	-	0.1	1 800	360	2 160
Regular	-	-	0.2	-	720	720

Methodology

- Cost calculation models for machinery included fixed costs, operational costs, and labor costs (euros per working hour)
- Cost calculation model for a tip truck included time-dependent and distance-depended costs (euros per km)
- Cost factors were collected for 22 ton excavator, 19 ton motor grader, 8 ton vibratory roller, and 130 kW wheel loader.
- Machine productivities were based on field study, manufacturer interviews and literature.

Methodology

Total cost calculations for test structures:

- **Mixed structure (#1 & #2)**

$$C_{Total} = C_{FA\ loading} + C_{FA\ transport} + C_{Aggregate} + C_{Mixing} + C_{Mix\ transport} + C_{Grading} + C_{Compact} + C_{Surface\ Aggregate} + C_{Aggregate\ Loading} + C_{Aggregate\ transport} + C_{Final\ grading}$$

- **Uniform structure (#3 & #4)**

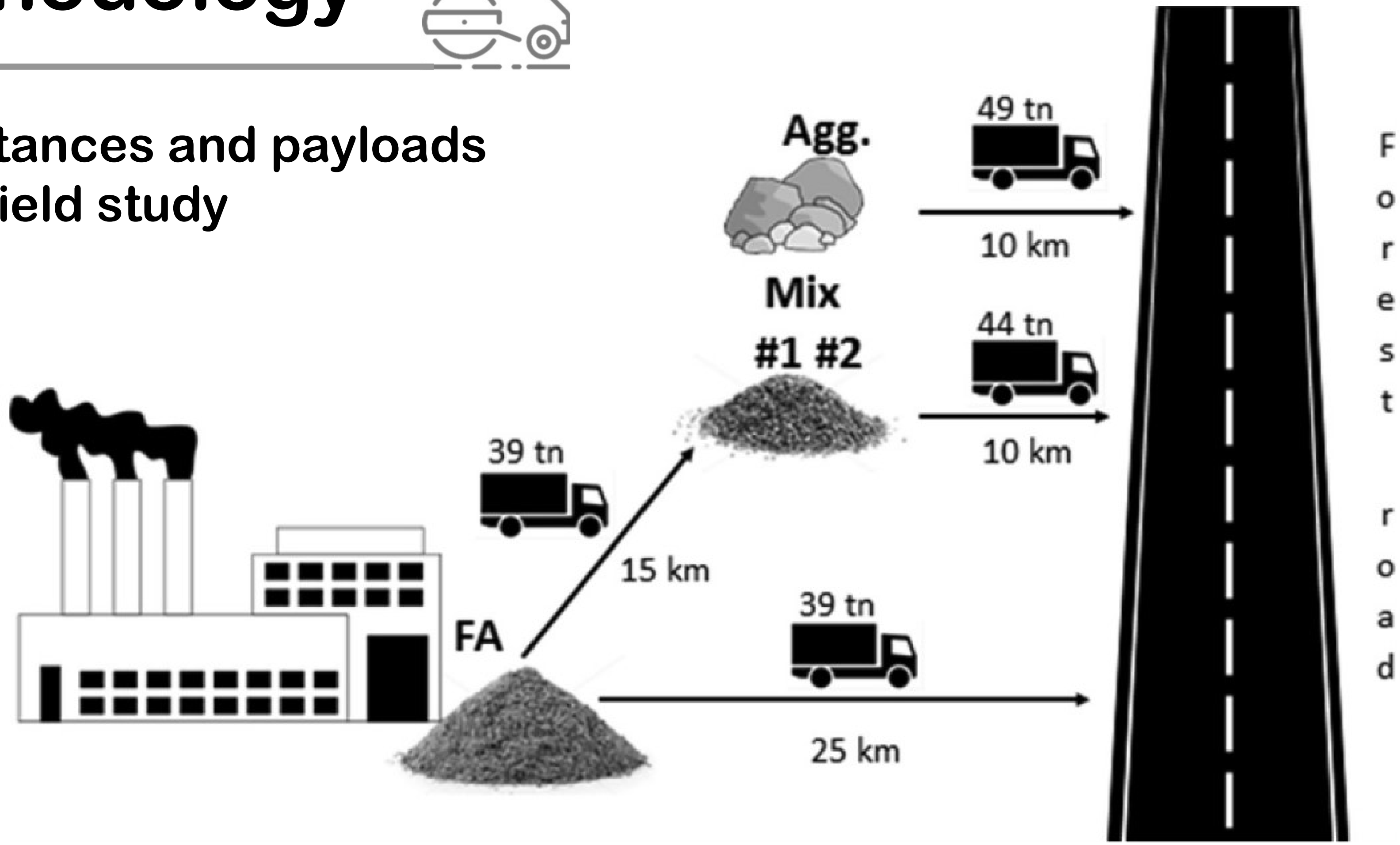
$$C_{Total} = C_{Sidebarriers} + C_{FA\ loading} + C_{FA\ transport} + C_{Spreading\ FA} + C_{Grading\ FA} + C_{Grading\ slopes} + C_{Compact\ FA} + C_{Surface\ Aggregate} + C_{Aggregate\ Loading} + C_{Aggregate\ transport} + C_{Final\ grading}$$

- **Regular structure**

$$C_{Total} = C_{Aggregate} + C_{Aggregate\ Loading} + C_{Aggregate\ transport} + C_{Final\ grading}$$

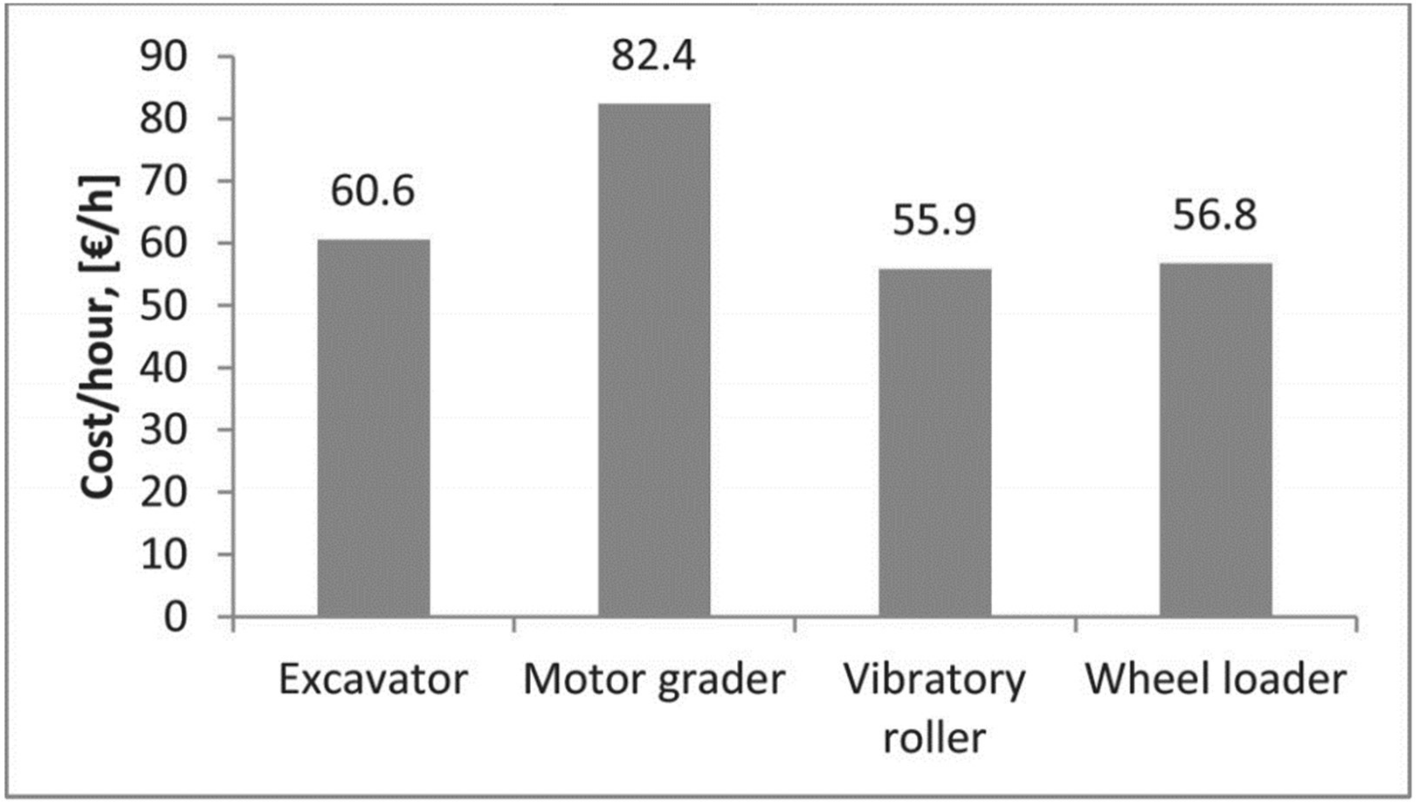
Methodology

- **Distances and payloads of field study**



Results

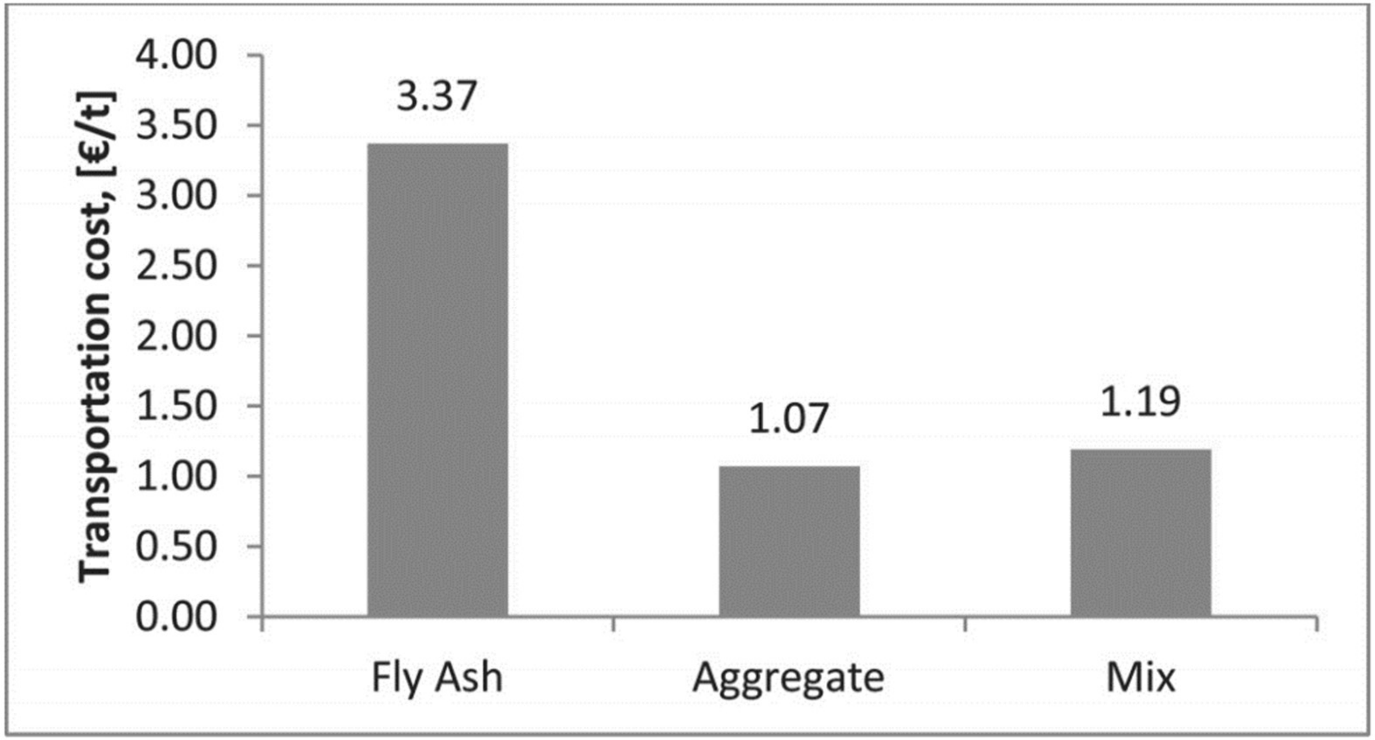
The low utilization time led to higher hourly machine costs.



Hourly cost for earthmoving machines.

Results

Transportation costs for the FA were approximately three times more expensive than for the aggregate or mixed material.



Transportation costs for construction materials, the unit is euros per ton.

Results

- The test structures 23 – 100 % more expensive than the regular
- The test structure #3 was the most economical option (lowest costs)
- Cost saving with the #3 was 60 347 €/km (landfill fee)
- Generally the cost savings decrease when FA transportation distance increases.

Cost of the reconstruction methods are divided into forest road work phases. (€/km)

	#1	#2	#3	#4	Reference
Sidebarriers			330	330	
FA loading	52	104	260	520	
FA transport	667	1335	3336	6673	
Aggregate	2772	2772			
Mixing	4514	5702			
Mix transport	895	1131			
Spreading FA			727	727	
Grading mix/FA	22	22	242	242	
Grading slopes			242	242	
Compact of mix/FA	126	168	209	419	
Surface Agg.	2772	2772	2772	2772	5544
Agg. loading	219	219	219	219	552
Agg. transport	593	593	593	593	1186
Final grading	22	22	22	22	22
Total	12654	14839	8953	12759	7305

Conclusion

- Result significance is highlighted when cost savings were calculated using the dumping charges (landfill fee). If fly ash is suitable from the technical point of view and harmless to the environment, it is possible to reach substantial financial benefits.
- The greatest possible quantity of fly ash used in forest road reconstruction reduces most of the dumping charge costs.
- In this situation, test structure #4 is the best of all the proper choices. If annually produced fly ash can be utilized completely for different applications, it is more important to minimize the utilization process costs (#3).
- The conclusion of our study: from the economic point of view the best choice is test structure #3. Moving forward, it is necessary to continue developing the construction techniques to make them more cost-effective. To enable more frequent fly ash construction, cost competitiveness should catch up with regular structure costs.

Thank you!

- **More information:**
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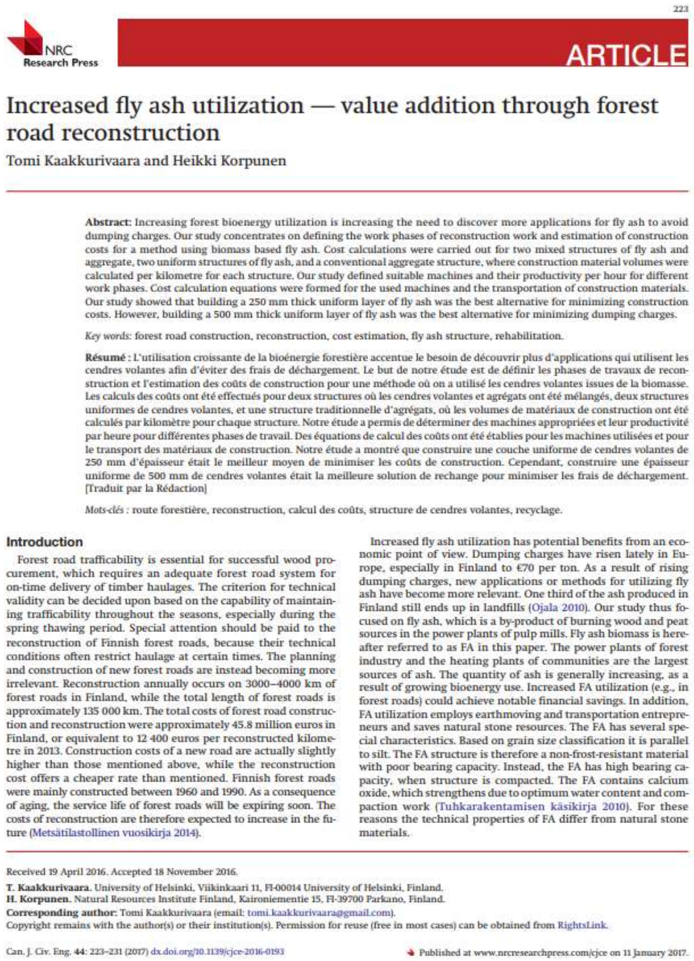

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ARTICLE

Increased fly ash utilization — value addition through forest road reconstruction

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Abstract: Increasing forest bioenergy utilization is increasing the need to discover more applications for fly ash to avoid dumping charges. Our study concentrates on defining the work phases of reconstruction work and estimation of construction costs for a method using biomass based fly ash. Cost calculations were carried out for two mixed structures of fly ash and aggregate, two uniform structures of fly ash, and a conventional aggregate structure, where construction material volumes were calculated per kilometre for each structure. Our study defined suitable machines and their productivity per hour for different work phases. Cost calculation equations were formed for the used machines and the transportation of construction materials. Our study showed that building a 250 mm thick uniform layer of fly ash was the best alternative for minimizing construction costs. However, building a 500 mm thick uniform layer of fly ash was the best alternative for minimizing dumping charges.

Key words: forest road construction, reconstruction, cost estimation, fly ash structure, rehabilitation.

Résumé : L'utilisation croissante de la bioénergie forestière accentue le besoin de découvrir plus d'applications qui utilisent les cendres volantes afin d'éviter des frais de déchargement. Le but de notre étude est de définir les phases de travaux de reconstruction et l'estimation des coûts de construction pour une méthode où on a utilisé les cendres volantes issues de la biomasse. Les calculs des coûts ont été effectués pour deux structures où les cendres volantes et agrégats ont été mélangés, deux structures uniformes de cendres volantes, et une structure traditionnelle d'agrégats, où les volumes de matériaux de construction ont été calculés par kilomètre pour chaque structure. Notre étude a permis de déterminer des machines appropriées et leur productivité par heure pour différentes phases de travail. Des équations de calcul des coûts ont été établies pour les machines utilisées et pour le transport des matériaux de construction. Notre étude a montré que construire une couche uniforme de cendres volantes de 250 mm d'épaisseur était le meilleur moyen de minimiser les coûts de construction. Cependant, construire une épaisseur uniforme de 500 mm de cendres volantes était la meilleure solution de rechange pour minimiser les frais de déchargement. [Traduit par la Rédaction]

Mots-clés : route forestière, reconstruction, calcul des coûts, structure de cendres volantes, recyclage.

Introduction

Forest road trafficability is essential for successful wood procurement, which requires an adequate forest road system for on-time delivery of timber haulages. The criterion for technical validity can be decided upon based on the capability of maintaining trafficability throughout the seasons, especially during the spring thawing period. Special attention should be paid to the reconstruction of Finnish forest roads, because their technical conditions often restrict haulage at certain times. The planning and construction of new forest roads are instead becoming more irrelevant. Reconstruction annually occurs on 3000–4000 km of forest roads in Finland, while the total length of forest roads is approximately 135 000 km. The total costs of forest road construction and reconstruction were approximately 45.8 million euros in Finland, or equivalent to 12 400 euros per reconstructed kilometre in 2013. Construction costs of a new road are actually slightly higher than those mentioned above, while the reconstruction cost offers a cheaper rate than mentioned. Finnish forest roads were mainly constructed between 1960 and 1990. As a consequence of aging, the service life of forest roads will be expiring soon. The costs of reconstruction are therefore expected to increase in the future (Metsätilastollinen vuosikirja 2014).

Increased fly ash utilization has potential benefits from an economic point of view. Dumping charges have risen lately in Europe, especially in Finland to €70 per ton. As a result of rising dumping charges, new applications or methods for utilizing fly ash have become more relevant. One third of the ash produced in Finland still ends up in landfills (Ojala 2010). Our study thus focused on fly ash, which is a by-product of burning wood and peat sources in the power plants of pulp mills. Fly ash biomass is hereafter referred to as FA in this paper. The power plants of forest industry and the heating plants of communities are the largest sources of ash. The quantity of ash is generally increasing, as a result of growing bioenergy use. Increased FA utilization (e.g., in forest roads) could achieve notable financial savings. In addition, FA utilization employs earthmoving and transportation entrepreneurs and saves natural stone resources. The FA has several special characteristics. Based on grain size classification it is parallel to silt. The FA structure is therefore a non-frost-resistant material with poor bearing capacity. Instead, the FA has high bearing capacity, when structure is compacted. The FA contains calcium oxide, which strengthens due to optimum water content and compaction work (Tuhkarakentamisen käsikirja 2010). For these reasons the technical properties of FA differ from natural stone materials.

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