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# GRAMMAGE AND STRUCTURAL DENSITY AS QUALITY INDEXES OF PACKAGING GRADE PAPER MANUFACTURED FROM RECYCLED PULP

*Corrugated packaging production is currently facing the challenge to ensure a satisfactory strength of packaging despite the continuous increase in recycled paper as the main fibrous component. This research addresses a very common technical problem for the corrugated board industry – the difficulty of predicting the properties of paper products produced from heterogeneous sources. Grammage and structural density, being easily available data, were examined as quality parameters of the most common categories of packaging paper in Europe. Grammage, ranging from 100 to 225 g/m$^2$, has been found to be a dominant parameter for estimating the strength properties of paper.*

**Keywords:** recycled paper, liners, fluting-medium, grammage, structural density, packaging

## Introduction

Due to favourable legislation [European Commission 1994, 2004, 2005] and environmental restrictions placed on the use of forest-based materials, packaging grade paper contains 80 to 100% recycled fibres [Adamopoulos, Oliver 2006; FEFCO 2012]. Recycled fibres tend to be broken or damaged and have different physical properties to virgin fibres. These differences in fibre properties contribute to weaker interfibre bonding and thus lower the quality (strength) of recycled pa-

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per or paperboard products [Ince 2004; Adamopoulos et al. 2007]; therefore, the use of additional process technology is necessary (mechanical refining, coatings, sizing, bonding adhesives, etc.) to compensate for the inherent disadvantages of recycled fibres. The process additions, however, increase manufacturing costs. A step towards a more economical and sustainable utilization of different packaging paper grades could be the classification of the different grades, therefore allowing the selection of the appropriate raw material for each end-use. Corrugated packaging companies are in need of tools to predict the strength properties of heterogeneous and time-varying raw materials (recycled papers) and to utilize the data in an optimal manner.

Grammage or basis weight, the weight per unit area expressed as $g/m^2$, is the most fundamental property of paper and paperboard. Paper is sold by weight but the buyer is interested in the area of paper per given weight. The paper manufacturer always strives to achieve all desired paper properties with the minimum possible grammage. The structural density of paper, the grammage divided by the structural thickness expressed as $kg/m^3$, is also an important property in papermaking with wide use in paper physics (e.g. the use of engineering calculations of strength and stiffness). The objective of the present work was to relate grammage and structural density with the mechanical properties of grade paper most commonly used by packaging companies throughout Europe, and to explore the most suitable quality parameter.

## Materials and methods

Twenty one types of paper were selected to cover different grades of liners and fluting-corrugating medium available on the European market for the production of corrugated board. The paper was provided by five European corrugated board companies and came from twelve paper suppliers from the global market. The characteristics of the paper are shown in table 1.

All the paper was tested for the following properties: grammage [ISO 536:1995], thickness [ISO 534:2005], compressive strength according to short-span test SCT [ISO 9895:2008], tensile strength [ISO 1924-3:2005], and burst strength [ISO 2759:2001]. Compressive strength was also determined for the liners according to the ring crush test RCT [ISO 12192:2002] and for the fluting-medium according to the corrugated crush test CCT [SCAN-P 42:81]. Before testing, the samples were conditioned at 23°C and 50% RH. The structural densities of the samples were calculated by dividing the grammage by the bulking thickness (determined according to ISO 534:2005 as the distance between two parallel plates resting on the paper with a specified force) and not according to the SCAN-P 88:01 standard, which requires the structural thickness, e.g. the thickness determined from the distance between two different spherical probes when the paper is fed into the nip at a constant speed. The structural thickness is

more accurate as surface unevenness is accounted for and therefore it is used for advanced paper physics.

**Table 1. Paper characteristics**

| Paper category/ Classification[1] | Grammage[2] [g/m$^2$] | Supplier |
|---|---|---|
| Liners | | |
| KL: brown kraftliner (predominantly made from primary kraft pulp) | 125, 140, 170, 170, 225 | No1, No2, No1, No3, No4 |
| TL: brown testliner (predominantly recycled fibre based) | 100, 115, 170 | No5, No6, No7 |
| BB: brown bicolor (predominantly recycled fibre based with burst index ≥1.6) | 105, 110, 110, 160 | No8, No4, No9, No9 |
| Fluting-medium | | |
| SCF: semi-chemical fluting (predominantly made from semi chemical primary fibres pulp) | 112, 127, 150, 150 | No10, No7, No7, No11 |
| RFM: recycled fluting-medium (predominantly recycled fibre based) | 95, 105, 110, 125, 160 | No7, No8, No12, No6, No11 |

[1] According to CEPI Containerboard [2012] classification code
[2] According to the supplier

## Results and discussion

In figs. 1 and 2, the strength properties are plotted against grammage and structural density. Only the statistically significant linear regression equations (ANOVA, P = 5%) were reported, and in the other cases, the data were plotted without fitting a regression line. The strength properties showed greater sensitivity with changes in the grammage than in the structural density.

The linear relationships with a positive intercept between all the strength properties and the grammage were obtained with coefficients of determination ranging from 0.725 to 0.915 in the case of the liners [fig. 1] and from 0.580 to 0.885 in the case of the fluting-medium [fig. 2]. In general, for both the liners and the fluting-medium, the influence of structural density on the strength properties was either non-existent or had a weak positive relationship [fig. 1, 2]. This suggests that grammage is a better estimator of the influence of the bulk structure of recycled paper on paper strength. No statistically significant correlation was found between grammage and structural density for either of the two paper categories (liners and fluting-medium).

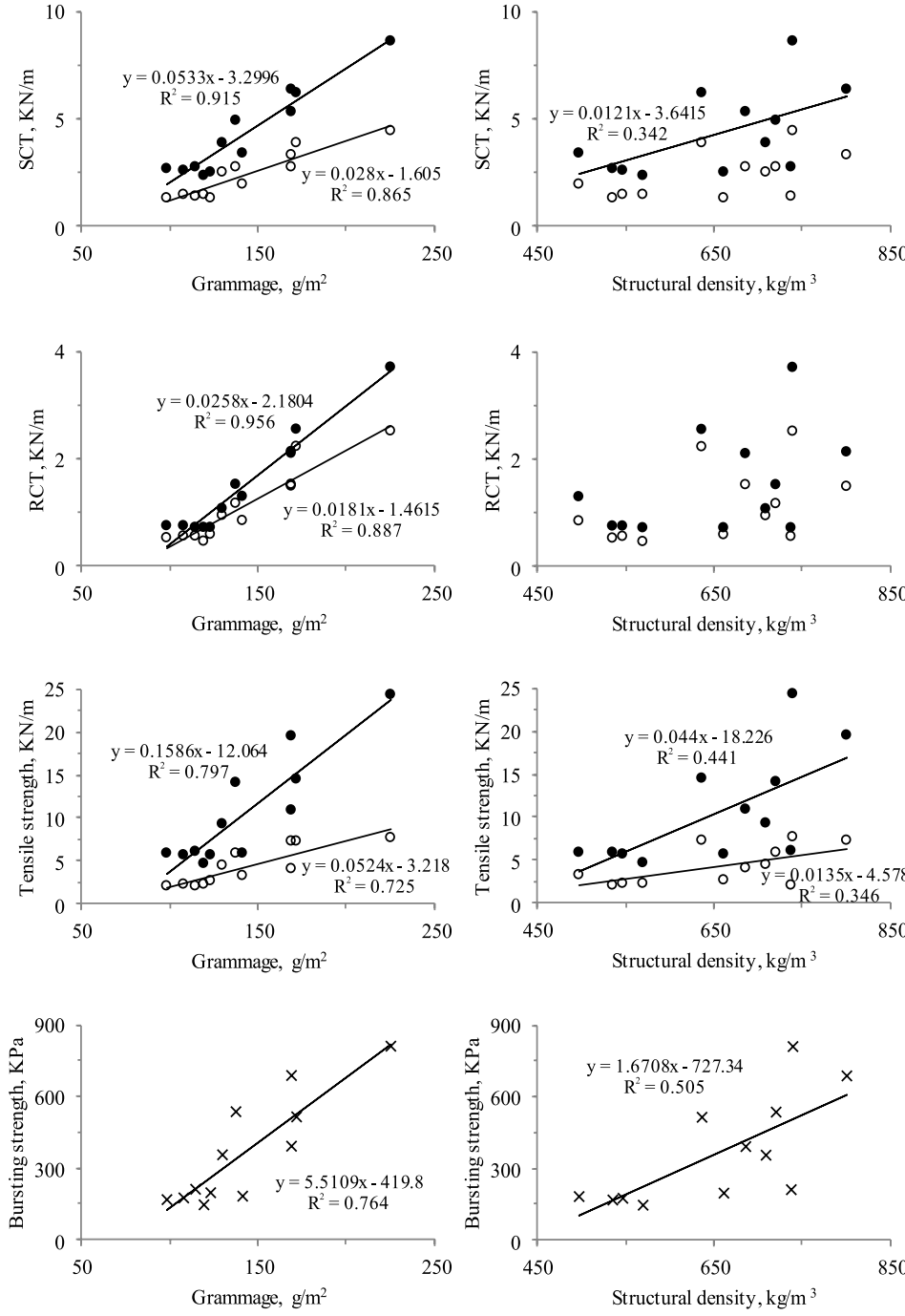


**Fig. 1. Relationships between grammage (left) and structural density (right) and mechanical properties of liners. Note: machine direction [●], cross direction [○]**

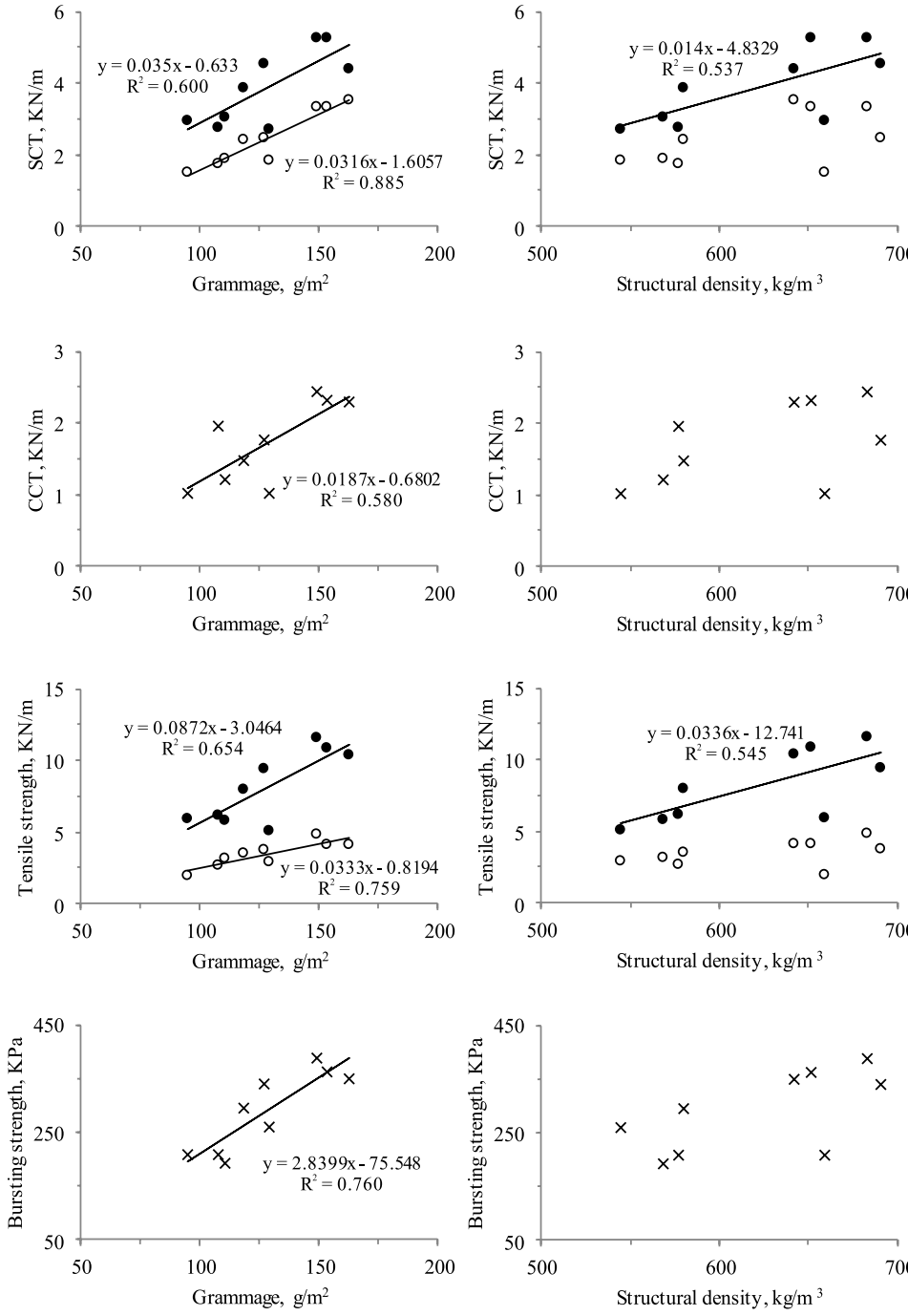


**Fig. 2. Relationships between grammage (left) and structural density (right) and mechanical properties of fluting-medium. Note: machine direction [●], cross direction [○]**

It should be noted that it was not part of this study's intention to identify the extent to which the strength of a specific paper grade within the liner or fluting--medium category is influenced by its structural characteristics, grammage, or density. That approach would require a different experimental design monitoring a number of parameters (ash content, content of strength additives, fibre properties etc.), and also take into account the formation parameters of the paper sheets [Nordström 2003; I'Anson et al. 2007]. This study, therefore, included a search for dependencies in each of the liner and fluting-medium categories. This approach is close to industrial practice, where the selection of grade paper for a specific packaging use is based on availability, cost and empirical quantification of performance.

## Conclusions

This study showed that the variety of packaging paper grades produced from heterogeneous recycled pulp in Europe can be characterized by their grammage, irrespective of the paper category or subcategory to which they belong. The results can be used for a quick prediction of the strength properties of recycled paper based on grammage, thus permitting sensible use in appropriate corrugated packaging applications.

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**List of standards**

ISO 534:2005 Paper and board. Determination of thickness, density and specific volume
ISO 536:1995 Paper and board. Determination of grammage
ISO 1924-3:2005 Paper and board. Determination of tensile properties. Part 3: Constant rate of elongation method (100 mm/min)
ISO 2759:2001 Board. Determination of bursting strength
ISO 9895:2008 Paper and board. Compressive strength. Short-span test
ISO 12192:2002 Paper and board. Compressive strength. Ring crush method
SCAN-P 42:81 Paper and board. CCT value and CCT index. Corrugated Crush Test
SCAN-P 88:01 Paper and board. Structural thickness and structural density

## GRAMATURA I GĘSTOŚĆ STRUKTURALNA JAKO WSKAŹNIKI JAKOŚCI GATUNKOWEGO PAPIERU OPAKOWANIOWEGO WYTWARZANEGO Z MASY PAPIERNICZEJ POCHODZĄCEJ Z RECYKLINGU

**Streszczenie**

Obecnie produkcja opakowań z tektury falistej stoi przed wyzwaniem, którym jest zapewnienie ich zadowalającej wytrzymałości, pomimo stałego wzrostu udziału papieru z recyklingu jako głównego komponentu włóknistego. W niniejszych badaniach zajęto się bardzo powszechnym w przemyśle wytwarzania tektury falistej problemem technicznym, a mianowicie trudnością w przewidywaniu właściwości produktów papierowych wytwarzanych z heterogenicznych surowców. Gramatura i gęstość strukturalna, czyli łatwo dostępne dane, zostały przebadane jako parametry jakościowe najbardziej powszechnych kategorii papieru opakowaniowego w Europie. Gramatura, mieszcząca się w przedziale od 100 do 225 g/m$^2$, okazała się być dominującym parametrem przy szacowaniu właściwości wytrzymałościowych papieru.

**Słowa kluczowe:** papier z recyklingu, linery, fluting, gramatura, gęstość strukturalna, opakowania

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