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EFFECT OF PERFORATIONS ON THE LOSS OF CORRUGATED CARDBOARD BENDING STIFFNESS

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Introduction

Shelf Ready Packaging (SRP) is secondary packaging with additional solutions for packaging functionality. Functional requirements needed for a good SRP include ensuring easy identification, easy opening, easy shelfing, easy shopping and easy disposal (Theppituck et al., 2013). SRP should be easy to open to simplify and expedite replenishment and to facilitate in-store supply chain execution (Coles, 2013). However, easy opening should not compromise the structural integrity of the package, which is needed for safe transportation and handling (Hellström and Saghir, 2007). Perforations on corrugated boxes can be used to open the packaging and to convert secondary packaging into corrugated tray or case displayed on the shelf.
The classic approach to Shelf Ready Packaging design is the empirical or trial-and-error method. These methods are time-consuming and expensive. Therefore understanding the effects of perforation lines on the mechanical integrity of packaging is essential to providing a better product.
An important structural parameter of corrugated cardboard as a packaging material is flexural rigidity or bending stiffness (Luo et al., 1992). High bending stiffness provides rigidity and strength to paperboard packaging (Kajanto, 2008) and reduces the tendency for boxes to bulge when the contents are pressed against the wall (Fellers, 2009). Bending stiffness depends on the layered structure of corrugated cardboard that has two characteristic in-plane directions of anisotropy (Garbowski and Knitter-Piątkowska, 2022).

Problem Description

It is important to understand the properties of perforated corrugated cardboard as an engineering material to understand where and how perforation decisions can impact the structural stability of the desired product. The aim of this paper is to identify the effect of perforations on the loss of bending stiffness of corrugated board in order to gain new insights into the structural properties. Furthermore, the perforation variables are analyzed and determined which one affect bending stiffness of corrugated cardboard the most.

Methods

Three-point bending tests on perforated corrugated cardboard were conducted on a tensile testing machine according to ISO 5628:2019. Three perforation variables were analyzed: Type of perforation, Angle of perforation position and Quality of perforated corrugated cardboard. 45 different test specimens are tested in direction MD and are compared using statistical analysis.

Figure 1

Real images of selected specimens

Results / Discussion

The maximum allowable deflection was calculated for each quality of perforated corrugated cardboard. The obtained results correspond to the limitation that ensure that the errors are less than 5%.

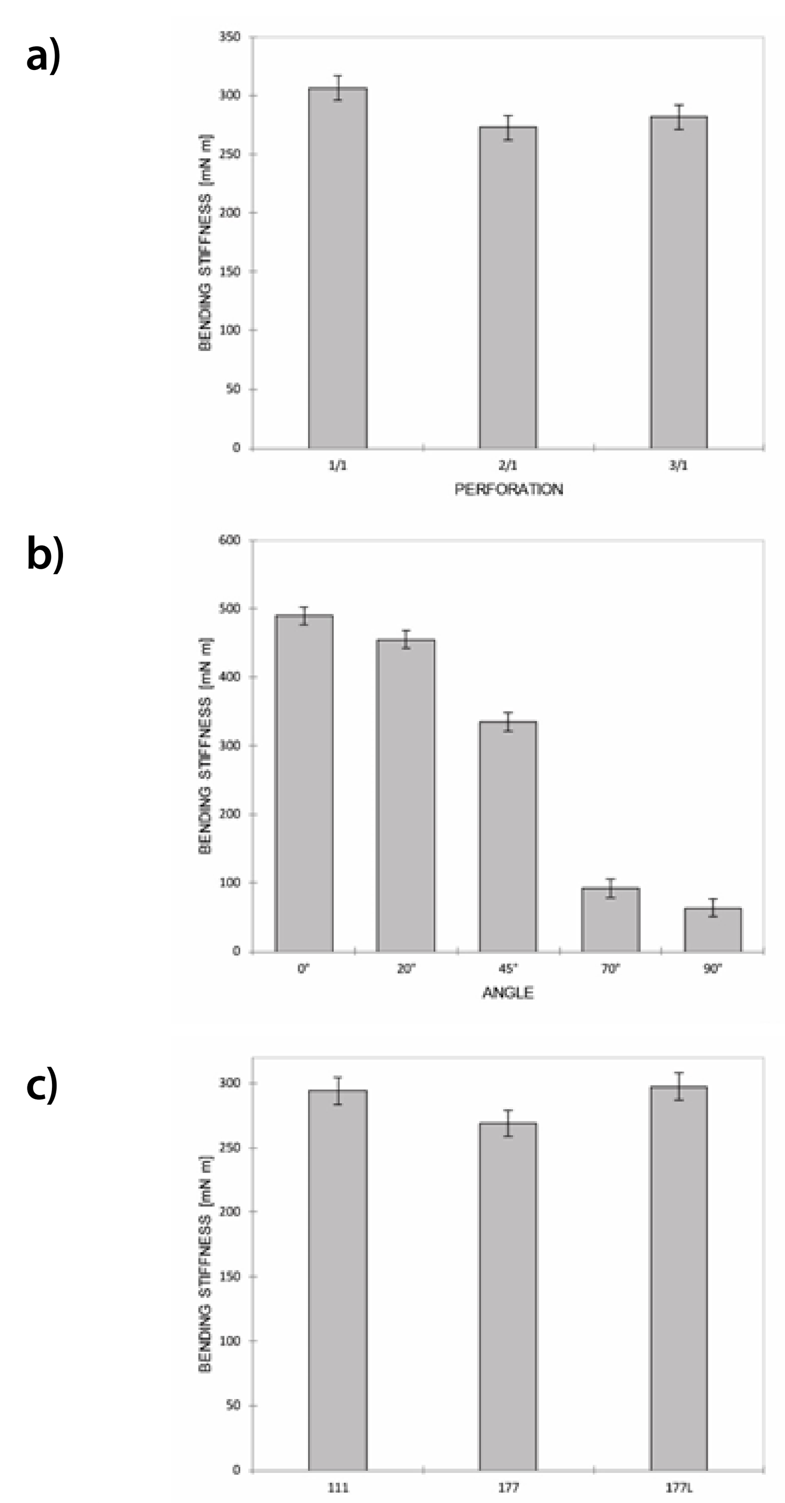

Figure 2

Main effect of variable: a) Type; b) Perforation; c) Angle; on the loss of bending stiffness

The results were statistically analyzed to quantify the effect of the perforations on the loss of corrugated cardboard bending stiffness and to determine which peforation variable most affects corrugated board bending stiffness.

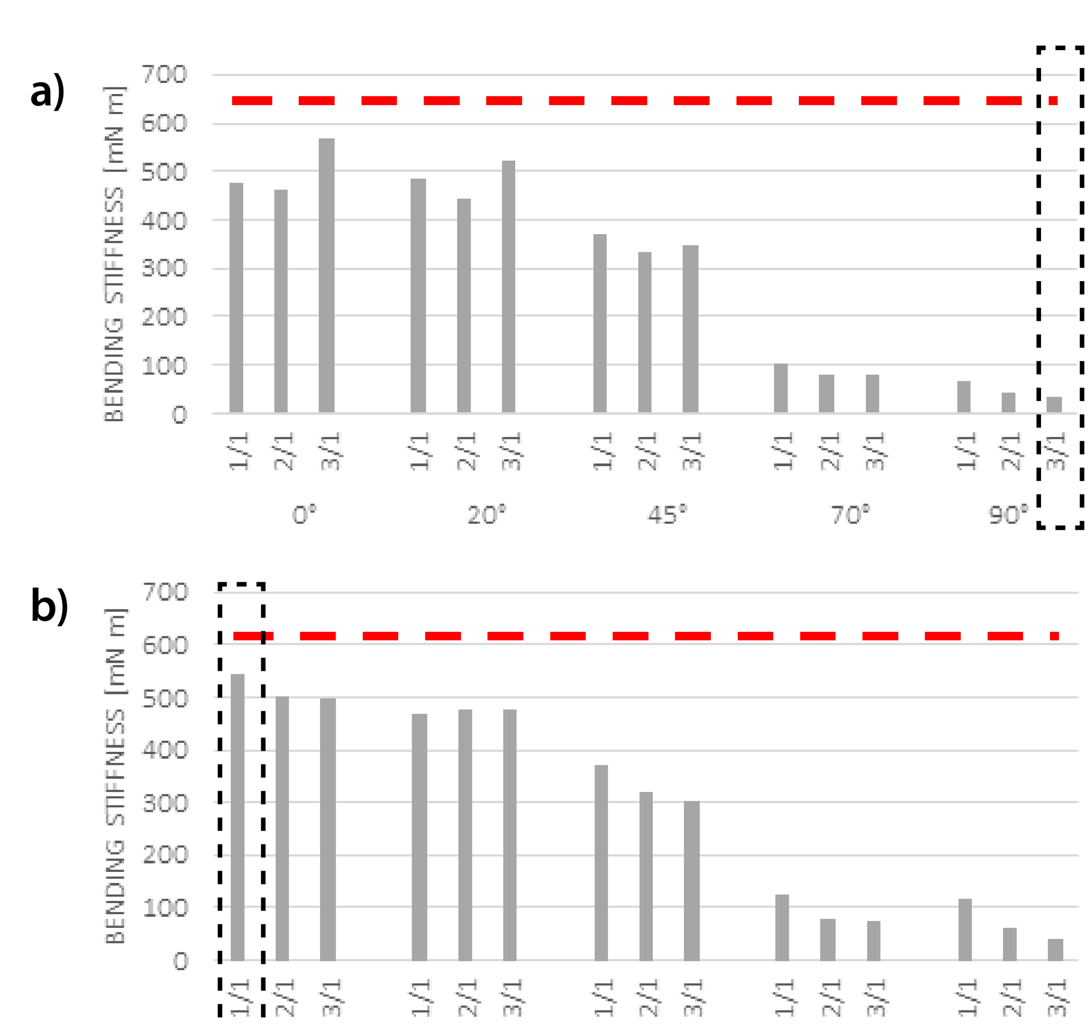

Figure 3

*Loss of bending stiffness for qualities labelled: a) 111; b) 177L; * red dashed line in Figures a, b) represent bending stiffness of reference specimen*

The most significant differences are seen and confirmed between the variable Angle of perforation position (Fig 2b); consequently, the variable Angle is the most influential among the explanatory variables. All perforation types had the lowest influence on loss of bending stiffness at angles 0° and 20°. The loss of bending stiffness is less than 36% at these two angles. The greatest influence on the loss of bending stiffness was at an angle of 90°. The values at an angle of 70° were close to the values at an angle of 90°, where at both more than 80% of the loss was seen. Quality labeled 177 has the lowest measured values, which is related to the lowest thickness, since the bending stiffness depends on the thickness of the material. The type with the smallest cut in the perforation line labeled 1/1 had the highest measured values, as expected (Fig 2a).

Conclusion

The three-point bending test is used to evaluate the protective capability of the package and by determining which variable has the greatest influence on reducing bending stiffness, it helps in the development of SRP to ensure the strength of the box during transportation. Statistical analysis has revealed that among the explanatory variables: Type of perforation, Angle of perforation position and Quality of perforated corrugated cardboard; the variable Angle of perforation position had the greatest effect on bending stiffness. Perforation at 90° has the greatest effect in decreasing bending stiffness, regardless of the quality of the corrugated cardboard or the type of perforation. When angled perforation lines are used, we recommend that an angle lower than 45° should be selected, while perforation lines in CD should be used as minimum as possible or should be used in conjunction with thicker board.

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