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# Cardboard Eco-Bundle as an Alternative for Collation Shrink Film

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## Abstract

Due to increasing pressure on brand owners and distributors to avoid single use plastics such as plastic bundle packaging, a new bundle packaging that consists of corrugated board only, has been designed. Obviously this new packaging should equally enable transportability. This study compares the transportability of bundles using corrugated board on the one hand and bundles using plastic collation shrink film on the other. In particular, the resistance to varying horizontal inertial forces is compared experimentally. All tested bundle packagings of corrugated board perform well above expectations and significantly better than shrink film packaging. All additional requirements regarding marketing, durability, consumer convenience, …are met.

## Graphical Abstract

Fast moving consumer goods are often transported and sold in bundles. In this research, a bundle packaging using corrugated board only has been tested in terms of transportability of the goods.

**Keywords**

Transportability, Collation Shrink Film, Corrugated Board Packaging, Horizontal Inertial Forces, Fast Moving Consumer Goods, Transportability

# 1. Introduction

## 1.1. Background

FMCG (fast moving consumer goods) are often distributed in bundles of 2 to 8 items. Various types of bundle packaging are being used: collation shrink film, corrugated board boxes, a corrugated board tray combined with collation shrink film, …

Bundle packaging, a specific type of secondary packaging, should meet various functional requirements such as:

- Bundle the goods for easy manipulation by the customer.
- Suitability for product branding.
- Allow palletization and safe transport of the goods.

Moreover packaging should comply with consumer perceptions regarding sustainability and, especially in Europe, the requirements of the "single use plastics" directive [1]. The recent SUP implementation assessment report [2] forces producers to find alternatives for collation shrink film.

In this research, a new type of bundle packaging, called eco-bundle, has been developed. It consists of a conventional corrugated board tray with two additional strips of corrugated board that are tensioned around the group of items. The tension in the strips should force the items to behave as a quasi-rigid, thus improving stability of a pallet load and transportability.[1,2] Depending on the items it may be convenient to add a paper based handle to facilitate consumer manipulation. As shown in **Figure 1**.

**Figure 1.** Paper based handle.

[1]Eumos 40509:2020 standard—Test method for load unit rigidity.

[2]DIN 55415:2022-09 Transport stability—Test methods to determine the transport stability of unit loads in intermodal transportation.

The eco-bundle evidently complies with the SUP directive. Several authors show that consumers in general perceive paper as a sustainable material for packaging. Some illustrative examples are given in [3]-[9]. Depending on the choice of the outer liner of the corrugated board, the quality of prints on the walls of the eco-bundle can be chosen between acceptable and perfect. Worries regarding deformation of images related to shrinking of collation shrink film are irrelevant. Paper based handles are state-of-the art and therefore the eco-bundle complies with the requirement of ease of manipulation by the costumer. The remaining functional requirement regarding the transportability of a complete pallet load, is described below for a specific case.

### 1.2. Objective

Collation shrink film is used for decades to bundle FMCG. Items are placed near to each other, the film is wrapped around these goods, the film is heated and squeezes the products together. During transport horizontal external forces occur [10] and the shrink film is expected to resist to these forces in an elastic way.

When using corrugated board and more specifically two strips of board that are tensioned around the items, these strips of board should squeeze the products together and resist to the horizontal transport forces. Unfortunately paper based materials such as corrugated board have a very limited elasticity. Therefore it could be expected that the strips of board might break when horizontal inertial forces occur. This would cause pallet loads to collapse and endanger save indoor and outdoor transport.

The objective of this research is to define appropriate tensioning of the strips of corrugated board and to measure the resistance of such bundles to horizontal inertial forces. The research takes into account that collation shrink film is under high social pressure from a sustainability point of view. Therefore the scope of this research is limited right from the start to corrugated board produced from recycled paper only. Within this scope, the influence of flute size and flute direction of the corrugated board should be evaluated.

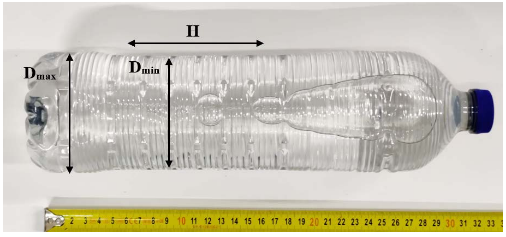
## 2. Material and Methods

### 2.1. Description of Test Case

The case that is selected for this research consists of 6 PET water bottles of 1.5 liter. Commercially available water bottles of a global bottling company have been used as shown in **Figure 2**.

The eco-bundle packaging comprises a corrugated board tray connected to two corrugated board strips. The connecting part is preferably situated along the longest side walls of the bundle in order to limit the free length of the strips. **Figure 3** shows the unfolded corrugated board and the finished (empty) eco-bundle.

Existing guidelines in the packaging industry can be used to design the details of the tray and to choose the footprint dimensions. In this case the eco-bundle is




| | |
|---|---|
| H (mm) | 125 |
| $D_{max}$ (mm) | 85 |
| $D_{min}$ (mm) | 79 |

**Figure 2.** Relevant bottle dimensions.

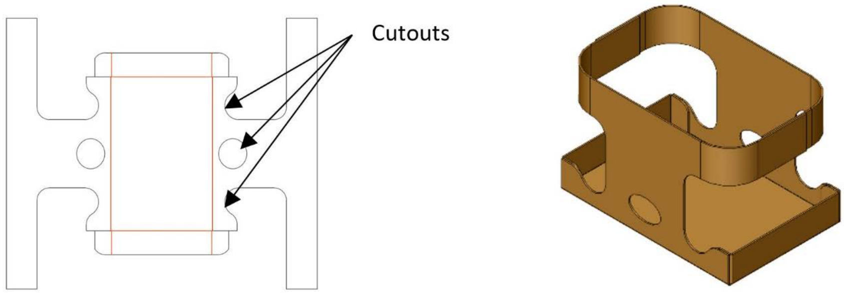



**Figure 3.** Corrugated board tray.

designed to be stacked on a euro-pallet (800 mm × 1200 mm) using the stacking pattern for these bottles if bundled using collation shrink film: 21 bundles per layer in 7 rows of 3 bundles limits the outer tray size to 267 mm by 171 mm. Obviously the largest outer diameter of a single bottle (88 mm) is more than half the final maximum width of the bundle (171/2 = 85.5 mm). The side walls of the tray part of the board are designed taking into account this narrow fit (cutouts in Figure 3). The width of the strips should be less than 125 mm, the height of the cylindrical zone of the bottles. In this case the width of the strips is 50 mm only in order to improve the nesting of the planar boards. When folded around the bottles, the strips overlap along the short side walls of the bundle. These overlaps allow the strips to be connected by an adhesive bond.

Three types of corrugated board NEN, NBN, NCN and two flute directions have been used in this research. Board thickness is indicated in Table 1.

All board types use 135 gram/m$^2$ test liner for the inner and outer paper and use 100 gram/m$^2$ "wellenstof" as a flute material.

Both flute directions are shown in Figure 4.

**H**: Horizontal, meaning that the flute direction is parallel to length of the strips.

**V**: Vertical, meaning that the flute direction is parallel to width of the strips.

It is known [11] that individual bottles tend to tilt under horizontal inertial forces during transport. To meet the criterium of transportability, the eco-bundle packaging should force the 6 bottles to behave as a quasi-rigid bundle, meaning that relative displacements of individual bottles must be prevented. This is achieved by tightening the strips around the bundle prior to establishing the adhesive bond. The theoretical circumference $L$ of the bundle with undeformed bottles is $L = 6 \cdot D_{max} + \pi \cdot D_{min}$, thus 758 mm.

**Table 1.** Dimensions.

| *Board Type* | *Flute name* | *Board thickness* |
|---|---|---|
| *NEN* | E | 1,5 |
| *NBN* | B | 3 |
| *NCN* | C | 4 |

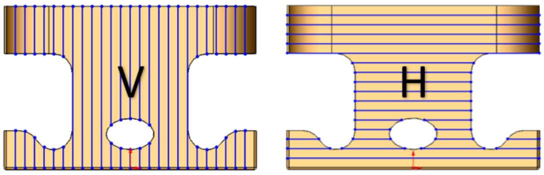



**Figure 4.** Flute direction.

Data from [12] show that a 135 g/m² test liner (the paper at the inner side of the corrugated board) has a tensile strength of 399 N for a width of 50 mm. The target tension force in the liner is limited to 70% of the tensile strength or 280N as shown in **Figure 5**. Since the corrugated board of the strips consists of two liners, the target tension force in the strips is limited to 560N. On the other hand the force needed to compress a bundle has been measured. The setup is shown in **Figure 6**, the result for 6 bottles is shown in **Figure 7**. A compression force of 560 N corresponds to a compression of 14.1 mm of the bundle. This compression should be created by the strips, thus causing a small elongation of the strips, estimated at 0.8% based on **Figure 5**. The strip length is therefore calculated as

$$(758\text{ mm} - 2 * 14.1\text{ mm}) * 0.992 = 724\text{ mm}$$

This strip length is to be considered as a starting point and is modified iteratively according to the results of the lifting tests (paragraph 3.2) for the specific configurations of corrugated board used in the study.

## 2.2. Description of Experiments

**Lifting test:**

The lifting test is described in [11] and shown in **Figure 8**. Two diagonally opposite bottles are grasped by hand and lifted. The bundle should behave as a rigid, meaning that all 6 bottles should move upwards simultaneously. If not, the actual strip length L is reduced by 1 mm and the test is repeated.

**RAHIF test: resistance to alternating horizontal inertial forces:**

The standard of the RAHIF test is found in[3] and a practical implementation is described in detail in [11]. A complete layer of bundles, in this case 21 bundles, are placed on a pallet. On top of this layer a dead mass of 570 kg is placed as shown in **Figure 9**. The pallet carrying the bundles and dead mass, is than put on a table that moves forward and backward. These movements are accurately controlled to generate a specific horizontal inertial force. This inertial

[3]Resistance to Alternating Horizontal Inertial Forces, applicable for bundled products, January 2023, L-iTL.

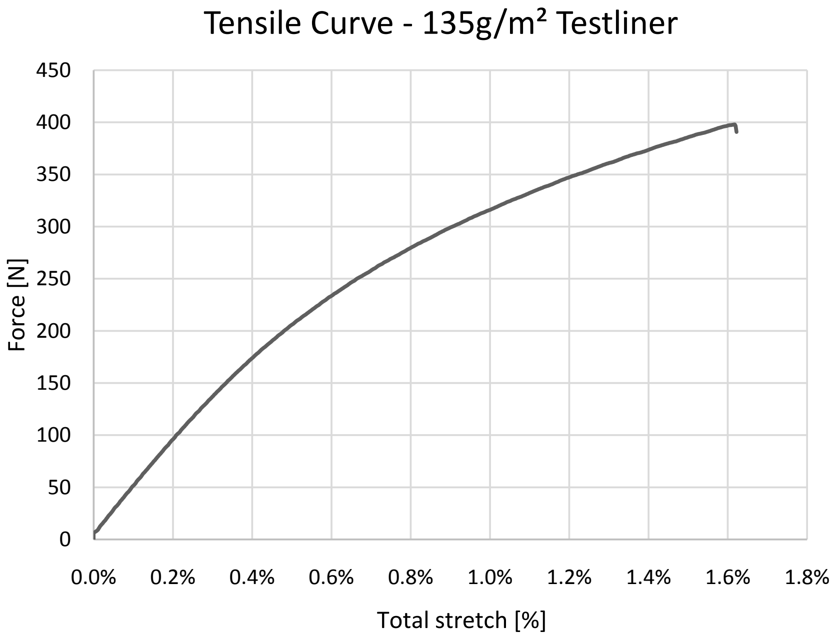



**Figure 5.** Tensile Curve, 135 g/m² Testliner, 50 mm wide samples.

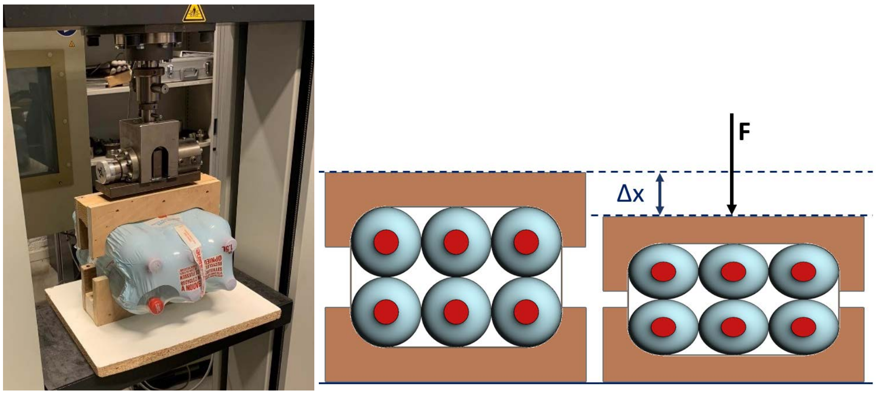



**Figure 6.** Compression measurement setup.

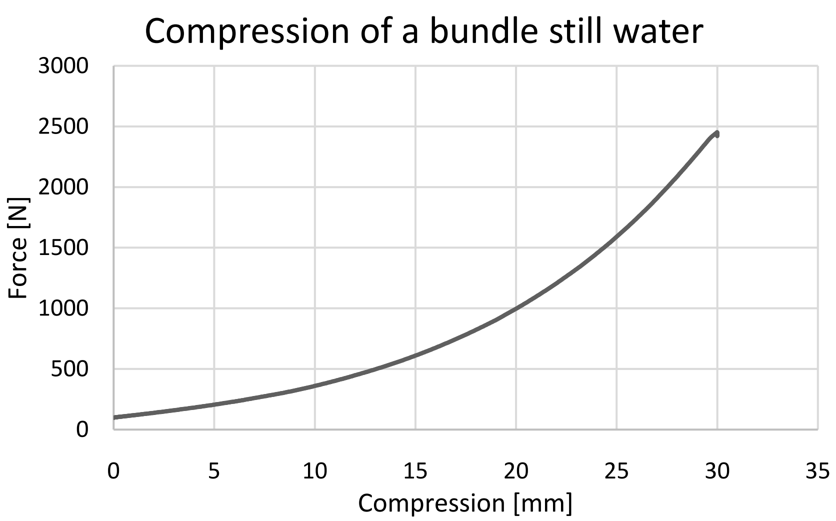



**Figure 7.** Compression curve water bottles.

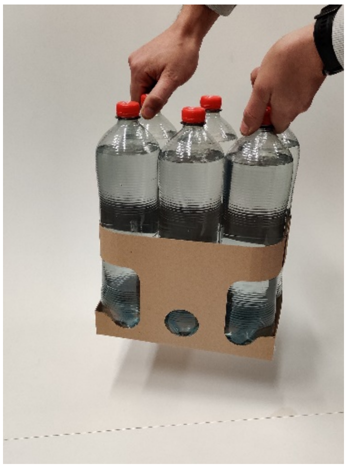


Figure 8. Lifting test.

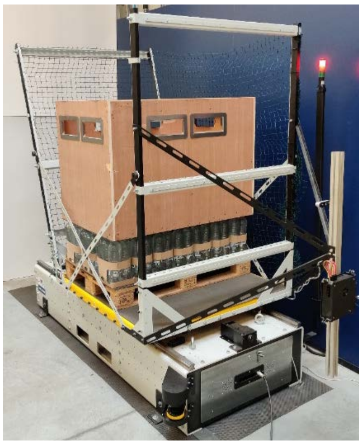


Figure 9. Increasing horizontal inertia forces test.

force is applied 50 times and then increased. Meanwhile the relative displacement between the rigid mass and the machine table is recorded. This relative displacement is a quantification of the average deflection of the bundles. The test is stopped as soon as the bundle packaging fails or when the deformation exceeds a specific limit. As a result a bundle packaging performance level is calculated. The test is repeated twice with fresh eco-bundle packaging (3 identical tests).

## 2.3. Preparation of Test Specimen

The corrugated board is stored at 21˚C and 55% RH. It is converted into an eco-bundle packaging in 4 steps as shown in Figure 10.

Step 1: Firstly, the plano is cut out of the larger board.

Step 2: Here, the tray is formed by folding up the low upright edges on the sides and the larger upright surfaces on the front and back. This can be done by placing the plano on a folding jig and using a male mold to push the plano through. Another well-known principle that is commonly used in the industry. To ensure that this bundle shape can be formed using this principle, a test setup was built as shown in Figure 11. The first flange (1) folds the small corners, the

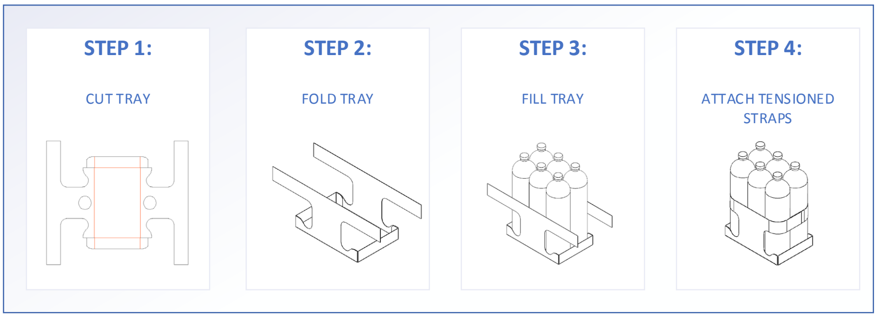



Figure 10. Packaging process.

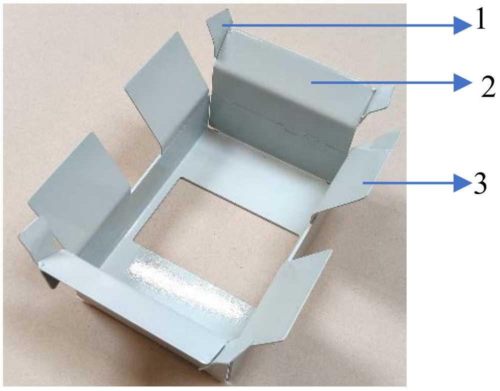



Figure 11. Prototype mal.

second flange (2) raises the ridges, and the third flange (3) raises the larger sides. Thanks to the male mold, pressure is also provided on the glued connection. Before the plano is pushed through the mold, glue is provided in the appropriate places. In this test setup, this was carried out by the Robatech concept C TRM4.

Figure 12 shows the process consisting of four steps and running from left to right. Due to the shape of the jig, the different cardboard flanges fold up in the correct order.

Step 3: Six bottles are placed inside the tray manually.

Step 4: This is the most critical step in the packaging process. The tray containing the six bottles is pushed into a narrow corridor as shown in Figure 13. In this corridor the bottles are squized, glue is applied on the overlapping parts of the strips, the strips are folded around the bundle and the adhesive bound is created.

## 3. Results

### 3.1. Results of Lifting Tests

The final results of the lifting tests are shown in Table 2.

### 3.2. Results of RAHIF Tests

The final results of the rahif tests are shown in Table 3.

The graphs recorded during the RAHIF tests are presented in **Appendix A**.

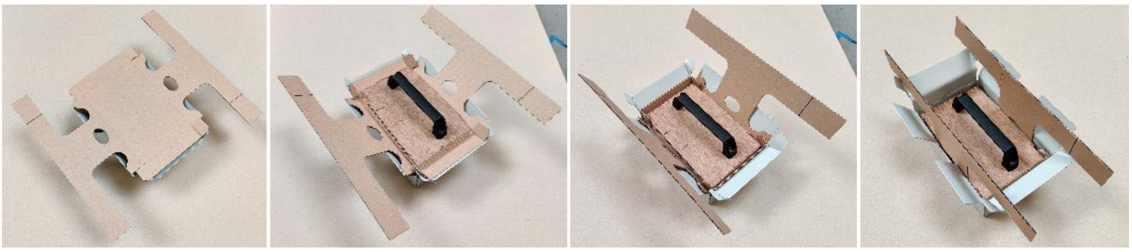


**Figure 12.** Tray folding process.

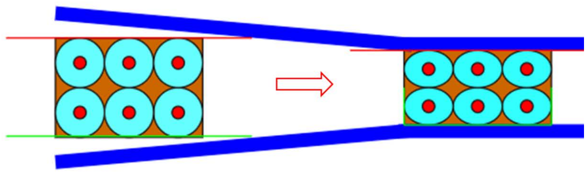


**Figure 13.** Concept narrowing channel.

**Table 2.** Strap lengths.

| | NEN | NBN | NCN |
|---|---|---|---|
| **Circumferential strap length** | 725 | 728 | 730 |

**Table 3.** Results of RAHIF tests.

| DESCRIPTION | Max Cycles | Score |
|---|---|---|
| Plastic_1 | 313 | **31** |
| NEN_V_1 | 454 | **45** |
| NEN_V_4 | 428 | **43** |
| NEN_V_5 | 477 | **48** |
| NEN_H_1 | 453 | **45** |
| NEN_H_2 | 426 | **43** |
| NEN_H_3 | 416 | **42** |
| NBN_V_2 | 504 | **50** |
| NBN_V_3 | 559 | **56** |
| NBN_V_4 | 513 | **51** |
| NBN_H_2 | 444 | **44** |
| NBN_H_3 | 456 | **46** |
| NBN_H_4 | 418 | **42** |
| NCN_V_2 | 540 | **54** |
| NCN_V_3 | 571 | **57** |
| NCN_V_4 | 518 | **52** |
| NCN_H_1 | 371 | **37** |
| NCN_H_2 | 428 | **43** |
| NCN_H_3 | 403 | **40** |

Visual inspection of the trays after testing shows that the corrugated board does not tear in or near to the adhesive. Tearing occurs in the following locations indicated in Figure 14 depending upon the position and orientation of the bundle in the layer of bundles that has been tested.

The results of Table 3 are graphically presented in Figure 15.

The graph in Figure 16 below shows the deflection every 50 cycles (average of 3 tests per packaging configuration.

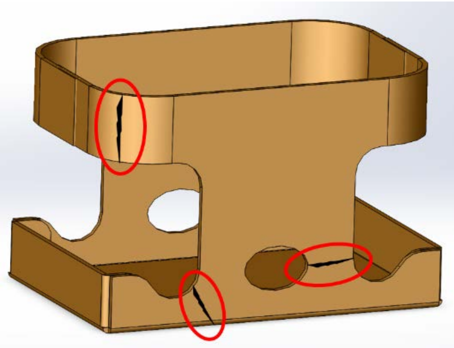


Figure 14. Most critical locations for tearing.

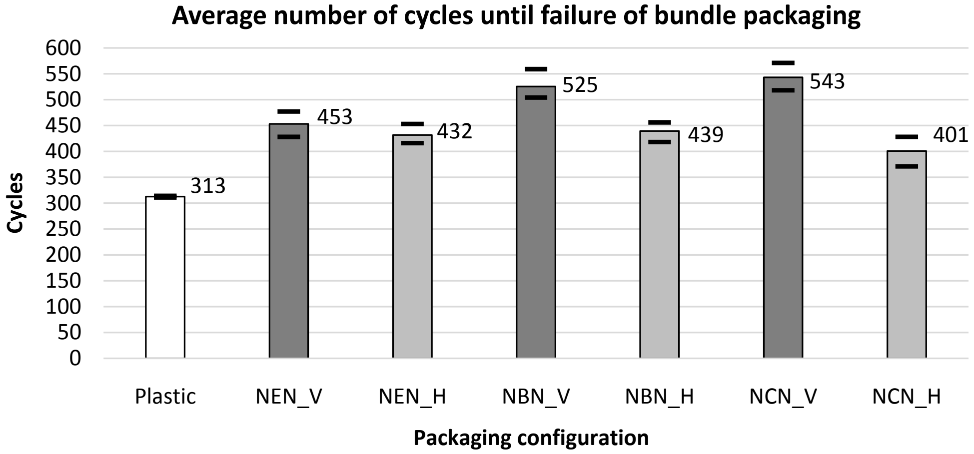



Figure 15. Total amount of cycles until bundle packaging failure.

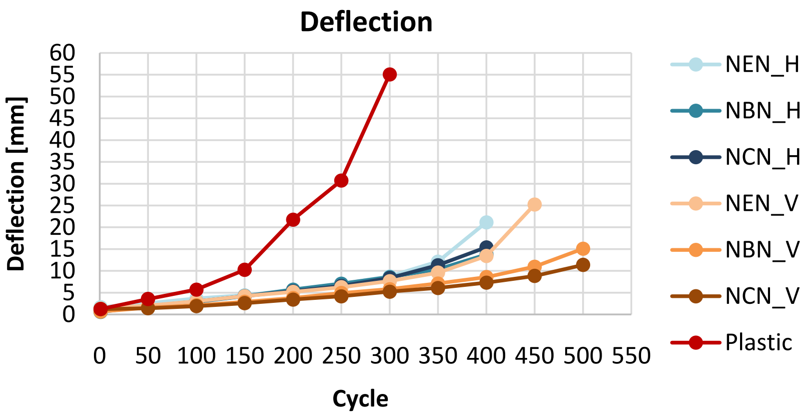



Figure 16. Deflection per cycle of load.

### 3.3. Discussion of the Results of the Lifting Test

The final values for the length of the strips depend on the type of corrugated board but are very near to the length that has been calculated, taking into account the dimensions of the bottles, the compression curve of a bundle of bottles and the tensile properties of paper.

### 3.4. Discussion of Results of RAHIF Tests

Figure 15 and Figure 16 show that:

1) All cardboard tray types score significantly better than the original plastic shrink film packaging.

2) The flute in vertical direction scores slightly better than the flute in horizontal direction. The influence of flute direction is greater for larger flute types.

One possible hypothesis as to why a vertical flute direction scores better is that the flute layer in the corrugated board is deformed in the rounded corners along the circumference of the bundle. The distance between the outer and inner liner is (in some cases locally) reduced, thus reducing bending stresses in the board. The larger the flute size, the higher the drop in these bending stresses.

3) The repeatability of the results of the RAHIF test is high (corresponding to results in literature).

4) Figure A1 in **Appendix A** shows that collation shrink based bundles resist to inertial forces corresponding to an acceleration of 1 $m/s^2$. They just meet the requirements of [4] and most likely the film properties have been adopted for this goal in the past decades. The eco-bundles resist to forces corresponding to 1.2 to 1.4 $m/s^2$, thus leaving space for optimization.

5) Figures A2-A5 also reveals the "creep" effect of film. Deflections tend to increase over the cycles of a single acceleration level. The corrugated board does not suffer from this creep effect.

6) Figure 17 shows two eco-bundles after the RAHIF tests (bottles removed). Most likely the final choice of the eco-bundle configuration will take into account also the visual aspects of the bundle upon arrival in the shop.

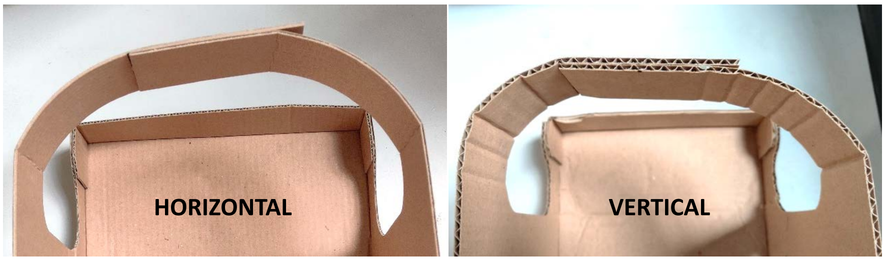



Figure 17. visual aspects related to flute direction.

## 4. Conclusions and Further Research

The conclusion of this research is clear and simple:

Eco-bundles can be palletized and transported since they resist better than conventional collation shrink based bundles to alternating horizontal inertial forces on condition that the strips are tensioned and glued to allow lifting of all six bottles by lifting two diagonally opposite bottles only.

Other aspects that were observed from the RAHIF tests:

- Vertical flutes are better than horizontal flutes.
- Thicker corrugated board performs better than thinner board produced from identical types of paper.
- The final choice between NEN and NBN types of corrugated board should take into account non-technical arguments such as cost, availability, production runs, …
- All tests have been performed using corrugated board produced from 100% recycled paper types. Using board produced from kraft paper would most likely improve the results considerably but there is obviously no need to do so.

Further research to be conducted is quite evident:

- Not even a single failure occurred because of failure of the glue or the glued area. Most likely the amount of adhesive and/or the overlapping area of the strips can be reduced.
- All tests were conducted on bottles containing still water. It is well known among packaging experts that still water is a very demanding product in terms of transportability. Therefore it can be assumed that the conclusion of this research can be extended to other liquids and other types of primary packaging.
- The tests have been performed using uncoated corrugated board after storage of the board in controlled weather conditions. The influence of more extreme weather on the eco-bundle behavior has to be evaluated. Probably the use of a biocoating can be recommendable to maintain the high performance level of the corrugated board.
- Certification of pallet stability according to the Eumos 40509 standard. To perform these tests several pallet loads of eco-bundles are required. Therefore these tests are recommended in the first phase of an industrial implementation of a packaging line using eco-bundles.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Appendix A

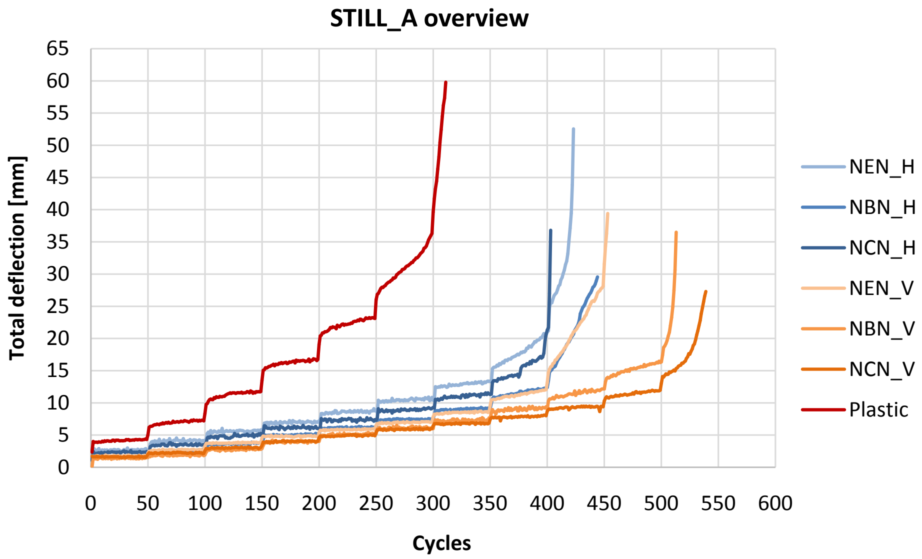


**Figure A1.** Deflection overview for distinctive packaging methods recorded in RAHIF tests.

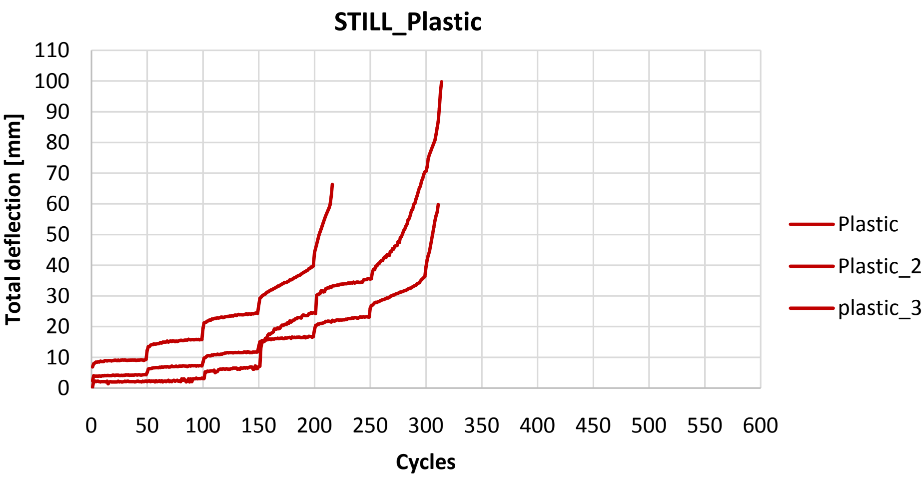


**Figure A2.** Deflection for plastic shrink film recorded in RAHIF test.

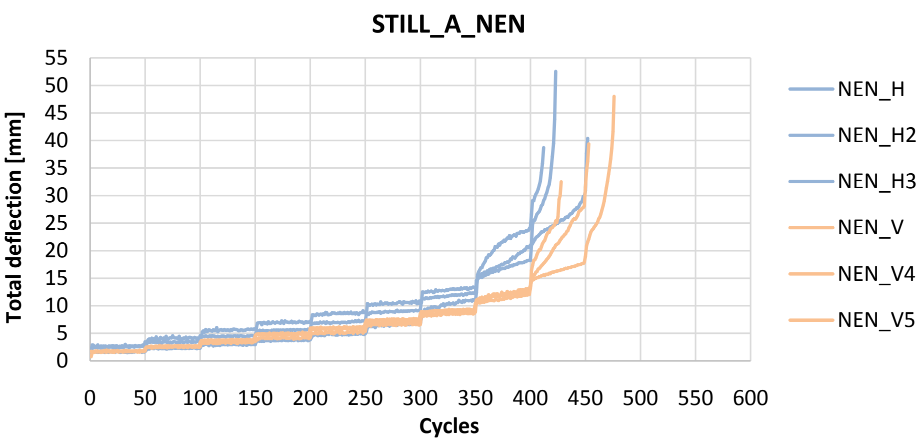


**Figure A3.** Deflection for NEN type corrugated board recorded in RAHIF tests.

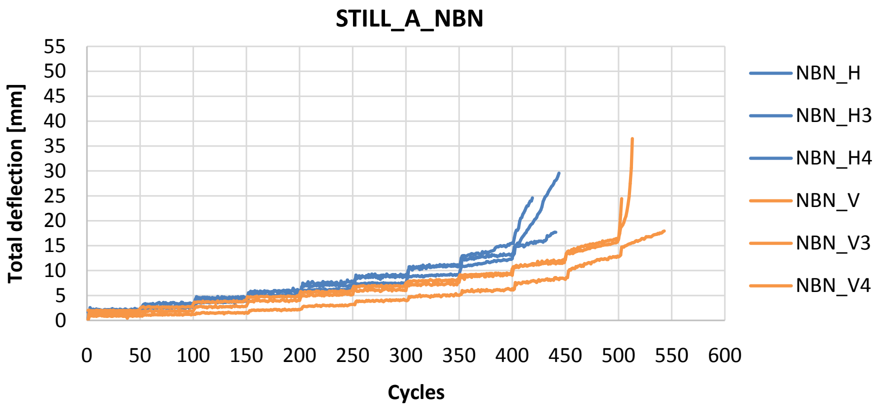


**Figure A4.** Deflection for NBN type corrugated board recorded in RAHIF tests.

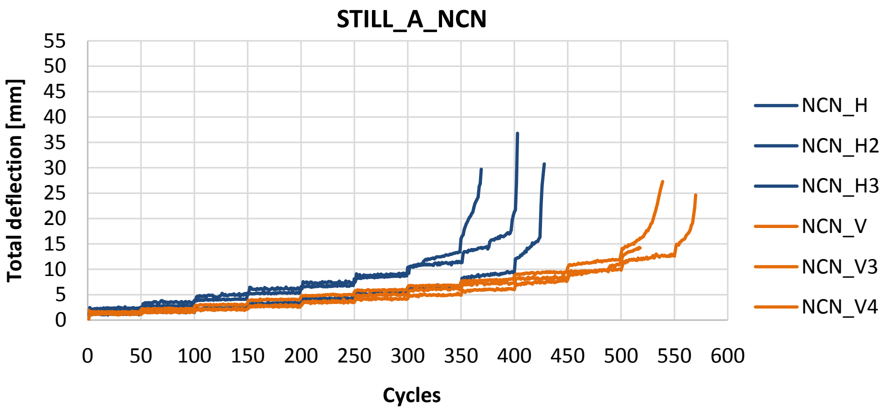


**Figure A5.** Deflection of NCN type corrugated board recorded in RAHIF tests.