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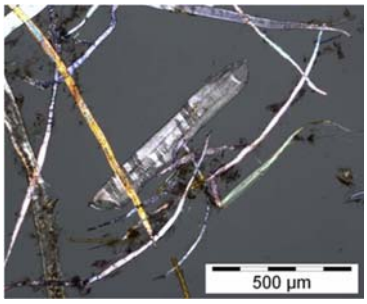

Main properties of recycled fibres reducing strength of paper – How to measure the strength potential?

Elias Retulainen, Janne Keränen, VTT

Workshop on 3rd of November 2015, Munich, Germany

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Outline

- Background; quality of recycled fibres
- A new approach for assessing the quality of fibres and paper for recycling
- Factors affecting the strength of paper
- New parameter; Integrity number
- Effect of recycling on integrity number
- Relationship of the integrity number with paper properties
- Conclusions

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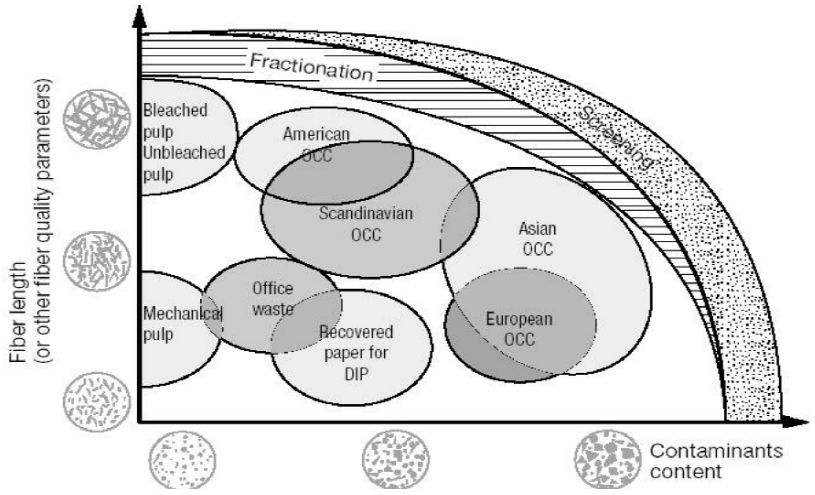
Characterisation of paper for recycling

New Grade Number	New Title	New Grade Description
1.04.00	*corrugated paper and board packaging*	Used paper and board packaging, containing a minimum of 70 % of corrugated board, the rest being *other packaging papers and boards.*

- EN 643 European list of standard grades of paper and board;
- Mainly based on the relative amounts of different paperboard grades in the material
- The geographical differences in same grade
- The quality tends to change with time



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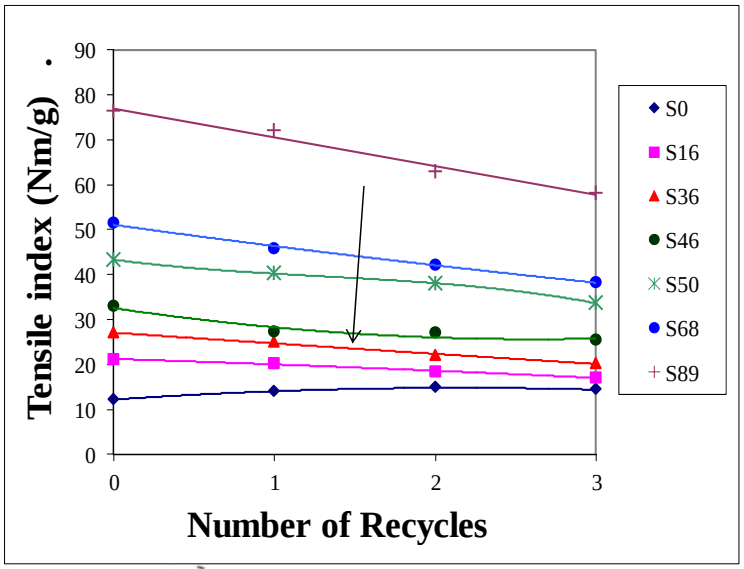
Effect of recycling and lignin content on tensile strength



Lignin content varied 21%-3%
Nguyen Thi Le Lien, 2001

Recycling does not necessary cause considerable changes in fibre or paper properties.
The main effects are caused by changes in density due to fibre flattening or stiffening.

→ The reduced quality of paper for recycling is not due to deteriorated fibre properties.

Increasing lignin content

BANGJI CAO, ULRIKE TSCHIRNER, AND SHRI RAMASWAMY Tappi 1998

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Fiber composition in certain mills using paper for recycling

Sample	Chemical hardwood, %	Chemical softwood, %	Mechanical softwood, %	Semi-chemical hardwood, %	Semi-chemical softwood, %
Newsprint mill 1 after deinking	34	27	39		
		61%			
Newsprint mill 2, after deinking	23	21	56		
		44%			
Paperboard mill, after screening	13	17	10	11	49

→ The quality of paper for recycling changes due mixing of different kinds of paper grades

→ Recycling loop is not degrading fibres but mixing non-optimal furnish materials

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Factors in addition to paper grade information should be considered

- Fibre morphology and fines
- Filler content
- Chemical composition of fibre material

- Fibre morphological parameters cannot be measured directly from paper !

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Characterization fibre material according to its strength potential

- With any solid material the strength is one fundamental quality
- No strength → not useful solid material
- If strength of product can be obtained easily (good strength potential) then there is more freedom to
  - optimise other product properties (optical, density, porosit..)
  - reduce material and energy consumption

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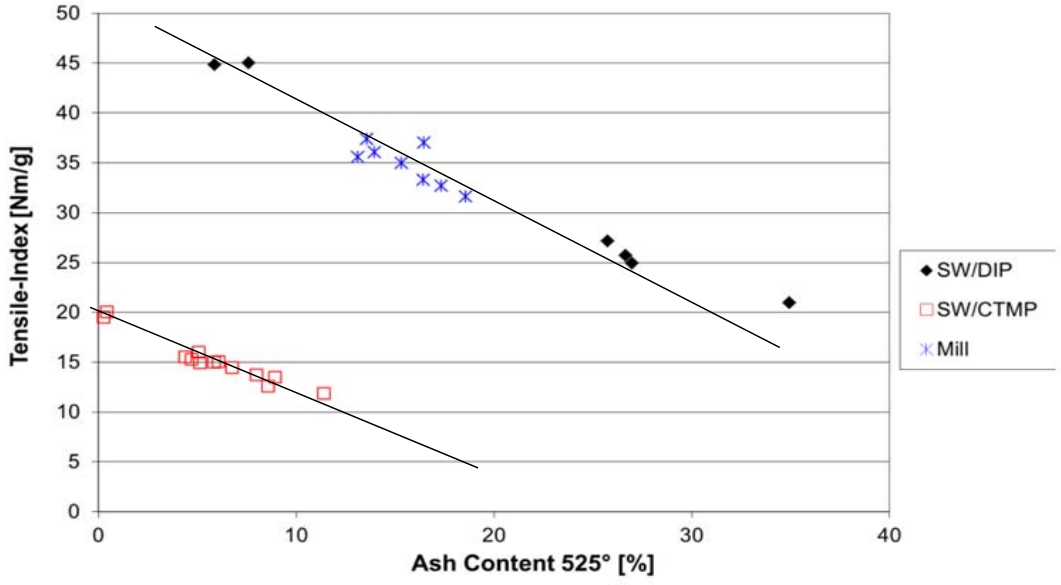
Filler reduces strength



Gert Meinl; Reffibre 2015

- Reduces load bearing fibre material
- Reduces number of interfibre bonds
- Weakens interfibre bonds

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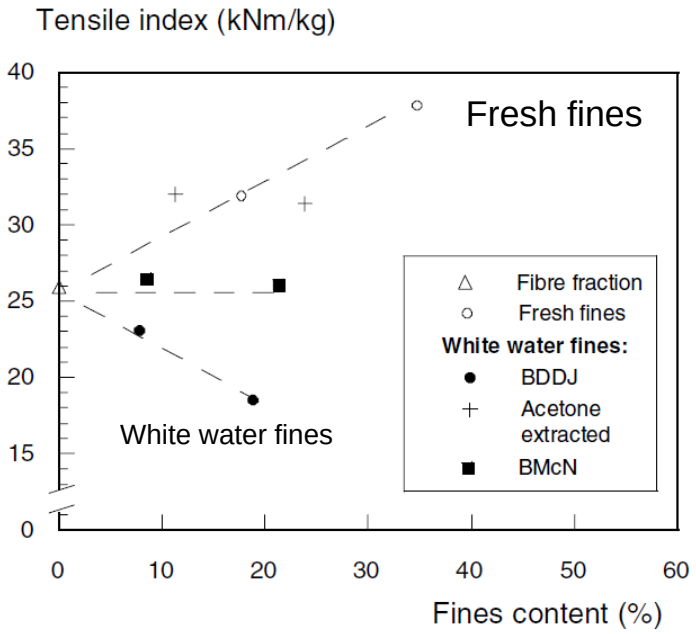
Fines can improve strength by improved bonding but recycled fines is not beneficial

Fines is not load- bearing material in fibre network like fibres.

Fines collect impurities due to their high surface area, they circulate in the white water system, contain stickies and ink



Rundlöf 2002

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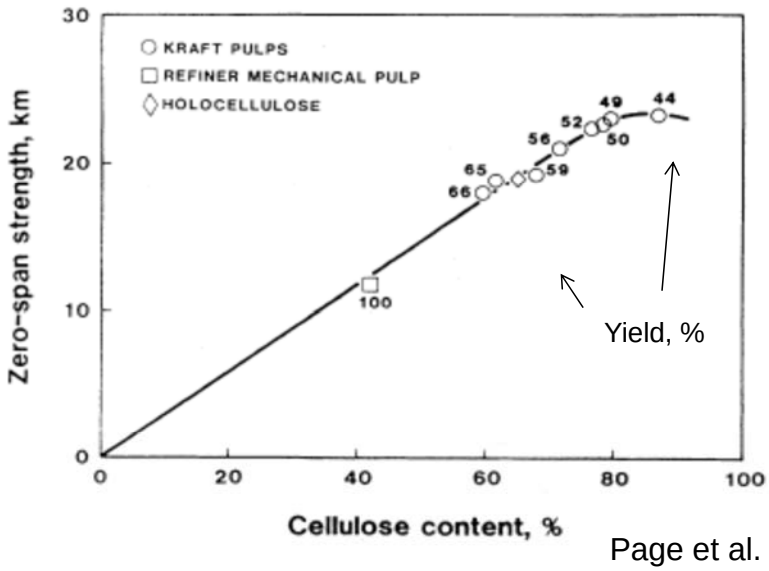
Effect of lignin removal increases fibre strength/weight



Page et al. 1985

Fig 1—Zero-span strength of well-bonded handsheets of black spruce pulps, plotted against cellulose content, derived enzymatically. The figures indicate % yield.

Fibre strength determines the ultimate strength of fibre network

Reducing lignin content increases fibre strength up to a certain point

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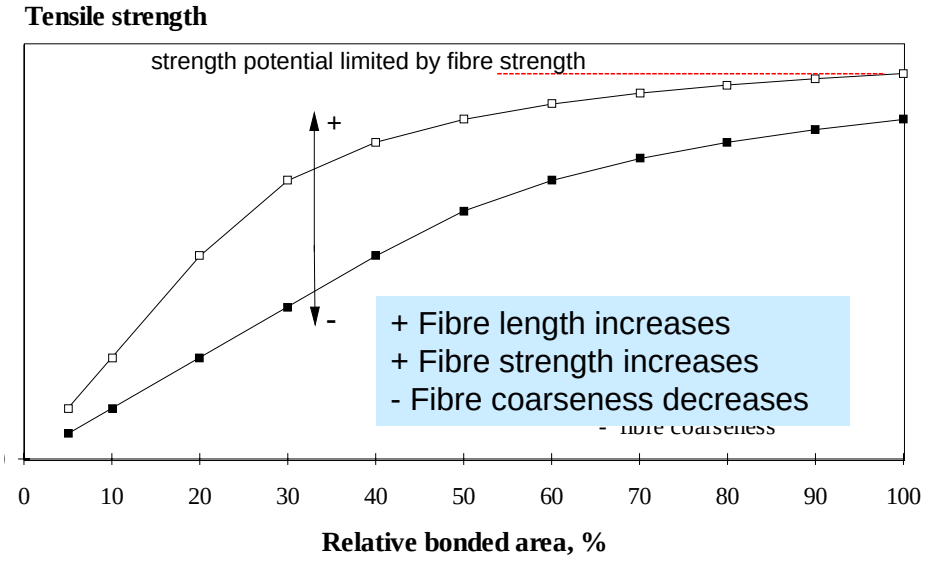
Effect of fibre length on strength



Modified Shallhorn-Karnis model (Retulainen 1996).

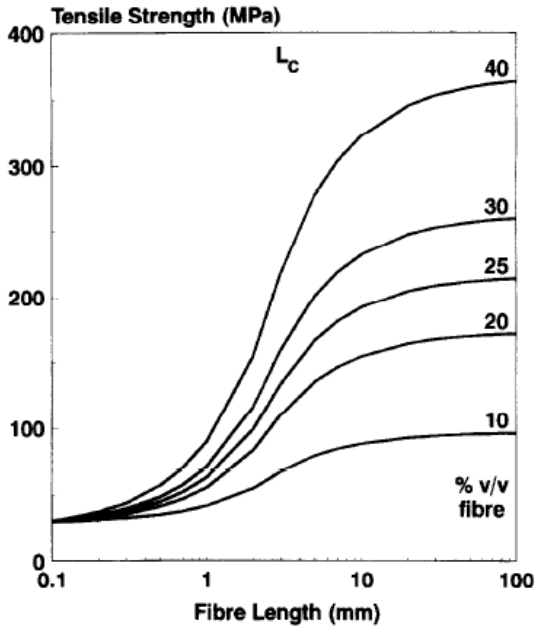


Figure 13 Kelly–Tyson prediction of tensile strength *versus* fibre length

J. L. Thon J. L. Thomason*, M. A. Vlug, G. Schipper and H. G. L. T. Krikort

Composi Composites Part A **27A** (1996) 1075–1084

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Integrity number for recycled pulp

- For estimation of the strength potential of the pulps:

Integrity number= $(1-\alpha Filler)*(1-\beta Fines)*(1-\gamma Lignin)*L*\frac{L}{c}$

- *L projected length weighted fibre length*
- *c fibre coarseness*

α, β, γ *constants,*

Estimates from literature:

α=1.9

β = 1.4

γ =1. 2

- The degree of bonding is not explicitely included,
- Based on assumption that bonding can be controlled separately by wet pressing, refining and strength chemicals

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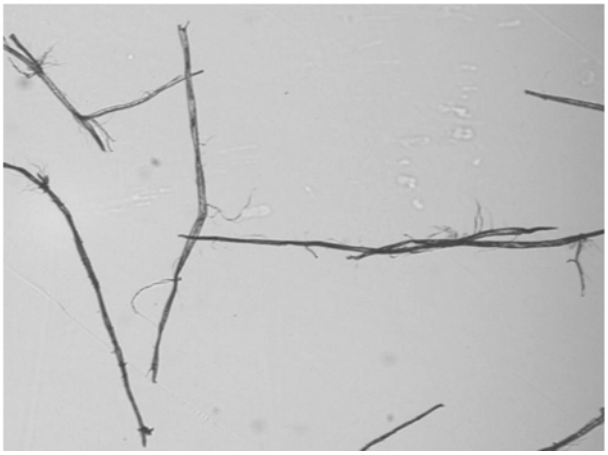
PulpEye pulp analyser



Metso Pulp Expert

Metso Pulp Expert measures:

Basic unit:

- Consistency & Drainage (CSF, SR°)

Optional modules:

- Fiber properties
- Shive content
- Optical properties
- Tensile strength
- Tear strength
- Burst strength
- Bulk
- Porosity
- pH and Conductivity from automatic sampling line

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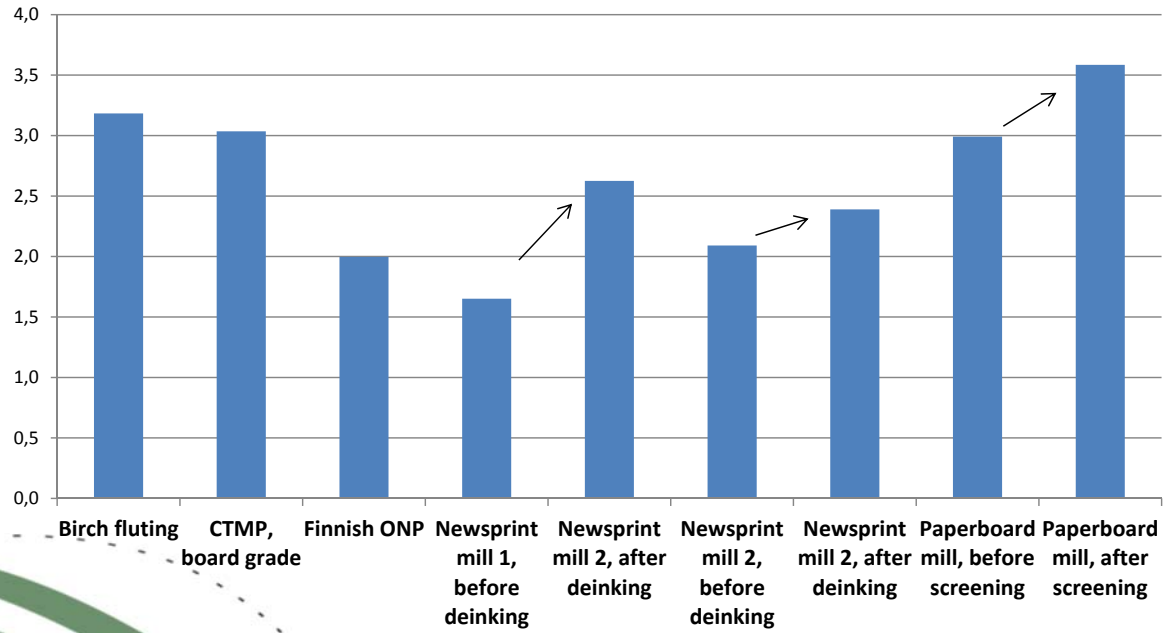
Effect of deinking or screening on integrity number



- *Constants used*
- *α=1.9*
- *β=1.4*
- *γ=1.2*

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Changes caused by deinking

Mill	Filler, %	Corrected lignin, %	Fines, %	Fibre length, mm	Coarseness, mg/m	Curl, %
Newsprint mill 1, before deinking	38,6	14,8	22,8	1,17	0,24	15,5
Newsprint mill 1, after deinking	18,0	15,3	19,2	1,14	0,19	16,1
Newsprint mill 2, before deinking	26,1	13,1	19,0	1,10	0,21	14,6
Newsprint mill 2, after deinking	15,1	14,5	19,2	1,10	0,19	17,8
Paperboard mill , before screening	17,4	12,0	15,7	1,18	0,19	13,8
Paperboard mill , after screening	13,2	11,2	14,8	1,23	0,19	13,8

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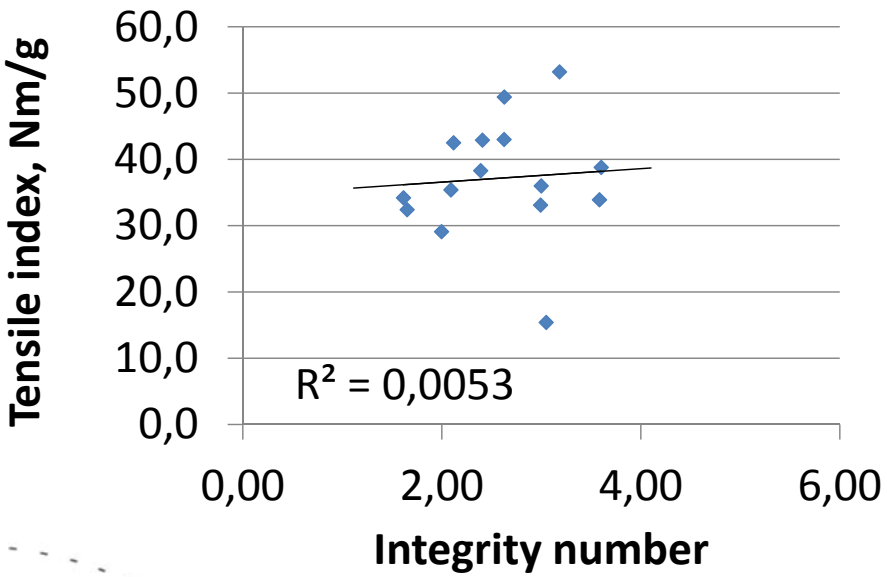
Correlation of integrity number with paper properties

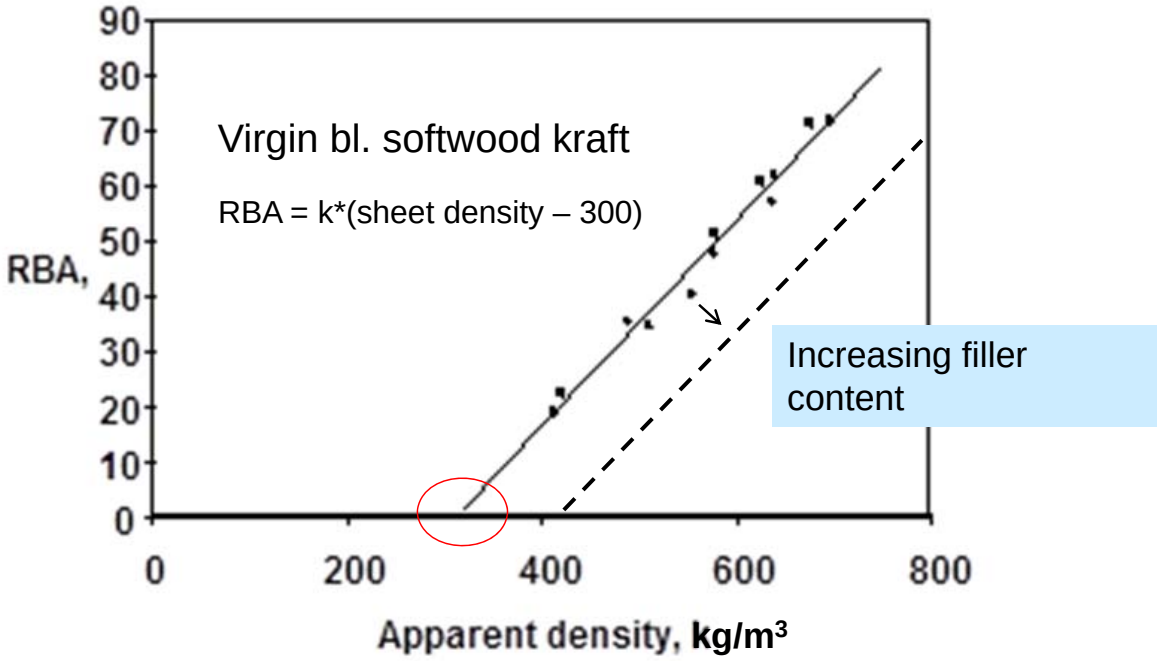


Constants used
α=1.9
β=1.4
γ=1.2

Integrity number does not contain bonding factor. Bonding is an important factor in strength properties of fibre network

We must include RBA in order to be able to evaluate strength

Relative bonded area of fibres depends on apparent density



RBA vs. apparent density (kg/m3) (Retulainen & Ebeling 1993).

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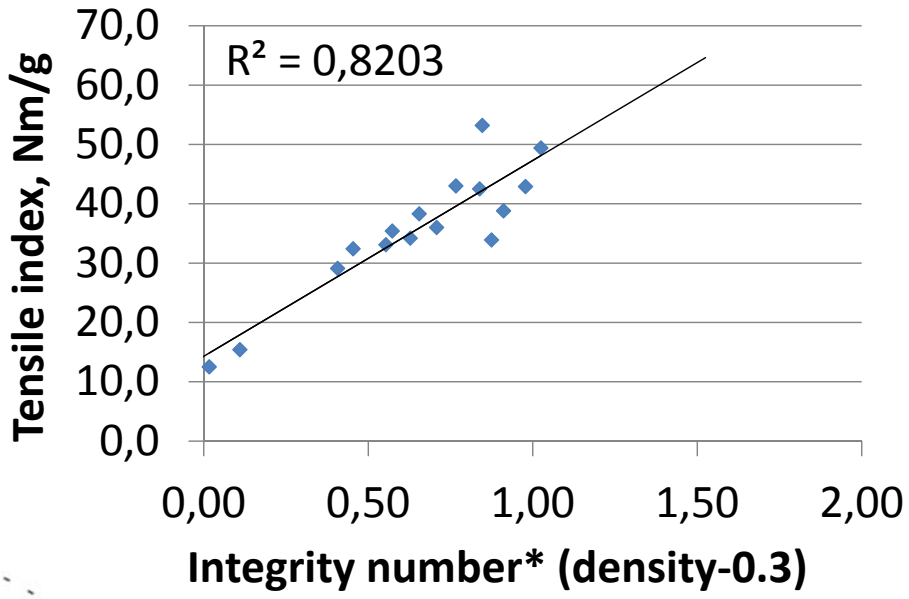
Integrity number vs. strength properties



Constants used
α=1.9
β=1.4
γ=1.2

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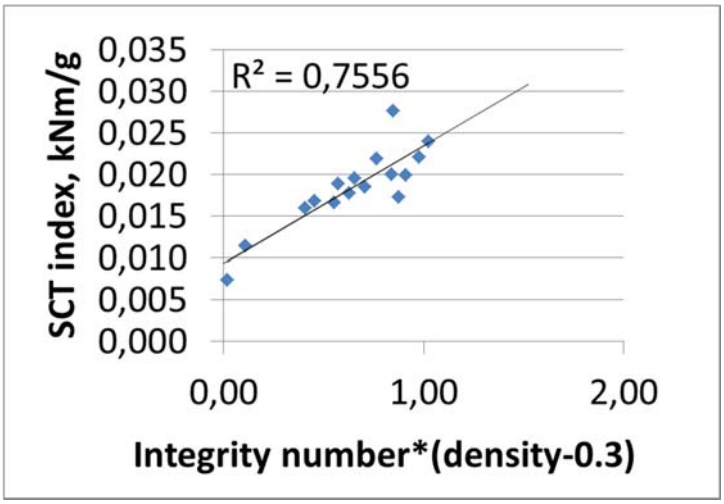
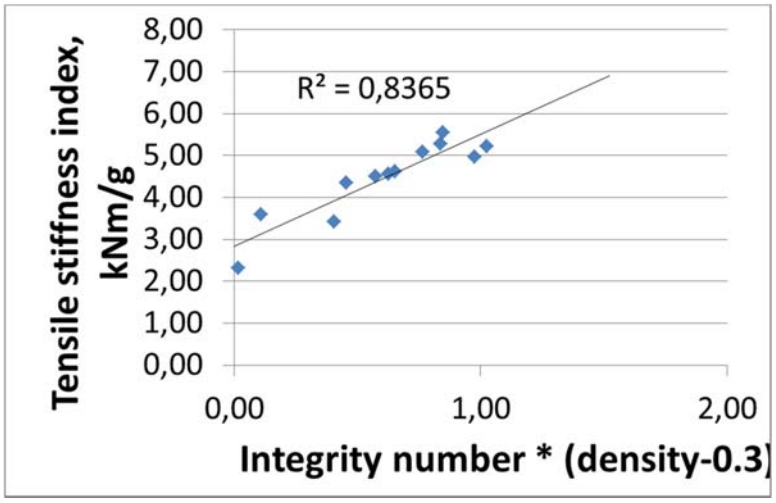
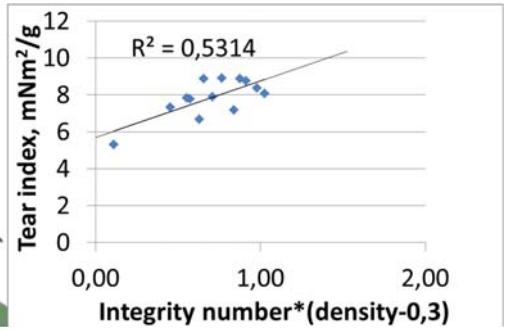
Short column compression test and tensile stiffness





Constants used
α=1.9
β=1.4
γ=1.2



Also correlation with tear strength

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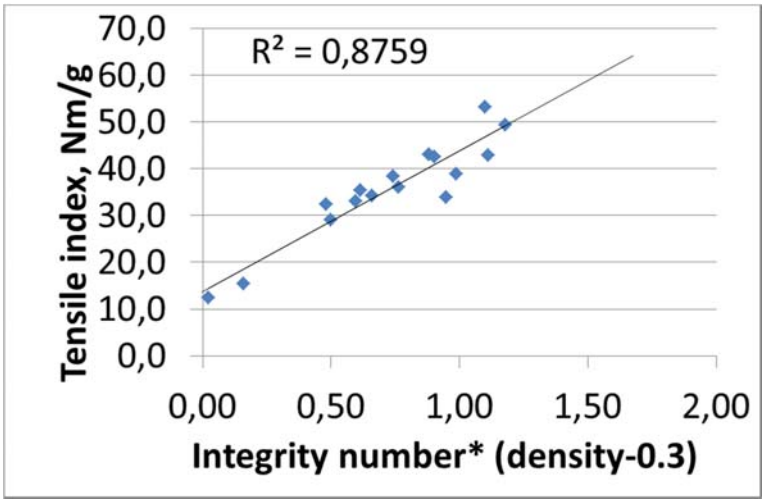
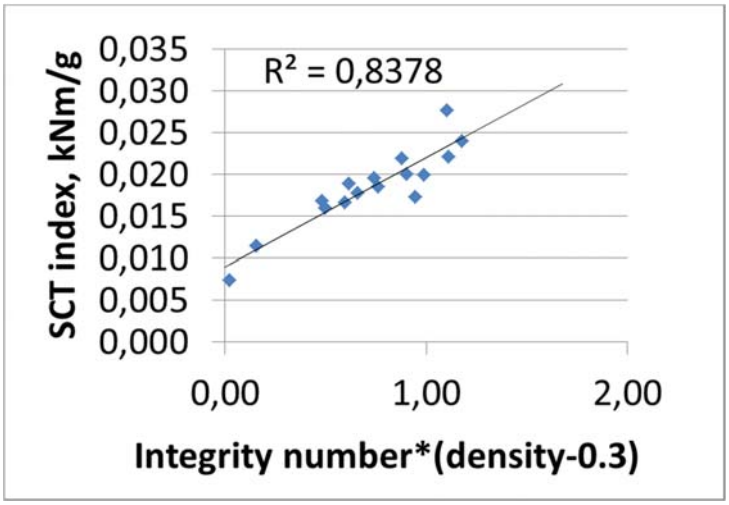
Effect of optimizing the constants (*α, β, and γ*) in the model regarding tensile strength

R² = 0,82 →



R² = 0,76 →



Constants used
α= 2.37
β= 1.54
γ= 0

In the material used, the variation in lignin content was limited, and could be left out, without reducing the significance. Additionally, the lignin is known to affect positively on compression strength.

Conclusions

- The proposed fibre integrity number approach for recycled pulp has potential to be used as a quality parameter for paper for recycling
- Integrity value gives information of the **strength potential** of the fibre material.
- When combined with paper density /RBA it correlates well with several strength properties of paper
- Integrity number is affected by deinking and screening
- Integrity number can potentially be measured using in-line analysers

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Thank you !