ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

OPTIMIZATION IN FOLDING CARTON PACKAGING DESIGN

M.Sc. THESIS

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Department of Industrial Product Design

Industrial Product Design Programme

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OLUKLU MUKAVVA AMBALAJ TASARIMINDA OPTİMİZASYON

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To all people who can’t throw away a package,

FOREWORD

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June 2016 Büşra Torgay
Package Designer

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ABBREVIATIONS

A	**:** Automatic
BCT	**:** Box Compression Test
C	**:** Customer Lock
CCT	**:** Corrugated Crushing Test
CLT	**:** Concora Liner Test
ECT	**:** Edgewise Crush Resistance (kN/m)
FEFCO	**:** European Federation of Corrugated Board Manufacturers
FL	**:** Fluting
G	**:** Glued Insert
I	**:** Interlocked
KF	**:** Kraft Liner
kN	**:** Kilo Newton
L	**:** Lock Tuck
NSSC	**:** Neutral Sulfite Semi Chemical
R	**:** Ready Glued
RCT	**:** Ring Crushing Test
RSC	**:** Regular Slotted Container
S	**:** Slotted
SCT	**:** Crushing Stiffness
SI	**:** Slotted Insert
TAPPI	**:** Technical Association of Pulp and Paper Industry
TL	**:** Test liner

SYMBOLS

CCT	**:** Corrugated crushing test
CD	**:** Counter machine direction
D	**:** Depth
ECT	**:** Edgewise crush resistance
$\mathbf{k_1}$	**:** Constant
L	**:** Length
MD	**:** Machine direction
RCT	**:** Ring crushing test
$\mathbf{S_B}$	**:** Geometric mean of bending stiffness
T	**:** Thickness of the board
W	**:** Width
Z	**:** Periphery of the box
$\boldsymbol{\alpha}$	**:** Take up factor

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OPTIMIZATION IN FOLDING CARTON PACKAGING DESIGN

SUMMARY

Optimization in folding carton packaging design research, investigates the structural conclusions of the decisions, which are taken in designing step, thus underlines the design affection on the products. Therefore, while taking the lifecycle of the package as a base, it puts forward the outcomes of design which starts its life with a customer need. This mentioned outcomes have been categorized to make easy to follow and contains the strength of the package, the cost, the duration of emerging and the total volume which is going out to the environment.

Exploring the results of the decisions which is made in the design step, seeing the affects of the topics by designers is highly important in taking the best judgement which benefits the converter and customer. Furthermore, the research supports the customer with a wider perspective which exhibits the possibilities and restrictions of the package.

In order to construct the research, the expectation from the customer needs, the purposes which are aimed and the point of place of packages in industrial design is mentioned in the thesis. The terms which aforesaid in the corrugated cardboard, the materials which generate it and the categorized final design structures are mentioned. These design categories are explained in a detailed way, including the area of usage, using conditions and their processess with their noteworthy points in design.

To discuss and interpret these mentioned results, a project is studied which is a package of six glasses. 24 different shaped boxes and 2 different inserts are specially designed for this set. These inserts are also made from 2 different corrugated cardboard materials which have seperate calipers. As a result, 60 designs are created and all their infromation have been written in an Excel document and the results are calculated from this database. In order to compose this document a special package program called ArtiosCAD is used. The drawings of the designs are carried out with Kongsberg sample maker, and the samples have been tested in BCT machine to measure their strength. By using the drawings of the program again, pricings are imported by the criteria and standards of the Camis Ambalaj San. A.Ş. in work preperation department.

By processing these information in Excel, comparisons and correlation graphics are built. At the interpretation step, by benefiting the commons and differs of the packages the behaviour of the corrugated cardboard in packages are examined. The ways of interpretating a design are discussed in case undesirable or unexpected consequences of manufacturing and transporting occur. Results attained from this project are not limited to this particular project, but also applicable for other corrugated cardboard packages.

OLUKLU MUKAVVA AMBALAJ TASARIMINDA OPTİMİZASYON

ÖZET

Oluklu mukavva ambalaj tasarımında optimizasyon çalışması, tasarım aşamasında alınan kararların, ambalajın strüktürü üzerindeki etkilerini incelemek, tasarımın ambalaj üretimindeki yerini ve önemini görebilmek için yapılmıştır. Bu nedenle müşteri ihtiyacı gözetilerek tasarlanan oluklu mukavva ambalajlar, çeşitli yönlerden incelenmiş ve ambalajın yaşam döngüsü ele alınmıştır. Ambalajlar üzerinde yapılan çalışmalar ve elde edilen sonuçlar ambalajın mukavemetini, fiyatını, üretim süresini ve toplam ürün miktarını içerecek şekilde sınıflandırılmıştır.

Tasarımcıların etkili oldukları konuların görülmesi, ambalaj üreticileri ve müşterileri için en doğru kararların alınması bakımından, tasarım aşamasında alınan kararların ortaya çıkardığı sonuçların incelenmesinin çok önemli olduğu görülmektedir. Bunun yanısıra çalışma, ambalaj ihtiyacı duyan müşterilerin ellerindeki olanakları ve kısıtları daha geniş bir perspektiften görmelerini sağlamaktadır. Bu sayede tasarım aşamasında verilen kararların, ambalajın sadece görünümünü ve kullanımını değil, ambalajın mukavemetini, oluşum süresini, fiyatını ve çevreye olan etkilerini de son derece etkilediği görülmektedir.

Yapılan çalışmaya temel oluşturması bakımından tezde ambalaj üzerindeki müşteri beklentilerinden, ambalaj ile ilgili amaçlardan ve ambalajın endüstriyel tasarımdaki yerinden bahsedilmiştir. Oluklu mukavva ambalajda bahsi geçen genel terimler ve ambalajı oluşturan malzemeler anlatılmıştır. Bu malzemelerle yapılan tasarımlar biçimlerine göre sınıflandırılmıştır. Oluklu mukavva ambalajda kullanılan ana hammadde kağıttır. Bununla beraber varolan değişik kağıt bileşimleri ve nitelikleri, farklı özelliklerde oluklu yapıların oluşmasına izin vermektedir.

Farklı çeşitlerde üretilen oluklu mukavvalarda mukavemet ve fiyat farkı görülebilmektedir. Aynı zamanda ambalajın üzerine uygulanan farklı baskı yöntemlerinin getirdiği farklı görünümler de elde edilmektedir. Elde edilen ambalajlar farklılaşan bu görünümleri sayesinde de ambalaj kullanıcısına, son alıcıya ve tüketiciye farklı izlenimler verebilmektedir.

Ayrıca oluklu mukavva ambalajlarda aynı kağıdın türevleri kullanılsa bile, ambalajlar yapılarındaki farklılıklar sayesinde farklı mukavemet göstermektedir.

Mukavemet farkını oluşturan sebeplerden tezde bahsedilmiştir ve ambalaj tasarımında mukavemet ile ilgili bilgiler ilgili formüllerle de desteklenmiştir. Çalışmada ayrıca hangi ambalaj türlerinde hangi baskı tipinin, kağıt türünün ve ne tür yapıların kullanıldığına dair bilgiler verilmektedir.

Çalışmada biçimsel farklılıklarına göre sınıflandırılan tasarımların, hangi sebeplerle hangi koşullarda kullanıldığı, hangi üretim biçimiyle oluşturulduğu ve bu tasarımlarda dikkat edilmesi gereken hususlar detaylı şekilde ifade edilmektedir.. Oluklu ambalaj türleri genel olarak üç kısma ayrılmaktadır. Literatürde bu ayrımdan tüp tarzı ve tava tarzı olarak bahsedilmektedir ve buna ek olarak sınıflandırmaya çoklu ambalajlar da katılmaktadır.

Çalışmadaki sınıflandırmalar çoklu paket olarak değil, kılıf yani ürünü saran ambalaj sınıflandırması altında toplanmaktadır. Mukavva ambalajların sınıflandırmasında sadece ürünün biçimi ve üretim yöntemi kullanılmaktadır.

Tüp, tava ve kılıf ambalaj olmak üzere 3 farklı kategoriden bahsedilmektedir. Bu sınıflar içinde de kapatılma yöntemine ve biçimine göre çeşitli farklılaşmalar söz konusudur. Örneğin; ürünü ambalajın içine yerleştiren hat içersinde kapatılması yani otomatik dolum, üretim sahası içinde kapatılması yani hazır kutu ve elle kapatılması yani manuel kutu gibi farklı yöntemler kullanılmaktadır. Bu farklı üretim yöntemlerinin oluşturdukları kutu tipleri de farklı amaçlara hizmet etmek üzere modifiye edilebilmektedir.

Çalışmada bir cam bir ürünün altılı olarak paketleneceği bir oluklu mukavva ambalaj projesi üzerinde inceleme yapılmıştır. Bu çalışma tüp tarzı kutular olarak adlandırılan, oluklu ambalajlar üzerinde yapılmıştır. Literatürde bahsi geçen şekilde, tüp kutular alt tipleri ve üst tipleri ayrı şekilde ele alınmış ve çaprazlama metodu kullanılmıştır. Bu melezleme metodu sonucunda projelendirilen özel ambalajlar için toplam 24 farklı biçime sahip kutu tasarlanmıştır. Tasarlanan kutuların içinde 2 farklı separatör kullanılmıştır. Seçilen seperatörler, amacı açından birbirine benzeyen ama kullanım ve üretim biçimi olarak birbirinden ayrışan seperatörlerdir. Otomatik ve yarıklı seperatör olarak bahsedilen seperatörler de oluklu mukavvadan yapılmış olup, bu seperatörler 2 farklı kalınlığa sahip olan malzemelerden üretilmiştir. Kutuların incelenebilmesi için sadece tasarımlarının karşılaştırılmasına ve tek çeşit malzeme kullanılmasına karar verilmiştir. Malzeme farkının da görülebilmesi açısından kutunun içinde yer alacak bu seperatörlerin çeşitlendirilmesi uygun görülmüştür.

Farklı kutu tipleri ve içerisine konan farklı separatörler ile elde edilen 60 ambalaj tasarımının herbiri ile ilgili bilgiler Excel tablosuna girilmiştir ve tasarımların herbiri için çeşitli sonuçlar hesaplanmıştır. Bu tabloların oluşumu için ambalaj sektörünün kullandığı ArtiosCAD programından yararlanılmıştır. Kongsberg maket alma masasında gerçeğe dönüştürülen bu tasarımlar, yapısal dayanıklıklarının ölçülmesi için BCT makinasına sokulmuştur. Çizimlerden yararlanılarak Camiş Ambalaj San. A.Ş. bünyesindeki iş hazırlama bölümünün oluşturmuş olduğu kriterler ve standartlar çerçevesinde ambalajların fiyatlandırmaları yapılmıştır. Fiyatlandırma aşamasında hesaplanan toplam kağıt ve tutkal miktarı ile beraber bıçak yerleşimlerindeki toplam atık miktarı göz önünde bulundurularak, ambalajların çevreye olan etkisi incelenmiştir. Tüm tasarımlar toplam 10.000 adetlik üretimler varsayılarak hesaplanmıştır.

Gerekli tüm bilgilerden yararlanılarak oluşturulan Excel tablosunda karşılaştırmalar ve ilişki grafikleri gösterilmektedir. Karşılaştırmalar fiyat, mukavemet, hız ve çevre olmak üzere dört farklı kategori oluşturacak şekilde ele alınmıştır. Bu kategoriler, tasarım adımının ortaya çıkarmış olduğu tablolar olarak görülmektedir. Grafiklerin yorumlanması aşamasında, tasarımların ortak ve farklı noktalarından faydalanılarak, oluklu mukavvanın ambalajdaki davranışı üzerinde durulmuştur. Bir tasarımcının, üzerinde çalıştığı ambalaj tasarımlarının üretiminde ve taşınmasında ortaya çıkabilecek istenmeyen veya beklenmeyen sonuçları nasıl yorumlayacağından ve buna bağlı olarak neler yapabileceğinden bahsedilmiştir. Ayrıca bu kategorilerin kendi arasındaki ilişkileri de incelenmiş ve yine tasarımcıların yararlanabileceği bir rehber niteliğinde olmasına dikkat edilmiştir.

Sektörel anlamda, hem ambalaj üreticileri hem de müşterileri için bu kategoriler eşit olarak değerlendirilmemekle beraber, araştırmada aralarında bir önem sıralaması yapılmamıştır ve farklı müşteri ve üretici gruplarının tercihine bırakılacak şekilde hazırlanmıştır. Buna rağmen bahsedilen kategoriler altında en yüksek ve en düşük mukavemeti gösteren ambalaj, en hızlı ve en yavaş tamamlanan tasarım, en pahalı ve en ucuz tasarım, çevreye en yüksek ve en düşük atık oluşturan tasarım olmak üzere çeşitli tasarımlar belirlenmiştir. Çıkan sonuçlar nedenleri ile ilişkilendirilerek değerlendirilmiştir. Sonuç kısmında tablo olarak gösterilen toplam 24 tasarım üzerinde, bahsedilen yüksek ve düşük noktalar işaretlenmiştir ve okuyucunun bunları karşılaştıracak şekilde incelemesine olanak verilmiştir.

Araştırma için hazırlanan ambalajlarda seçilen ürüne uygun olacak tasarımlar olmakla beraber, çıkartılan sonuçlar yukarıda belirtildiği gibi oluklu mukavvanın genel davranışına ışık tutma amaçlıdır. Bu nedenle başka ürünler için çok daha farklı tasarımların ve malzemelerin kullanılabileceği ve buna bağlı olarak da farklı tabloların oluşacağı unutulmamalıdır. Araştırma oluklu mukavva ambalaj sektörü için hazırlanmış olsa da, aynı malzemeyi kullanan diğer sektörlerin de bu çalışmadan yararlanabileceği düşünülmektedir. Bu sektörler arasında sergi, mobilya, aydınlatma, ulaştırma, sahne tasarımı ve görsel sanatlar sayılabilir. Bunun yanısıra oluklu mukavvanın en çevreci malzemelerden biri olması, hafifliği ve izole edici özelliği gözönüne alındığında, mukavvanın kullanılabileceği diğer sektörler olarak mimarlık, iç mimarlık ve inşaat mühendisliği alanında da bu çalışmadan yararlanabileceği öngörülebilir.

1. INTRODUCTION

Package is, as the simplest explanation, contains, protects and promotes the products. Even these three aims emphasize the significance and multiple faces of the packages. Moreover, in lifecycle of the packages, from production, distribution and retailing, through to disposal all comprise a commercial activity. Thus, designers endeavor to balance financial, functional and marketing performance of the packages, at every stage of design. (Stewart, 2007, s. 5). Aside from the tasks of packages, they are also designed products and like all the products, packages have responsibility to the environment. Corrugated board – as a paper based packaging – has an environmental advantage over most other materials, as it is a natural material, biodegradable and recyclable for multiple times (Stewart, 2007, s. 63).

From the need of the package to the final consumer, corrugated board die cut packages pass through some phases. Each phases affect the next steps in design's manufacturing line. Thus, design step, as being an early stage of prosess, plays especially an important role. In this dissertation, these effective roles of design will be displayed as possible optimisation approaches.

1.1 Purpose of Thesis

This dissertation discourses the optimum design of a package with a given brief and restrictions for the designer. On the other hand, it will not mention the package needs and determining the package specifications, which are especially significant for the buyer of the package. The specifications of the folding carton packages still depends on experiences of the buyers, know-how and other buyers' knowledge. The information of process is scantiness because of its complexity and variety of the situations. A further work can be done for the buyers and the decision on the optimum specifications for their product or service.

This research can be useful for:

- Seeing the package as a designed product,
- Understanding of the comprehensive process of design and manufacturing of packaging,
- Forseeing the situtations and factors which affect the strength, cost and duration of the process,
- Assisting the design decisions when the designer encounters contradictions, and
- Seeing opportunities for optimization, which leads to lesser waste and carbon footprint.

1.2 Methodology

1.2.1 Literature review

Corrugated Shipping Containers written by George G. Maltenfort have prepared especially for the engineers of the packaging industry. Despite being old, the book comprehends significant subjects, not just manufacturing but also designing, transporting and safety issues. “Optimum package design” chapter was a begining step for the dissertation. The chapter took account of most of the situtations without passing the conflicting criterias.

Comparison study written by Yingzhe Xiao and Xihai Hao is helpful about the comparison of the three different kinds of package with the explaining photographs. However, probably as being just an article not a dissertation, it does not have a proper explanation on the tests and comparing criterias of the packages are few and brief. (Yingzhe Xiao, 2014).

Chen, Zhang and Sun emphasizes the importance of the moderate packaging in their article “An Overview of the reducing principle of design of corrugated box used in goods packaging”. The paper gives the definitions of the moderate packaging and overpackaging, and their realized significant around the world mentioning that China (also other developing countries) still has to improve itself in this area. The paper summarizes the reducing principle in design of corrugated box as; optimal combination of raw materials, optimal selection of prism type, optimisation of overall design of box and the cost control of packaging. (Jing Chen, 2011) Although mentioning the overall designing of box, it does not comprise the design of the box and inserts but generally technical part like the forming process, size and proportion, and palletizing.

1.2.2 Research

Research encompass a series of designed packages special for specific glasses and their manufacture process and outcomes such as cost and production time. It focuses on the different types of designs with nearly same dimensions -changing according to their package type- to prove the strength of the design decisions. The results of the research helped to see, which design is faster and cost effective or which design is more environmental as well as having adequate strength.

To design these mentioned variations, ArtiosCAD, a specialized package CAD program is used. All packages are drawn and their required data is detected with the help of the program such as their manufacturing dimensions and total area. Each packages and inserts -if exist- have been given specific codes according to their top and bottom design types and flutes.

With the program's manufacturing tool, the designs' diecuts have been generated. This data set enables to calculate how many boxes will be gained from each sheet and how many sheets are needed in order to reach the commissioned quantity. General information on the flutes and papers, which are decided for the designs are used to calculate ECT (Edgewise Crushing Test) of the paper combinations. With the area and the periphery of the designed boxes and inserts, the weight and estimated BCT (Box Compression Test) values are reached. The real BCT values from tests have been used in comparison of the boxes while the estimated and real BCT values are also compared to give a general clue of using formula.

All the reached values on each packages have been put in topics; cost, strength, speed and environment in Excel and designs are compared for the best designs with their reasons.

1.3 Hypothesis

The study of optimization of folding carton relies on literature and the research findings, which create a better understanding on the package design process. The importance of the designing phase of the package cycle is exhibited with both the design variations and production process after design step, which are underlining the outcomes of the design.

To change these outcomes, optimization of the design makes possible to create a faster and cost effective production, more environmental package with adequate strength. The list of all the designs and their comparison helped to distinguish between the designs' results underlining their hows and whys. While the dissertation contains mainly the choice of the design, the research also involves the importance of the chosen flute and insert. As the optimum package have to be an adequate solution in given environment conditions, the designer should stay between this optimum choises and keep away from both over and under packaging.

The diversity of the designs displays the common traits of the packages thus the theory behind the structure and their effect on the strength, environment, cost and speed. As the designers focus on their main subjects, tends to get close to over or under packaging therefore they need guiding. Without foreseeing these outcomes, both the designer and customer find the finished product neglected and not comtemplated. To prevent these ineffective products, these measures and calculations are required. Harrington also underlines the significance of the measurement. "Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it" (Harrington, n.d.). The quantitative test method enables the writer to establish a link between the design and technical data

2. CYCLE OF THE PACKAGE

2.1 Need of Package

Paperboard Packaging Council's book "Ideas and Innovation" describes the folding carton as; a container of varying size and shape made from bending grades of paperboard or small flute corrugated board; which is typically printed, cut and creased, folded and glued, and delivered flat to the customer where it is filled with product for distribution retail outlets (Paperboard Packaging Council, 2000, p. 0.102).

When a product, service or a development become a need, their cycle begins. Package cycle also starts with a need, however this need can occur from more than one reason. Technological developments, commercial reasons, new graphics, new products, economic reasons, optimization, transporting or stacking problems etc. all can be reasons for a new folding carton package. The folding carton provides:

- Billboard impact
- Graphic impact
- Product differentiation
- Brand identification
- Superior product protection
- Exceptional communication of product information
- Variety of shapes, sizes and designs
- Superior environmental performance
- Creative merchandising oppurtunities
- Product visibility
- Ease of packaging, storing, distributing and shelving (Paperboard Packaging Council, 2000, p. 1.103)

All these contributions make package an important necessity that is why the packages enter a cycle more than the product itself. Without withdrawing the brand identity, making a package more convenient in these mentioned topics is a challenge.

2.2 Determining the Package Specifications

Aformentioned needings generates a set of specifications for the packages, these specifications can be categorized in groups or checklists. Kirwan (2012) mentioned these as functional requirements, which should be met at every stage of supplier/consumer interfaces in chain. Kirwan also includes secondary distribution pack and tertiary palletization in these specifications.

Packaging requirements can be categorized (Table 2.1) with respect to:

- Protection, preservation and containment of the product to meet the needs of the packaging operation and the proposed distribution and use within the required shelf life
- Efficient production of the packaging material, the pack in printing and converting, in packing handling, distribution and storage, taking account of all associated hazards
- Promotional requirements of visual impact, display and information throughout the packaging, sale and use of the product." (s. 25)

With the increasing awareness and consciousness of the environmental problems, health issues and importance of sustainability, these requirements became more comprehensive. With the new millennium, environmental packaging design specialists established, as environmental legislations increase in order to attempt in reducing the global warming and other natural disasters (Stewart, 2007, s. 10) (Table 2.2). Optimization thus, became more than a choise, a necessity to fulfill the environmental responsibilities.

In addition to these customer factors, Ideas and Innovation book (2000) mentions the consumer factors, such as; product protection, convenience features, consumer expectations etc. (p. 0.201) (Table 2.3).

Table 2.1 : Categorized packaging requirements for the products.

physical requirements	protection of product
	preservation of product
	containment of product
	maintaining itself along the operation and distribution
	maintaining itself within the required shelf life
efficient production	efficient packaging material
	efficient pack in printing and converting
	good packing handling
	distribution and storage
	being prepared to associated hazards
promotional requirements	powerful visual impact,
	competent display and
	effective information throughout the packaging, sale and use of the product

Table 2.2 : Sustainability way in packaging requirements (Kirwan, 2012, s. 26).

environmental responsibilities	minimizing product waste
	improving the quality of life
	protecting the environment
	managing packaging waste through recovery and recycling.

2.3 Decision of Suitable Material, Production and Print Method

In order to meet the desired requirements of the package, customer have to make some decisions on material, production and print method. Overall appearance and graphic have to be decided simultaneously as the package design can affect the production and print method, and vice versa.

A sophisticated customer knows and can write an adequate brief for the package designer, which emphasized the package specifications; overall design, material, printing method, how to be transferred and where and how to be sold to final customers. However, sometimes product to be packaged is new, or one which has not be shipped before by the particular user. In this case, Maltenfort (1988) suggests finding a package used by a competitor for a similar product and taking it to the (package designer) or box maker to make a similar one for his product (p. 129).

Table 2.3 : Consumer factors (Paperboard Packaging Council, 2000, p. 0.201).

consumer factors	product protection	phyical barrier
		pilfer protection etc.
	convenience features	product visibility
		opening and reclosing features
		ease of home storage
	meeting consumer expectations	practical expectations
		psychological expectations
	mandatory and informational copy required for making an informed purchase	
	enhancing and promoting the quality and key features of the product	
	post consumer use and disposal	
	environmental considerations	

To guide the customers in selecting the suitable material, there are tables, which shows the advantages of the materials according to flute types and maximum load limits according to their ECT (Edge Crush Test) results. To sum up the specific questions, which customers have to ask themselves are;

- The nature of the products being packed,
- The total weight of the box
- The size of the box

- How the cardboard box will be stacked, stored and transported. (Box Basics, 2016)

2.3.1 Corrugated board and flute types

Corrugated board is explained in Ideas and Innovation (2000) as, combined multiple sheets of paper, into a corrugated structure which consists of a wavy, fluted corrugating medium (fluting) and one (single-face) or two (double-face) sheets of linerboard glued to the corrugating medium (p. 0.108) (Figure 2.1). To obtain stronger material, fluting part can be multiplied as well as liner sheets and it is also possible to modify the structure (Figure 2.2), prism type and glue etc.

Corrugated boards can be used for primary, secondary and tertiary, in addition to that, inserts are also made from corrugated cardboard in order to separate the products or support them. Regarding to its usage area and the product, the overall thickness of the board is selected which is determined by its height of the board (Figure 2.3) (Table 2.5). Thicker flutes are more suitable for secondary and tertiary packages while thinner ones are mostly used in primary packaging with their high printing, diecutting, folding and gluing quality (Paperboard Packaging Council, 2000, p. 0.108) (Table 2.4).

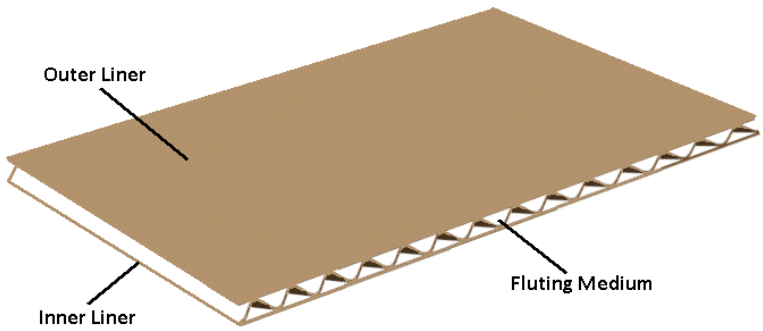


Figure 2.1 : Corrugated board structure (retrieved from:http://www.packingsupply. in/app/webroot/blog/wp-content/uploads/Board. gif 01.02.2016)

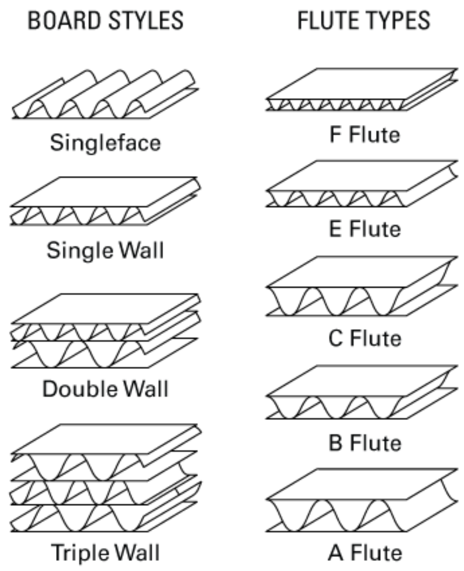


Figure 2.2 : Board and flute types (retrieved from: http:// www. Kakavisual. co.id/wp-content/uploads/2015/03/corrugated-flute-types.png 01.02.2016)

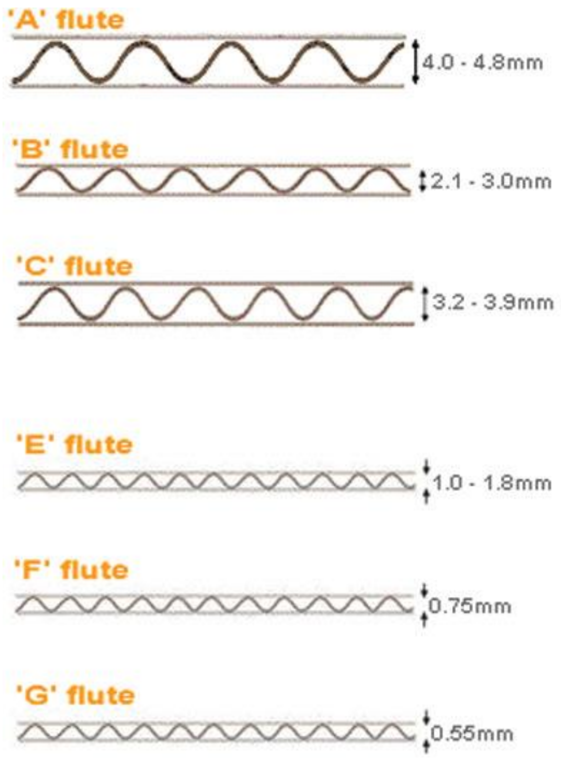


Figure 2.3 : Single wall flute calipers (retrieved from: http://www. packaging-gateway.com/projects/smurfit_mbi /images/smurfit-1.jpg 01.02.2016)

Table 2.4 : Advantages according to the flute types (Box Basics, 2016).

Flute Types	Flutes/Foot	Thickness	Advantages
B Flute	42-50	3 mm	Good cushioning, stacking and printing
C Flute	34-43	4 mm	Good stacking, strength and crushing resistance
E Flute	94	2 mm	Greatest crush resistance and printing surface
EB Flute	94/42-50	5 mm	Good printing surface and can hold large and heavy items
BC Flute	42-50/34-43	7 mm	Can hold very large and heavy items

Table 2.5 : Maximum suggested load according to edge crush test results (Box Basics, 2016).

Types of Construction	Edge Crush Test	Maximum Suggested Load Limit (lbs)	Maximum Suggested Load Limit (app. Kg)
Single	23	20	9
Single	26	35	15,8
Single	29	50	22,7
Single	32	65	29,5
Single	36	75	34
Single	42	80	36,2
Single	44	95	43
Double	48	100	45,3
Double	51	120	54,4
Double	61	140	63,4

2.3.2 Paper types

Paper types are shown at the below table (Table 2.6) according to their usual using layer of corrugated boards.

Kraft Liner (KF)

Kraft liner is a paper type, which is produced from softwoods' pulp by entering a process with sulphate or alkali. In corrugated cardbard production, it can be used as in and out liner. Natural colour of kraft is brown but the liner can be partially or entirely bleached. However, any bleaching method can reduce the strength of the kraft between 5-10%. White kraft liner is also known as "white top" and its coating top of it makes a smooth and bright surface –coated white top kraft liner- which is preferred for high quality printed packages. (Oluklu Mukavva Sanayicileri Derneği, 2015, s. 41)

Test Liner (TL)

Test liner, which used for corrugated cardboard, is produced from waste paper fibers. It is produced as double layer of which top layer is dyed. Like kraft liner, it can also be used as in and out liner, however, especially in tropical environment, because of being a recycled paper, the test liner packages are much weaker. White test liner can be made by using extra pulps, which are specially bleached waste papers. Imitation kraft liners, which are high strength papers, are produced from specially chosen waste papers which top layers are dyed.

Table 2.6 : Paper types according to their using place in corrugated board.

Paper types	Outer liner (printing surface)	Kraft liner(KF)	bleached unbleached
		Test liner (TL)	bleached unbleached
		Cartonboards	Solid bleached board (SBB/SBS/GZ) Solid unbleached board (SUB/SUS) Folding Boxboard (FBB/GC/UC) White lined chipboard (WLC/GD/GT/UD)
	Inner layer	Kraft Liner (KF)	bleached unbleached
		Test liner (TL)	bleached unbleached
		Schrenz	
		Cartonboards	Solid bleached board (SBB/SBS/GZ) Solid unbleached board (SUB/SUS) Folding Boxboard (FBB/GC/UC) White lined chipboard (WLC/GD/GT/UD)
	Fluting medium	NSSC	
		Test liner (TL)	
		Recycled fluting papers	
		SC fluting	
		Schrenz	

NSSC (Neutral Sulfite Semi Chemical)

NSSC is used as corrugation medium, which is produced from hardwoods that have short fibers such as birch and eucalyptus etc. Both mechanical and chemical prosseses are used in production of NSSC and its fiber structure enables conserving its form with the help of humidity and temperature. NSSC papers are used in boxes which require high BCT or resistance to humidity while storing.

Recycled Fluting Paper

Fluting is also used in corrugation as middle layer. As all its layers are secondary fiber, resistance is low, however using special raw materials or some additives may help its durability.

Except the papers from above there are; SC fluting, schrenz and many other types of paper in industry.

2.3.3 Cartonboard types

In order to using areas of the packages, the customers determine the types of the cartonboard. Cartonboards differ from each other according to their pulp processes, these are chemical, mechanical and recycled fibre pulp processes. Combination of them generate the boards (Figures 2.4 2.5 2.6 2.7). Desired strength, graphic efficacy or the affordability plays a role in choosing the cartonboard type, such as; while SBB have an excellent printing surface with chemical bleached pumps, SUB have water resistancy and can be used where strength is important (Table 2.7).

The design of the folding carton boxes is not affected from the types of the cartonboard, however cartonboard easily alter the final appearance of the box and the cost, as the printing method can be changed according to the board. Moreover, the inserts; which are used for separating the products, protect from outside effects or strengthen the boxes, usually do not contain cartonboard layers. Basic types of cartonboards are listed below:

Solid Bleached Board (SBB/SBS/GZ)

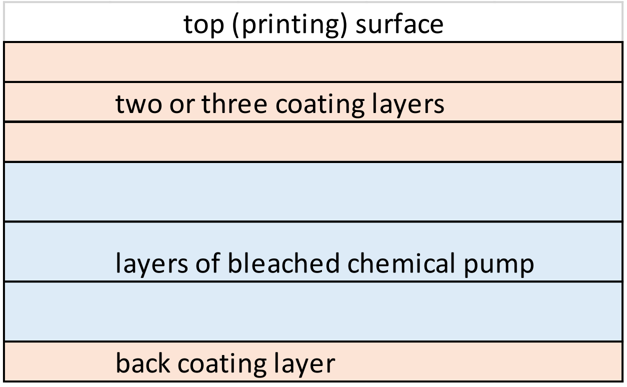


Figure 2.4 : SBB/SBS/GZ illustration (Association of European Cartonboard and Carton Manufacturers, 2016, s. 4)

Solid Unbleached Board (SUB/SUS)

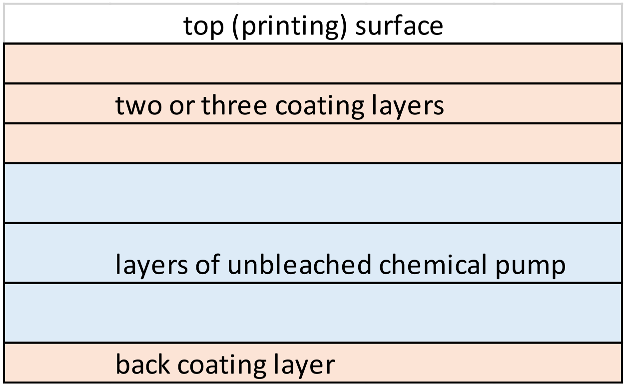


Figure 2.5 : SUB/SUS (Association of European Cartonboard and Carton Manufacturers, 2016, s. 4)

Folding Boxboard (FBB/GC/UC)

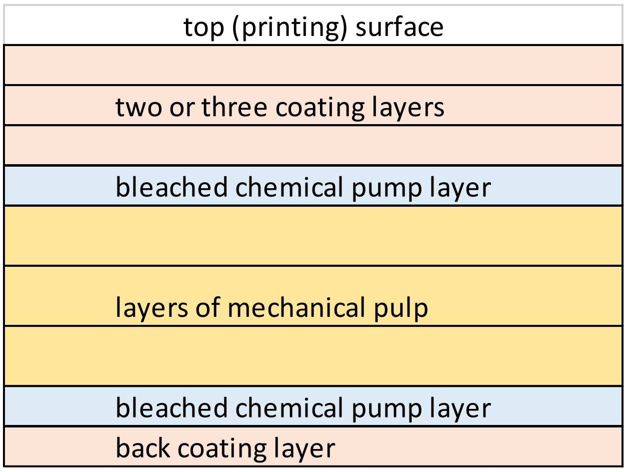


Figure 2.6 : FBB/GC/UC (Association of European Cartonboard and Carton Manufacturers, 2016, s. 5)

White Lined Chipboard (WLC/GD/GT/UD)

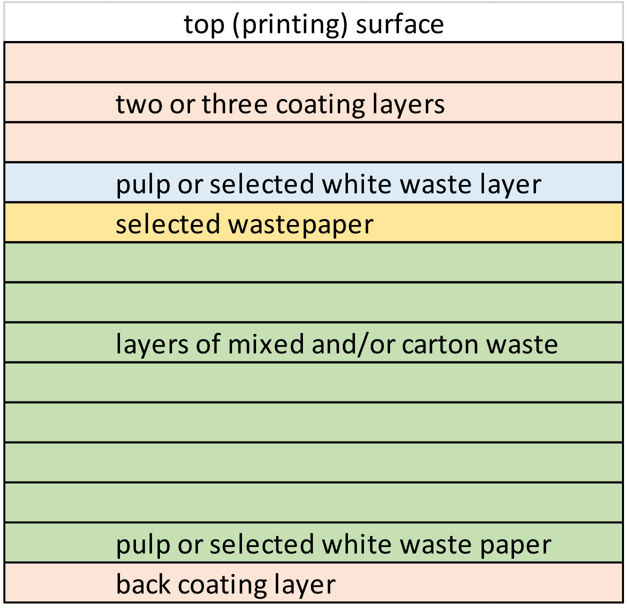


Figure 2.7 : WLC/GD/GT/UD (Association of European Cartonboard and Carton Manufacturers, 2016, s. 5)

Table 2.7 : Typical uses and characteristic comparison of some cartonboards (Paperboard Packaging Council, 2000, p. 0.109).

Board Type	Typical Uses	Characteristics
Uncoated Solid Bleached Sulfate (SBS)	Base sheet for waxing or extrusion polycoating: Frozen Food	Wood bending qualities Water/moisture resistance White sheet throughout
Clay Coated Solid Bleached Sulfate (SBS)	High end packaging: Foods, pharmaceuticals, cosmetics, health care products	Excellent bending qualitiest Excellent printing surface White sheet throughout
Clay Coated Solid Unbleached Sulfate (SUS)	Heavy duty packaging: Beverage carriers, hardware, concentrated soaps and detergents	Tough, strong, tear resistance Water/moisture resistance Excellent printing surface Good wet strength

2.3.4 Production and print methods

Carton and cardboard packaging enable various printing processes, each have unique performance and production characteristics. According to the graphic of the package and using area, production and print method are chosen. The book, Ideas and Innovation, summarizes these factors for selection of a specific process as;

- Length of the run (order quantity)
- Complexity of the graphics
- Quality requirements
- Color requirements
- Register tolerance
- Desired ink coverage
- Make-ready time
- Cost of plate and die preparation (Paperboard Packaging Council, 2000, p. 0.402)

There are some primary printing processes used in cardboard packaging; flexography, offset, letterpress, gravure and digital printing. Generally, offset, flexography or flexo printing processes are used by modern cardboard package manufacturers.

Flexography

This process is an adaptation of letterpress, which is the oldest process in the industry. Printing plate is made of rubber or photopolymer. It is a direct printing method, which the image areas to be printed are raised above the non-image ones. In flexo, the ink is transferred first onto an anilox roll then it transfers the ink to the raised portions of the printing plate cylinder. At the end, the cylinder transfers the ink to substrate (Figure 2.8). Flexo, which exclusively is web-fed process, can be used on most materials however reproducing all color hues are difficult (Association of European Cartonboard and Carton Manufacturers, 2016, s. 10) (Paperboard Packaging Council, 2000, p. 0.403) (Figure 2.9).

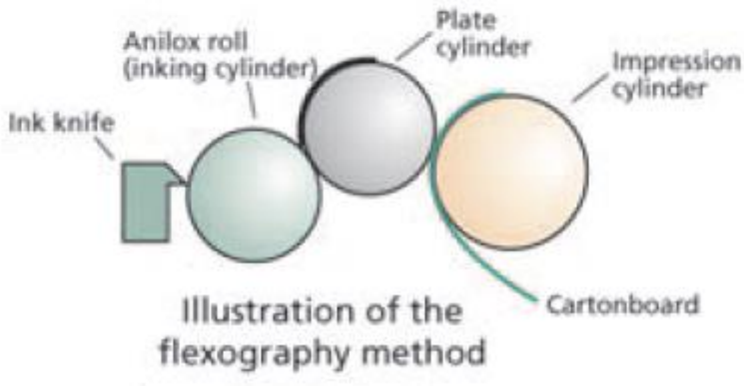


Figure 2.8 : Illustration of the flexography method (Association of European Cartonboard and Carton Manufacturers, 2016, s. 10).

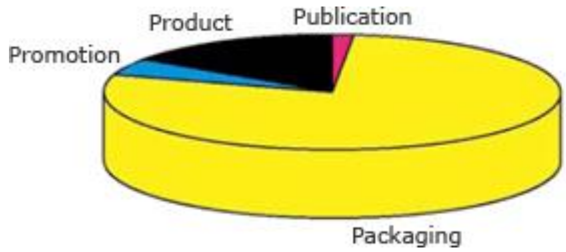


Figure 2.9 : Flexography using area pie chart (Printing processes, 2016)

Offset

Offset is the most common printing method for cartonboard. (Paperboard Packaging Council, 2000, p. 0.403) Mostly sheet-fed offset method is used which the printing press is fed with cartonboard sheets. In contrast to flexography, offset is an indirect printing method. The printing cylinder sets off (hence “offset”, means plate does not directly contact the substrate) the printing ink onto a rubber-covered blanket cylinder, which transfers the ink/printing image to the cartonboard sheet.

The image and non-image areas are distinguished from each other by the use of chemical properties (Association of European Cartonboard and Carton Manufacturers, 2016, s. 10). The printing plate is attached to a cylinder that is covered in water before the ink is applied. When the ink is applied to the plate, the surfaces that accept water repel the ink, but ink remains on the imaging surfaces that repel the water (Figure 2.10). Offset printing’s quality is excellent and it is economical for both short and low runs. However, it is mentioned in prepressure website that promotional material is gradually migrating to digital printing, while some packaging printing is moving to flexo (Printing processes, 2016) (Figure 2.11 2.12).

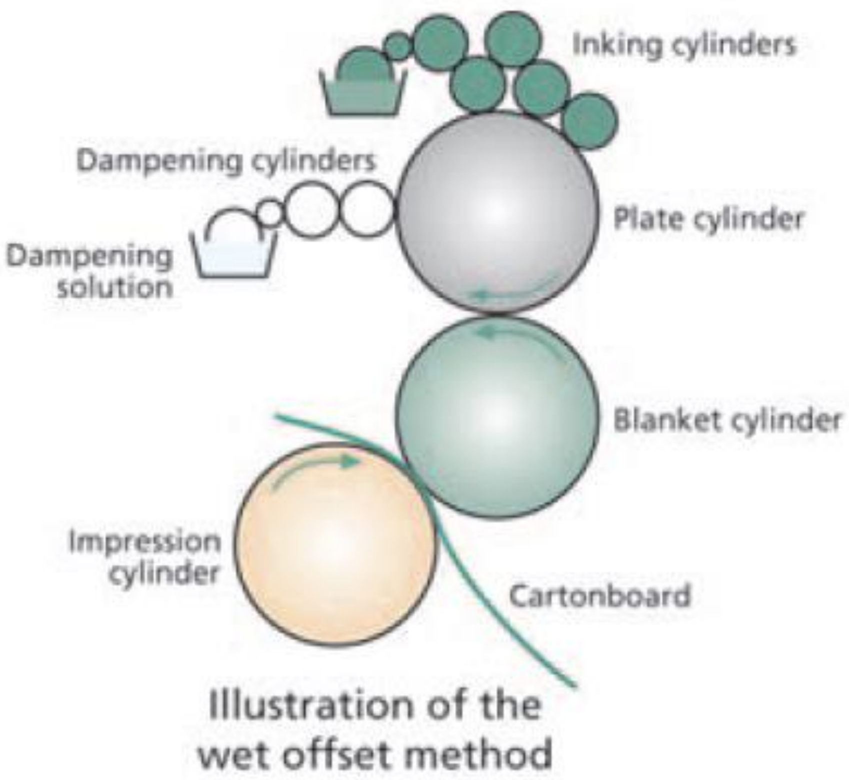


Figure 2.10 : Illustration of the wet offset method (Association of European Cartonboard and Carton Manufacturers, 2016, s. 10)

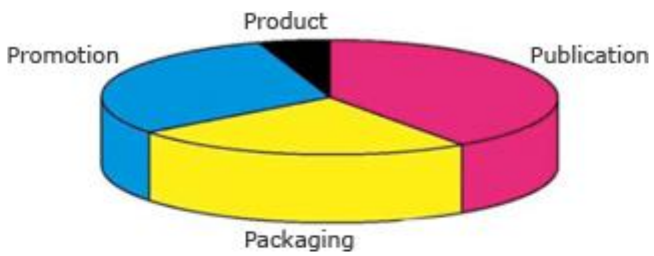


Figure 2.11 : Offset using area pie chart (Printing processes, 2016)

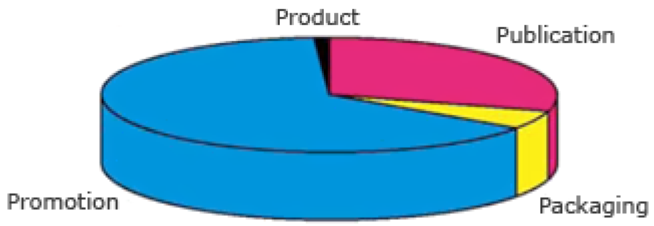


Figure 2.12 : Digital printing using area pie chart (Printing processes, 2016)

2.4 Determining Overall Appearance and Graphic

Package designer has to comprehend all the knowledge and more, which told above with their advantages and possibilities to create and start the package's lifecycle. Even a brief from a keen customer can just submit the area with their borders and resources. The designers' role is considering all the process and creating –not finding- the best possible solution with the given background, environment and technology.

2.5 Designing the Package

Even at the beginning of the planing and designing of the package, designer has to consider all the factors which have been mentioned above. These factors were the customers' and the consumers' however, these aren't the only factors but the starting points. The package designer is on a significant place where all the choices and decisions are taken by the various disciplines of the manufacturer. That is why manufacturing factors will be taken into consideration at design step. Naturally, after manufacturing, the packages will be trasported first to products' manufacturing area to be packed, then to the sale point. All the transporting conditions must be mentioned by the customer and they should not be missed by the designers.

2.5.1 Studying suitable package design style for the product(s)

All designers establish a library to facilitate their designing process according to their area and -if there is- manufacturing plants. FEFCO _ ECBO codes for the different variations of design is the most common of these guides. All the package designs are drawn with specialized lines in CAD programs to distinguish their properties (Figure 2.13). Ideas and innovation also approach the same subject with a different aspect. Writer composed a new library, first taking the book as a base, and then included "cutting in halves" and "crossbreeding the designs". So the designs are now represented differently with their top and bottom types, and this method enables to create modified designs (Tables 2.9. 2.10 2.11 2.12 2.13) (Figure 2.14). In order to give a more descriptive demonstration, some photographs of corrugated cardboard boxes are given in appendice B with their types explained.

It is inevitable that there are some special packages, which are hard to categorize in this library however creating branches is always possible.

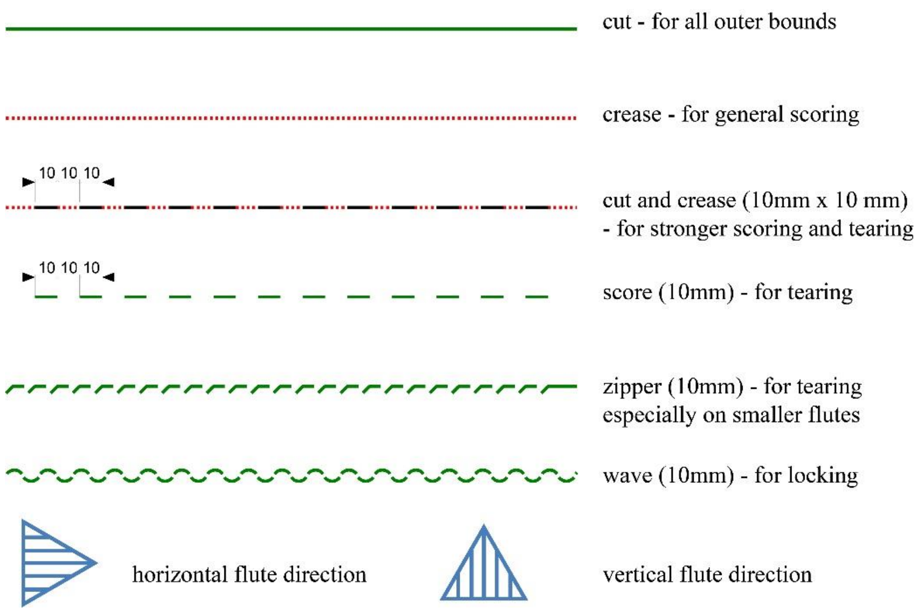


Figure 2.13 : Commonly used lines and flute direction symbol in computer drawing used for paper packaging. Drawn in ArtiosCAD

Except the box or the package of the products, there are particular inserts, which have some duties inside the box (Table 2.8). These also can made of varied flutes and paper combinations according to the need for the product or the outer box. Combination of the box and its inserts create different solutions, for example using tougher insert of high grammage of paper, can save cost for the box using lesser grammage. Furthermore, if a smaller caliper becomes enable, the printing quality result will be much better which is desirable for all customers. Maltenfort (1988) emphasized that corrugated board is the most commonly used material for cushioning, but least understood. For the most part, he says, using it is mostly an art, rather than a science (p. 134).

Table 2.8 : Packages and inserts according to their level as primary, secondary and tertiary.

Inserts (Interior fitments)	Primary Package	Secondary Package	Tertiary Package
Glued type	Tubes type box	Tubes type box	Pallets
Automatic type	Tray type box	Tray type box	Displays
Slotted type	Sleeve type box	Sleeve type box	
Wrapping type		Displays	
Support type			

Remarkable part of the inserts is that using overplus or gratuitous amount of inserts make the cost exceeds two or three times higher. While the area of the insert goes wider, the area of outer box has to become larger to fit the insert in, therefore the cost surpass the adequate amount much more than predicted. Chen and others (2011) emphasize the importance of the volume of the package, that the volume of commodity after packaging is usually larger than that of the commodity itself, sometimes by 5-10 times (p. 997). Therefore, even a small change have the ability to affect the result enormously, which is making the dimensions a major issue with a precise decisions.

As it can be understood from the tables of the types of the boxes, inserts also can be the same part of the box itself, glued or slotted. Though making the m² of the outer box higher, using a combined design does also have benefits. Firstly, every design needs a dieboard for the manufacture process if it isn't a RSC. That means, each insert also needs a dieboard, manufacturing process, -if exist- a gluing process and transporting. The control points of the package will expand and as well as the duration of the process. The timing will be crucial as without the box or the insert the package will not be ready for filling and shipping to the customer and final consumer. Maltenfort (1988) also concluded that boxes, which are containing partitions and dividers can achieve economies over RSCs (p. 50).

Table 2.9 : Package styles as tube, tray and sleeve types.

package styles	tube type	top
		bottom
	tray type	two seperate piece
		one combined
	sleeve type	one side open
		both side open
		no open side

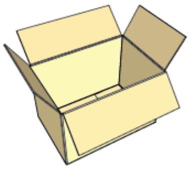
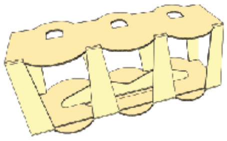
package types		properties
tube type		usually suitable for higher products provides a wide range of different designs requires a folding process in conventer’s plant
tray type		usually suitable for lower products can be use as one piece or two piece closed ones provide elegant appearance closed ones especially use large areas
sleeve type		usually use for multiple products usually use for rigid poducts low board area suitable for all dimensions

Figure 2.14 : Package types; tube, tray and sleeve, with their brief properties.

Table 2.10 : Tube type boxes according to their bottom and top designs

tube type box		
bottom part		**top part**
slotted		
lock tuck		slotted
ready glued		lock tuck
	X	
interlocked		slotted insert
slotted insert		customer lock
glued insert		interlocked

Table 2.11 : Tray type boxes according to their piece, bottom and top designs.

tray type					
two seperate piece			one combined		
bottom		top	bottom		top
four point corner		four point corner	four point corner		four point corner
customer glued	x	customer glued	customer glued	x	customer glued
customer locked		customer locked	customer locked		customer locked
open tube style		open tube style			lock tuck
		sleeve			

Table 2.12 : Sleeve type boxes divided by their panel and manufacturing type.

sleeve type		
panel		manufacture
one side open		ready glued
both side open	x	customer lock
no open side		customer glued

Table 2.13 : Insert types which can simultaneously be one or more of them.

insert type
glue
automatic
slotted
wrapping
support

2.5.1.1 Tube type boxes

All tube boxes here are categorized according to their gluing points. Glue flap and the connected parts locate at the first and the last panel of the design. From the working scores, the design folds and glue part overlaps on the last panel, which gets the name as manufacturer's joint (Figure 2.15).

Length (L) and width (W) is the base of the box, and depth (D) is the heigth of the box with length always is the bigger of the side panels. If the panels' order is L-W-L-W, the last panel width generally is lesser than the width according to flute of the box. If the box is E flute the last panel becomes "W-1 mm", respectively; for B flute "W-2 mm".

Tube style boxes can have different numbers of side, generating triangle prisms, octagonal prisms etc. However, the palletizing and transporting circumstances lead to rectangular prisms most favoured.

Tube style boxes, which have been divided here as top and bottom parts (Table 2.10) (Figure 2.16) can be designed by crossing them. These half parts of designs will be mentioned below.

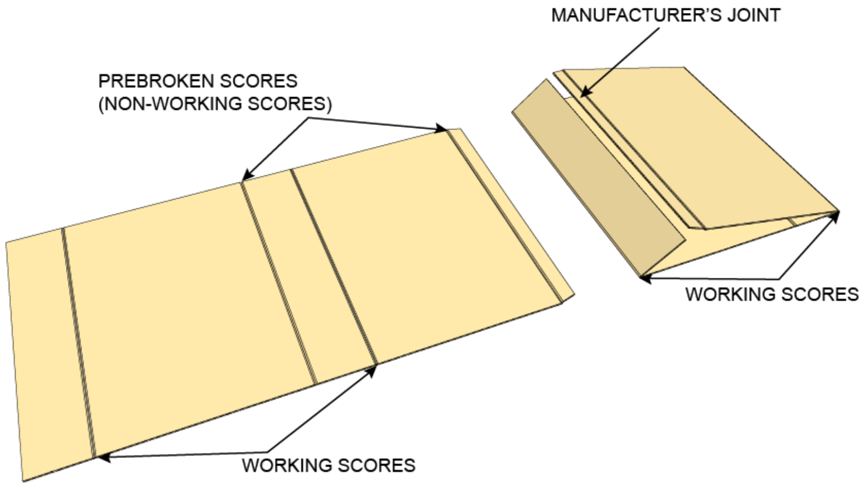


Figure 2.15 : General tube style box rule of scoring and gluing in manufacturer's plant (Paperboard Packaging Council, 2000) redrawn with ArtiosCAD.

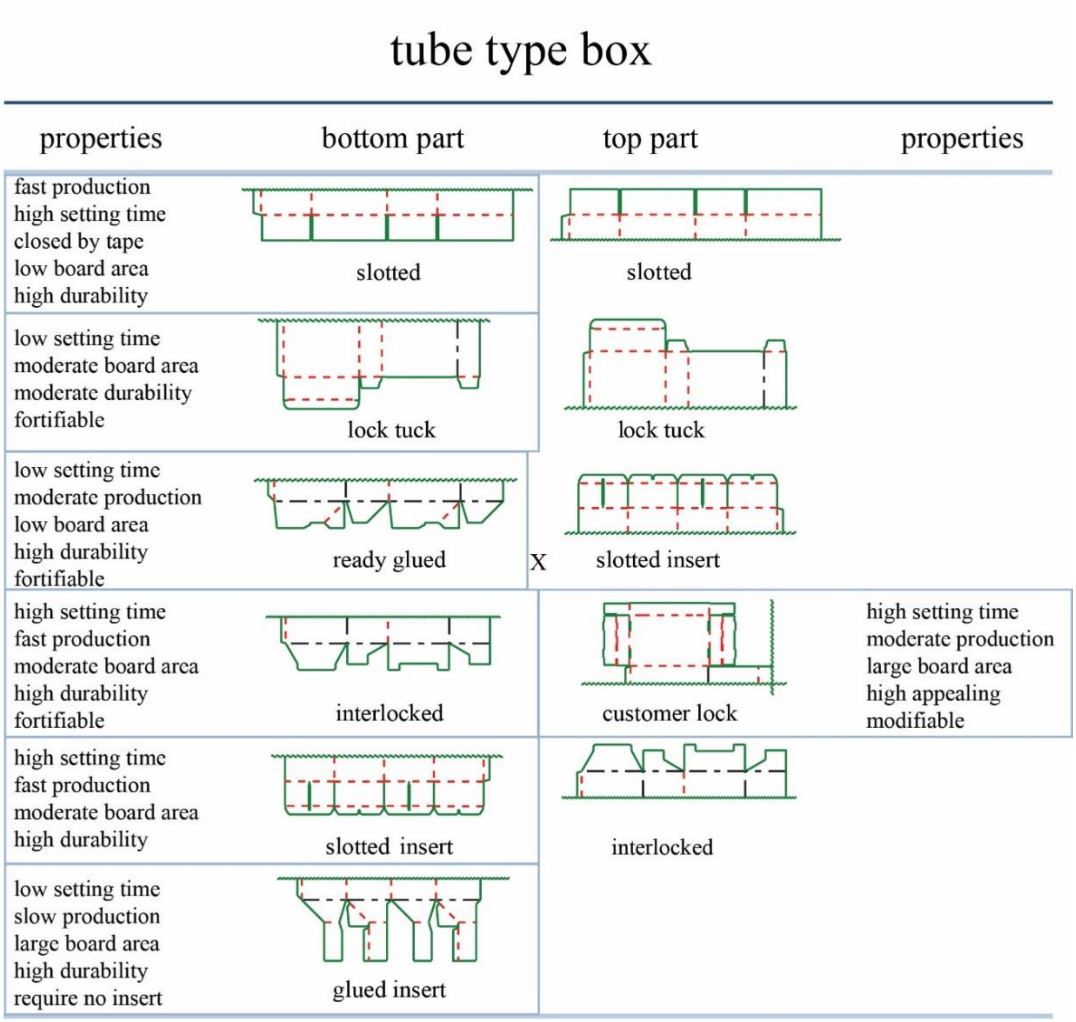


Figure 2.16 : Tube type boxes with example for each style for crossbreeding with their properties

Slotted (for both bottom and top) (closed by the customer with usually ducktape)

Slotted is the simplest types of closing types in tube types. Eventhough the other box types need a diecut, RSC (Regular Slotted Container) does not need one for flexo print. RSC is a tube style box, which two sides are as the figure below (Figure 2.17 2.18). The machine creates the creases, which generates the L, W and D surfaces, then cuts the slottes according to the desired gap, thus emerging the simplest and the most common use type of box. Because of it's shipping capacity and uncomplicated utilization, it is mostly used for secondary packages.

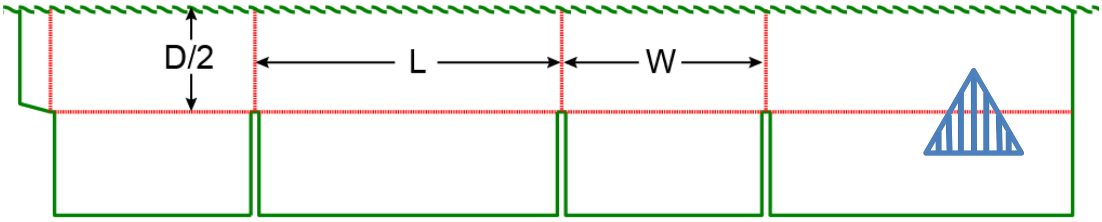


Figure 2.17 : Half of a slotted box bottom (European Solid Board Organisation, 2016)

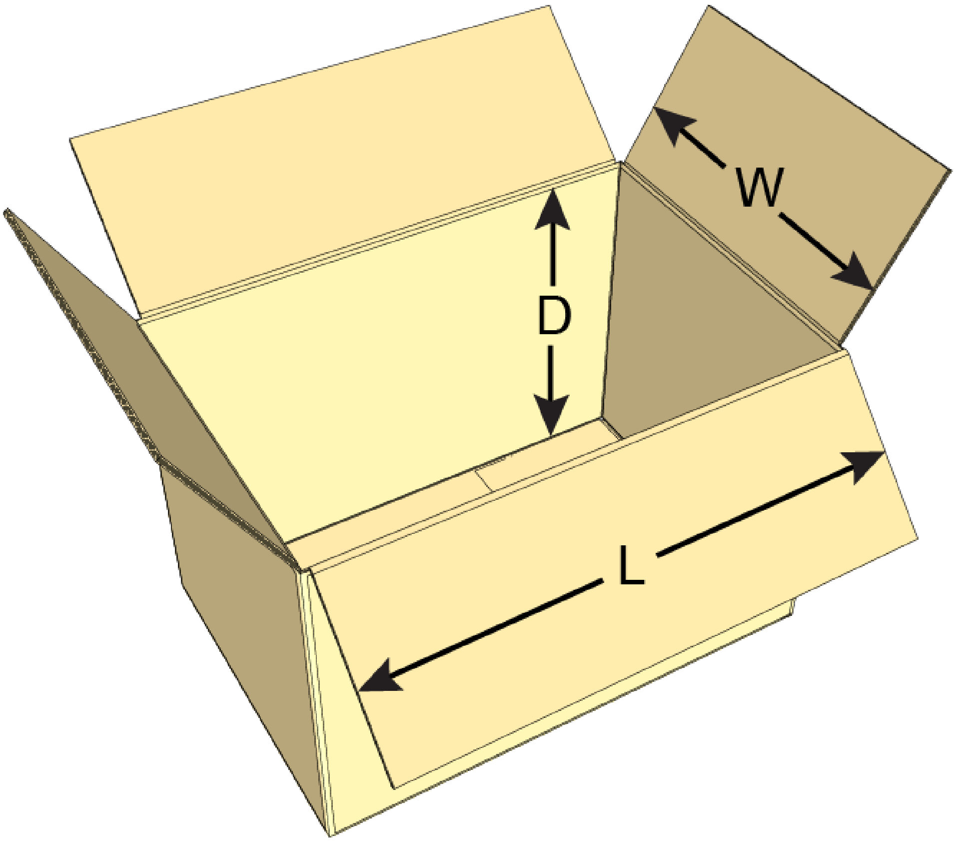


Figure 2.18 : Regular Slotted Container (European Solid Board Organisation, 2016)

Lock tuck (for both bottom and top) (closed by the customer)

There are different types of lock tucks (Figure 2.19) according to the caliper of the package or the customer needs. Lock Tuck can fasten with their setbacks (Figure 2.20) and other details with the help of the flaps on each size. Flaps are also made the lid surface more sturdy so it will not fall inside the box. Lock tuck can be used for both size at the same time such as medicine boxes. Lids of the two sides can change to front or back side panel (Figures 2.21 2.22) with regard to their graphic, usage or the customer needs. Moreover, using different locking types for top and bottom can help to distinguish the sides, ensuring the opening from the top side.

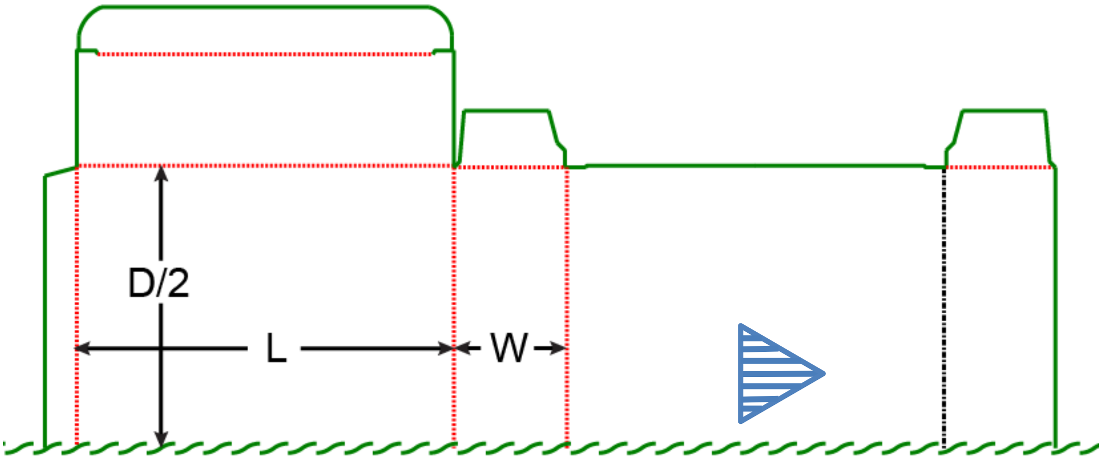


Figure 2.19 : Lock Tuck on the tube style box with the flaps (European Solid Board Organisation, 2016)

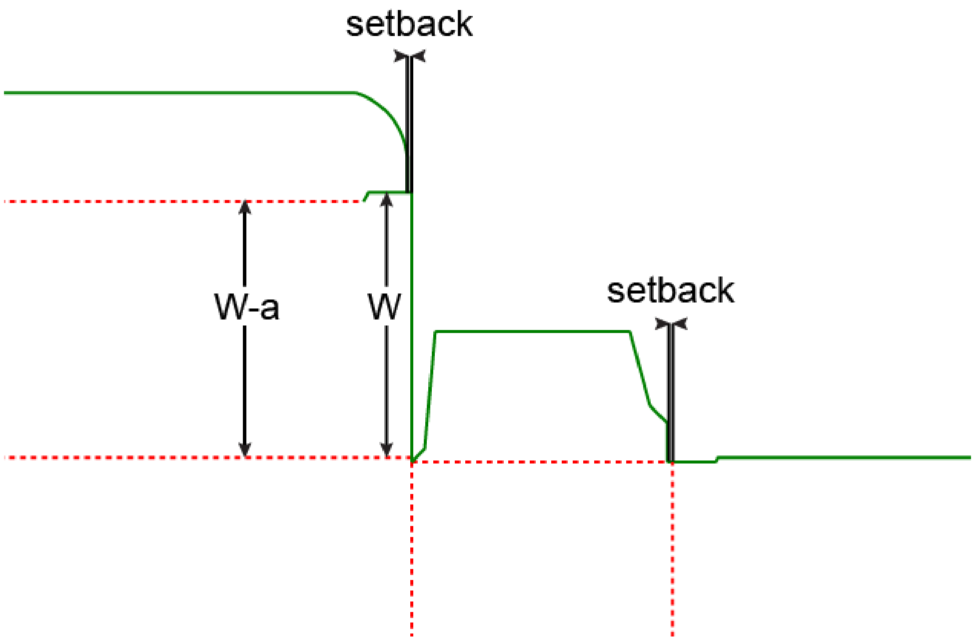


Figure 2.20 : Lock Tuck with the setbacks to ensure the closing (Paperboard Packaging Council, 2000)

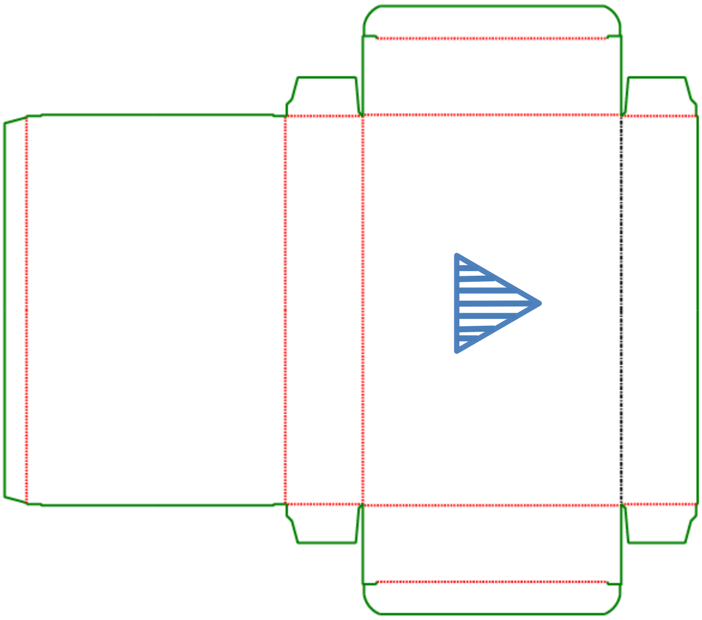


Figure 2.21 : Airplane style straight tuck, lids are on the same surface of the box (European Solid Board Organisation, 2016), (Paperboard Packaging Council, 2000)

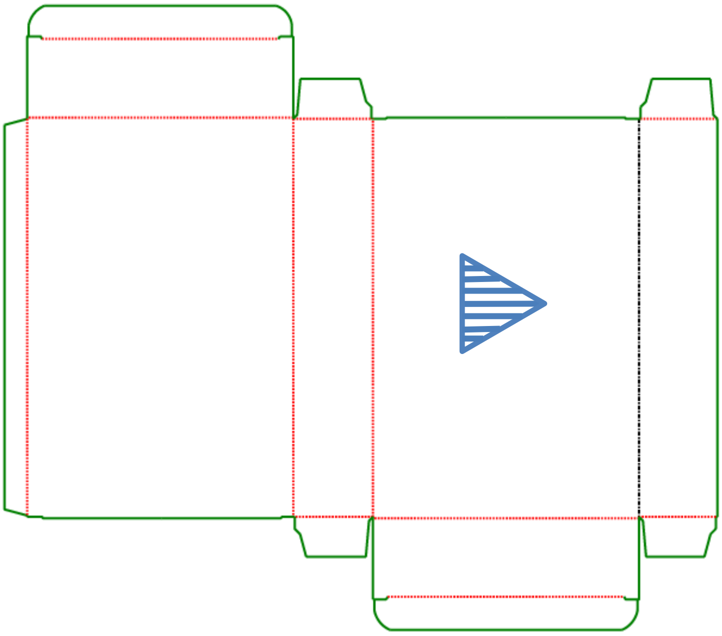


Figure 2.22 : Standard Reverse Tuck, lids are on the different surfaces of the box (European Solid Board Organisation, 2016), (Paperboard Packaging Council, 2000)

To strengthen the lid sometimes a tongue lock (Figure 2.23) is added to the front and back surface of the box. It is also closed by the customer and it is very useful when the ratio between the length and the width is high, as it ensures the lid not to open easily or look gapped and add more security to the package. Tongue lock can be added in various styles in tube style boxes, trays and sleeves with different looks and sizes. Setback tolerances of the locks depend on the caliper of the material in order to make it not so difficult to tuck in and not so easy to pop out.

It is also possible to create a durable box with a double tuck, in order to protect the product inside (Figures 2.23 2.24). Also ensuring the lid closed, tongue lock also can be doubled as intertwined or two seperate along the front panel of the box. As a special case of double tuck, a void volume can be created, which called as platform in Ideas and Innovation book (Figures 2.25 2.26). This platform can serve as a cushioning for the products which are vulnerable to end damage (2000, p. 1.633). With opening holes specific for the product, it also helps the product not to rock inside the box, decreasing the wearing of package.

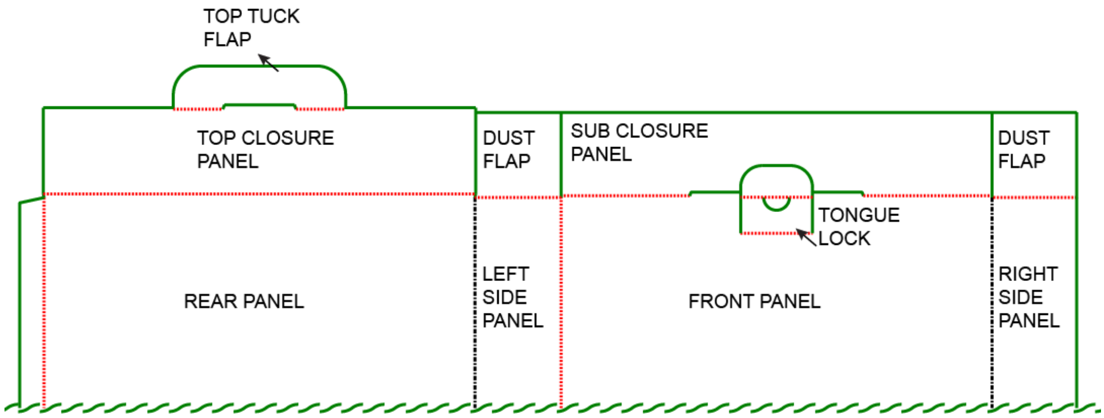


Figure 2.23 : Tongue lock on a double lock tuck box (Paperboard Packaging Council, 2000) redrawn at ArtiosCAD

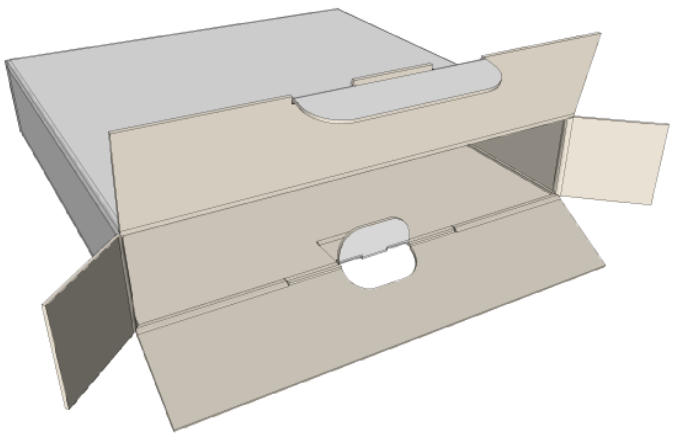


Figure 2.24 : 3D view of a double lock tuck box (drawn with ArtiosCAD)

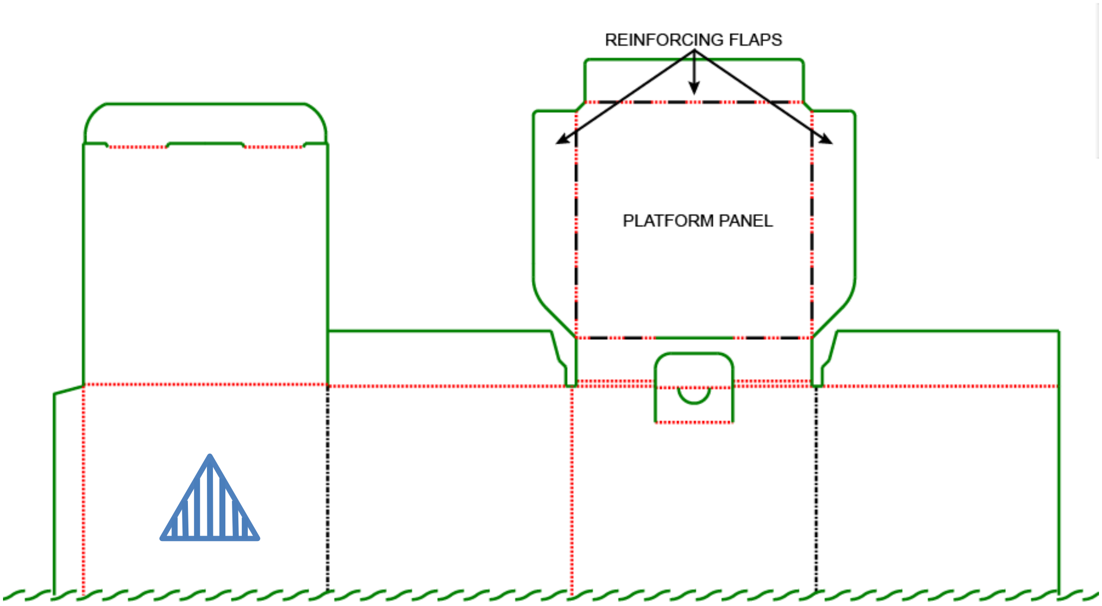


Figure 2.25 : A platform panel on a double lock tuck (Paperboard Packaging Council, 2000, p. 1.633) redrawn with ArtiosCAD

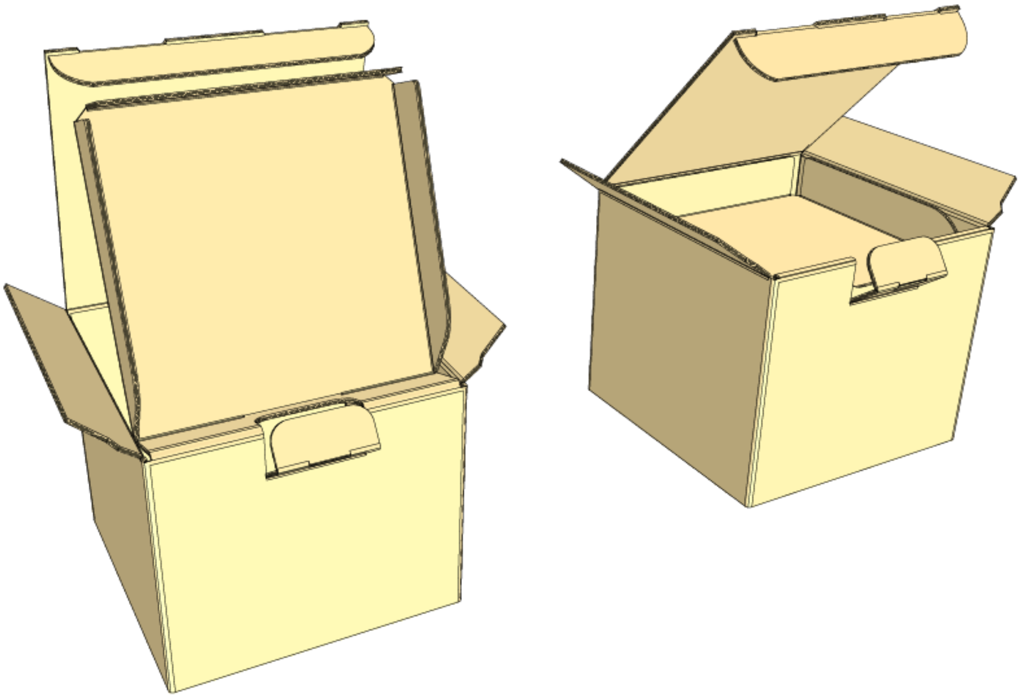


Figure 2.26 : 3D view of a platform panel on a double lock tuck.

Ready glued (preglued) (mostly for bottom) (auto-erect bottom)

Ready glued boxes (Figures 2.27 2.29) are glued in the converter's plant and shipped flat to the customer's plant where they have been set by hand to use. Not all the converters are capable to glue them as they require a speacial facility, however it makes a lot faster setting up for the customer. Nevertheless, it is still essential to check according to the production volume, as in low production using ready glued would not be so logical. Eventhough it is highly used as a bottom lock, as a closed tray, it is possible to use for both sizes, bottom and top.

For ready glued boxes, usually lock tuck (Figure 2.28) is used for top part which makes them a common design in different sectors. All the specification which are told above about tuck lock also is viable in these boxes such as the setbacks and tongue locks.

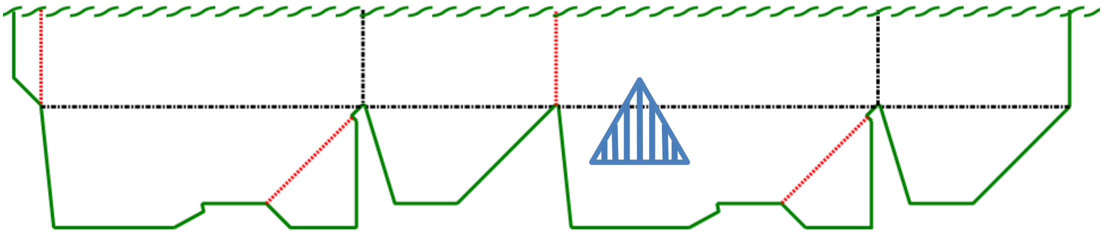


Figure 2.27 : Ready glued box (European Solid Board Organisation, 2016)

For heavier products, there are differentations and details for auto erect boxes such as using flaps or changing sides and enlarging the glued surfaces (Figure 2.28 2.29). The logic of the preglued boxes stays same eventhough the dimensions can make it look distinct.

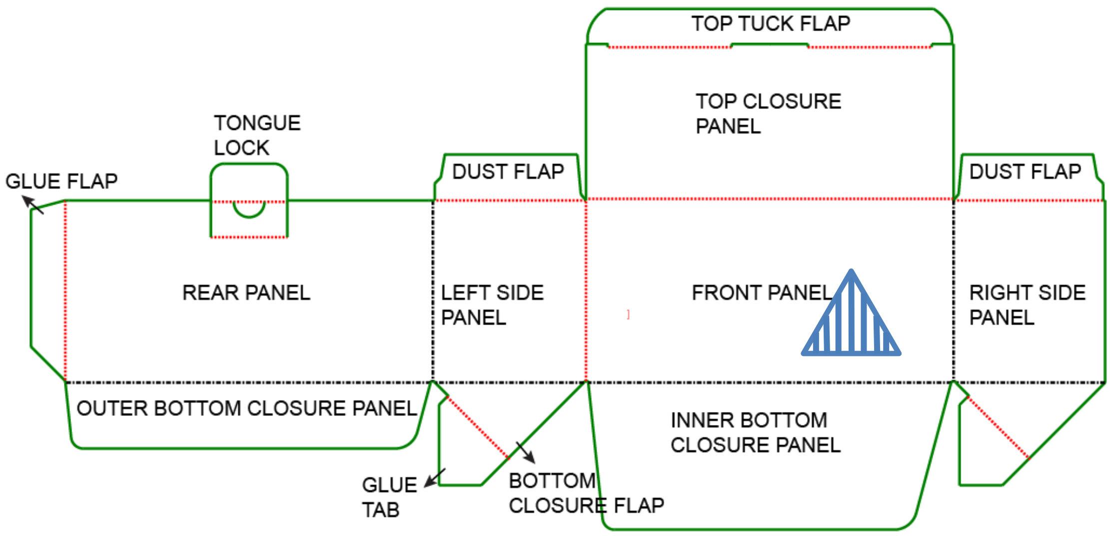


Figure 2.28 : Ready glued reinforced bottm for heavier products (Paperboard Packaging Council, 2000)

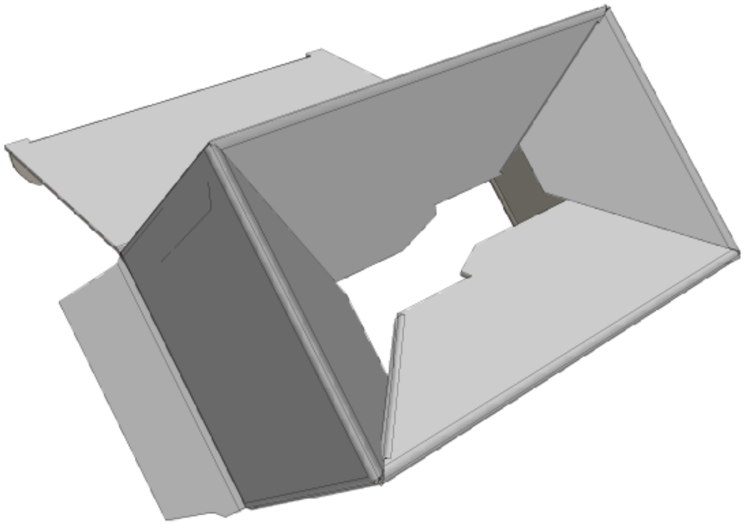


Figure 2.29 : 3D view from bottom part of a ready glued tube style box (drawn with ArtiosCAD)

Interlocked (snap lock) (houghland) (usually for bottom) (closed by customer)

"1-2-3 Bottom" also is used for interlocked tube style boxes while Houghland name comes from the inventor's name. It is widely used by the different sectors as it does not require a high production line or a more complicated production line (Figures 2.30 2.31 2.32 2.33). Like ready glue boxes, these can be also shipped flat and erected by hand easily as the name suggest 1 – 2 – 3.

Snap lock box is also used for especially big packages as it just requires a side glue flap. If a ready glued package's dimensions exceed the print or production line capacity, the design will be seperated in two or more parts and glued to each other by their glue flaps in converter's plant. After that, the customer can set the box by hand however the sight of the box will be distorted by the look of paper sides.

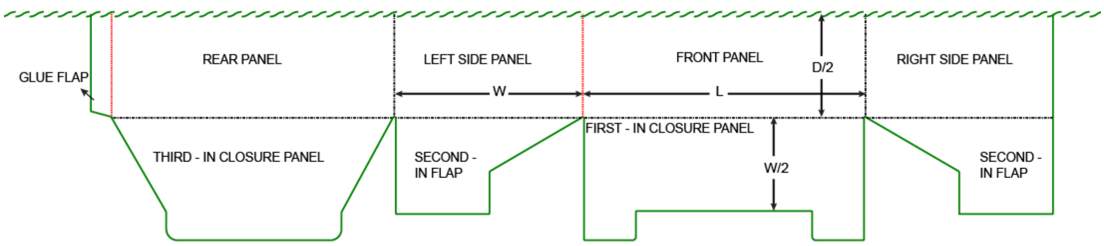


Figure 2.30 : Interlock tube style box (Paperboard Packaging Council, 2000)

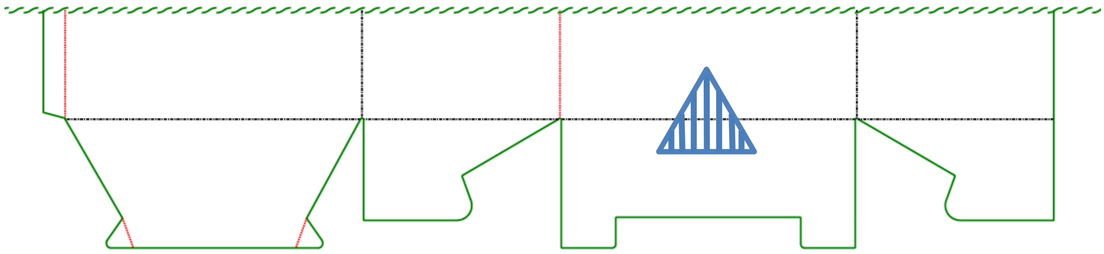


Figure 2.31 : Additional security on the third closure panel on interlock (Paperboard Packaging Council, 2000)

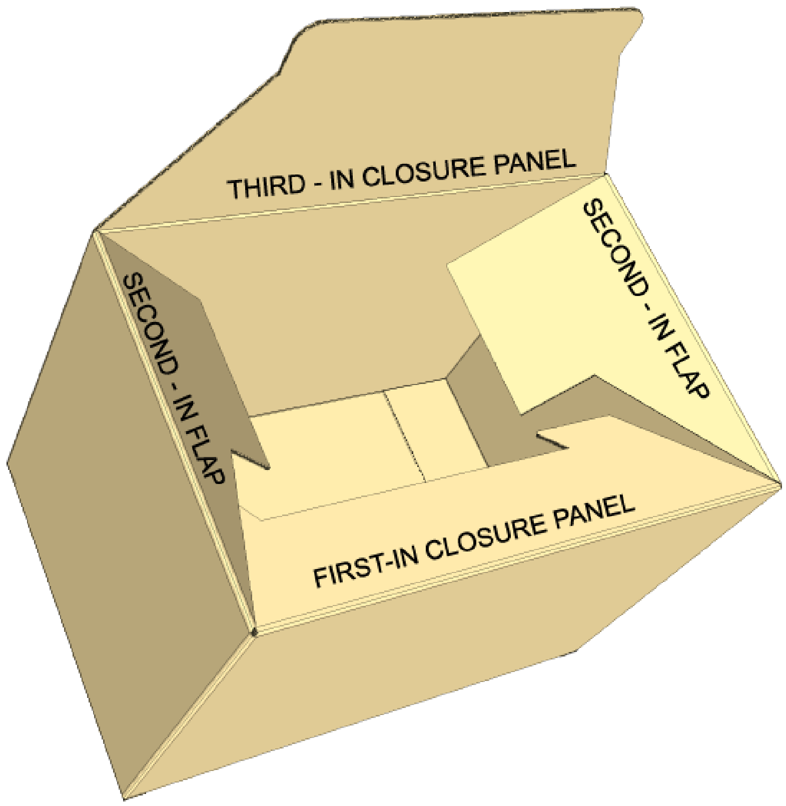


Figure 2.32 : Closing sequence on interlock bottom (a.k.a 1-2-3 bottom) (Paperboard Packaging Council, 2000)

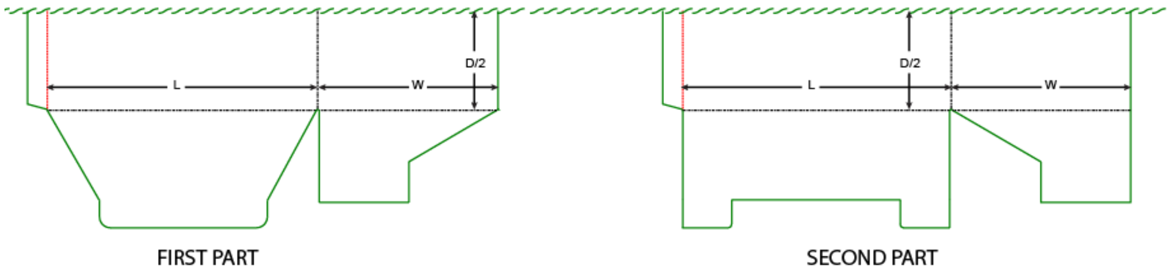


Figure 2.33 : First and second parts of the box when splitted in two for big boxes

Slotted insert (for both bottom and top) (closed by customer)

The boxes which have self insert and seperation parts are special for some occasions like multiple product packages that should be separated from each other. These products can be fragile products such as glass cups or scratchable materials. In order to protect these items, inserts' dimensions are adjusted not to increase the wasted paper.

Slotted inserts can be used for both sides and these double inserted ones would be really tough as there are extra surfaces and corners which fortify themselves (Figures 2.34 2.35). In order to smooth the tucking, the slots are arranged according to their caliper again to stick on the "just right" fineness. The design also can be set to adapt for a number of different sections such as; two, four and six as mostly used forms (Figures 2.36 2.37). One criteria which must be taken into account is the length of the flaps, if the products in the box are breakable thus shoudn't hit each other. The flaps have to be long enough to prevent the contacts and strikes between the products inside.

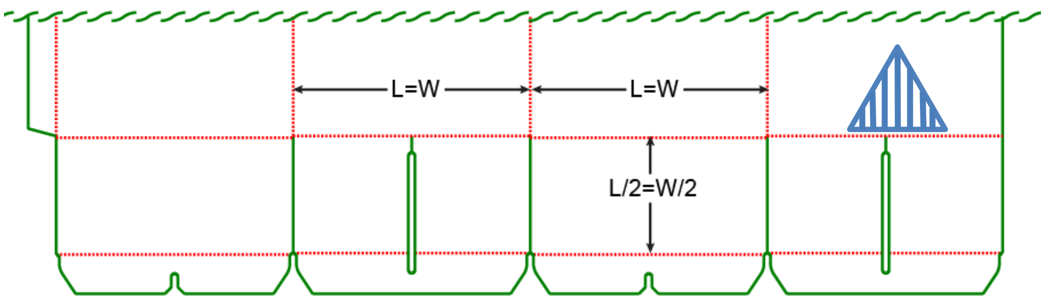


Figure 2.34 : Slotted insert tube style box which divides the box in four section. (drawn with ArtiosCAD)

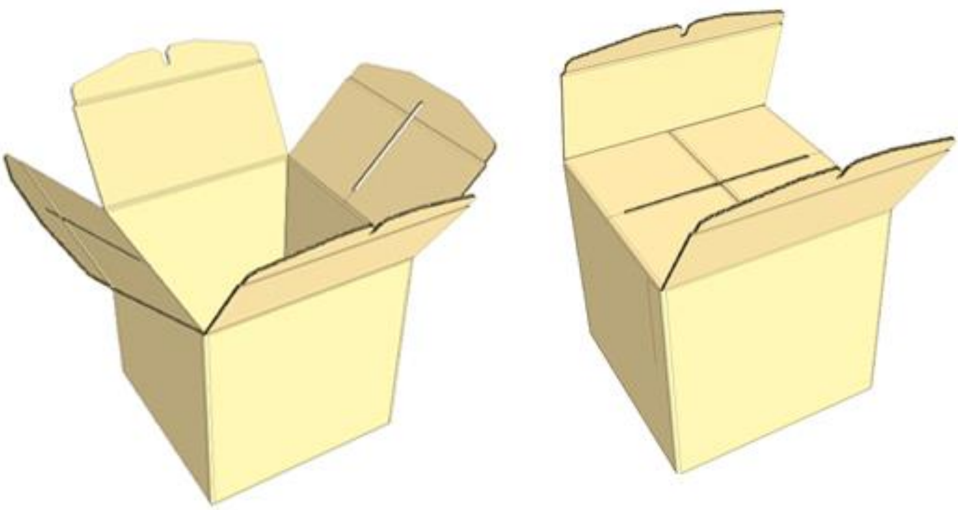


Figure 2.35 : 3D view of a slotted insert tube style box with four section.

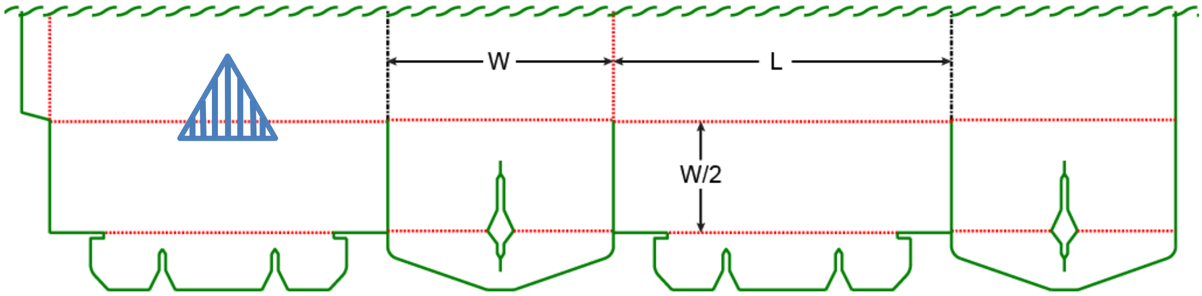


Figure 2.36 : Slotted insert tube tyle box which divides the box in six section. (drawn with ArtiosCAD)

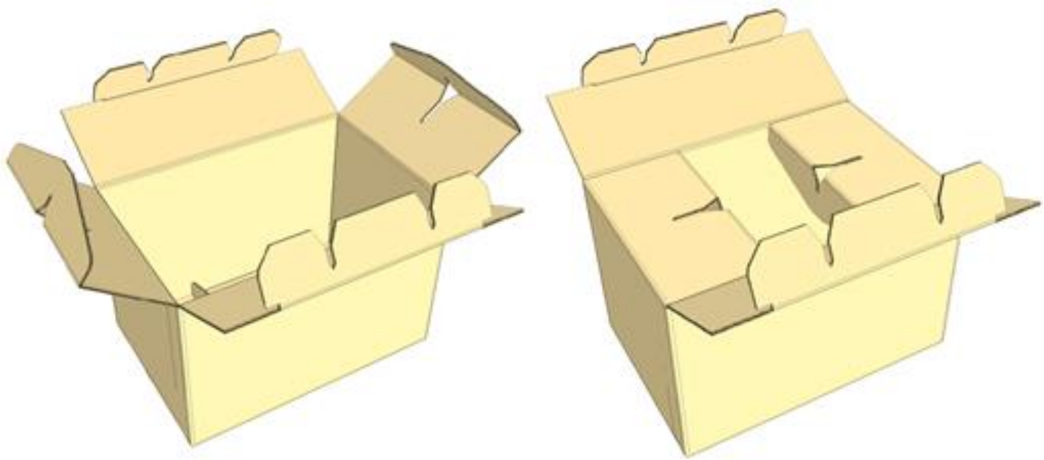


Figure 2.37 : 3D view of a slotted insert tube style box with six section.

Glued insert (for bottom) (auto – erect bottom)

Similar to slotted insert tube style boxes, glued insert boxes are also used for multiple product packages. The inserts glue each other in conventer's plant like ready glued boxes and shipped flat to customer's place. It can be erected by a single movement creating two, four or six sections, depending its design (Figures 2.38 2.39 2.40 2.41). As it doesn't need an extra insert or separation both the shipping parts and diecut of designs reduce. With their great capability of easy establishing, it creates a fast filling, however the process inside the converter's place is much more advanced and complicated. The designing itself is also a challenge as there are lots of criterias to take into account.

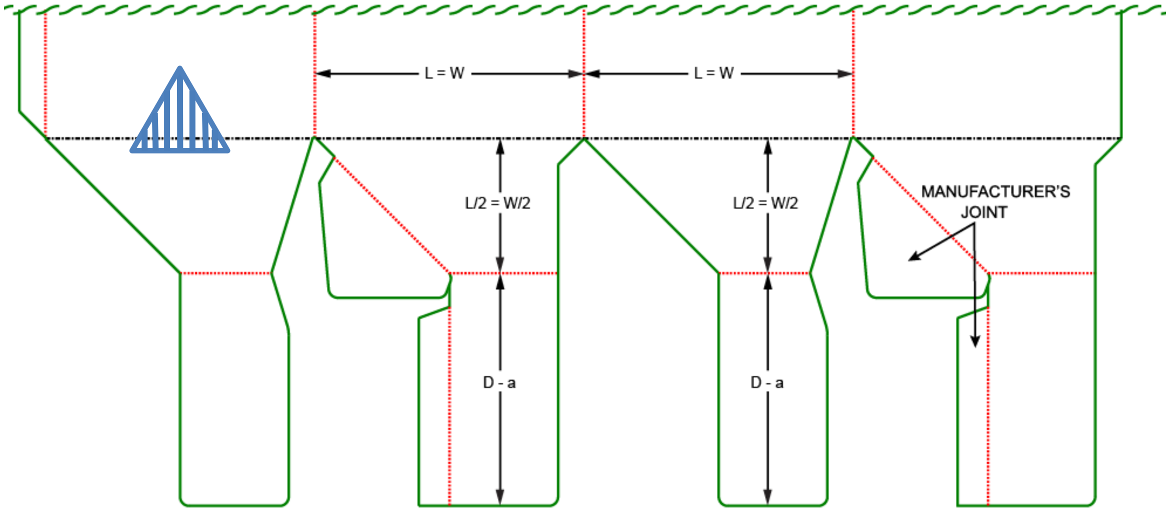


Figure 2.38 : Glued insert tube style box which divides the box in four equal sections.

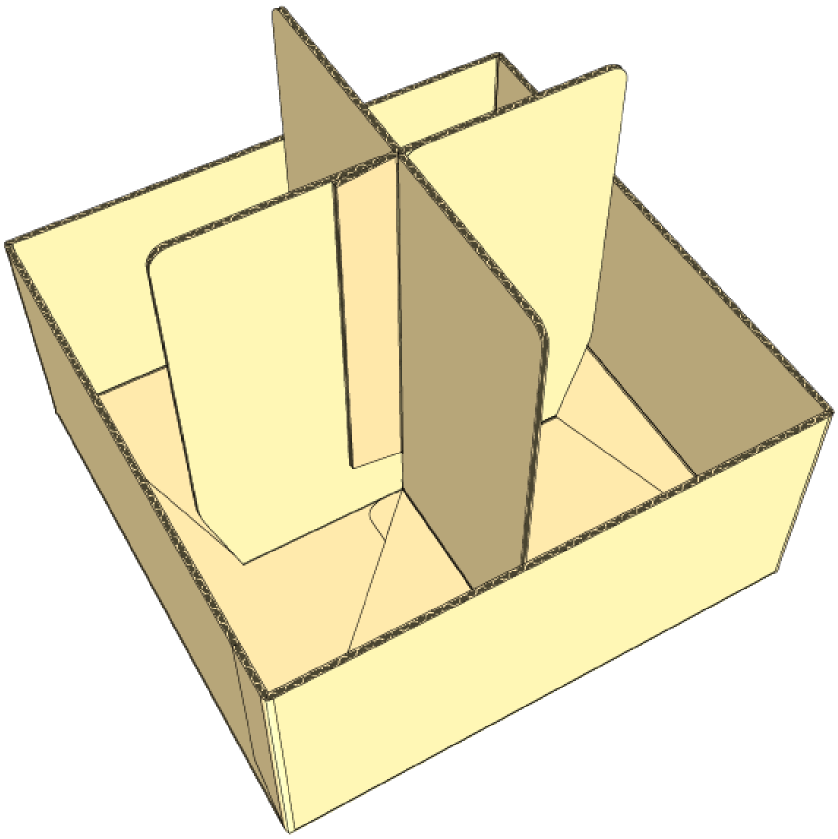


Figure 2.39 : 3D view of a glued insert tube style box with four equal sections

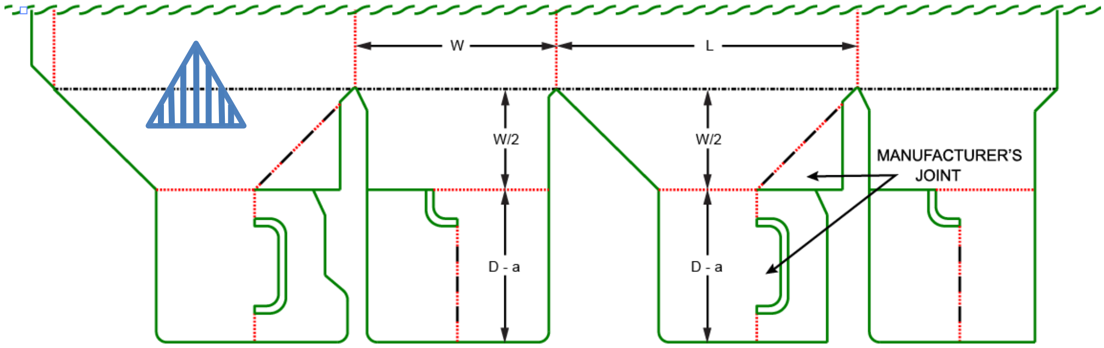


Figure 2.40 : Glued insert tube style box which divides the box in six equal sections.

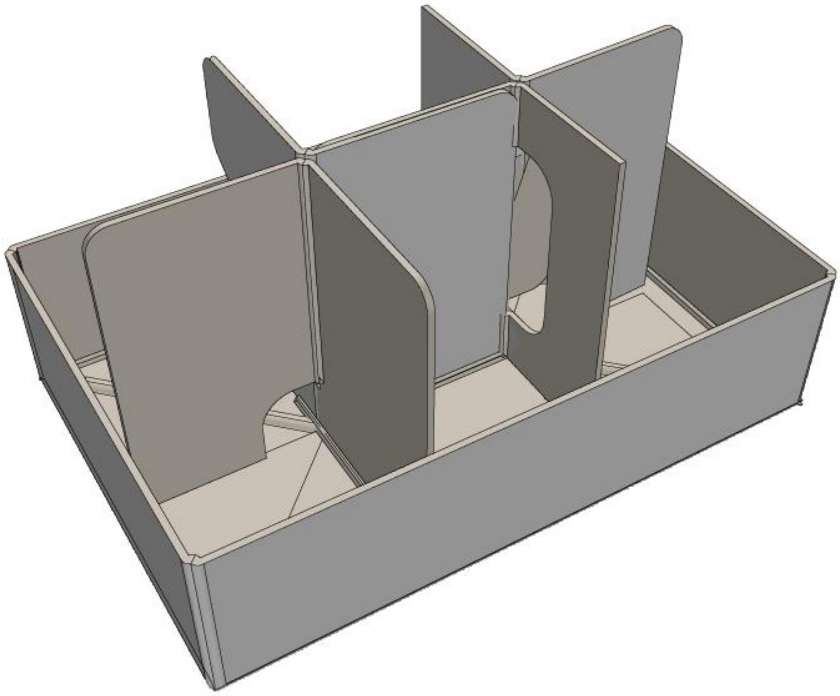


Figure 2.41 : 3D view of glued insert tube style box with six equal sections.

Customer lock (for top of tube style box) (closed by customer)

Customer Locks will be told in trays with more details as they are actually tray style boxes. However they can also be adapted to tube style boxes to create different designs and more sophisticated boxes. Their closing principle is stucking an extensive face to inside of a panel or box (Figures 2.42 2.43). Slots, gaps, expanded sides, locks can be used to create, and their common point is that they have to be locked by the customer as they always have to be shipped flat to the customer.

Some designs both comprise glue and the help of the customer to be erected. But if the design does not consist a gluing part inside the converter's plant, the cost and the process time will reduce in favor of the customer however changing the filling time and the cost of employment.

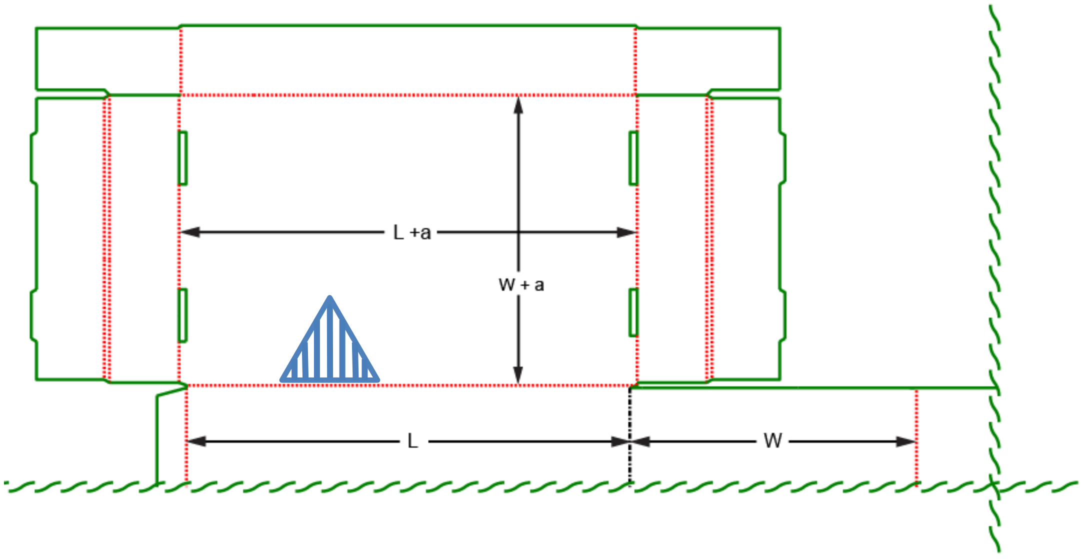


Figure 2.42 : Walker lock top part as an example to customer lock for tube style box.

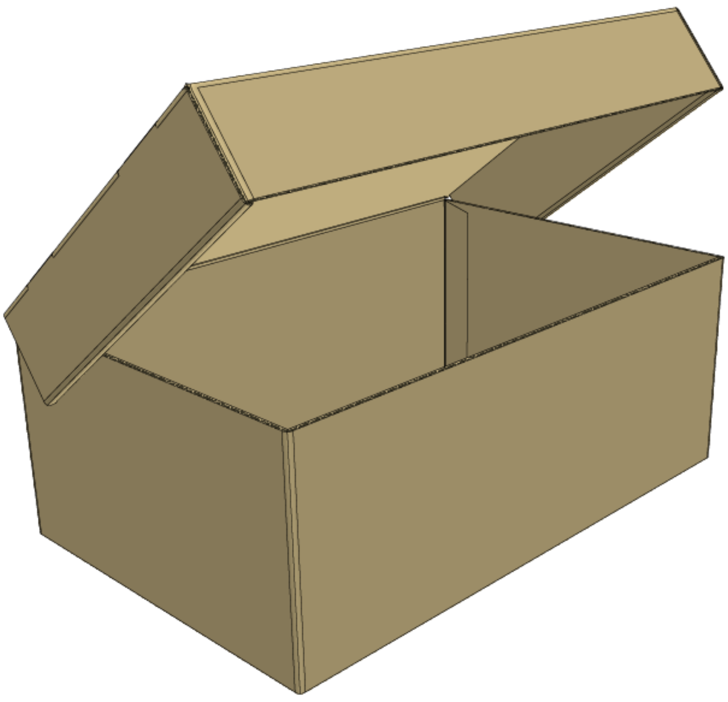


Figure 2.43 : 3D view of walker lock top part for tube style box.

2.5.1.2 Tray type boxes

Tray type boxes are also a huge family and unlike composite tube styles they can be divided to both separated and composite styles (Table 2.11) (Figure 2.46). These seperate boxes also can be generate from an open tube style boxes which as the table suggest.

Trays also can be divided according to their setting up, as auto erect or customer locked. They are shipped flat again independently from their setting up styles. Easiest way to distinguish a tray is that bottom or top panel is in the center of the design and from each margins the side panels come (Figures 2.44 2.45). The center panel which will become top or bottom, can be different forms, rectangular, triangle, hexagon octagon etc. Rectangular trays are always preferable because of their optimum waste loss while palletizing and transporting.

Side panels can be single wall or double wall, which allows a wide range of designs for tray and some of them are hardly recognizable as trays (Paperboard Packaging Council, 2000, p. 2.000).

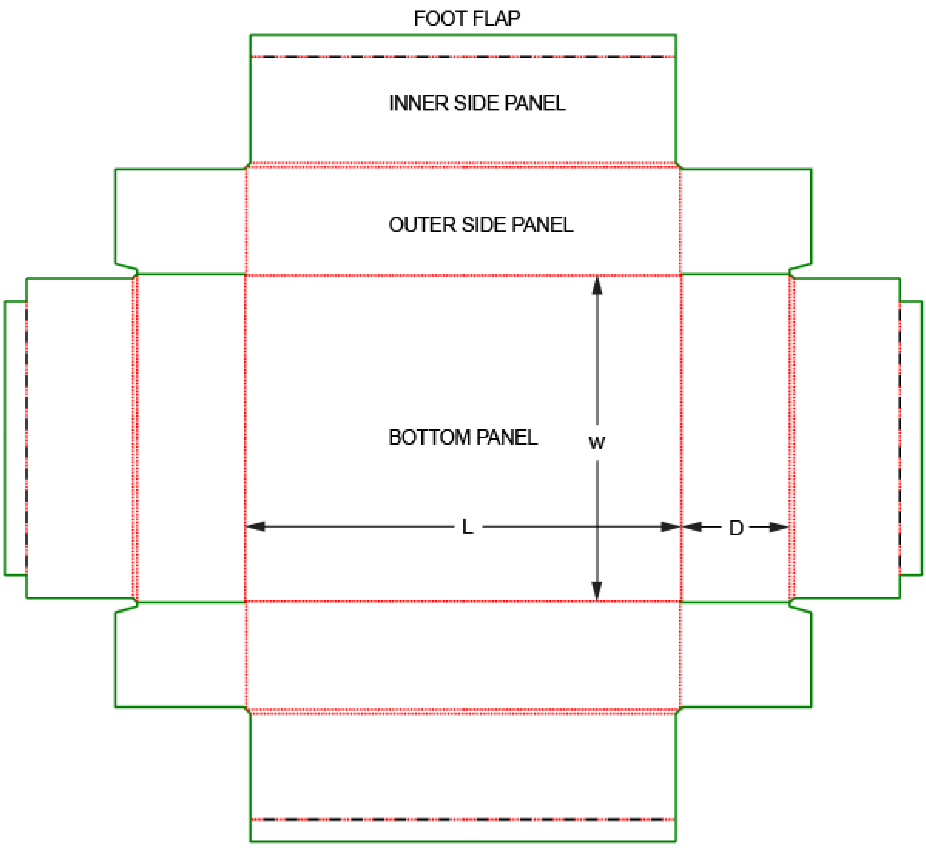


Figure 2.44 : General example to tray style box (Paperboard Packaging Council, 2000) redrawn with ArtiosCAD.

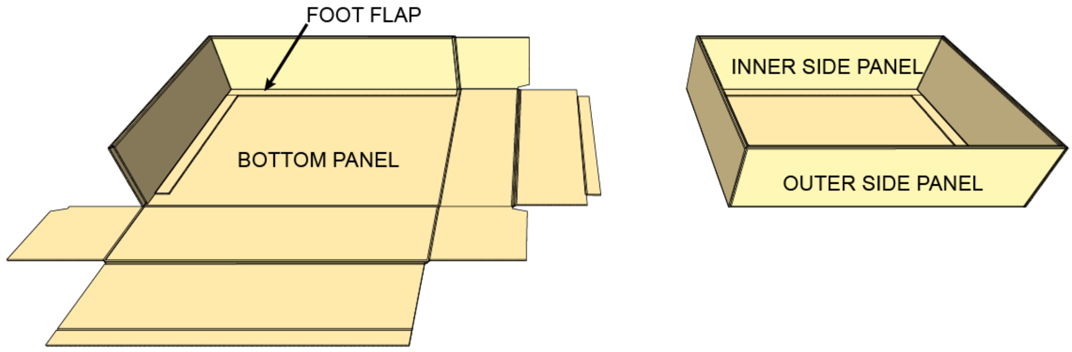


Figure 2.45 : 3D view of a tray style box (Paperboard Packaging Council, 2000) redrawn with ArtiosCAD

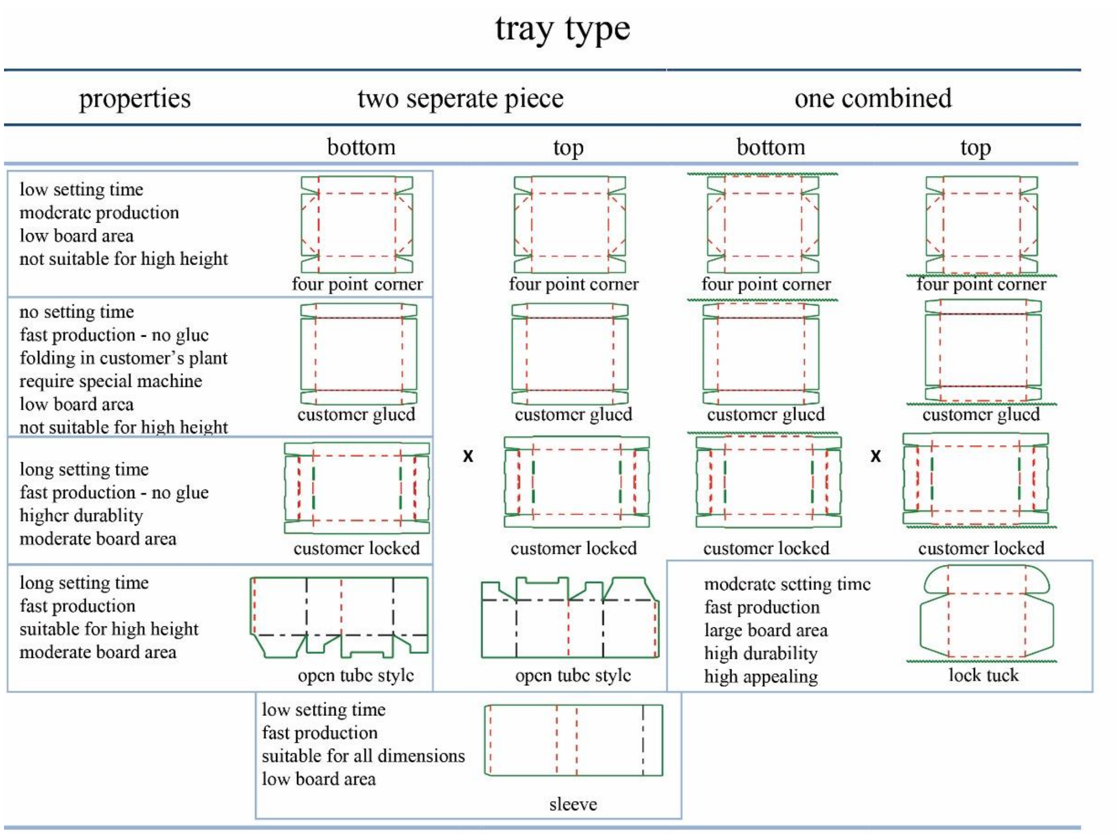


Figure 2.46 : Tray type boxes with example for each style for crossbreeding

Four point corner (both for two separate and combined; both top and bottom) (auto-erect)

Four point corner trays are glued in converter's plant to be shipped flat to customer's. Two opposing side panels' corners have diagonal creases which are less than 45° (typically 43-1/2°) to be glued to the glue flaps of their cross panels (Figures 2.47 2.48). While erecting the tray, the flaps drag each other across the botttom panel and natural friction prevent the tray from collapsing again (Paperboard Packaging Council, 2000, p. 2.101). All the details such as setback intervals, glue flap angles and overall dimensions depend on the converter's machine.

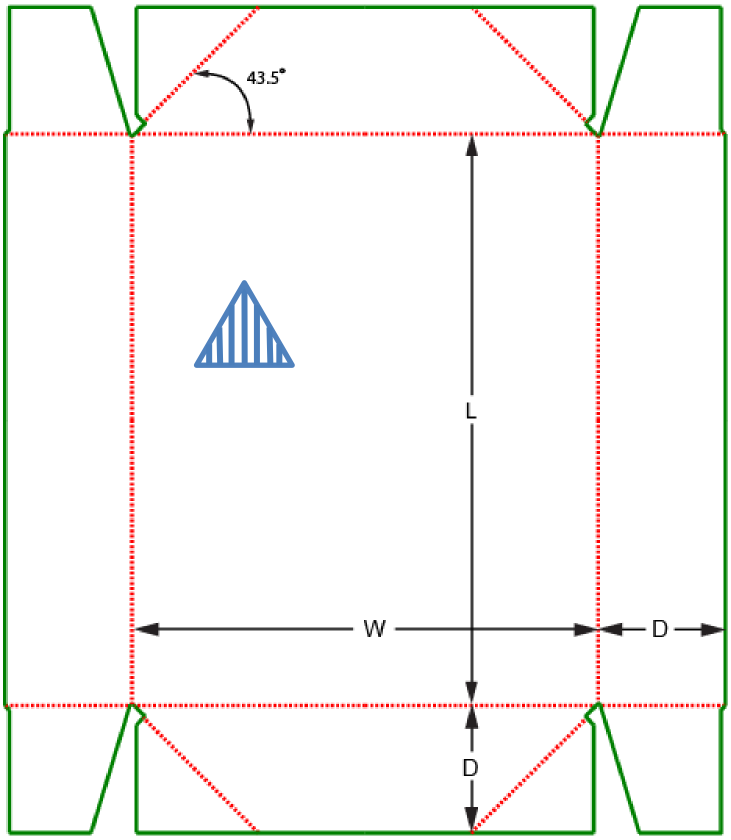


Figure 2.47 : Four point corner tray redrawn with ArtiosCAD (Paperboard Packaging Council, 2000)

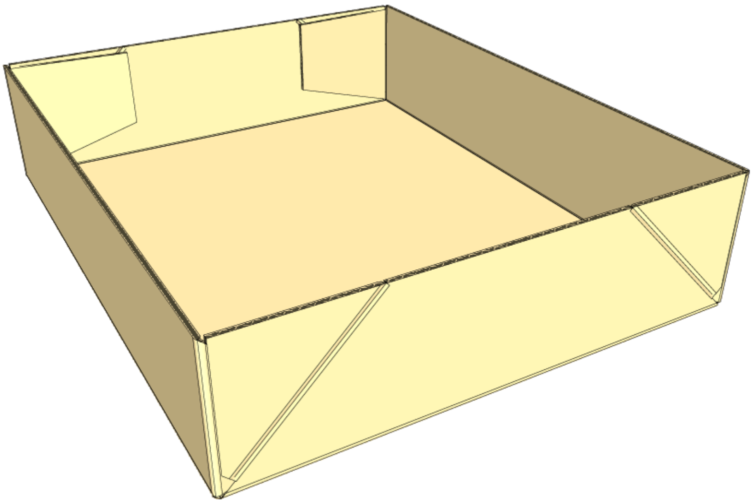


Figure 2.48 : 3D view of four corner point tray redrawn with ArtiosCAD (Paperboard Packaging Council, 2000)

Customer glued (both for two separate parts and combined, both for top and bottom) (customer glued)

Customer glued trays look like four corner trays however they don’t have a crease to be folded and glued in converter’s plant (Figures 2.49 2.50). Customer’s machine forms and glues the trays and at the same time puts the products inside the tray along the same process. The details of the trays alter according to this machine, such as the angles and dimensions of the glue flaps. Also the metric of the cut and crease lines play an important role here. Except the significance of them on stacking, transporting and shelf life of the packages, machine’s intensity can require special cut and crease blades for the tray or design.

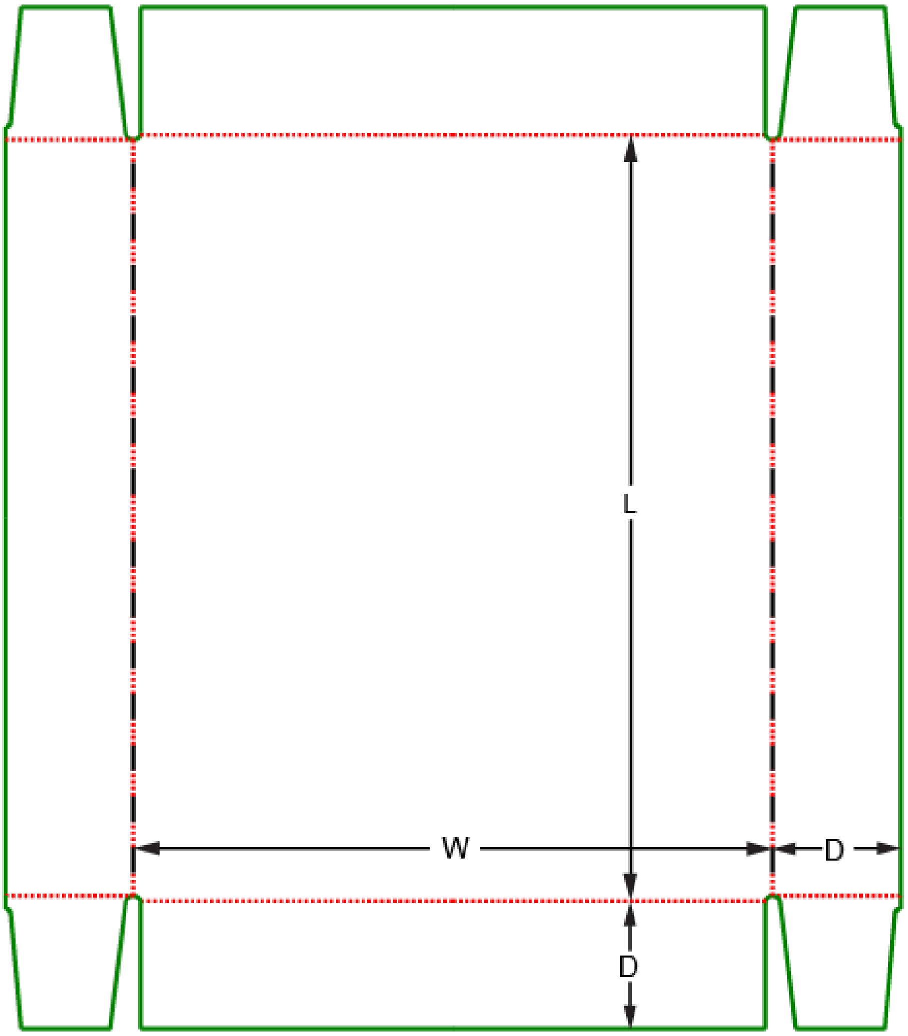


Figure 2.49 : Example for a customer glued tray drawn with ArtiosCAD.

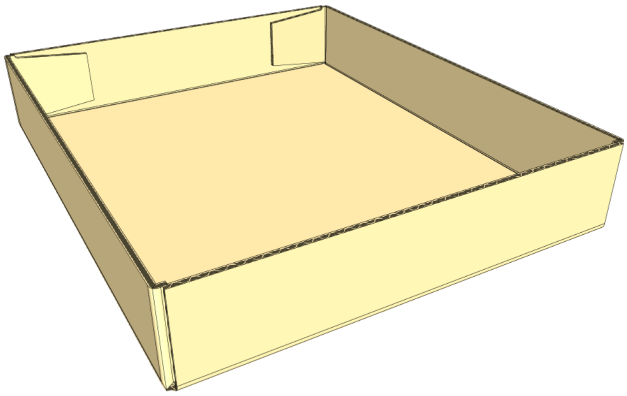


Figure 2.50 : 3d view of the customer glued tray of above.

Customer locked (both for two separate and combined, both for top and bottom) (customer locked)

Customer locked tray as the name suggests, are locked after the converter's plant and shipping. Even it doesn't look as strong or durable as glued trays, especially double wall trays -if the interlocking details are absolute- provides a tough structure (Figures 2.51 2.52).

Locks can have a various shapes and dimensions according to their flute, dimensions or using area. Trays also enable some inserts or extra panels because they will not get through a machine process for erecting.

As there are lots of styles of these trays, Ideas and Innovation (2000), mentions them as having special names such as; stripper lock, retail carton, cake lock tray, pinch lock tray, walker lock tray, arthur lock tray, foot lock double wall, kwikset (this tray is both converter preglued and customer locked), frame-vue tray etc. (pp. 2.104-2.501).

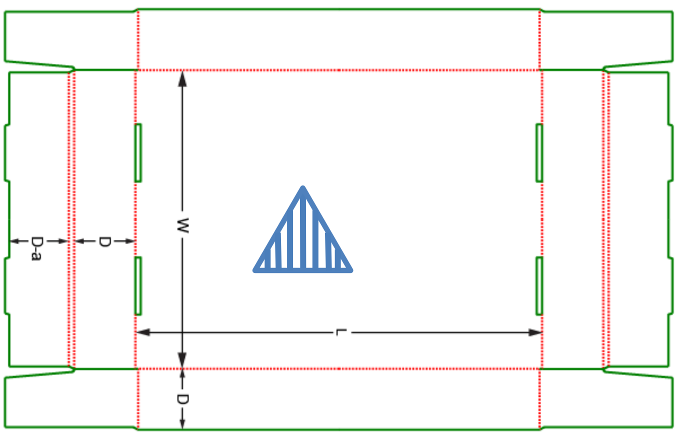


Figure 2.51 : Walker lock tray, an example to a customer lock tray redrawn with ArtiosCAD (Paperboard Packaging Council, 2000).

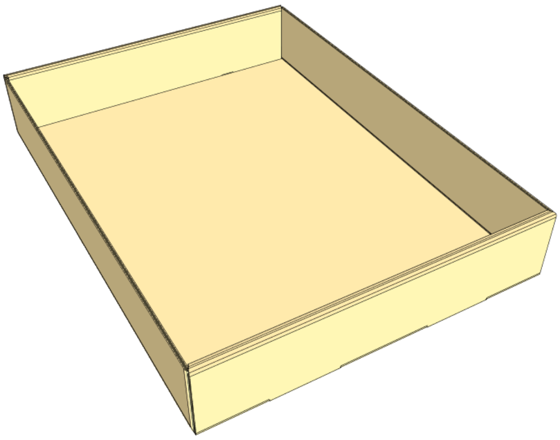


Figure 2.52 : 3D view of walker lock tray which is closed from two sides.

Open tube style (for two separate; both for top and bottom) (customer lock, glued or auto-erect)

Eventhough they are not real tray types, it is possible to use them as they are. Without lids or bottom parts of the boxes and combining them with trays, tube styles or sleeves can create tray type designs (Figure 2.53). They have been told in tube style boxes in detail.

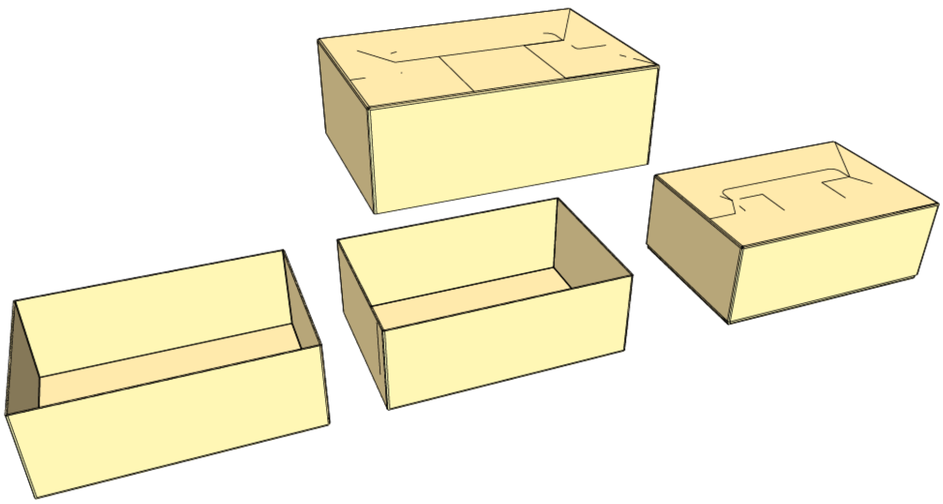


Figure 2.53 : 3d view of two open imterlock tube style box used as two separate trays

Sleeve (for two separate; for top)(customer lock, glued or auto-erect)

Beside being a standalone design style, they can also be used as lids in separate tray styles (Figure 2.54). Moreover it can take different prisms such as triangle and octagon etc. They will be detailed further in sleeve types.

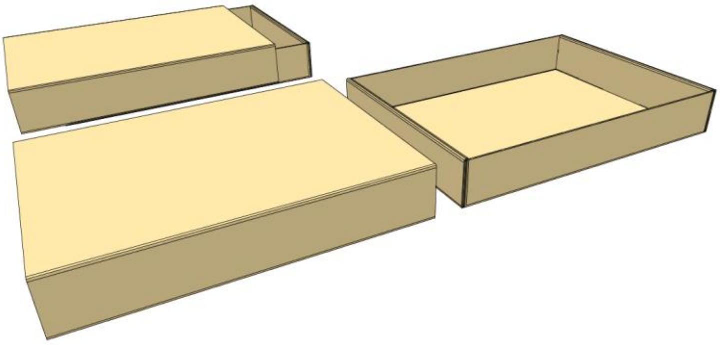


Figure 2.54 : Customer lock (walker lock) tray with a sleeve type lid (Match box)

Lock tuck (for combined; for top) (customer lock, glued)

Lock tucks on a tray can take further roles or looks such as special flaps, charlottes (Paperboard Packaging Council, 2000). They cover side panels both make an extra strength and also prevents the lid from sinking inside the box if the side of the trays don't have supporting flaps. Anchor locks, slots and labels can be used on lock tucks to prevent opening without intention. Moreover wing flaps which resides both sides of tuck flap take the role of locking the tray (Figures 2.55 2.56).

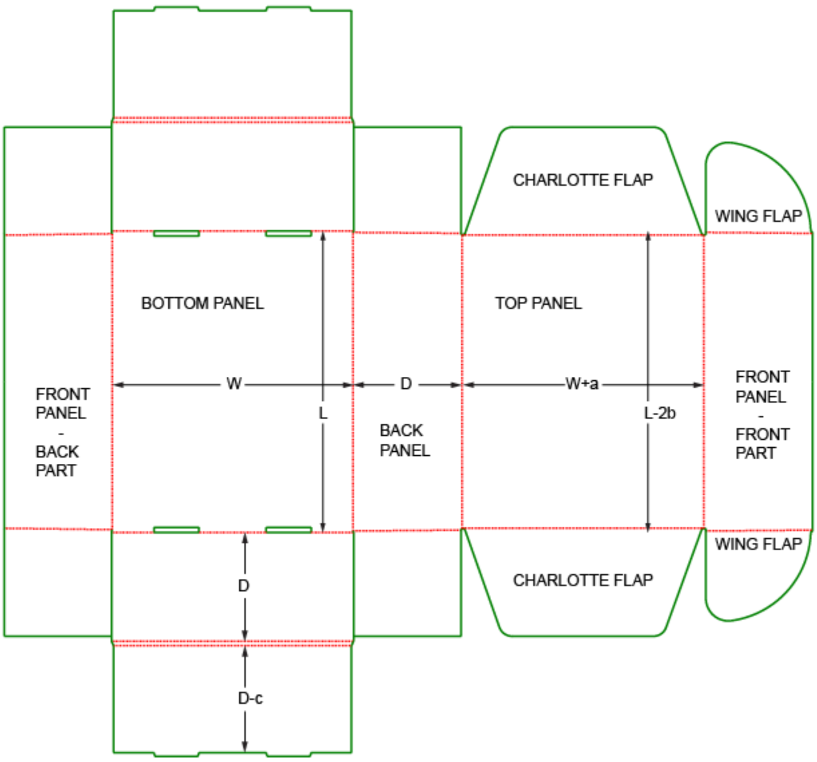


Figure 2.55 : Combined tray with walker lock bottom and lock tuck with charlotte and wing flaps.

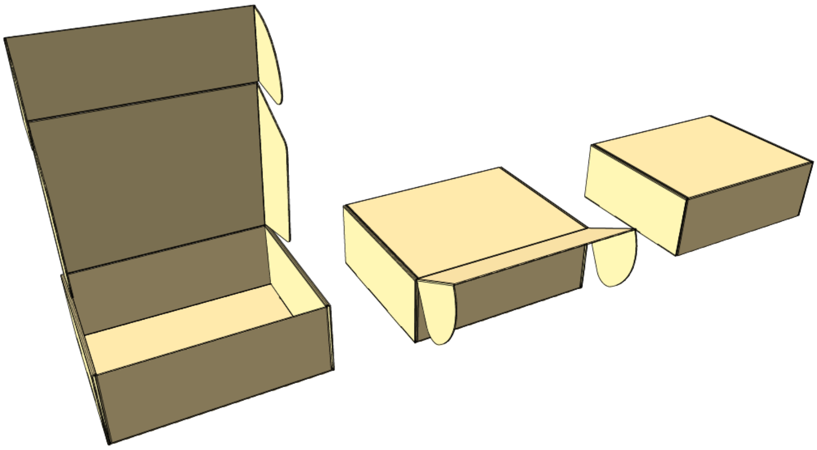


Figure 2.56 : 3D view of a walkerlock tray with lock tuck, closing steps.

Customer glued (for two separate; for both and bottom for combined; for bottom) (customer glued)

Customer glued tray types have process in customer's plant therefore need to be designed according to the manufacture line and machines of customer. For combined styles, lids and flaps (Figures 2.57 2.58) can be added to the design however all these should be checked in the machines to see the speed of the folding and filling and clear the errors.

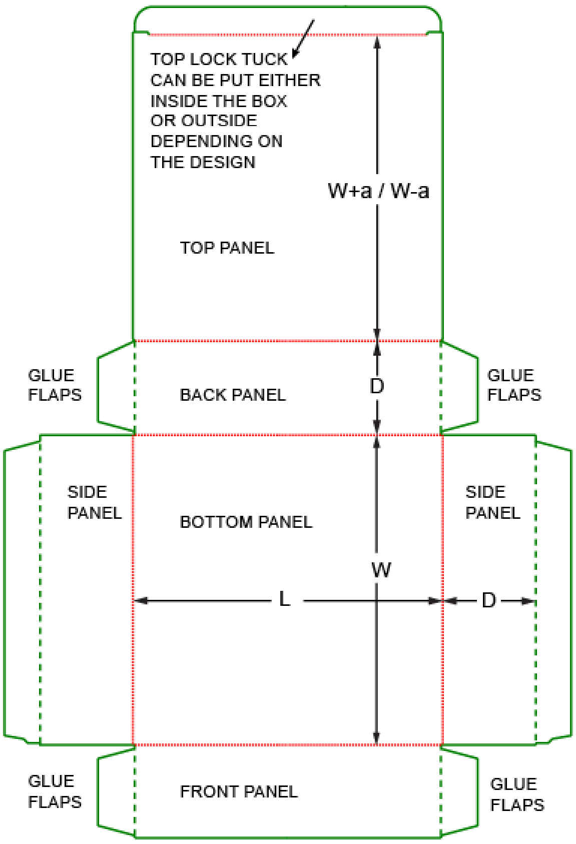


Figure 2.57 : Customer glued tray with lock tuck which is designed for machines

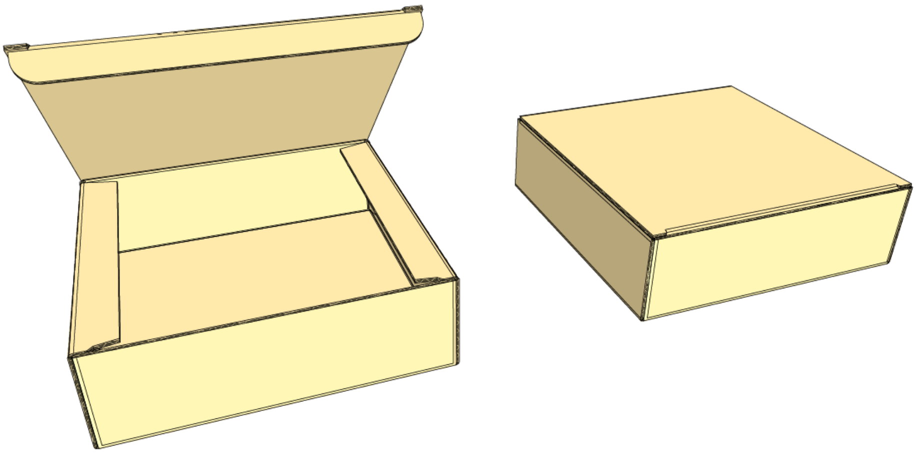


Figure 2.58 : 3D view of customer glued tray with lock tuck, closing lock tuck inside box.

2.5.1.3 Sleeve types

Sleeve types are similar to tube style boxes however, they can be either ready glued, customer glued or customer locked (Table 2.12) (Figure 2.59). Furthermore, sleeves wrap the products with partly or completely open sides and the front and the back panels are either open or close. As the name suggests they are just sleeves not boxes.

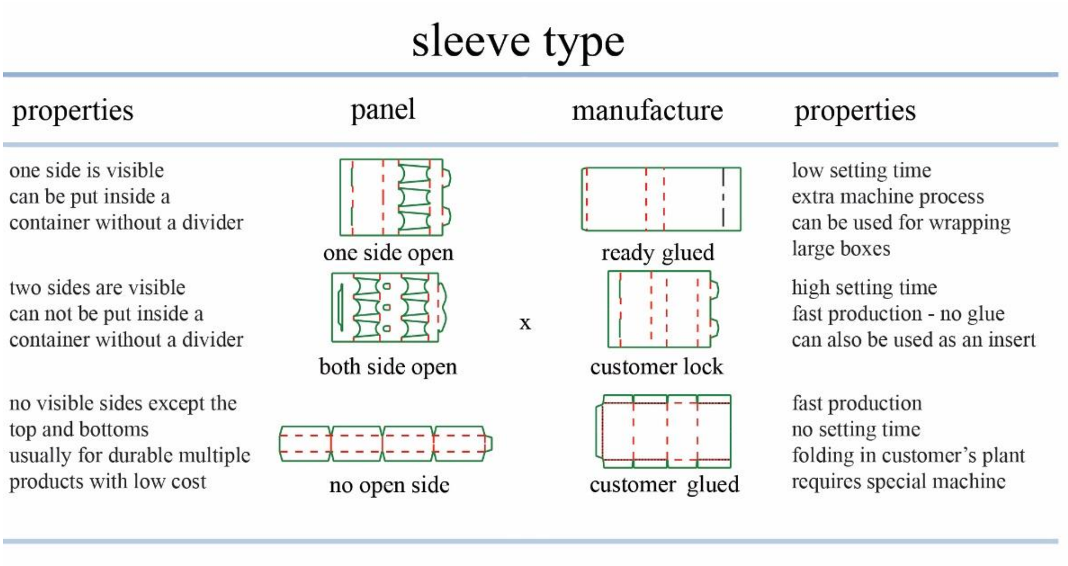


Figure 2.59 : Sleeve types with example for each style for crossbreeding with their properties

Ready glued

Ready glued is the one that has the most similarity with the tube style with side panels are open (Figure 2.60). These sleeves are not used as stand alone boxes instead they are used as a closer or an extra wrapping like an accessory. For example, an unprinted RSC (Regular Slotted Container) with a printed sleeve makes both economical and sophisticated package style. As some products are too big for a nicely printed ready glued tube style package, they need a different kind of design.

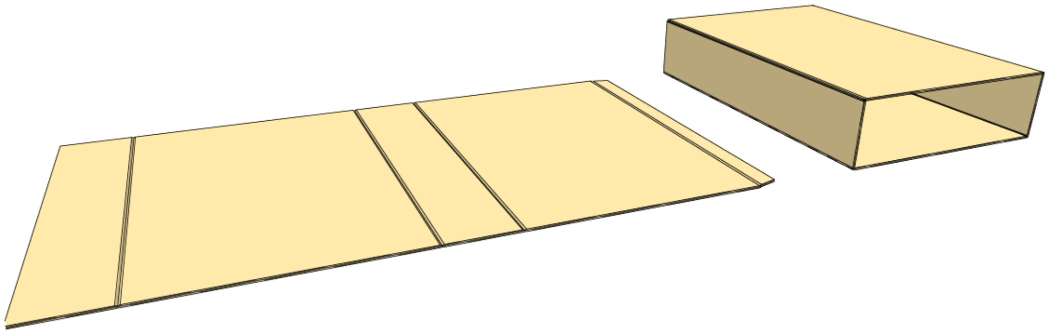


Figure 2.60 : 3D view of open (left) and closed (right) ready glued sleeve type.

Customer lock

Customer lock sleeves like the other customer lock tube styles and tray styles need some lock tabs (Figure 2.63). They can be fastened both by hand and machine, according to the customer needs and resources.

They take the shape of the products and have to be precisely measured in order to be maintained during the palletizing and shipping. They are mostly used for multiple packaging products such as cans and bottles.

Customer glued

Customer glued sleeves while wrapping the four sides of the products, the sides are partly open enough to hold them still (Figures 2.61 2.62). They are put without any glue or fold on the automatic lines of the customer's plants after manufactured in converter's plant. That's why all the angles, dimensions and diecut specifications are made according to the customer's machine execution. As seen in the figure from below, sometimes to fortify the gluing areas to prevent opening, perforation lines are put.

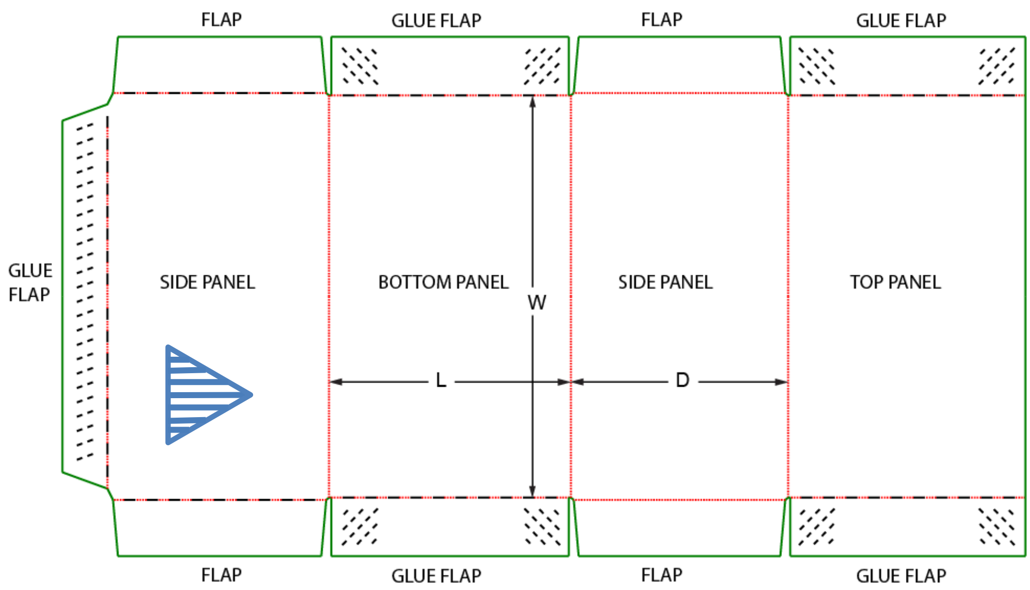


Figure 2.61 : Customer glued sleeve with all sides are closed a.k.a Wrap Around Box

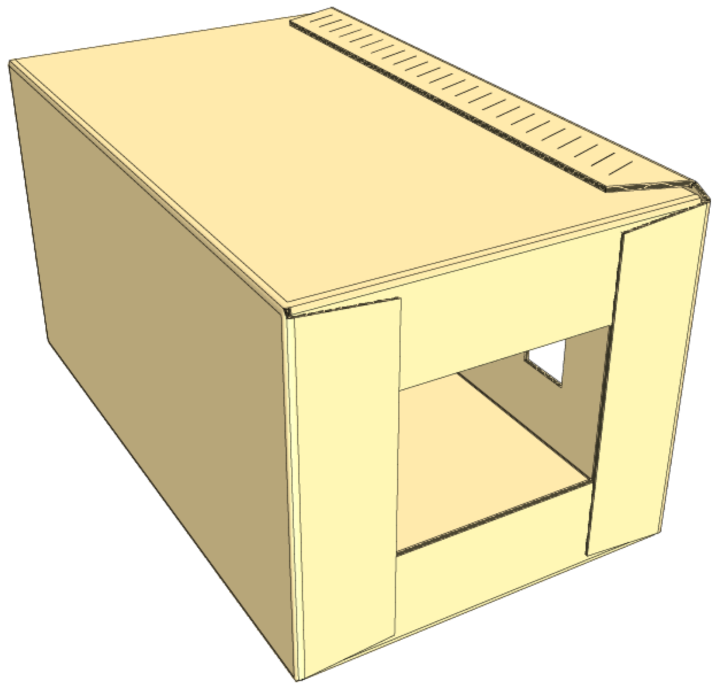


Figure 2.62 : 3D view of a customer glued sleeve a.k.a. Wrap Around Box

One side open

As the name suggests, the sleeves can be distinguished and specified by their sides. One side open sleeves have the advantage of both showing the products (Figures 2.63 2.64) and also protects them from each other without a separation in a container, if there is a possibility of break or scratch. To ensure the product not to pop out too much from the package, the aperture need to be measured accordingly. Likewise, closing too much blocks the customer to see the product thus having a low visibility.

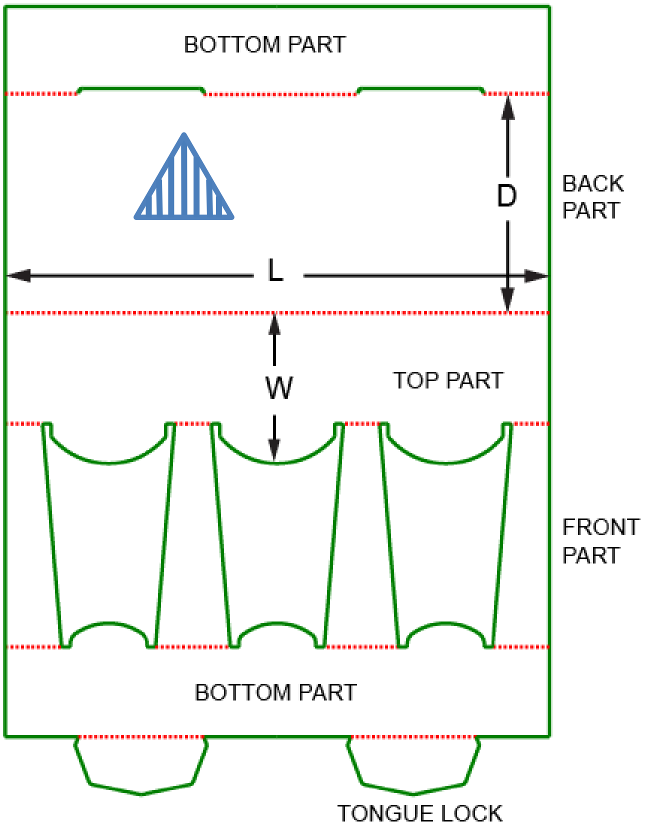


Figure 2.63 : Customer lock sleeve with one side is open, special for three glasses.

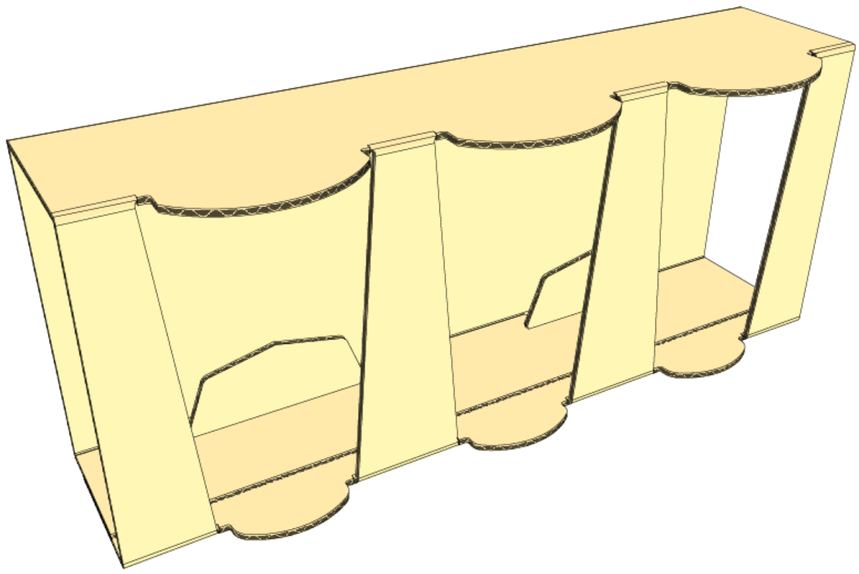


Figure 2.64 : 3D view of a customer lock sleeve with one side is open.

Both sides open

The picture below shows a sleeve which can hold six products, therefore there is self-inserts for between the products. Without this separation it is also possible to show the two sides of the products (Figures 2.65 2.66). Similar to one side open sleeves, the measurements play an important role, furthermore putting multiple sleeves inside a container require an extra separation for breakable products. It also should not be forgotten that these sleeves can be used for the products which has high capability of self - standing and sleeves are not suitable for flexible products.

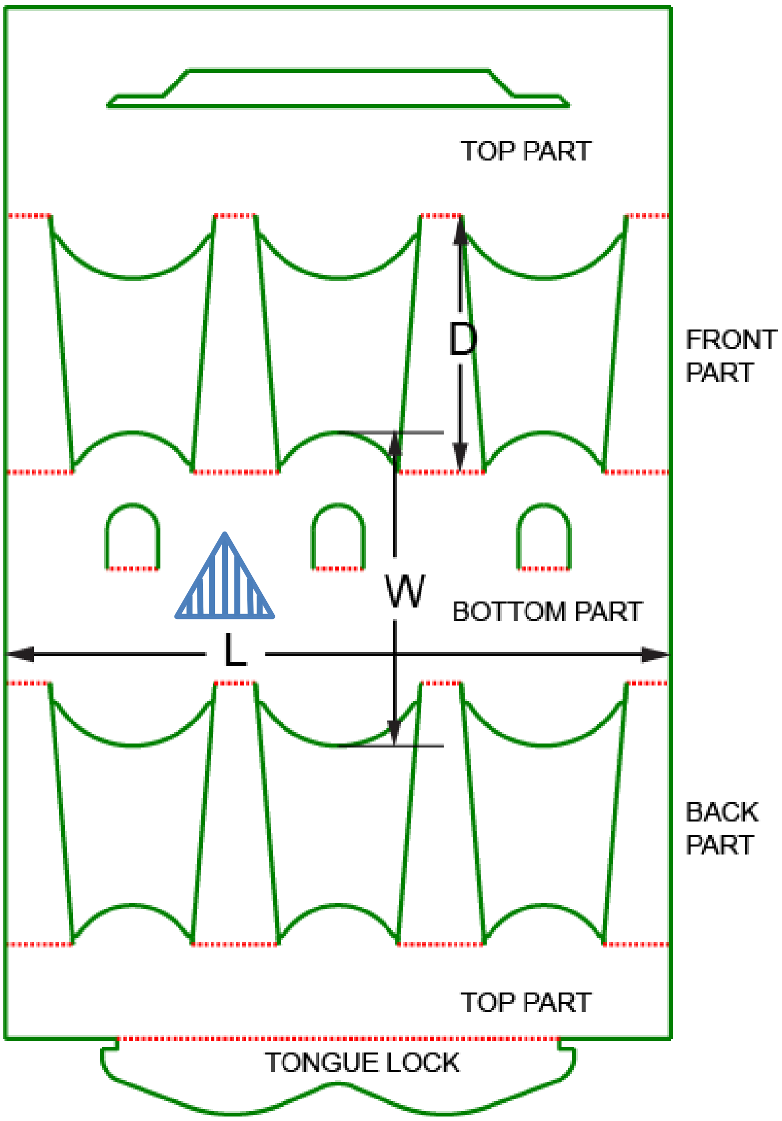


Figure 2.65 : Customer lock sleeve with two sides are open, special for six glasses

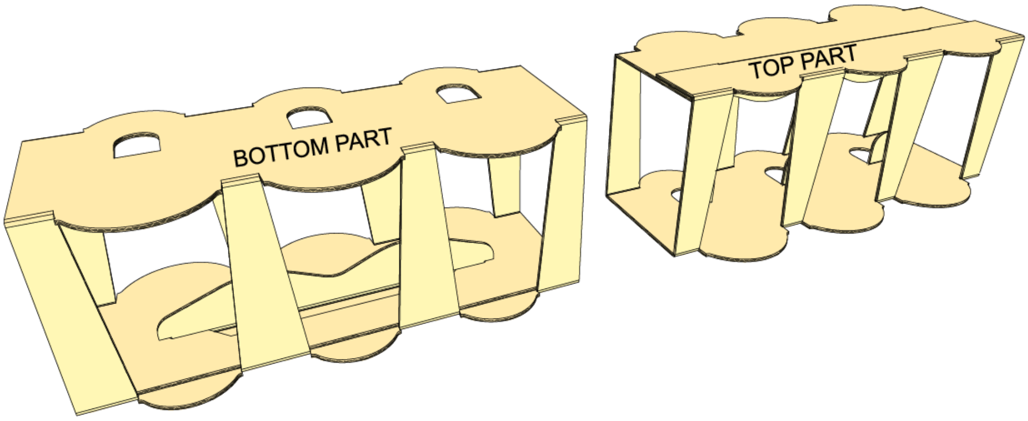


Figure 2.66 : 3D view of a customer lock sleeve with two sides are open.

No open sides

These sleeve types mostly intend on protecting products with a high speed and low cost. That is why their top and bottom flap surfaces have minimum area, just enough to hold the product (Figures 2.67 2.68). Some of them keep a small window on one or more panels for barcodes or the information about the product for the customer.

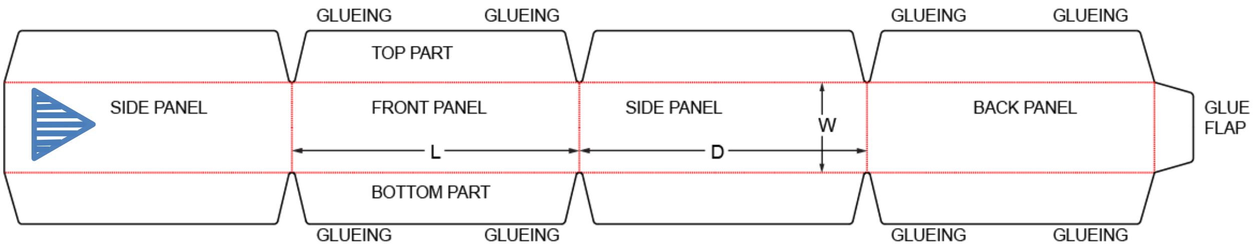


Figure 2.67 : Customer glue sleeve with no side is open, designed for machine.

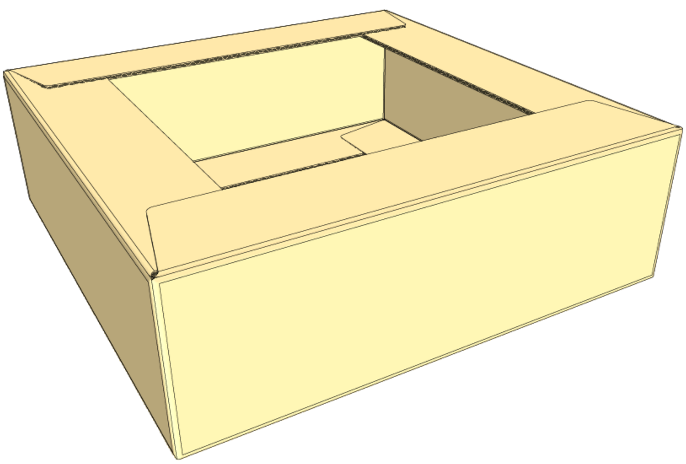


Figure 2.68 : 3D view of a customer glue sleeve with no side is open.

2.5.1.4 Insert types

Inserts are difficult to categorize but easy to crossbreed with multiple ones as they have no boundaries (Table 2.13) (Figure 2.69). They are numerous and special for the product, furthermore for every new product a new insert can be designed. Some mostly used ones will be given here to understand overall. Each category can be crossbred with each other as long as the process and the machine is suitable.

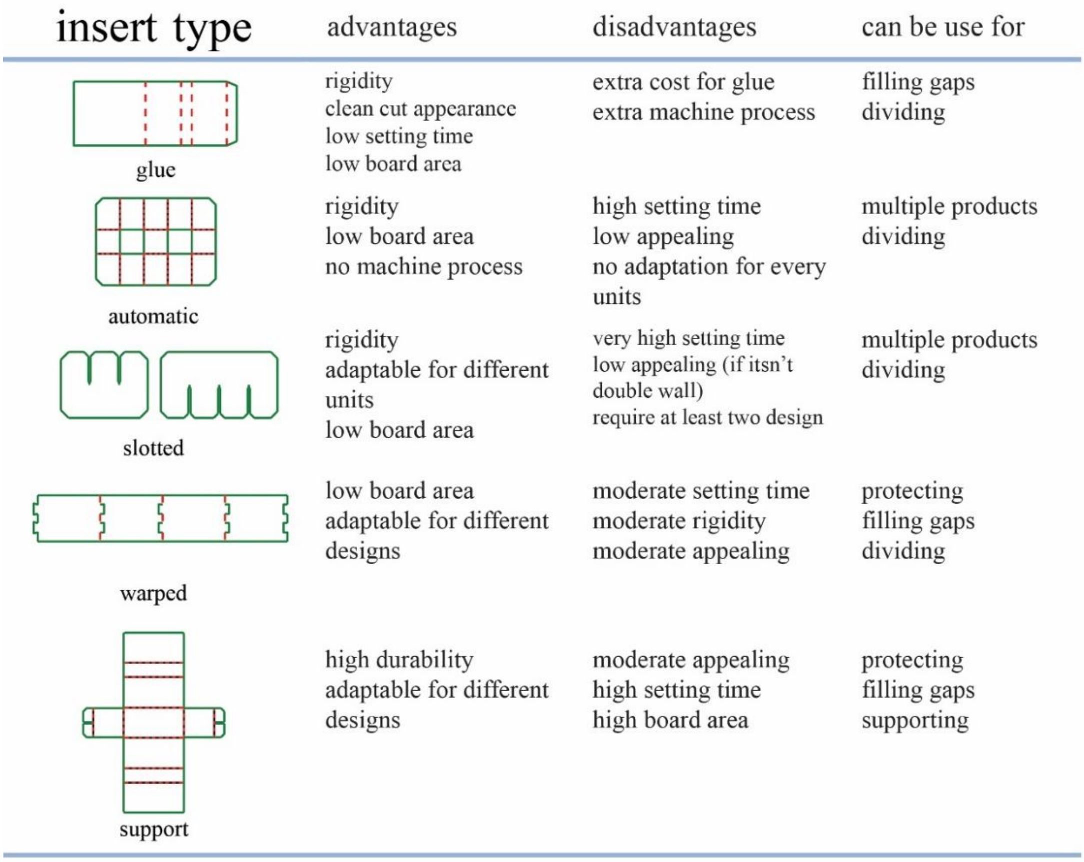
Although the designer can think of many solutions for an insert, the filling process and the number of the parts have to be taken into consideration. Every extra part makes the process more costly and slower while every hardship for filling creates false labour for the workers. While designing the insert the simplest and the smallest one should be chosen as long as the aim is managed.

Just like the importance of the flute directions in packages, inserts also hold a very strong potential for different directions when needed. General rule is always keeping the flute direction parallel to the vertical line. However, for example slotted inserts for droptest use horizontal direction for protecting from every side of the package.

Glued inserts

Glued inserts as the name suggests, provide and secure their shape with the help of a glued place (Figures 2.70 2.71). Although it has to enter a folding machine, which increse its production time and cost at the same time, the insert becomes rigid enough without too much cardboard, giving a clear cut appearance. Another advantage of it that it doesn’t require a setting up by a person or machine, saving a high time for the manufacturer which sometimes become more advantageous than others.

Glued inserts can be used in order to fill a gap while setting products apart each other. For the given example, using horizontal flute as seen, will be wise in order to set the crease lines perpendicular to direction, also when it is erected, vertical lines will support the package.



insert type	advantages	disadvantages	can be use for
glue	rigidity clean cut appearance low setting time low board area	extra cost for glue extra machine process	filling gaps dividing
automatic	rigidity low board area no machine process	high setting time low appealing no adaptation for every units	multiple products dividing
slotted	rigidity adaptable for different units low board area	very high setting time low appealing (if itsn't double wall) require at least two design	multiple products dividing
warped	low board area adaptable for different designs	moderate setting time moderate rigidity moderate appealing	protecting filling gaps dividing
support	high durability adaptable for different designs	moderate appealing high setting time high board area	protecting filling gaps supporting

Figure 2.69 : Insert types with their advantages and disadvantages.

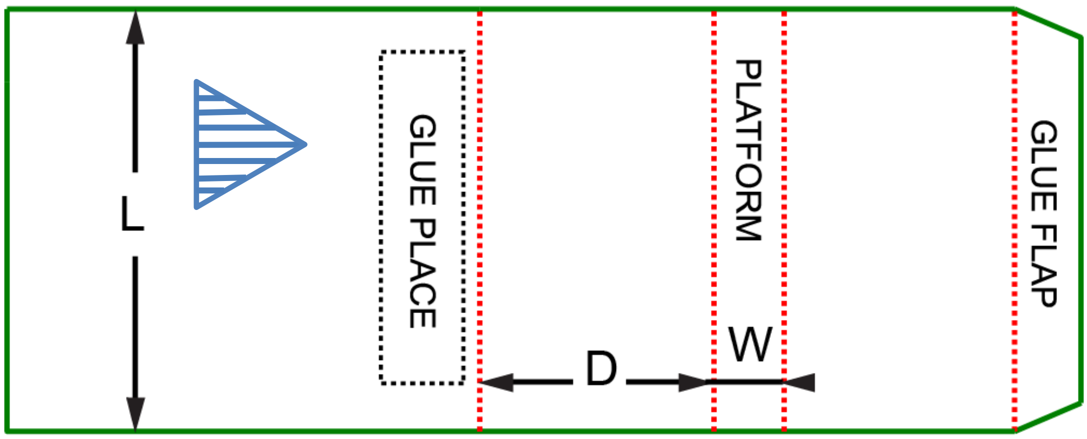


Figure 2.70 : An example to glued insert which creates a void with the volume of D x W.

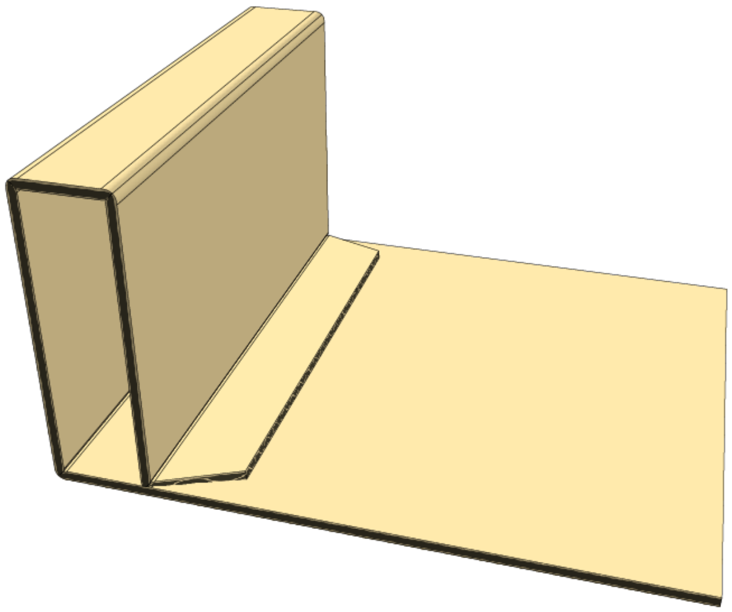


Figure 2.71 : 3D view of the glued insert with the platform

Automatic inserts

Automatic inserts which is probably the most clever ones, ensures numerous same or similar products without touching each other, mostly used for fragile objects such as glasses. With 90° and -90° corners, it creates half or full rooms, providing reliable corners for the strength of the box (Figures 2.72. 2.73). With a little adaptation of the design; 4, 6, 8, 9, 12 rooms can be created, providing the empty middle parts as squares, it is possible to set steady designs. As seen in the figure using the flute direction vertical, it supplies the box and protects the products from vertical impacts.

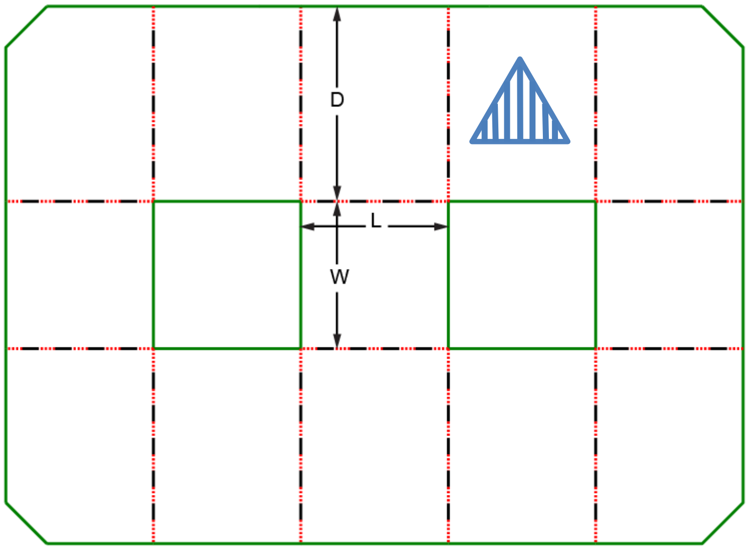


Figure 2.72 : Automatic insert speacial for six products which have the dimensions of L x W x D.

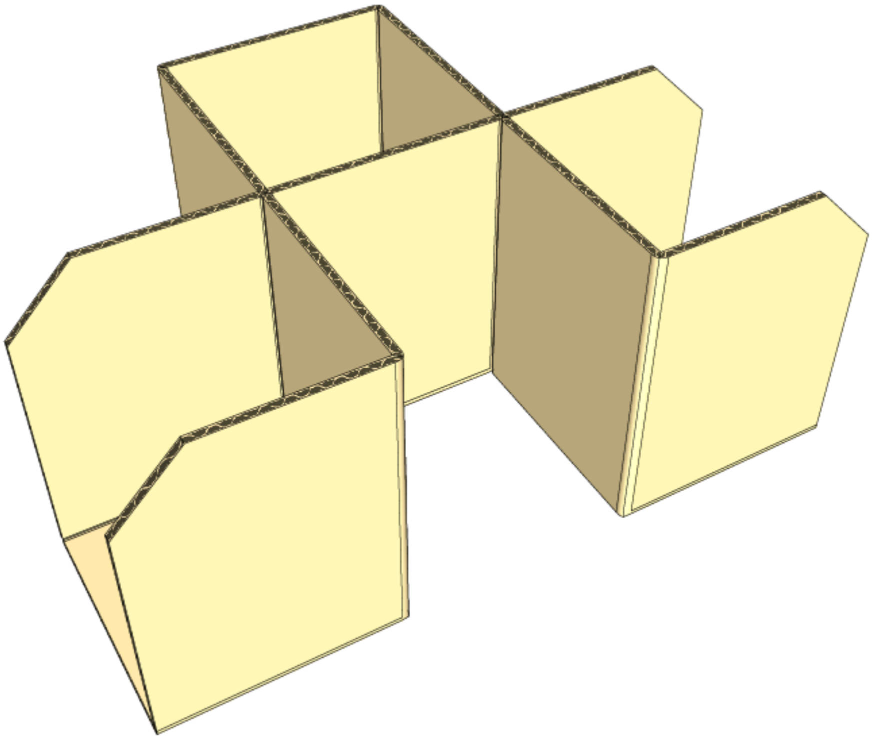


Figure 2.73 : 3D view of the automatic insert for six product, creating six rooms with L x W x D dimensions.

Slotted inserts

Slotted inserts are used for similar purpose as automatic ones, dividing multiple same or similar fragile objects. One of their advantage is that they can create more various numbers or discrete designs (Figures 2.74 2.75). For example, using double walls by creating creases, both provides a clean cut apperance and fortifies the package. Moreover by changing the distance between the slots, it is possible to be used for completely different objects, if the depth is provided somehow. One more using area can be dropbox packages, to create them, all surfaces of the box should have void. With setting the distances and numbers, it is possible to create these voids in four surfaces with slotted inserts. One more good advantage of these inserts are using low area of materials but creating intense corners on the vertical. If the package is not for dropbox it is wise to use vertical flute direction, otherwise in order to provide the voids, the flutes should be horizontal. One disadvantage of them, that the slotted inserts require a high setting time to make ready to use in package. If the numbers of the slots for every side is different, it also demands a caution to prevent an error in setting.

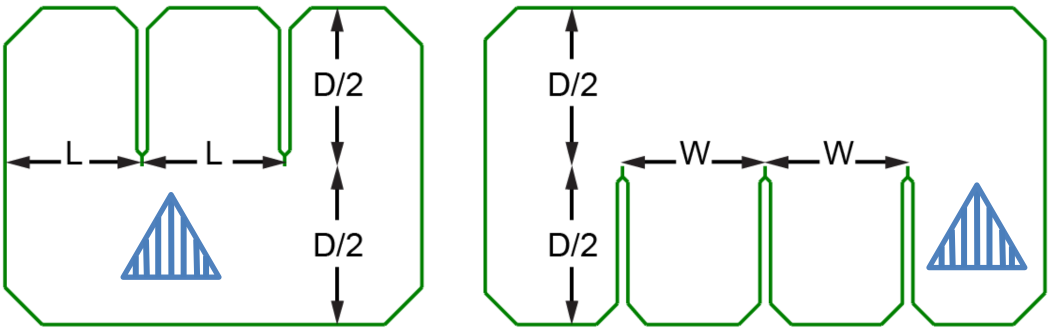


Figure 2.74 : Slotted insert with two slots and three slots. Using right amount of them generate 12 equal rooms for products

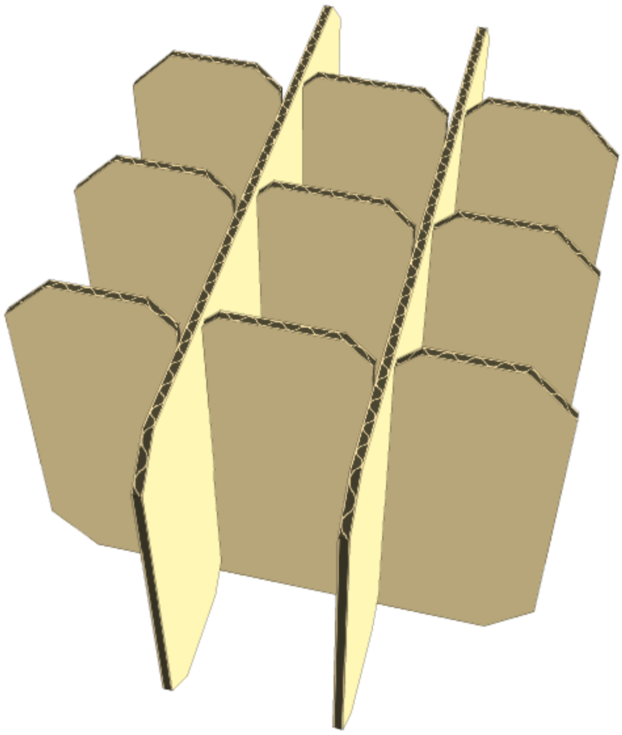


Figure 2.75 : 3D view of slotted inserts with 12 rooms for products.

Wrapping inserts

Wrapping insert can differ in shape and size in order to adapt the product and the condition of the package. Every insert can be modified to put more tasks, the wrapping can also be altered added in other inserts. It can wrap some or whole of the product, or corroborate some part of the product. Especially the products which are not uniform tend to wobble inside the package. In order to secure moving parts, they should be wrapped or held with specialized holes and slots. For closing, both glueing and locking is suitable, and choosed by the designer according to the customer needs. Using place and the product itself can alter the flute direction, for example for the figure below, to compensate the vertical affects, choosing vertical flute direction seem sensible (Figure 2.76 2.77). However here, there are offset parts on each side to create voids, thus using horizontal flute direction will be wiser, while ensuring more determined creases for each corner. As seen in the example, wrapping insert is both protecting the product and supporting the gaps by filling them. Their setting times and board areas can differ according to their design, but usually they are low on setting time and area.

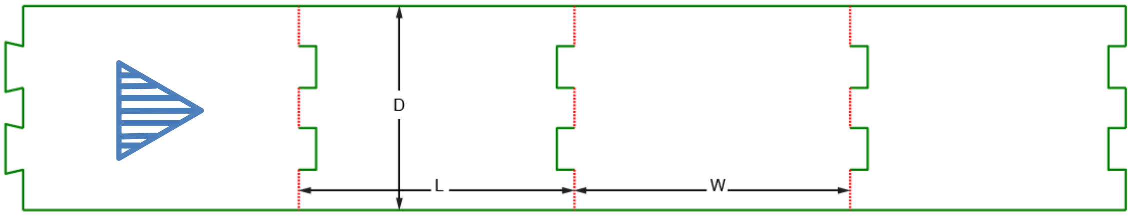


Figure 2.76 : A wraping insert which protects the product from outside. (customer lock)

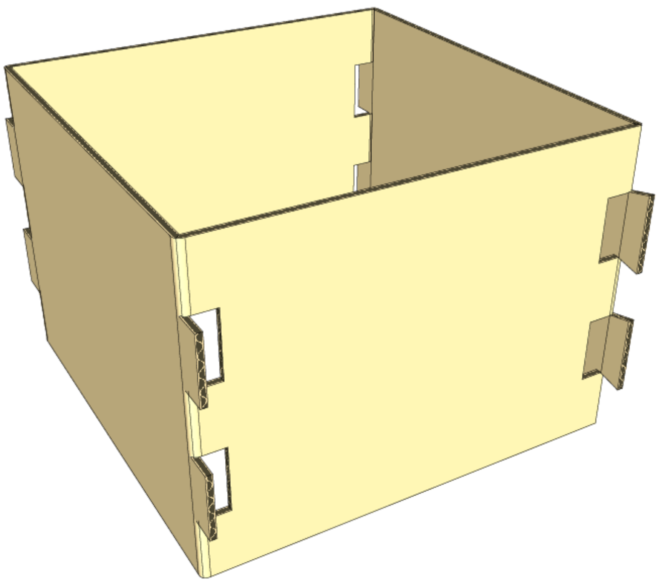


Figure 2.77 : 3D view of wraped insert, this one also creates a void from all sides. It both protects and manages the extra surface.

Support inserts

Support inserts, as the name suggests provide the gaps. Some of them, like in the example, are really durable having more surface than a box, compensate from all sides against the impacts (Figure 2.78 2.79). Creative adaptations can be made on these, such as creating extra slots for locking, putting holes to embed a product in etc. It depends on the creativity of the designer, and the product itself with its stacking and transporting situations. Supporting inserts require more setting time and board area than wrapping ones. So they are more suitable for more valuable products or more hardship transports. As seen in the figure in order to ease the locking, the flute direction is vertical.

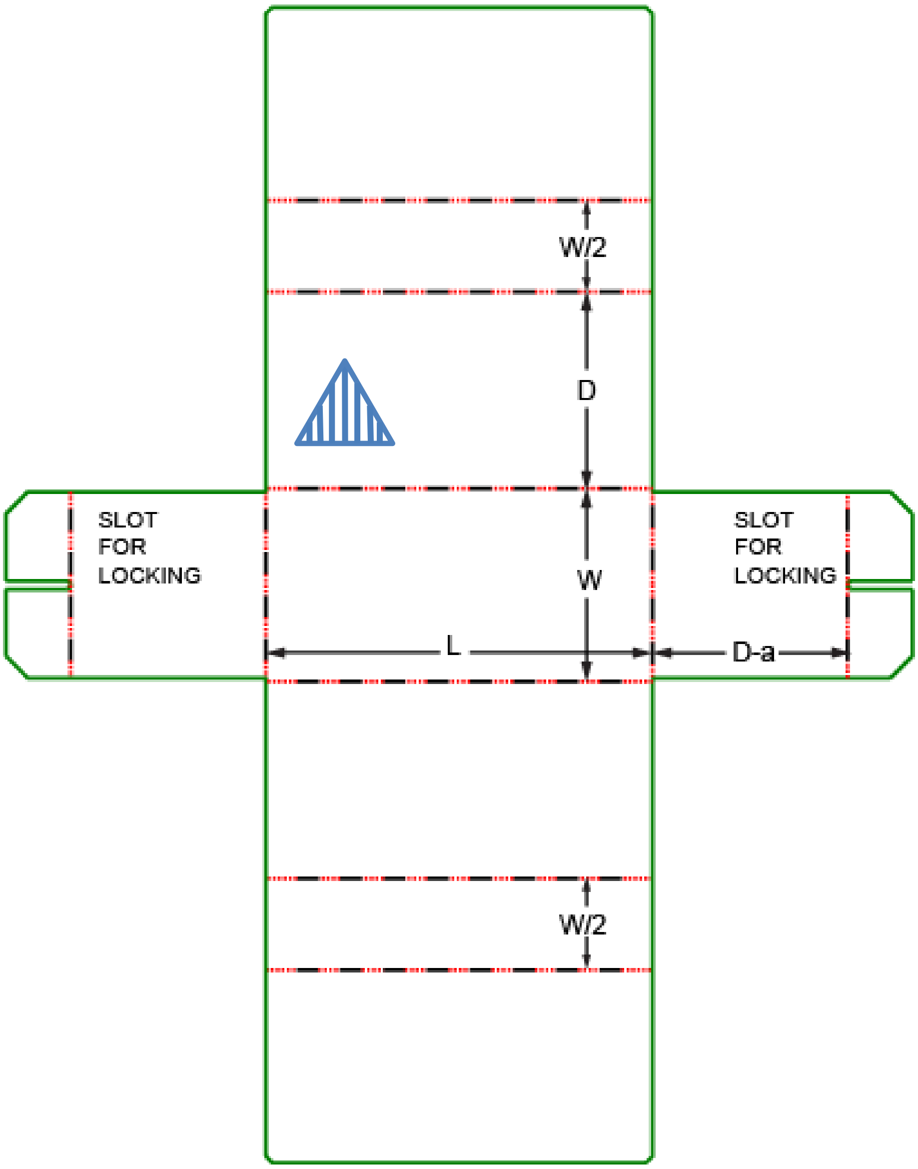


Figure 2.78 : An example to supporting insert, especially a durable one to fill the gaps inside the packages which can be adapt according to dimensions.

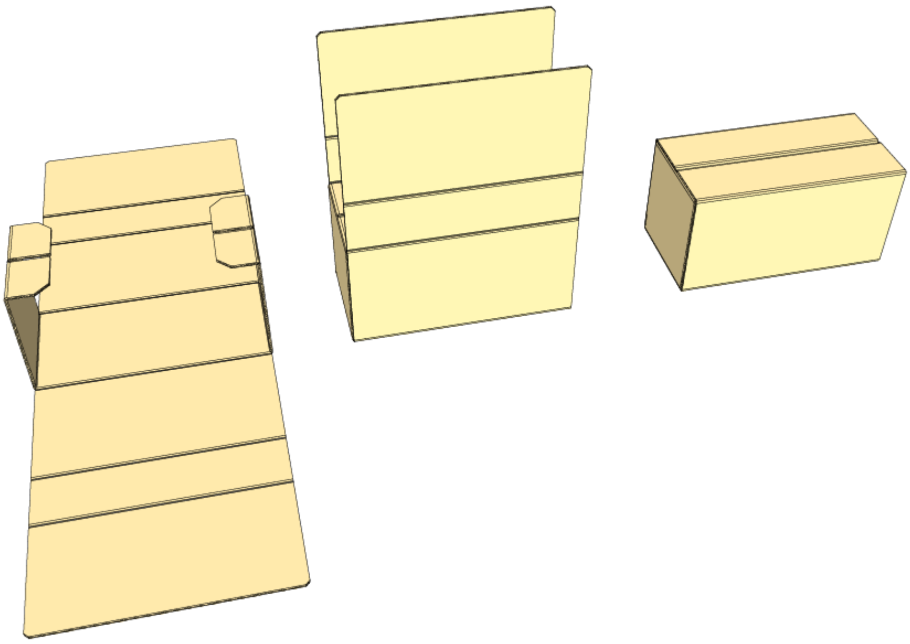


Figure 2.79 : 3D view of the supporting insert for closing steps.

2.5.2 Material and its effects on the design

Studying the design is mentioned first but the material or flute decision should be resolved with the design of the package. It can be said that, they are determined simultaneously as some designs are more suitable for specific flutes. For example; ready glued tube style boxes are mostly used with E and B flute corrugated board however, there isn't a rule that other flutes can not be used, as newly designed flutes such as D flute also can be used for ready glued boxes.

As the technology keeps on new structure on flutes and materials, knowledge from older books such as Corrugated Shipping Containers becomes outdated. "Along with the same lines, a thinner column bends more easily than a thicker one. Therefore, all things being equal, any step towards maximizing caliper is a step towards optimizing the box." (Maltenfort, 1988, p. 149). On the other hand, D flute falsifies this theory, with less caliper, it passes the B flute on ECT and FCT results (Camiş Ambalaj San A.Ş., 2015). Therefore, technological progress should be taken into account for optimization as well as the designs.

Paper combination can be selected afterwards according to the product which will be packaged. As mentioned before especially the cartonboard of the corrugated board is chosen specifically by the customer to give the right impact on the customers, for their elegance or economy. To reach a tougher or more fiscal material, changing the paper and grammage is the right thing to do, converters make tests to find the optimal combination for a specific product (Figure 2.80). Horticultural goods' packages need a special paper like NSSC to endure the moisture of the products. If the product is solid enough to carry itself, using recycled paper will be enough. Maltenfort (1988), indicates that the optimum board combination is the one that inner liner is the stiffest, the weakest liner is in the center, and the second stiffer lines is on the outside. He continues that, holding the flute structure in place is enough for the center layer's strength (p. 149). On the other hand, Jing (2011) discourses that with using high strength corrugated for middle layer, electrical household companies reduced their five layers of cardboard to three layers (p. 994).

To understand the possibilities and advantages of the corrugated cardboard, we have to look into the papers or liners (Figure 2.80). Their specifications with their grammage and toughness, generate the cardboard, which make a package robust enough for transport and stacking.

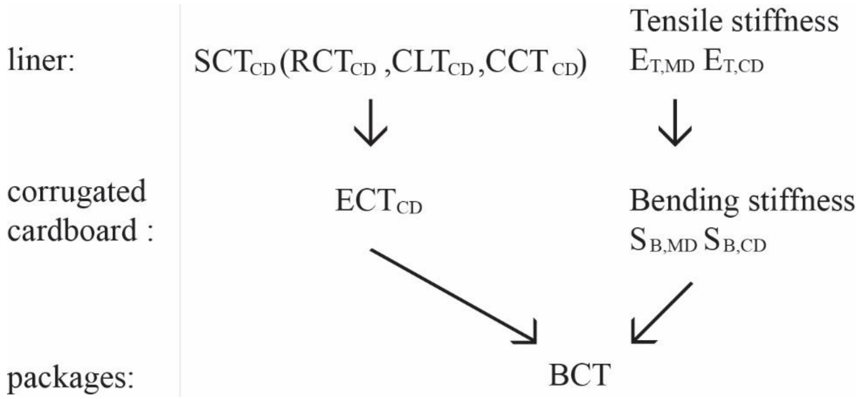


Figure 2.80 : The correlation between the paper, corrugated board and the box

2.5.2.1 The edgewise crush resistance and edge crush test (ECT)

ECT is the one of the important tests to predict the stacking strength of the package with their close connections to each other (Table 2.14).

A test piece from a corrugated board gets a load on its flutes, which perpendicular to the test plates. The load should be in a given speed, usually 10-5 mm/min. The maximum compression force that the piece sustain without any failure is it's edgewise crush resistance in kN/m. (Markström, 1999, p. 19). There are different test standards of varying institutions such as TAPPI, JIS, FEFCO etc. (Figure 2.81)

TEST ITEM	FEFCO		EN	
	NR(YEAR)	TITLE	NR(YEAR)	TITEL
EDGE CRUSH RESISTANCE ECT	TM 8 1997	EDGEWISE CRUSH RESISTANCE OF CORRUGATED FIBREBOARD	3037 1996	DETERMINATION OF EDGEWISE CRUSH RESISTANCE UNWAXED METHOD (FEFCO)

ISO		TAPPI	
NR(YEAR)	**TITEL**	**NR(YEAR)**	**TITLE**
3037 1994	DETERMINATION OF EDGEWISE CRUSH RESISTANCE UNWAXED METHOD (FEFCO)		
13821 2002	DETERMINATION OF EDGEWISE CRUSH RESISTANCE WAXED EDGE METHOD	TP 811 OM-02	EDGEWISE COMPRESSION STRENGTH OF CORRUGATED FIBREBOARD USING THE CLAMP METHOD (SHORT COLUMN TEST)
		TP 841 CM-03	EDGEWISE COMPRESSIVE STRENGTH OF CORRUGATED FIBREBOARD USING THE MORRIS METHOD

Figure 2.81 : Comparison of the test methods for ECT (European Federation of Corrugated Board Manufacturers, 2004)

ECT can also be measured by calculating the papers RCT and CCT values, which means their compression strength of liners and fluting medium (Markström, 1999, p. 40). The formula is specialized for single (2.1) and double wall (2.2) corrugated boards. For single wall;

$$ECT = 0{,}73 * \left(RCT_{l1} + \alpha CCT_f + RCT_{l2}\right) + 1{,}6 \tag{2.1}$$

For double wall;

$$ECT = 0{,}69 * \left(\sum RCT_{l1} + \sum \alpha CCT_f + \sum RCT_{l2}\right) + 2{,}27 \tag{2.2}$$

Where;

RCTl1 = Ring crushing test of first liner

RCTl2 = Ring crushing test of second liner

CCTf	= Corrugated crushing test of fluting medium
α	= take up factor of the flute

Markström (1999) explains take up factor as the ratio of the length of fluting medium to the length of liner (p. 40). As can be understood from this explanation, wider the fluting thickness is higher the ratio and take up factor. While this ratio augments the ECT and thus BCT strength of the corrugated board, the weight of the material is detriment to environment. Jing (2011), also underlines the advantages of the light weight base paper, which makes the overall weight less and thus more convenient handling and transportation (p. 993).

Table 2.14 : Take up factors for flute, which is used in Edgewise Crushing Test (FEFCO, 2011).

Flute	**Height of the corrugated member* mm**	**Flutes/m length of the corrugated board web**	**Take-up factor**	**Glue consumption g/sqm, glue layer**
A	4,8	110	1,50-1,55	4,5-5,0
B	2,4	150	1,30-1,35	5,5-6,0
C	3,6	130	1,40-1,45	5,0-5,5
E	1,2	290	1,15-1,25	6,0-6,5
F,G,N	0,5-0,8	400-550	1,15-1,25	9,0-11,0

2.5.2.2 Bending stiffness

Bending stiffness can be explained roughly by the thickness of the material, as it is influenced from the neutral bending center line of the sheet from the surface liners (Markström, 1999, p. 10). It is defined as the relationship between the applied bending moment and the deflection within the elastic region (Markström, 1999, p. 31).

In order to keep the bending stiffness high, not just the initial state of the material but also converting and production phase of the package is very important. As the thickness is the keypoint of the bending stiffness, while converting and manufacturing of the board and box, the crushing of flutings occurs, resulting a lower thickness and bending stiffness.

Bending stiffness of the corrugated board is taken very significant to measure the stacking strength of the box. Higher the bending stiffness of the corrugated board, better the whole corrugated board material, which participate in bearing the applied load.

2.5.2.3 Box compression test (BCT)

BCT is originally a test to measure the stacking strength of corrugated board packages however, it is also useful to see the performance potential of the package, which can predict the load bearing properties under modern transport conditions (Markström, 1999, p. 7). Testing method and instruments for corrugated boards book define the test that holds on an empty and sealed box between flat parallel plates, which compress at a constant speed of generally 10-13 mm/min. The maximum force and strain are recorded when a compressive failure occurs. Test methods of FEFCO, EN and others differs from each other and have to behold for these diversities (Figure 2.82). The test conditions hold an important role in determination of the value, the calibration and adjusting of the test machines should be done regularly.

TEST ITEM	FEFCO		EN	
	NR(YEAR)	TITLE	NR(YEAR)	TITEL
COMPRESSION RESISTANCE OF THE BOX BCT	TM 50 1997	DETERMINATION OF THE COMPRESSION RESISTANCE OF CORRUGATED FIBREBOARD CONTAINERS	12048 2000	COMPLETE, FILLED TRANSPORT PACKAGES - COMPRESSION AND STACKING TESTS USING A COMPRESSION TESTER

TEST ITEM	ISO		TAPPI	
	NR(YEAR)	TITEL	NR(YEAR)	TITLE
COMPRESSION RESISTANCE OF THE BOX BCT	12048 1994	COMPLETE, FILLED TRANSPORT PACKAGES - COMPRESSION AND STACKING TESTS USING A COMPRESSION	T 804 OM-2	COMPRESSION TEST OF FIBREBOARD SHIPPING CONTAINERS

Figure 2.82 : Comparison of the test methods for BCT (European Federation of Corrugated Board Manufacturers, 2004)

Although BCT is highly preferred test by the customers and conventers to set their specifications, practical tests have shown that only 20-35% of the measured values can be relied upon (Markström, 1999, p. 9). To ensure the conclusion and expectancy, a safe factor of 3-5 times is used, according to the stiffness and rigidity of the product which will be packaged.

Before the production of a test subject, the package's BCT value can be achieved, depending on corrugated cardboard and box specifications. McKee equation (2.3) is the widely known formula to measure a RSC (Regular Slotted Container) using its length and width dimensions, bending stiffness (2.4), ECT and caliper of the board.

$$BCT = k_1 \times (ECT^b)^x \times (S_B^b)^{1-x} \times Z^{2x-1} \quad (2.3)$$

Where;

k1 = constant

ECT = edgewise crush resistance

Sb = geometric mean of bending stiffness

$$S_B^b = \sqrt{S_{B,MD}^b} \times \sqrt{S_{B,CD}^b} \quad (2.4)$$

Z = periphery of the box

For a simplified version for the equation (2.5), bending stiffness is replaced with the caliper of the board;

$$BCT = k_2 \times ECT^b \times T^{0,5} \times Z^{0,5} \quad (2.5)$$

On the other hand it is recommended by Popil (2013) that, using the formula in full form helps to reach more accurate data (p. 37). The formula does not include the height of the box, it is mentioned that if the depth/periphery is bigger than 1/7, the formula can be relied upon, otherwise the performance of the box decreases eventhough the formula shows the same result. Aloumi et al. (2015) presents their conclusion, because of the wall buckling, the box became weaker as the height inceased and the formula becomes unreliable and overestimates the real results (pp. 129, 137).

BCT and other strength measuring tests don’t make sense when the product to be packed isn’t investigated enough. The sturdiness of the product itself, also specify the required strength value for the package (Yapca, 2016). For example; squashable products, flexible packages or powder products can not preserve their shapes, therefore the corrugated cardboard box has to endure all the stacking and keep itself undamaged during the transport. Liquid carrying plastics, because of their dynamics while being being transported, tend to move and create pressure on inner side of the package and damage the box. On the other hand, solid and durable products are able to carry themselves so their BCT value don’t need to be high as the forementioned squashable, flexible or liquid ones. That’s why, the safe factors change according to the products, as mentioned above, between 3-5.

2.5.3 Flute direction and its effects on design

Flute direction is a close knit factor with the design itself. This means, some of the standard packages have preset flute directions, which mentions on all designs with the international rectangular of symbol. Thus, while working on the designs, designer knows the best, considering the design and where to use for the packages. Though new packages or inserts have to be examined in order to find the optimum direction.

To utilize the inserts and packages, looking stacking direction is the main method. Thus the packages’ flute directions are always parallel to their height. However, some packages having low width, are stacked horizontal, thus their flute direction becomes vertical to their height. Another situation is horizontal pressures to protect the object if it is fragile. Using horizontal dropbox inserts are mentioned in slotted inserts to counter and protect against these pressions.

On the other hand, the creases parallel to flute directions interfere the straight folding of the corners. As the structure of the corrugated cardboard is not homogen, unlike the cut lines, crease lines become inconsistent and displays indecisive corners on the boxes and inserts. The visual apperance becomes a little bad, that’s why some companies prefer horizontal flute direction especially for primary packages which are seen on shelves by customers. However, changing the flute direction requires a better secondary package, because the strength of the primary box is low. As they are completely company decisions, next step of this process should be told by the company, or advised by the designers.

2.5.4 Diecut area usage and utilization on design

The amount of the area usage always encounter the designers with an advantage and disadvantage. Higher the area, stronger the inserts and boxes however, cost and weight also become higher, which is not preferable by both designer and customer. On the other hand, in some situations the area and strength can work together. Maltenfort (1988), explains that by changing the direction of the package, both area can be reduced and also strength of the box significantly increases (p. 150). So the designer should be aware of the possible arrangements in order to find such a convenience.

Design of the package should always carry the smallest dimensions possible, for savings. At some points there are ways to reduce the dimensions of the package. But the real savings can not be done without the diecut dimensions and conditions. As the dimensions of the production lines for both press and folding processes are specific according to the machines, designs are nested in optimal way to diecuts considering these manufacturing situations. As a result, the alignment and total dimensions of the nest of packages become more important than the design itself.

The picture (Figure 2.83) displays a difference of x mm by changing the dimensions of the flaps. Right hand one is the original design nesting however, in Y direction it exceeds the maximum dimensions of the roll paper of cartonboard. By reducing the flaps, it is calculated that in original design unit price is 0,8961 TL while the reduced one is 0,6278 TL. If the order amount is 10.000 units, total saving becomes 2,683 TL (Camiş Ambalaj San. A.Ş., 2015). Along with the savings, by using smaller paper roll, thus reducing the waste, environmetally advantage is also gained by this small clipping. While, here the paper roll requires the extra provident processes, there can be numerous reasons such as; diecut dimensions, unit of items, graphic settlement of the package, the length of the roll paper etc.

While working on designing the suitable package, the ratio of overall dimensions of the box should be considered. Maltenfort (1988), reminds that favourable RSC box with respect to board area will result when ratio of length to width to depth is 2:1:2. Unfortunately, the forementioned conditions such as; printed matter, shape of the contents, pallet arrangements, packaging machinery and limitations, number of the units to be packaged etc. intrude these kind of calculation for a desired ratio (pp. 151-152). The best board area doesn't have to be the optimum solution for a package design however, while designing the package, it is best to keep these optimum ratio in mind, when there is a chance to decide.

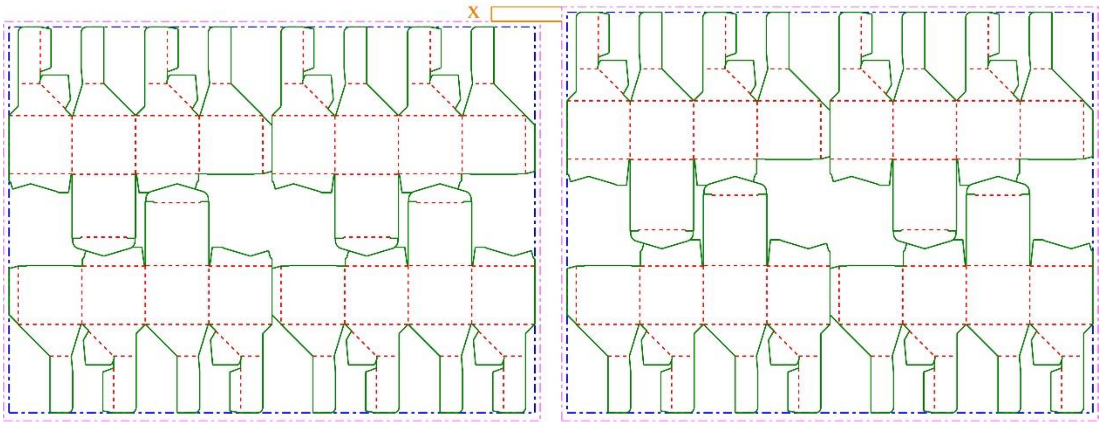


Figure 2.83 : The two different nest of same design with four units. In Y direction there is difference of x mm

3. RESEARCH

3.1 Using McKee Formula and BCT Test

To gain results on strength, McKee formula is thought to used, however normally for a more reliable result, BCT is applied to produced RSCs in real test conditions. The research is made for different designs which are not suitable for this test, however the dissertation's main purpose is the comparison of the designs. Thus the results should be taken as references, not real BCT values.

Corrugated Shipping Containers book dwells on the assumption that McKee formula is good to apply on inserts, with the same principle, the tube style packages can also be calculated. The writer also mentions that eventhough the formula doesn't contain the height of box, actually it makes a difference in the real life conditions. When the ratio of periphery/height becomes less than 7, the formula begins to deviate and diverges from real life results (Maltenfort, 1988). As the designed boxes fulfill this ratio, using the formula should stay in reasonable range. However, the designs are neither RSC nor all of them have full length inserts, this fact obctructs the using of the formula. Moreover, as the length and width of the packages are similar to each other, and the used materials are same, seeing the differences of the results with formula becomes impossible.

Eventhough the test is designed for RSC packages, research elaborate on different tube style boxes. Not changing the main package type also allows the researcher a reasonable comparison method with the test. However testing on tray type boxes or sleeve types could make an impractical testing. The real aim is not finding the exact BCT result but viewing and verifying the results and making a comparing measurement.

Another BCT's significant situation is using produced packages, this also have to be ignored as producing needs at least 28 dies, causing a high cost and unfeasible for the researcher. Thus, a sample maker is used to produce numerous packages, which have been tested. As they don't hold the same characteristics of a produced one, the samples are doubled which is a reasonable amount for the tester. For all these inappropriate situations, researcher choose to see the both McKee formula's results to compare with BCT and BCT test results to compare the designs.

3.2 Introducing the Research Structure

3.2.1 Designs

The designs are specially made for six pack glasses. The glass is chosen from Paşabahçe, which is commonly used water glass in Turkey, die code 52052. Glass is approximately 70 mm in the widest diameter and 100 mm height (Figure 3.1). It has an asymmetric shape that the base is narrower than open side, thus designs are studied according to the shape which hinders them from hitting each other. As all the packages are designed for same six glasses, they have similar dimension in 3D when they are set, showing difference around 2-5 mm according to the box style.

Figure 3.1 : Paşabahçe glass is used for six pack designs, diameter 70 mm and height 100 mm.

As mentioned before, designs are crossbreedings of tube style boxes. By this method using six different bottom parts and four different top parts 24 designs are obtained for analyzing. All the designs are made of three different materials, while all the packages have the same flute and paper combinations, inserts are made from two different flutes but with same paper combinations. Box material is E flute with the combination of 180 gr/m² GD cartonboard for outer liner, 100 gr/m² testliner for fluting medium and 100 gr/m² testliner for inner liner. First insert material is E flute with the combination of

140 gr/m² testliner for outer liner, 100 gr/m² testliner for fluting medium and 100 gr/m² testliner for inner material. Second insert material shares the same paper combination but B flute. The differences between the two materials will help to see the effect of the take up factor clearly.

All 60 designs will be listed in the appendices A with their 2D design view, technical drawing and 3D design view including open and closed view and insert design. Design code names encodes; top style of box, bottom style of box and insert style, with their first letter, respectively. These codes can be explained as;

Abbreviation for boxes;

S: Slotted

L:Lock Tuck

R:Ready Glued

I:Interlocked

SI:Slotted Insert

G:Glued Insert

Abbreviation for inserts;

A:Automatic Insert

S:Slotted Insert

E:E flute material

B:B flute material

3.2.2 Topics

Designs are examined on four different tpicss: cost, strength, speed and environment. These topics are first mentioned in hypothesis that, an optimum package is the one, which is cheaper, stronger, faster and more environmental. In order to display the logic behind the reasons and outcomes of the designs, diagrams are created for all the topics. The data from the designs are placed on excel to calculate and compare the results with graphics.

3.2.2.2 Cost

The materials are the main elements which constitutes the cost, corrugated cardboard is a sandwich which is built from paper layers and glue (Figure 3.2). The papers' prices differ according to their manufacturer and structure, Kraft paper is more expensive than testliner and there are numerous cartonboards combinations according to their using area.

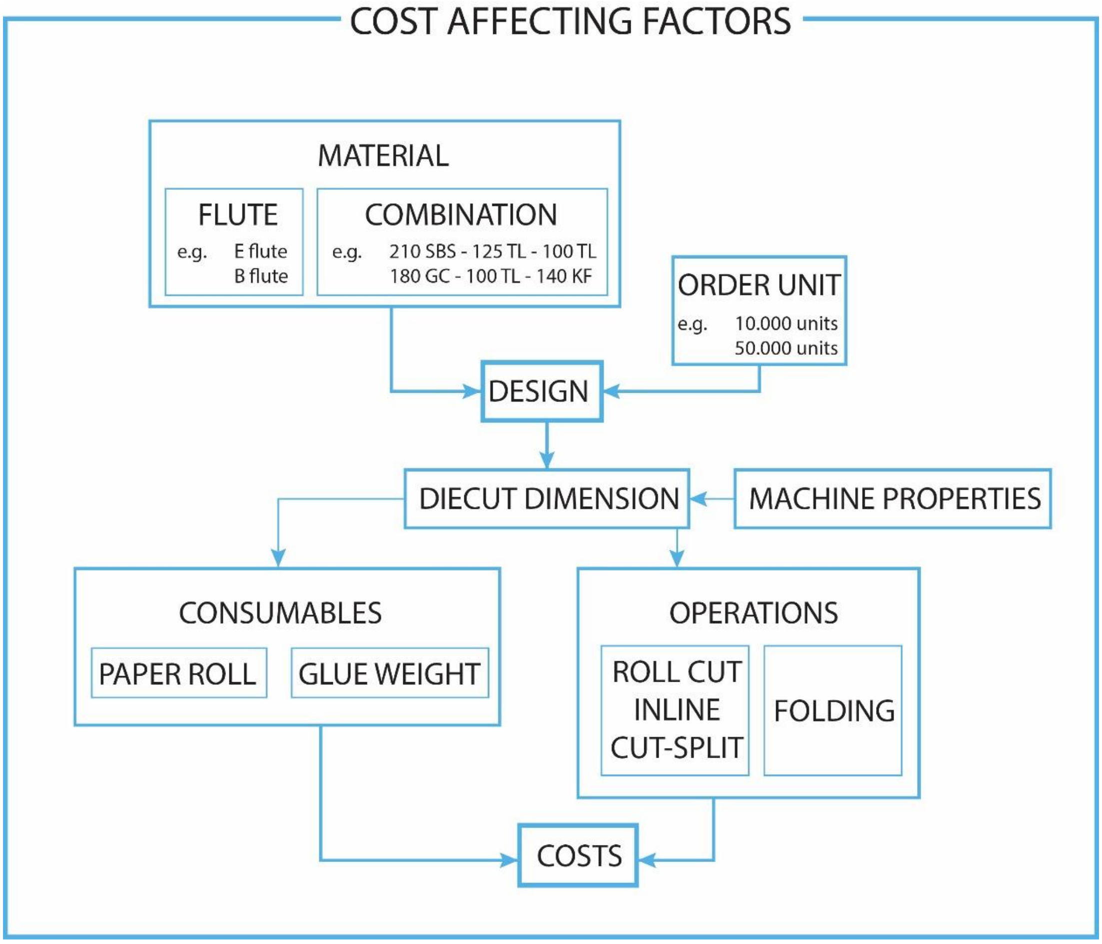


Figure 3.2 : Cost affecting factors diagram on design.

Cost also depends on the data of the used total sheet for the specific box, which depends on the dimensions of diecut. The diecut dimension is affected from the LxWxD and the settling of the designs, which changes the number of the design unit per diecut. Higher the unit per diecut, lower is the sheet pieces. Although, normally the graphic of the boxes alters the settling and number of them, here we will disregard it, supposing the artwork enables all kind of settling for diecut.

Operational processes can not be distinguished from the cost as all the designs require a different manufacturing time and sequence for cutting and folding.

3.2.2.3 Strength

Strength is one of the most significant attributes of a design. Just looking in diagram (Figure 3.3) will not help the customer to foresee the result of the design. Every detail, surface, gluing and lock can change the behaviour of the design. Even it is shown that test conditions can not predict the outcome, and therefore according to the product, the safe factors are being used to ensure the safety of the packages.

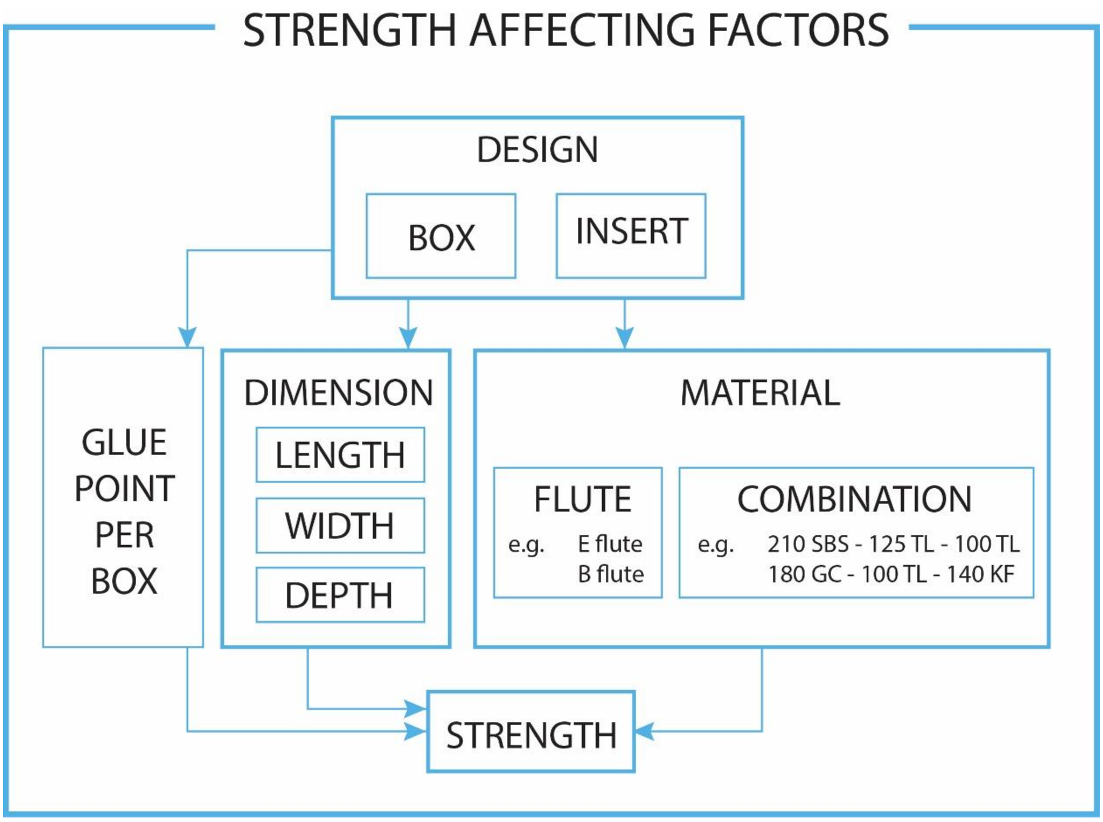


Figure 3.3 : Strength affecting factors diagram.

With the McKee's formula it is proved that the materials and the dimensions are the main factors in calculating the strength. Also, not just the size, but their ratios become significant to predict the box under pressure. It is mentioned in BCT section, that McKee formula acts imponderous therefore, the design of the six pack glasses is controlled by its dimensions of length, width and depth. The take up factors, their prism structure and calibrations of flute also appear in all kinds of strength experiments, as they have been studied and will be studied thoroughly by both the manufacturers and institutes.

The weaknesses and the fortifications are also the main elements on the strength of the boxes. These properties especially become visible when there is glue consumption.

3.2.2.4 Speed

Calculating the speed is one of the tricky part of the designs as while they can be studied one by one, there are so many points which makes the result rather unforeseeable (Figure 3.4). On the other hand, it can be valid for all the processes through the design and manufacturing. Speed is calculated seperately mainly as manufacturing and setting. The design of the box or insert changes manufacturing as not all the designs require the same steps, especially the foldings.

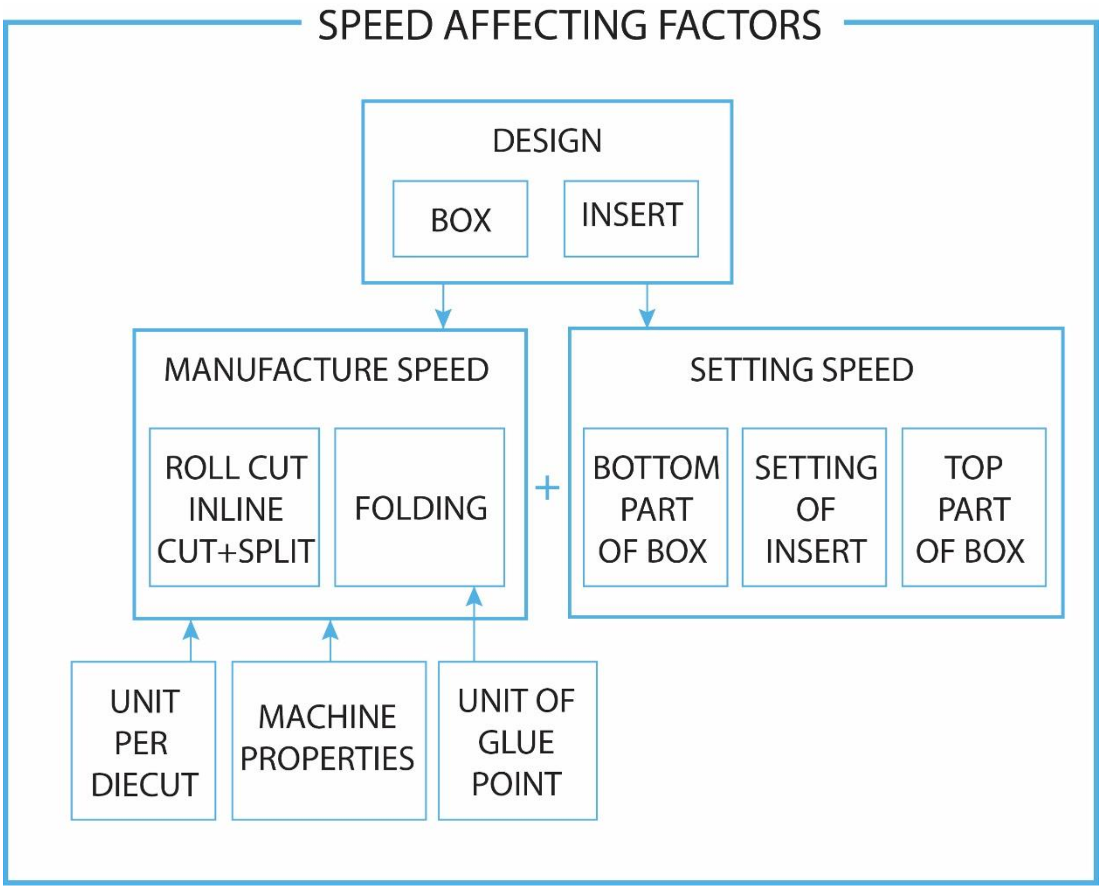


Figure 3.4 : Speed affecting factors diagram.

The machine selection can be varied for best option to optimize the speed and efficiency. This mentioned time also consists of the setting for the machine also, as a design which needs just a side gluing requires half an hour for machine setting, a glued insert box needs two hours.

On the other hand, gluing process save time for other manual operations too. That’s why also calculating the setting, filling and closing of box should be thought. The manual operations such as taping the slotted box and insert can take away more time and resource than forementioned machine settings. Thinking all the process in their context will help the customers to see and elect the possible choise.

3.2.2.5 Environment

The total weight of the box and the waste is taken as the main element of the environmental affect (Figure 3.5), as the damage for nature can be understood from this data. While the weight of the box and insert and their glue consumptions become dangerous harm, waste is static loss as they can not be used in package, directly goes to recycling centers with best chance.

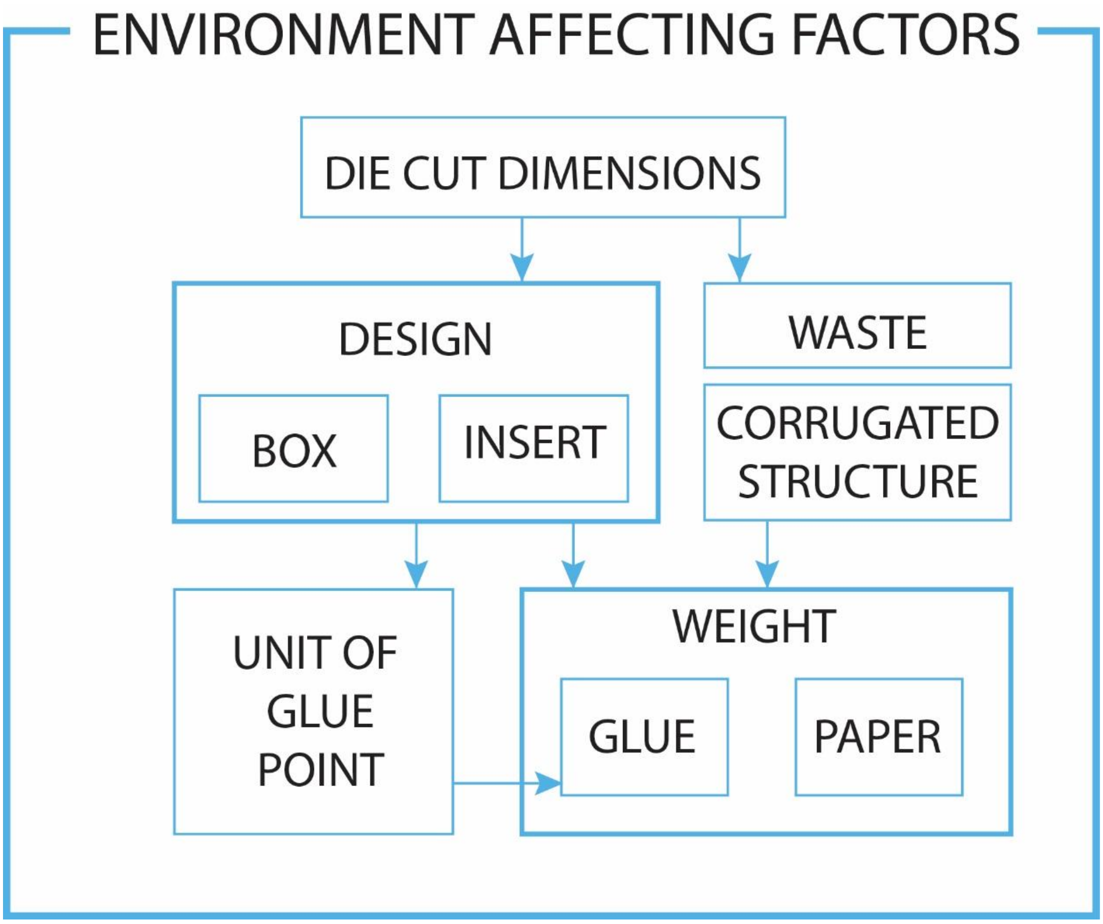


Figure 3.5 : Environment affecting factors diagram on design of box and insert.

All the designs which increase the gluing points, actually increase the ill effect. Therefore while increasing the strength and speed, an environmentalist customer or company would want to change the design, aiming to fortify their corporate identity and seeking other ways to stengthen their packages.

The structure of corrugated board also changes the glue and paper consumption just like in the strength diagram. While the prism of the corrugating medium consumes different amounts of glue for bonding, take up factor directly changes the weight of the board. The chemical composites of the processes and consumables also play critical role, using more environmental friendly ones should be the priority of the converter's.

3.2.3 Research conclusions

3.2.3.1 Conclusions on strength

In order to give the most underlining results for strength of the packages; the comparing graphics of same bottom parts and top parts have been shown. Cumulative effects of the boxes and inserts together create the strongest and the weakest ones. BCT values are gathered from test results, which have been done on 28 designs including inserts with each of them having two samples. Tests are held in laboratory of Camiş Ambalaj San. A.Ş. Eskişehir factory. The test machine is Devotrans which is operated according to TAPPI T804 standard to measure their compression values.

Looking at the graphic of the BCT test results (Figure 3.6), it can be seen that the big differences emerge firstly because of the insert variations. Changing the top of the package's results make little movements for blue columns. The highest one, customer lock, gains its endurance from the lids' double walls creating a powerful resistance under pressure. Lock tuck and customer lock have a clear similarity with undivided surface on their top. As both of them have high durability, it can be said that one piece surfaces have a contribution on strength. Lock tuck and slotted insert result near values to each other, though having a completely distinct designs. Lock tuck, eventhough seems a little weaker to others, supporting flaps and continuing surface form a rigid package. On the other hand, discontinuous types especially slotted box, despite having double layer, products low strength. As slotted insert box has more similarity to slotted, it can be assumed that, slots are contributing a support for each other thus provide a better result than slotted.

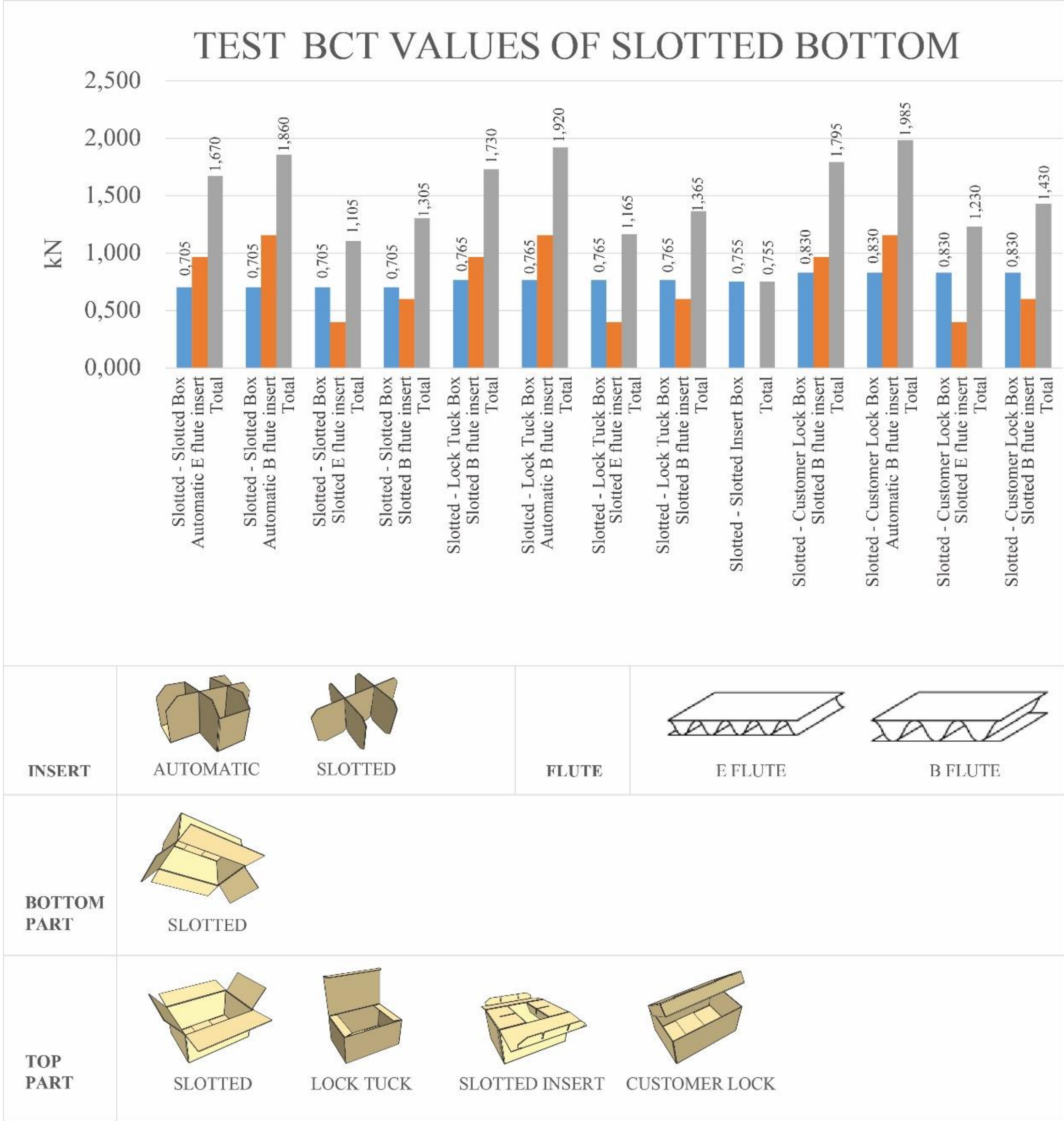


Figure 3.6 : Box Compression Test conclusions on slotted bottom packages.

The test results independent from the inserts and inserted boxes have been shown (Figure 3.7). In here also, the advantage of the customer lock become visible without the intervene of the bottom part. As mentioned above, the double wall of the lid and locking system play a significant role on strength, eventhough this double wall fortifies just the front of the package. Another prominent part is the interlocked boxes which have a high BCT value. As the tests do not consist of interlocked top parts, it is not a certain interpretation, however overlapping and locking boards can be the reason. As the board area is less than the lock tuck, we can assume this cause. Though, it is surprising that ready glued boxes do not surpass the others despite having a glueing process. It can be estimated that diagonal creases used for gluing process, reduce the strength of the boxes. The results of the lock tuck display that for both top and bottom, they establish a good structure.

Figure 3.7 : Without insert pieces and inserted boxes the Box Compression Test results of the boxes.

The graphic (Figure 3.8), similar to the previous one, consists of BCT values arranged according to their top parts but including E flute inserts to include the results of the slotted and glued insert bottom boxes. The first remarkable outcome is that the slotted insert top has low strength. On the other hand, when slotted insert is used as bottom, box shows a high strength.

Here, it has to be mentioned that the object or objects to be packaged, play noteworthy roles. The chosen object, an ordinary water glass, has a wider diameter on top than bottom. Thus, in order to block the contacting top surfaces, the design have to be created according to this fact. For the designs of slotted and glued insert, an extra insert won't be needed and if the top part do not have a divider feature, the bottom part have to cover all the objects till the top point of the glasses and surface of the box. Vice versa if there is a dividing top such as the slotted insert, the bottom part will not require a full separation. As a result, slotted insert top boxes, to minimize the board area, the slotted and glued insert bottom parts has been left short, while the slotted and glued bottom inserts have to be left in full height to cover the glasses.

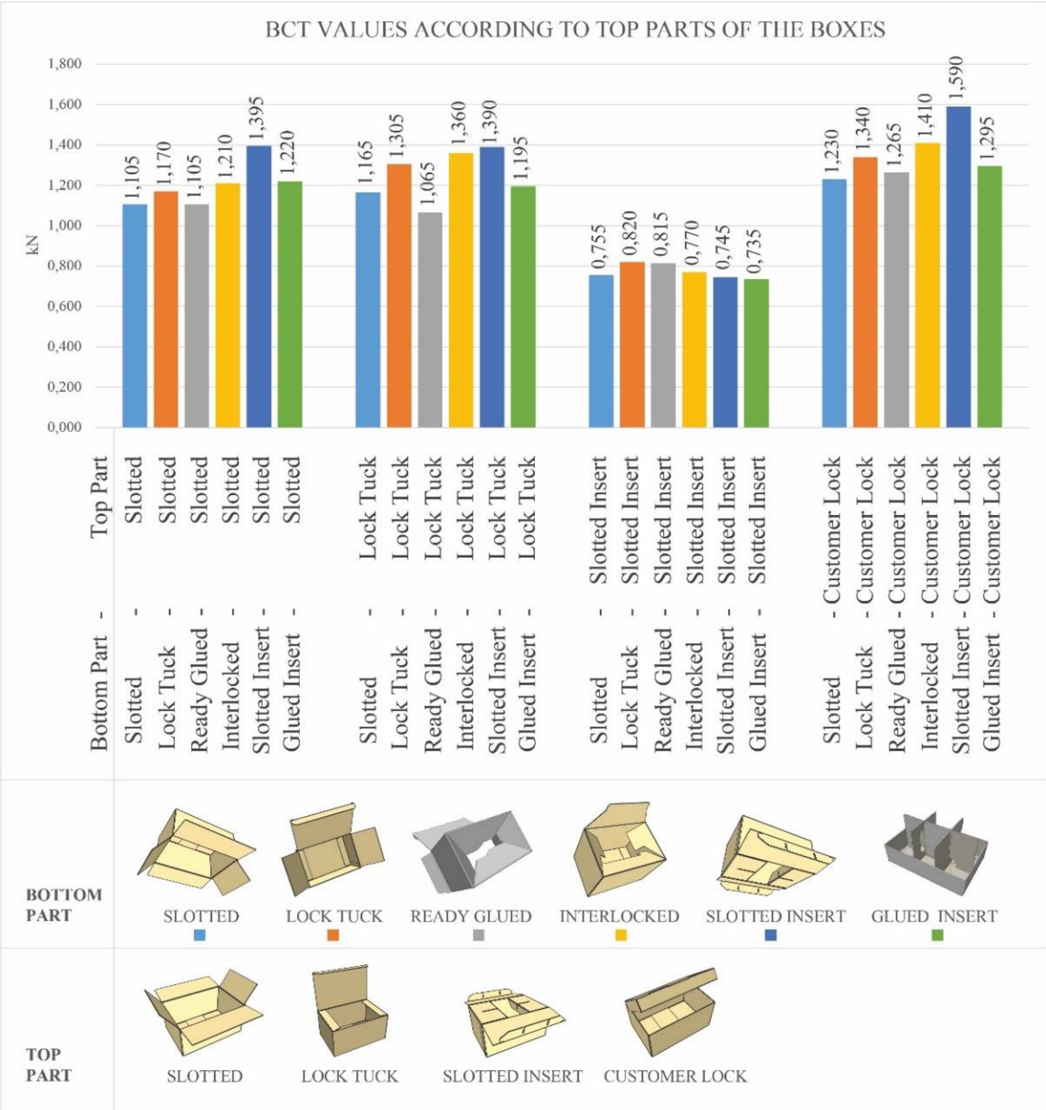


Figure 3.8 : Box Compression Test results of boxes according to their top part, the results are with the inserts of E flute.

Without the support of the insert and short slotted insert, the slotted insert top boxes display low results. Eventhough the extra E flute inserts are used in first four type of bottom boxes, the glued insert boxes forms a strong construction. If ready glued boxes and glued inserts are compared, it is seen that vertical reinforcings become the original ones to fortify the box structure. The customer lock box also confirms this result by having vertical double walls.

To emphasize the results of the slotted and glued inserts strength factors, The graphic (Figure 3.9) just contains these boxes. If the slotted insert top boxes are excluded as the reasons of explained above, the slotted inserts which have double walls display higher strength. Slotted insert bottom's structure separating the objects with full two length and width walls and locking systems help the box a high strength under pressure. On the other hand, glued insert bottom box, despite the fortifying glueing points, in order to be glued in converter's plant, has less walls and areas thus, it loses strength. The sharp drops of the slotted insert tops are explained above, that the objects, which are packaged, need to be the starting point in designing, and forming occurs according to its criterias and needs. If the glass wasn't a self-carrying object but fragile we have to keep the inserts always in full height and if the glass' form was straight, again the height should be the same as the object.

The compare the results of the inserts, one of the bottom types will be enough, as four different inserts are designed for two designs with E and B flutes. Glued and Slotted insert boxes which do not need an extra insert design will be compared to each other specifically. However while comparing its results with the boxes and inserts, their strength will be taken as a sum as if they have inserts.

As seen in the graphic (Figure 3.10) the flute difference gives a reasonable result, as B flute having a higher take up factor, consuming more grammage per m^2, thus show more strength. This also verifies the thicker the board is greater the ECT results and BCT values as a consequent. All the diagrams for every designs these patterns can be seen.

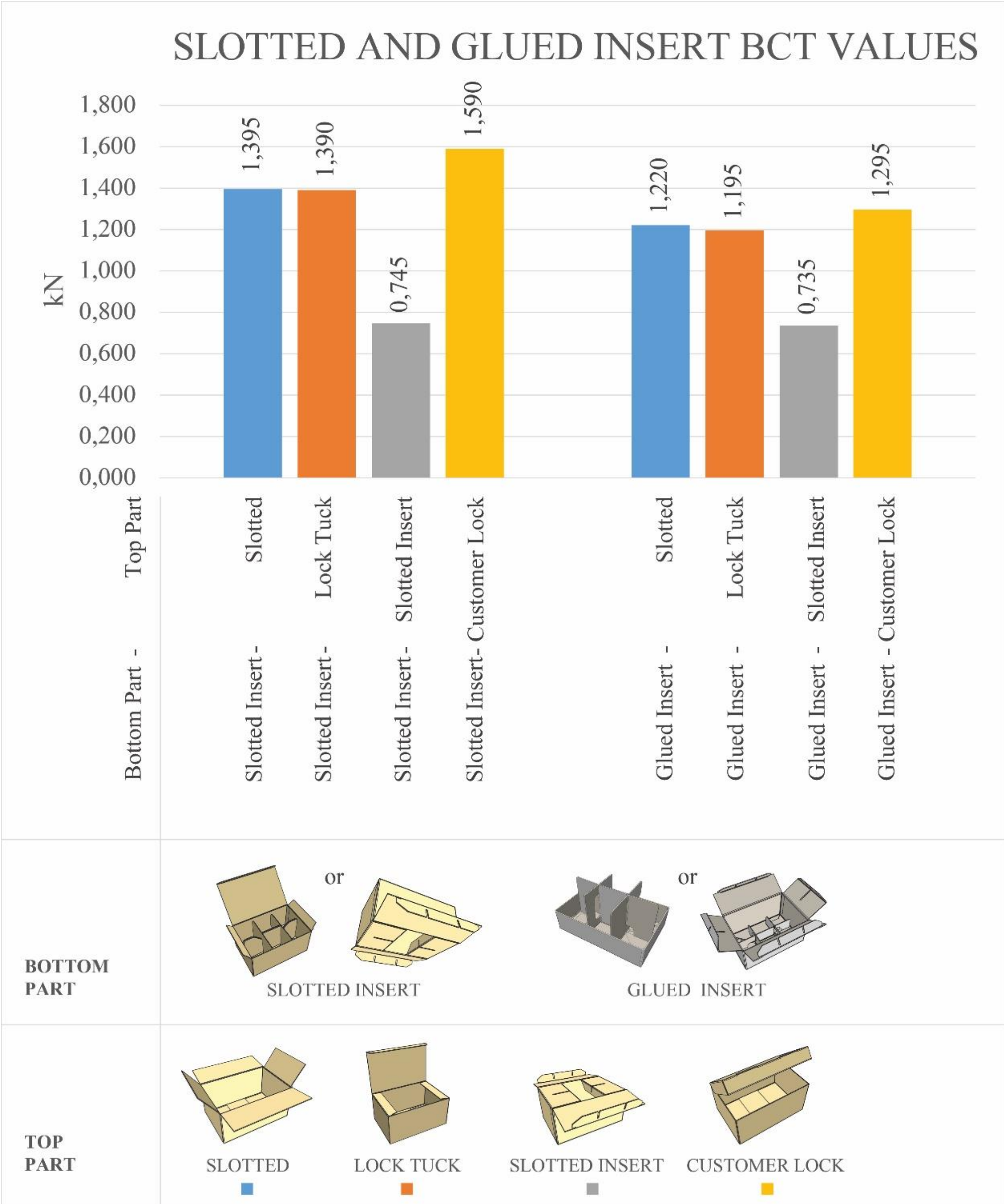


Figure 3.9 : Comparison of slotted and glued insert bottom boxes according to their Box Compression Test results.

Automatic and slotted inserts create a more drammatical change in their BCT tests. First of all, to compare the BCT test results and McKee equation, it can be said that periphery theory can help to compare the designs and dimensions but it is not reliable on end results in numerals to predict their real strength. The difference can be seen clearly as in the figure, estimated strength results tend to give higher values in slotted inserts, but lower in automatic inserts. Apparently, just the dimensions and materials of the packages or inserts aren’t enough to calculate. The unmeasured base piece of the automatic insert makes the estimated BCT low, while the splits of the slotted makes the estimated BCT high. As Maltenfort (1988), indicates the reinforcing and weakening points have to be thought. For instance; manufacturer's joint is a strength point while an incision is a weakness. Every extra corners and breaks make contribution and loss, thus resulting new values. Maltenfort assumes every reinforcings gain 0,05 adding factor and every weakening decline 0,05 decreasing factor (pp. 96 - 97). As a result, being knowledgable about these factors helps the designer in their decisions in order to gain the optimum one.

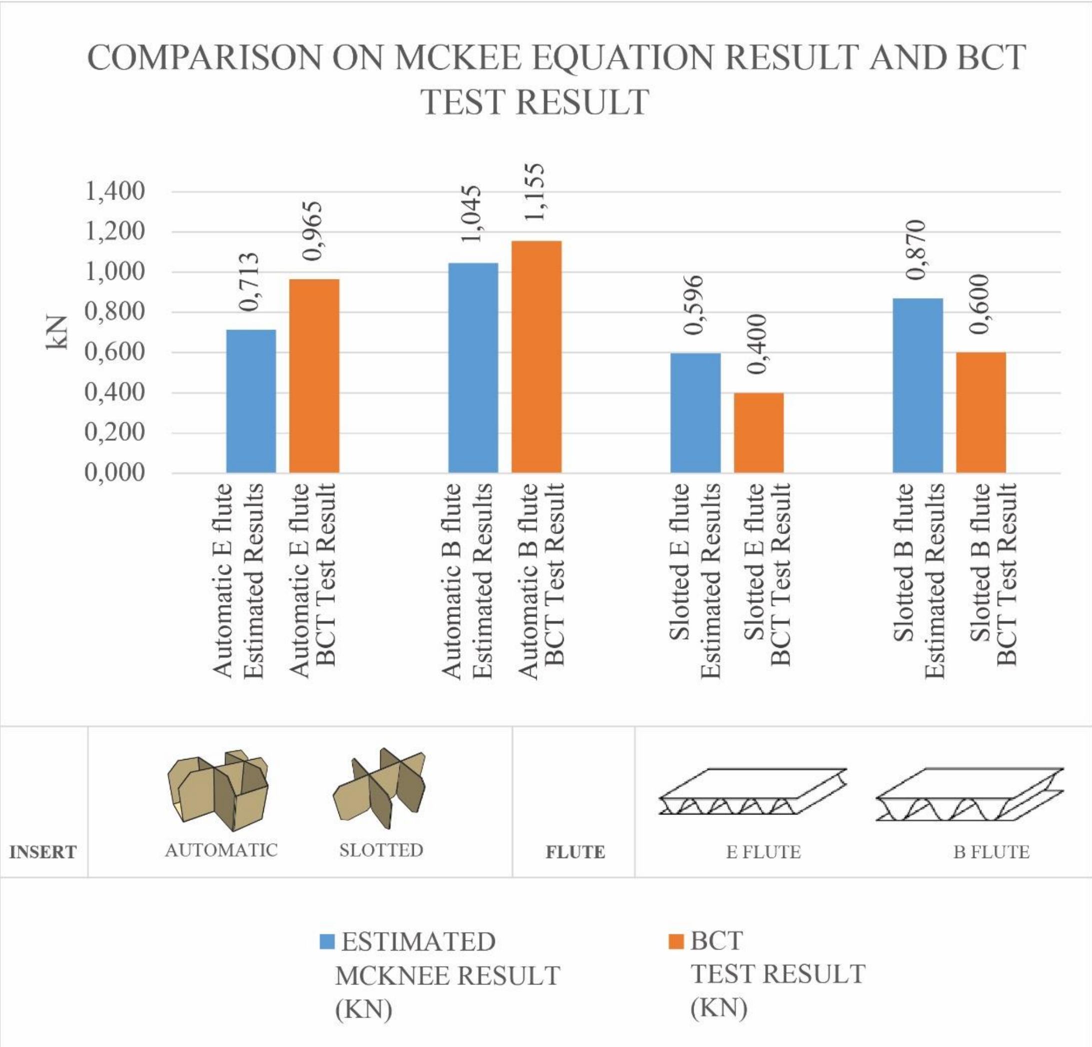


Figure 3.10 : The inserts' kN results of Box Compression Test and McKee formula.

The difference between an automatic and slotted insert can be explained with the periphery, the fortifying crease lines and attached surfaces. The length and width dimensions are wider in automatic inserts than slotted ones, thus while the slotted one has the periphery of (L+2*W), the automatic one's is 2*(L+W). Another strength factor is that an automatic insert consists of one unseparated and union piece. On the other hand, slotted inserts consist of two or more pieces without a connection. Moreover a significant strength comes from corners, it is seen that while an automatic insert has 4 corners and 2 double corners, slotted insert has just 2 double corners.

3.2.3.2 Conclusions on cost

The cost topic covers nearly all the criterias of the designs except the period after the packages reach the customers plant. The materials and their specifications, the diecut, the machines and their properties, the duration of the total manufacturing time, order unit and the destined time to transport are all the factors, for research however, the termination time is excluded. These are also depicted in the topic of the cost graphic. The reflection of the designs on costs will be interpreted to comprehend their relation.

Comparison according to the packages’ bottom types displays that the results are close (Figure 3.11). Slotted Insert top makes a distictive between the other types whereas the slotted and glued insert bottoms are not so different from the boxes with extra inserts. The graphic which is arranged to show the top types of the boxes (Figure 3.12) also shows the emphasis of the cost effect of slotted inserts, in which Slotted – Slotted Insert package has the lowest cost. Even the overall result resembles the BCT results, there are samples don’t behave similar, for instance; slotted insert bottom boxes have a good endurance under the test while the price isn’t too high from the average, instead; they are cost effective between their categories of top types of the boxes.

To depict the cost of the insert with and without, as all the inserts are same with each other, only the slotted bottom box packages are displayed in the graphic (Figure 3.13). The first impression is that there isn’t much difference between the E flute and B Flute cost. This fact makes the usage of a higher take up factor much more attractive as there is a difference for their strength. Moreover, the cost difference between the slotted and automatic isn’t too distinct, if the strength diversity is checked. Probably the gap between them reduce because of the extra cost of the slotted inserts to be fit. If there is a suitable machine avaible for this process, the slotted inserts can become challenging against the automatic inserts with its cost.

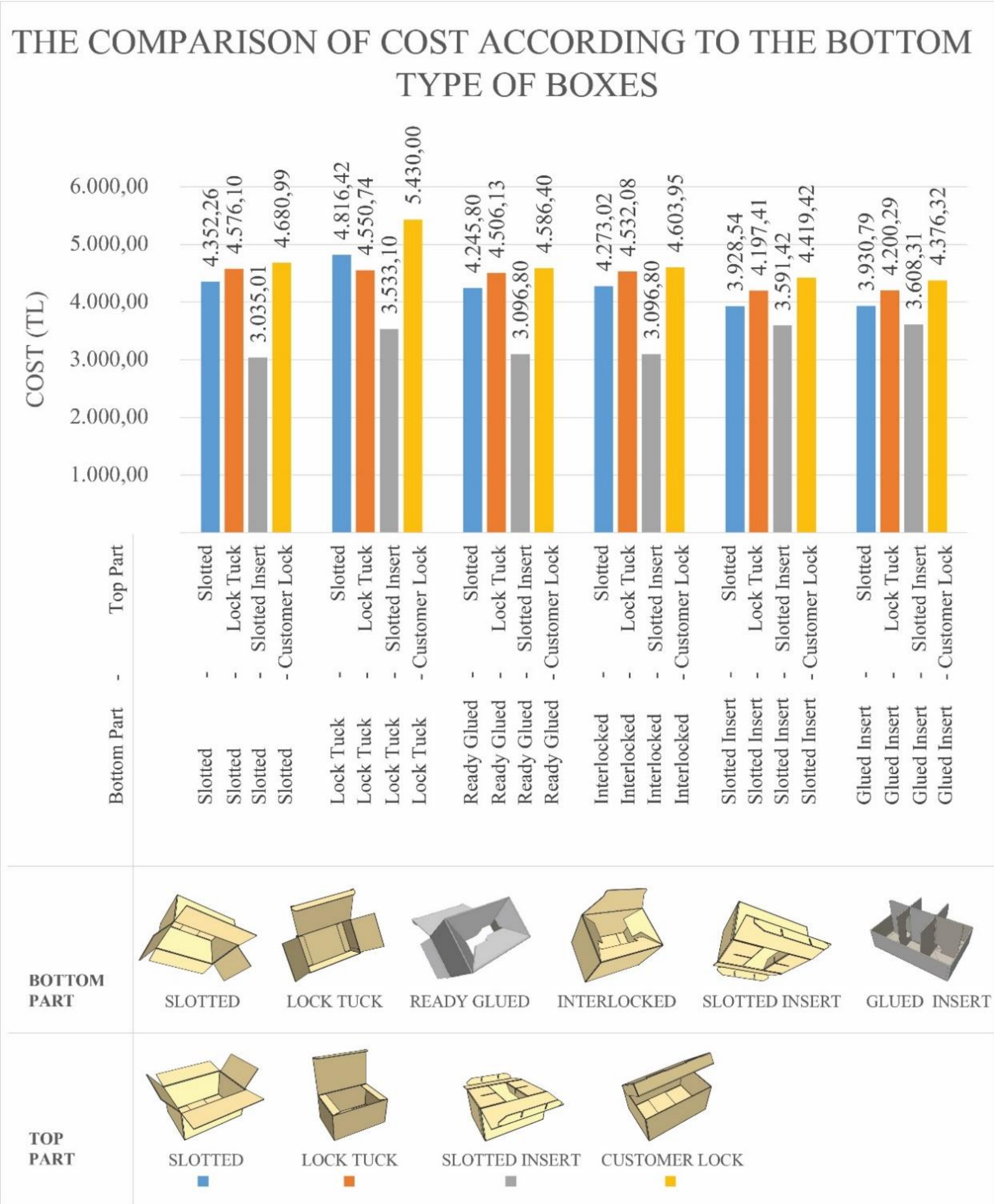


Figure 3.11 : The comparison graphic of the costs of designs according to their bottom type including inserts.

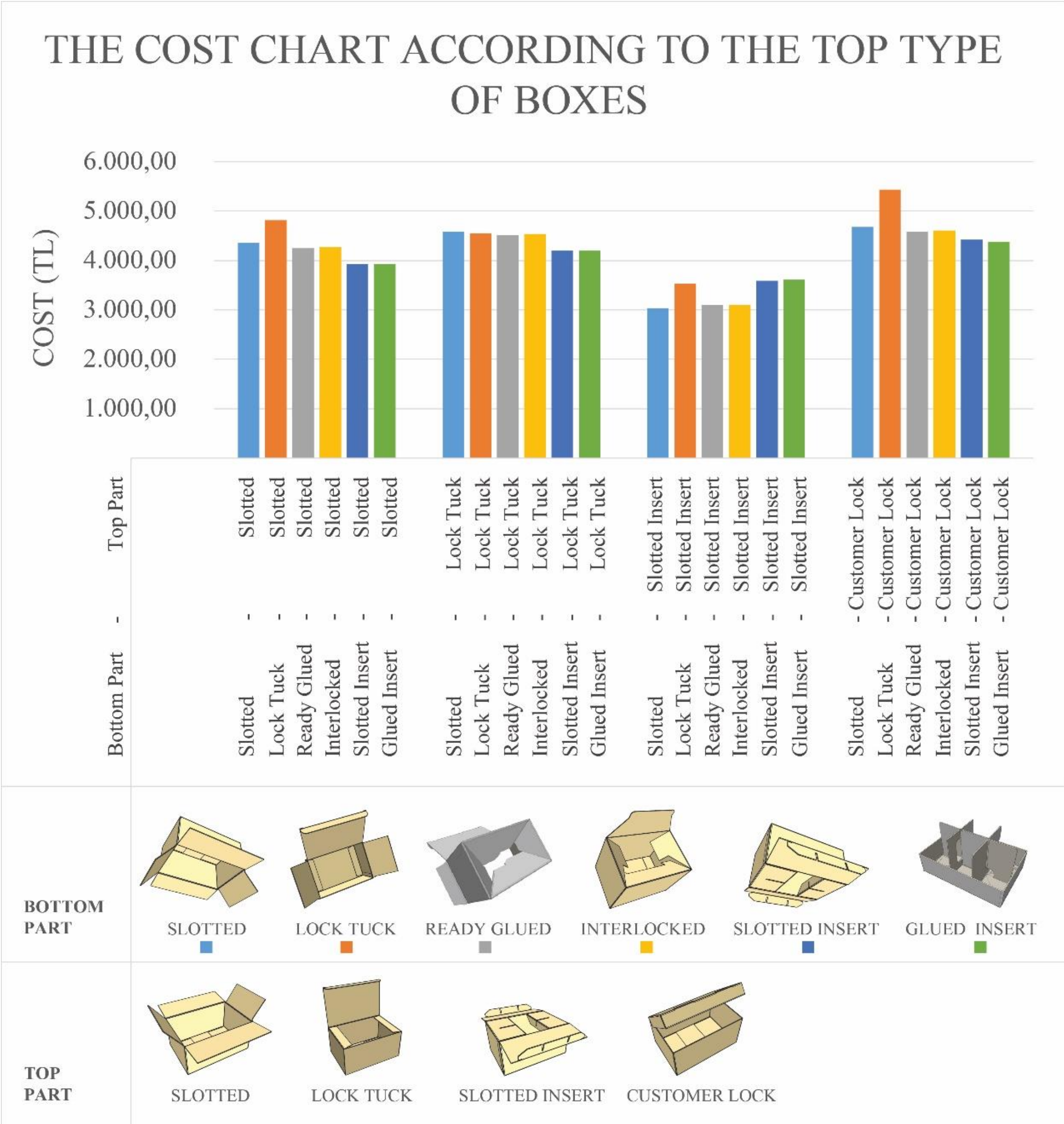


Figure 3.12 : The comparison graphic of the costs of designs according to their top type including inserts.

The graphic which displays both BCT results and costs, underlines the proximity between two topics however they are not replica (Figure 3.14). There are deviations because of the factory processes and the durations which are the elements of the cost topics. The similarity between them chiefly comes from the total usage of the paper and glue. If the cost of the slotted insert top boxes and BCT values are compared, they don’t look very cost effective, as despite their prices their strength are lower than expected. On the other hand, Lock Tuck – Lock Tuck, Interlocked – Slotted, Interlocked – Lock Tuck and Interlocked – Customer Lock boxes shows a high durability in spite of their comparatively prices.

Figure 3.13 : Comparison of the inserts in the slotted bottom boxes.

To sum up the all these data, the correlation between the strength and cost is undeniable (Figure 3.15) however, it is not like the correlation between the total usage of paper with glue and cost (Figure 3.16). Of course all the managements of manufacturers can show dissimilarity depending on their strategy. However, the deviations between the cost and strength actually is a relaxing information that cost effectiveness does not always mean low strength.

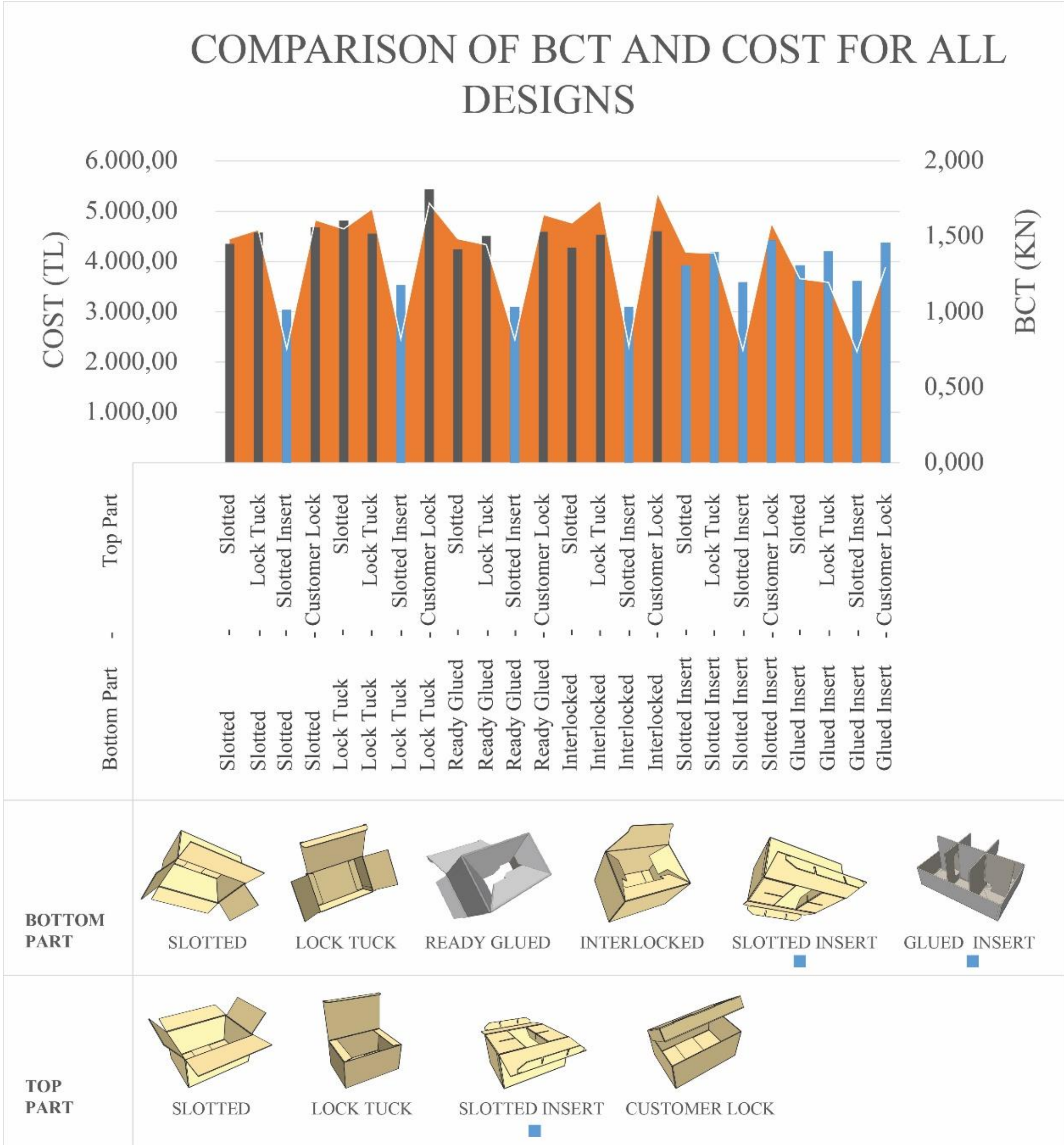


Figure 3.14 : Comparison of Box Compression Test results and the cost of all designs including the inserts.

Cost is a cumulative result of the factors as told in the cost topic and graphic, and there are ways to gain higher strength with a little change in the price. The high dependence of the paper and glue usage to the cost also is a signal for the manufacturers, as the competition between the paper and glue industries ensure a better result in their financies. That’s why the companies periodically change their papers and suppliers by making auctions and bids.

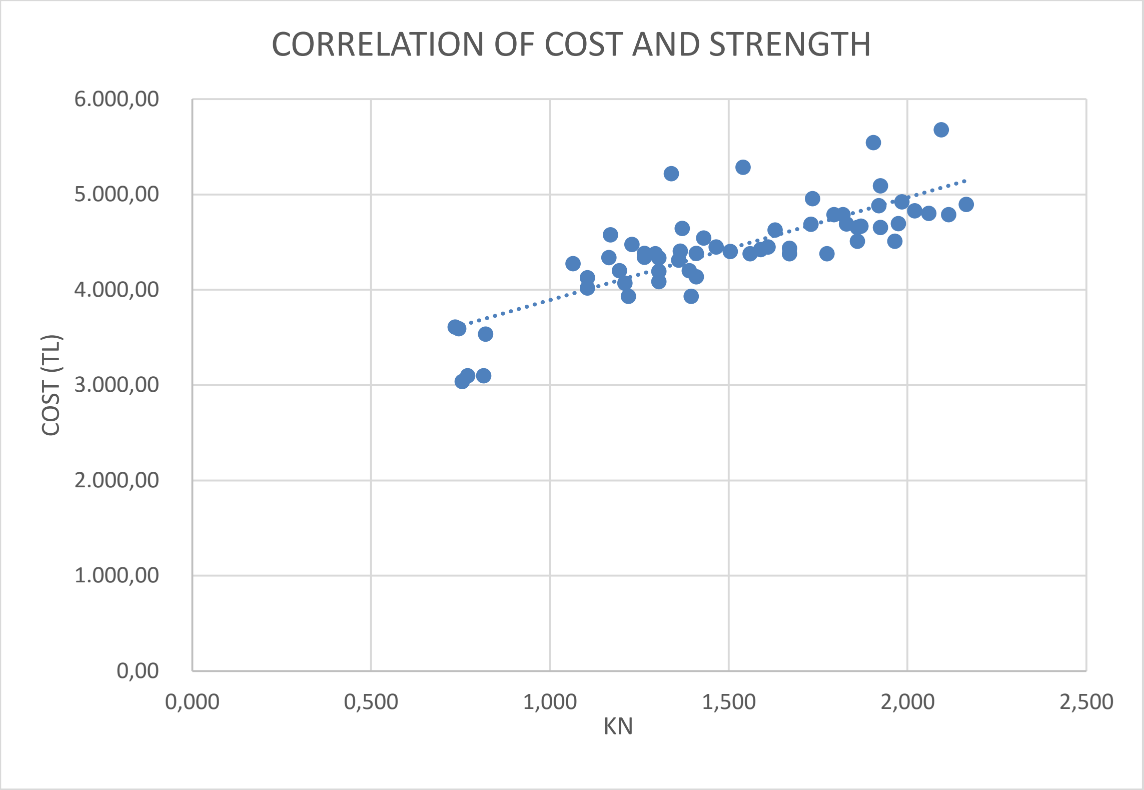


Figure 3.15 : Correlation of cost and strength of all desingns of research.

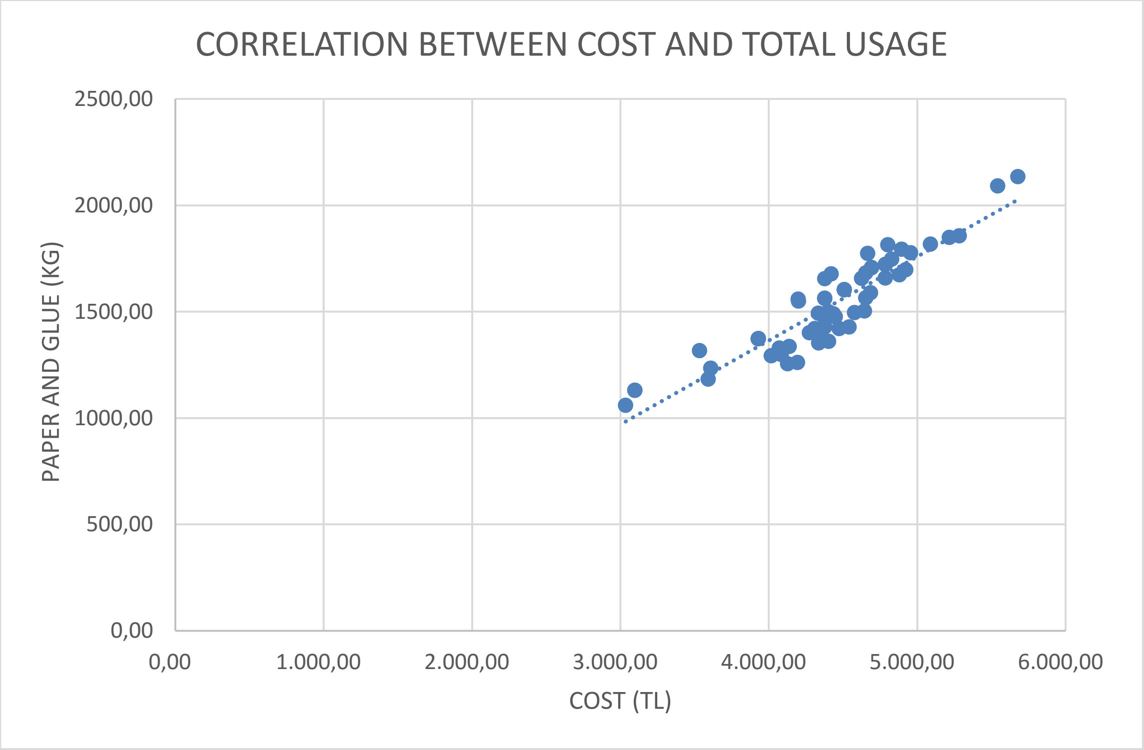


Figure 3.16 : Correlation between the total usage of paper and glue with the cost including the inserts.

3.2.3.3 Conclusions on speed

The information on speed is gathered from the measurement from two different sources, to cover all the process of the design. Dissimilar to other topics, the speed measurements have been done with people who work with machines and fill the products in and close or seal the packages. While gathering the data, it is seen that manufacturing time and setting, filling and closing times are kept in two separate plants, one is the converter's and the other is the customer's. The lack of communication can lead to wrong decisions, for example; if the customer needs a package quickly, they choose a design which can be rapidly filled and closed. On the other hand, chosen design can require a long time for machines' settings or the process may run slow. This information should be exchanged by two sides in order to find the right design. Conclusion of speed generally dwells on these two separate processes; converter's and customer's.

The speed graphic for all designs (Figure 3.17), has been drawn especially to highlight an unexpected difference on the inserts. The advantages of the slotted inserts can not be deniable. On the other hand, if the dimensions of the inserts do not allow a machine process for setting, manual process has to be used and takes so much time. In this case, the dimensions are too small for the machine, thus the time is calculated as it will be set manually which takes two working days. To display this, the graphic shows the difference between the automatic and slotted inserts with the self insert boxes also. It is clearly seen that the self – insert ones have a big advantage as they do not require an extra insert setting and putting inside the package.

Looking at the compared graphic of manufacturing and employment times of the designs (Figure 3.18), it is seen that employment time which means; setting, filling and closing of the box, is 3 or 4 times of the manufacturing time. High peaks are again the results of the slotted inserts.

The boxes which are slotted inserts, customer lock and interlocked can be set by only manually. To gain the sensible results, all the employment times are taken as manual jobs, eventhough others can be set, filled or closed by machine. Aside the slotted insert difference, the other designs which have long employment times are customer lock and slotted style boxes.

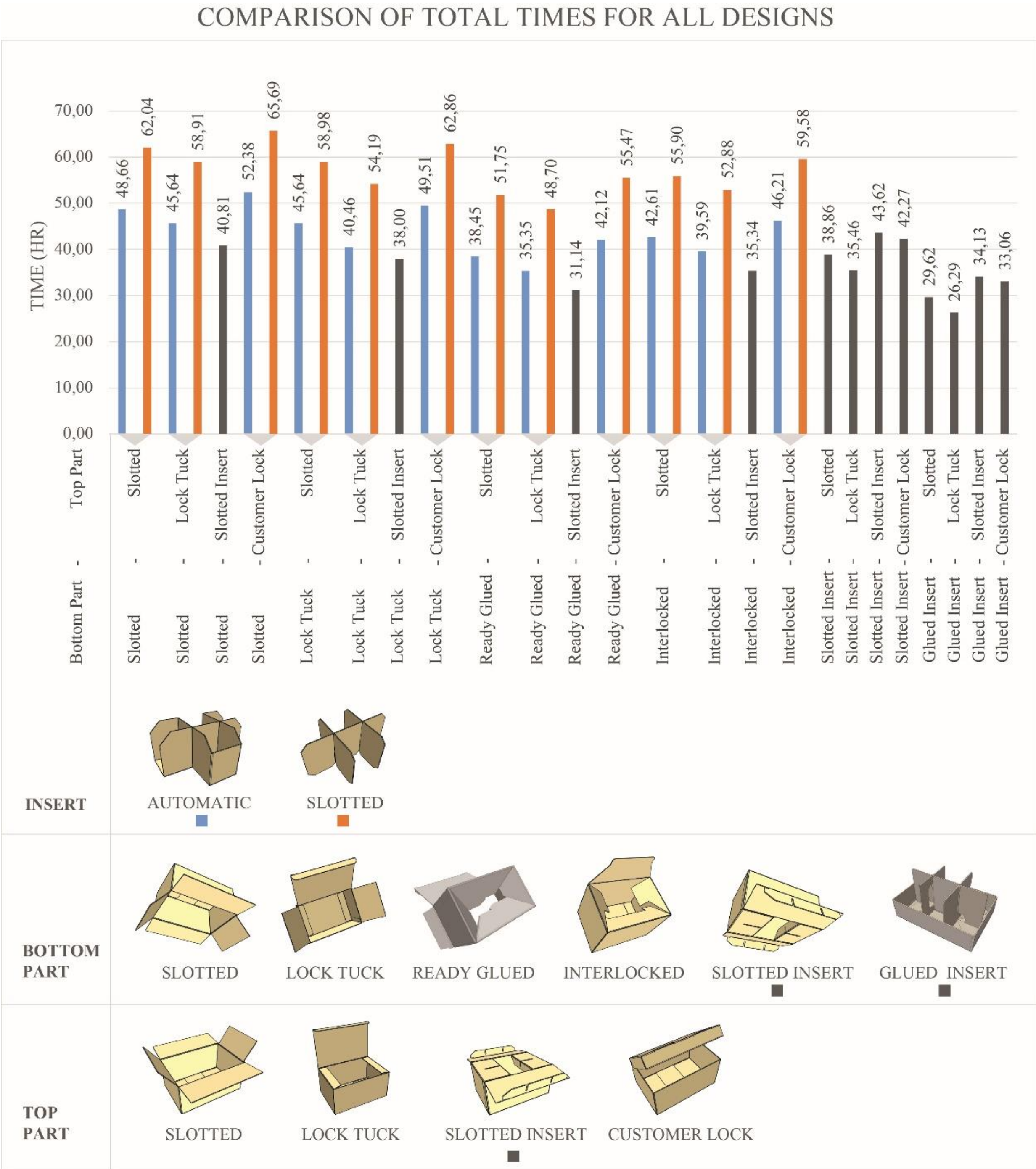


Figure 3.17 : The sum of manufacturing and employment time for all designs.

Slotted boxes while having so many advantages in other topics, they have to be sealed by duck tape which is a disadvantage for employment time. The designs that have shortest employment times are especially the self insert ones as expected. They save an important duration from setting the insert and putting inside the boxes. Especially glued insert and ready glued boxes have highest setting times, 1500 and 1700 units per hour respectively (Çelik, 2016). As a result glued insert boxes will be the first choice for the customer, if their products and units are suitable.

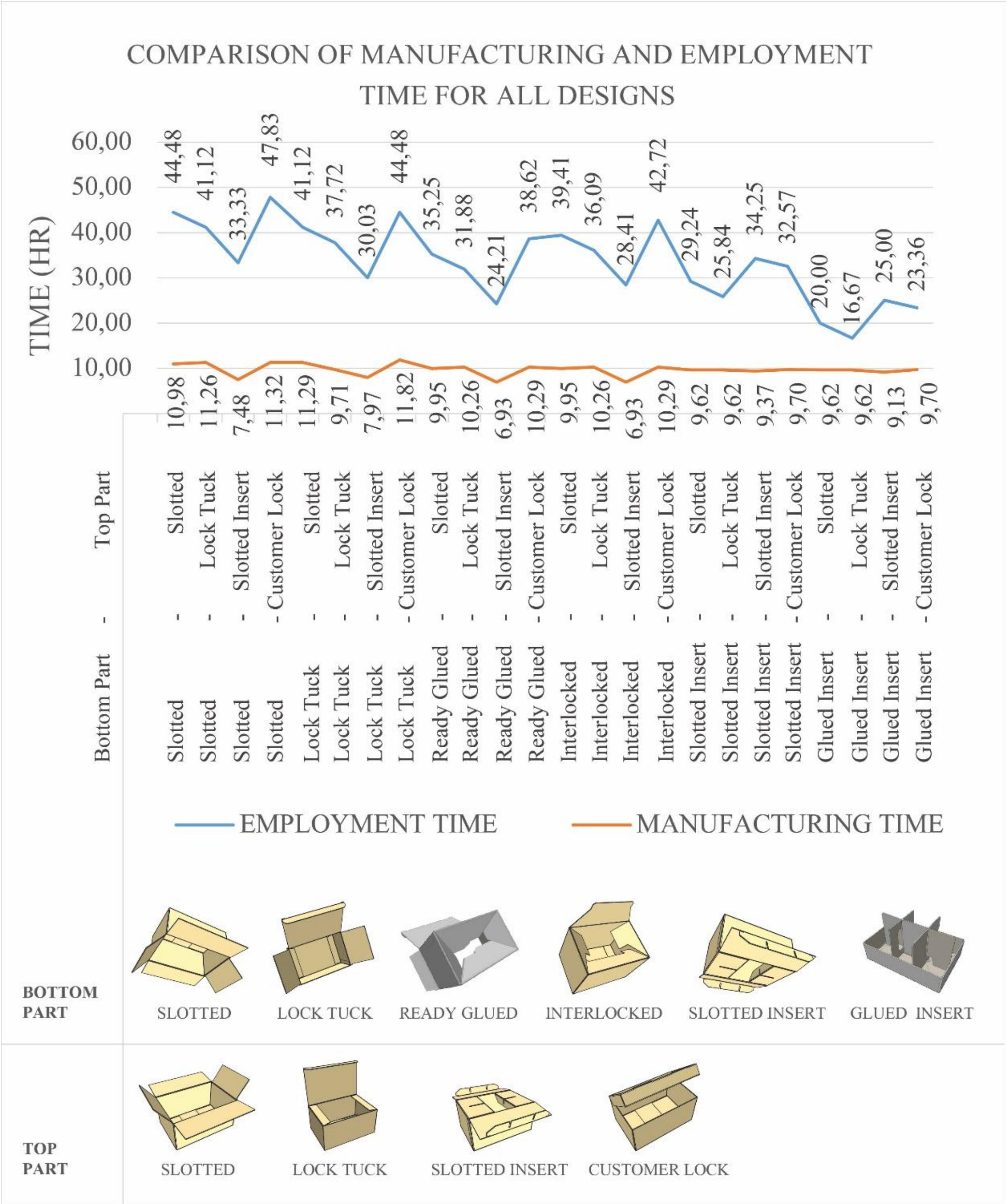


Figure 3.18 : Comparison of manufacturing and employment time for all designs with inserts.

The manufacturing times are much more harder to speak for converter's plants, as even the machines have a capacity which are told by the producer, it depends on people who operate them. The experience and the knowledge of the operator play a significant role in time and the result of the quality (Bartık, 2016). Bartık also explained that; errors, sudden stops or breaks change the duration of the machine which deviate the results. The durations for manufacturing are gathered from process preperation of Camiş

Ambalaj San. A.Ş. They collect all the average hours from manufacturing of packages and categorize them according to their box type. This also covers the time for setting the machine itself, as all the process is arranged special for the design because of the gluing places and the dimensions. The converter's plant can be used to manufacture some types better than the others. Consequently, every factory should prepare their graphics according to their knowledge and machines.

There isn't seen any relation between the total time and strength (Figure 3.19), which is an advantage especially for some fast jobs, that the customer will not lose any endurance. This information can help the designer for quick projects, distinguishing fast ones from the slower ones and selecting the desired strength and cost.

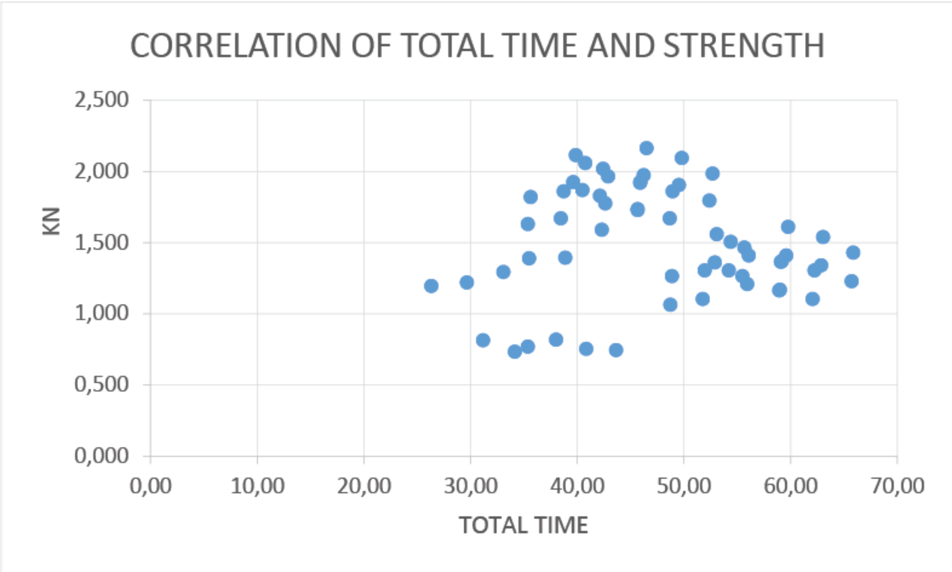


Figure 3.19 : Correlation graphic of sum of manufacturing and employment time and strength in kN.

On the other hand, there is a high proportion between the cost and manufacturing time (Figure 3.20). Even there are so many criterias which change the cost of the packages, in real factory conditions, the pricing also contains the total amount of running time of machines and some of them also working time of employees. For the research the total working time of employees are excluded as this is inspected also under this speed topic. Also, to underline the direct relation between them, just the manufacturing time is displayed in the graphic.

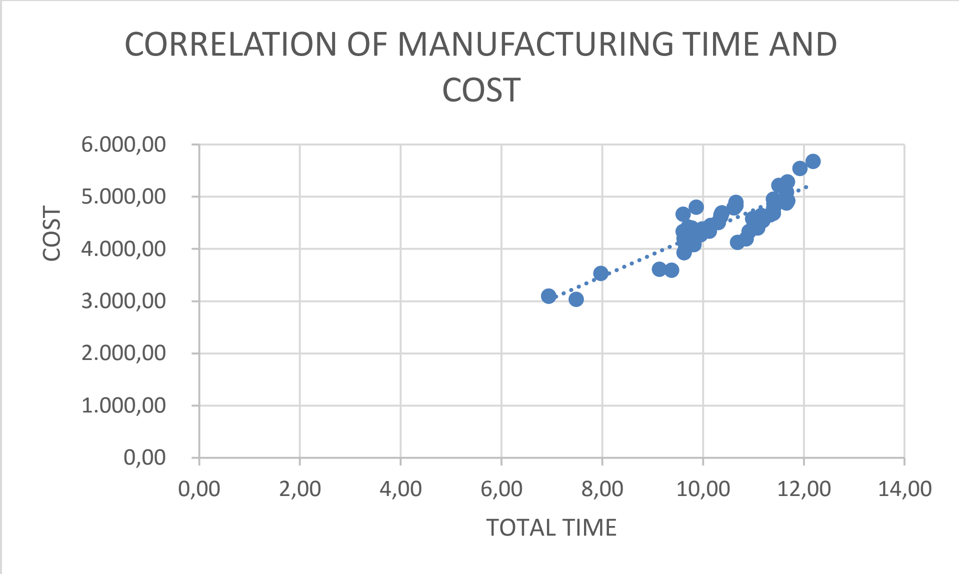


Figure 3.20 : Correlation time of manufacturing time and cost of the boxes.

3.2.3.4 Conclusions on environment

In generating the results on environment, the total paper and glue consumptions are taken into account, which are calculated from the drawings with ArtiosCad. Apart from these data, the waste percent is also accepted as a critical rate, as waste percent discretes the unused paper and glue consumption in the manufacturing. Beside the total burden of these paper and glue, the waste becomes more significant so an environmental package is accepted as having the lowest percent of waste and without high consumption. The reason why paper and glue weight are chosen as an indicator is that the component of the used environment’s sources can be calculated through them. These components are; material inputs and outputs, energy input and output, water input and output, transport, emission to air and emission to water (FEFCO, 2011, pp. 20-26). All these values mostly bear on waste, paper and glue consumption. While calculating the boxes with inserts, the consumption of these inserts are also taken into account, as they can not be thought apart from design itself.

Comparison graphic of paper and glue consumption reveals the overall connection on them, which is mostly in direct proportion (Figure 3.21). As most of the glue consumption comes from the lamination, means the glueing process between the liners, the paper area is the primary reason in glue usage. The small deviations mostly occurs from the glue which is used in the folding process and existence of the inserts.

Therefore, to simplify the results and the graphics, some of them do not display the used glue amount.

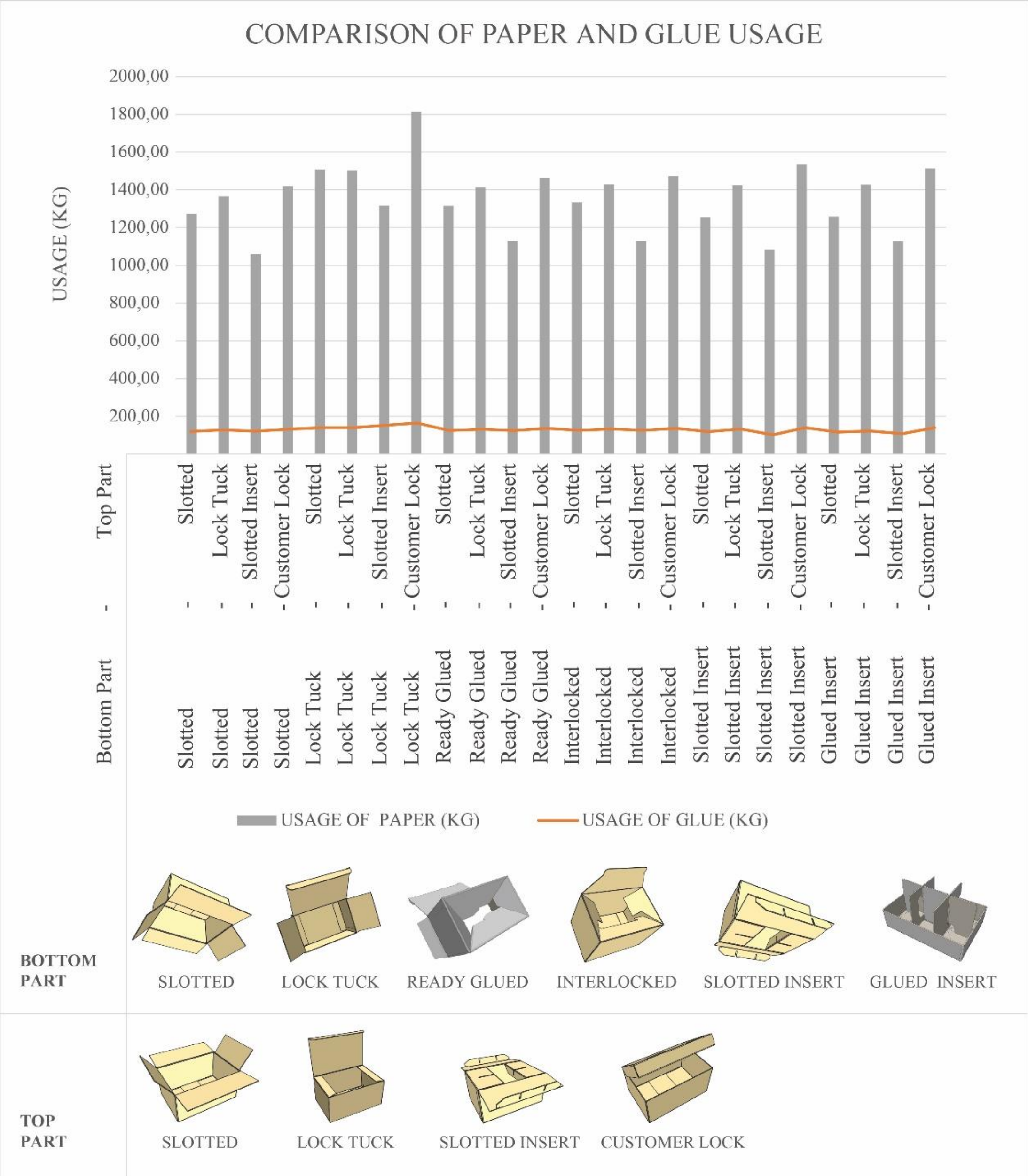


Figure 3.21 : Paper and glue consumption of all designs including inserts.

Before investigating the waste percentage of the packages, the paper consumption data is gathered to display the results of all designs and compare them. The graphic for comparing according to the bottom types of boxes (Figure 3.22), somehow gives the similar behavior for each group. Thus preparing the data is harder to reflect.

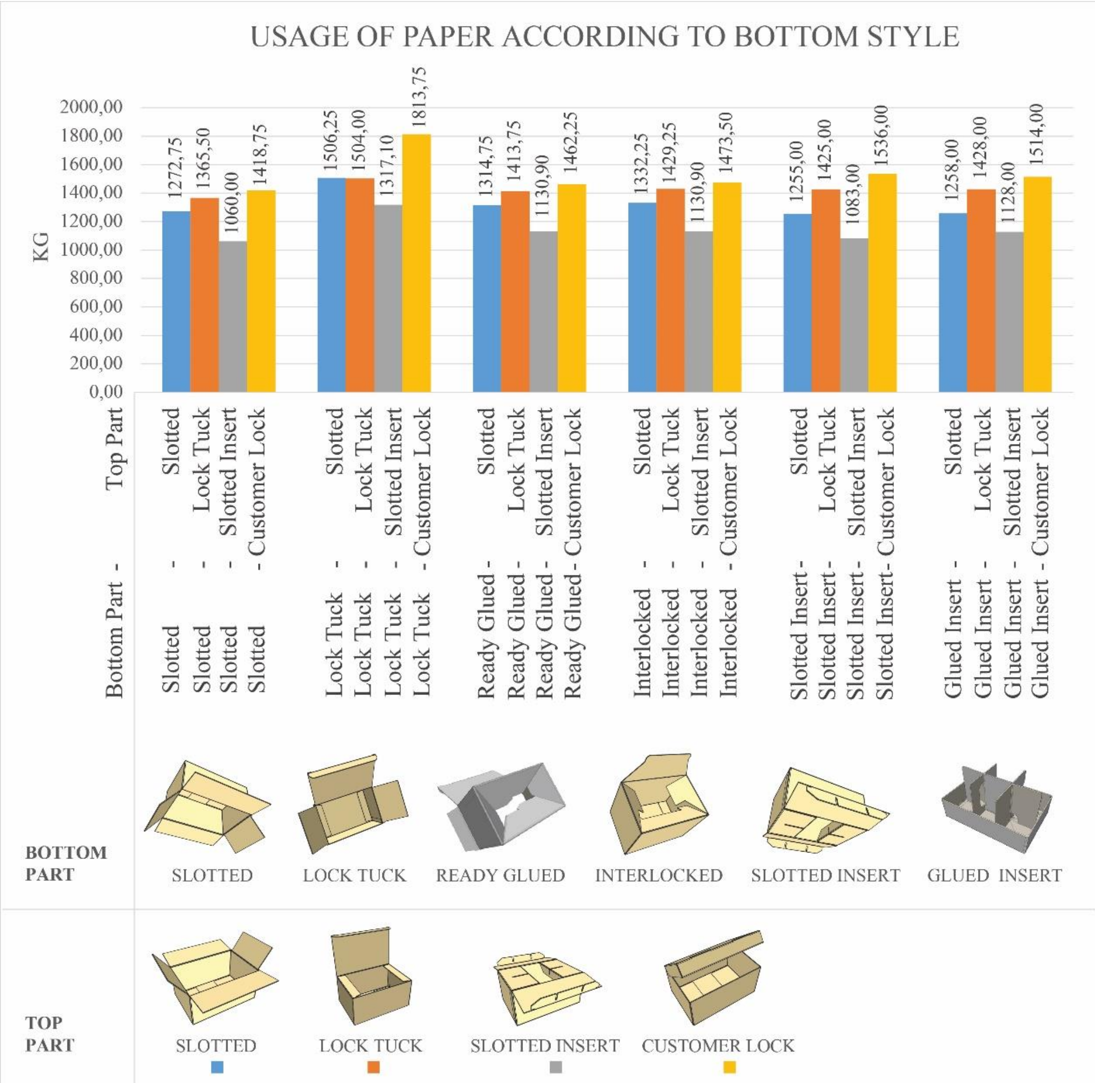


Figure 3.22 : Usage of paper for boxes with the inserts according to their bottom style

On the other hand, aligning according to their top types, overall assumptions can be made better (Figure 3.23). First reflection from the graphic is the low consumption of paper in slotted insert top boxes. This is the difference of the absence of the inserts. To check the validity of this hypothesis, the glued insert bottoms can help. The structure of the glued insert needs more area than the slotted, the results shows slightly lower according to the extra insert ones, however much higher than slotted insert boxes. This also relevant to the shape of the product which is packages, as it’s mentioned before. The glued insert requires full protection until top, while the slotted insert top provides the glasses’ touching each other. Another prominent point in the graphic the high usage of paper in lock tucks. The design of them, which ensures the bottom not to make curvature under the pressure of the products, also increase the paper usage as expected. Another high result again comes from the full lid boxes, customer locks. Double wall and the full lid emerge extra paper usage. Looking at these high and low points in weight of paper, the similarities between the strength and paper usage can be seen. To verify the correlation, another graphic will be drawn.

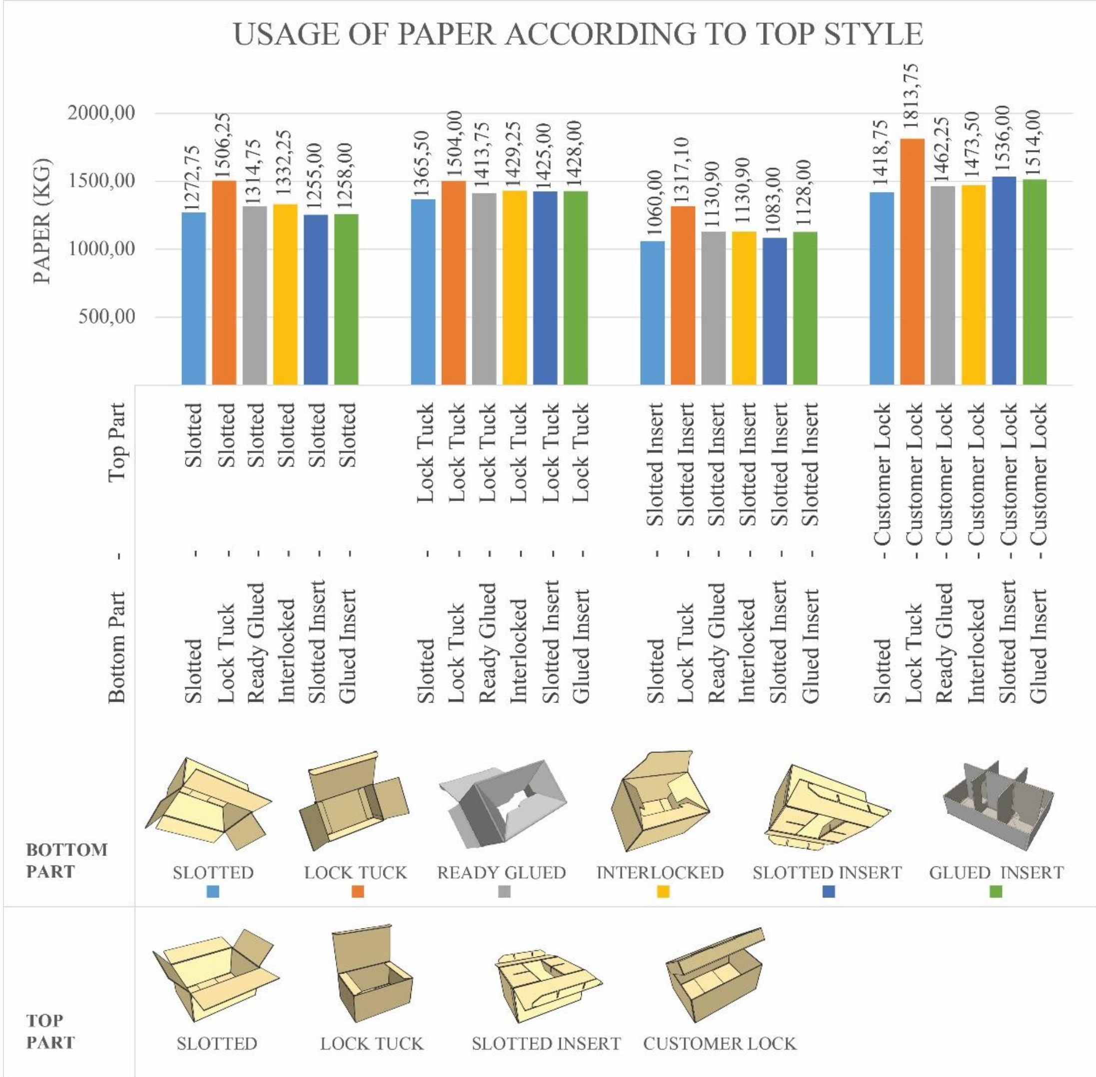


Figure 3.23 : Usage of paper for boxes with the inserts according to their top style.

Waste percentages are given in the graphic (Figure 3.24) with the paper and glue consumption which shows that, there isn't a direct relationship. While looking at the waste percentages, to draw a logical sense, the nesting design of the diecuts should be examined. Thus the diecuts of designs having highest and lowest waste percentages are chosen as; Lock Tuck – Customer Lock and Glued Insert – Customer Lock as highest percent, Slotted – Slotted and Slotted – Slotted Insert as lowest percent. The waste parts can be discriminated by looking at grey dyed areas (Figure 3.25). Looking at their shapes, it is clearly seen that straight and flat designs emerge a fit diecut, while the customer lock design creates void areas resulting high waste percentages. On the other hand, judging by its shape isn't the right approach. The nesting of the Lock Tuck – Lock Tuck below, even it has a twisted shape, their nesting results an intimate order. As a result, Lock Tuck – Lock Tuck gives lower waste percentage, only losing efficiency from the left and the right sides of the diecut (Figure 3.26).

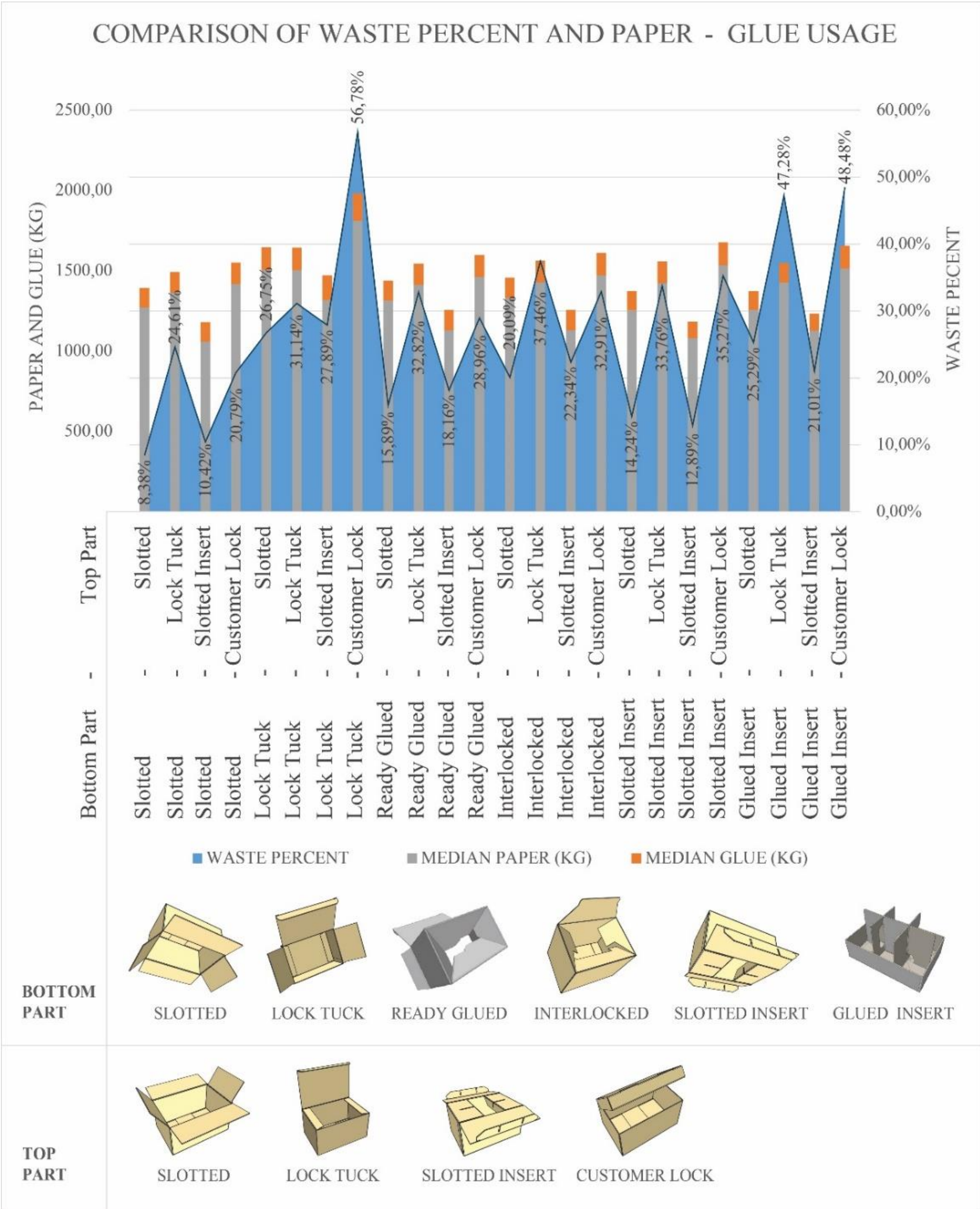


Figure 3.24 : The comparison graphic of waste percent and paper and glue usage of boxes with the inserts.

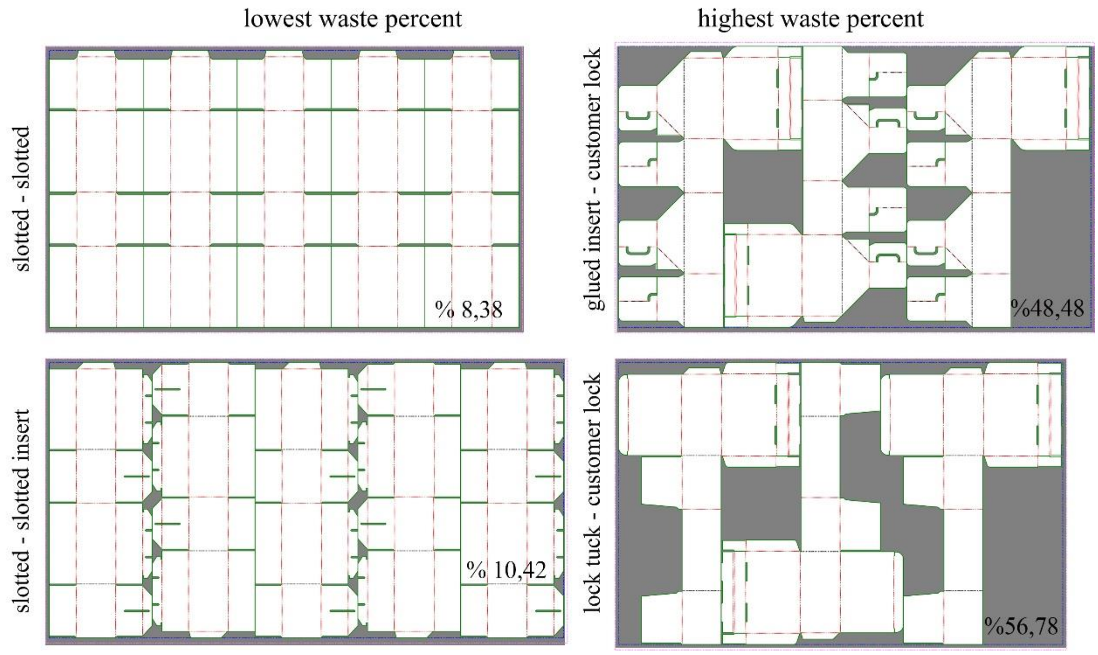


Figure 3.25 : Two lowest waste percent designs and two highest waste percent designs' diecuts.

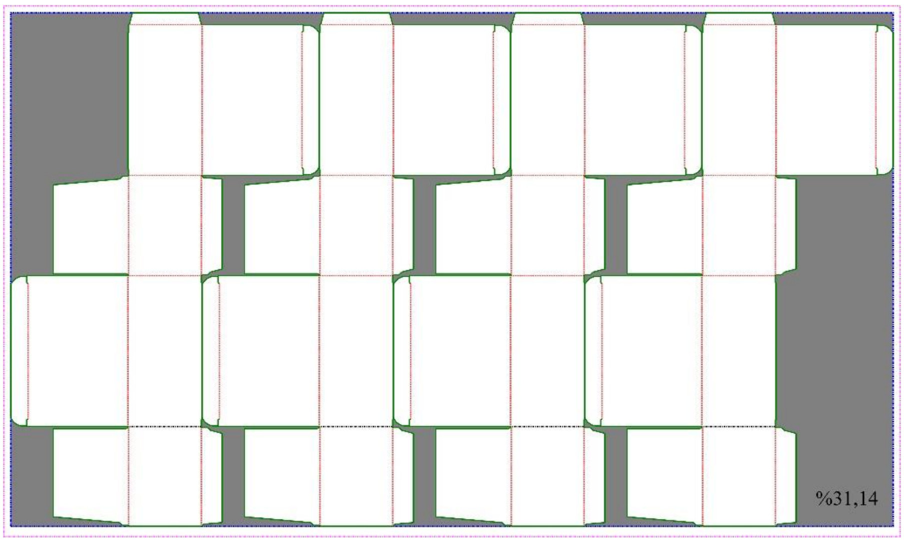


Figure 3.26 : The diecut of Lock Tuck bottom – Lock Tuck top design.

The correlation graphic about the total kg and waste percentage (Figure 3.27) draws a linear line, however judging by this graphic may be improper as the waste areas and percents depends on the diecuts' nesting, as explained before. On the other hand, if this doesn't require fortifying for the product, keeping away from using high weight of paper and glue is the right thing. As predicted before, BCT and weight of the product do have a direct relationship, as seen in the graphic (Figure 3.28).

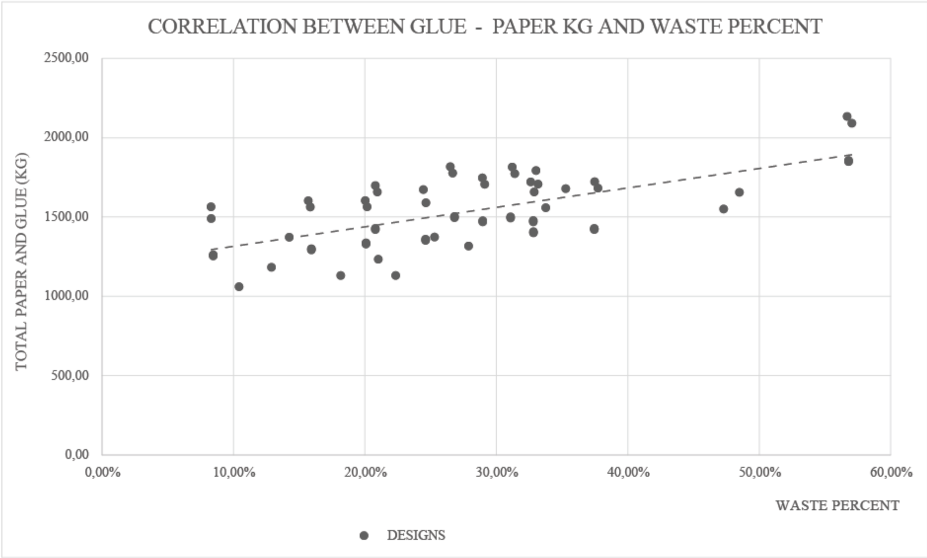


Figure 3.27 : Correlation of total kg and waste percent of all designs with inserts.

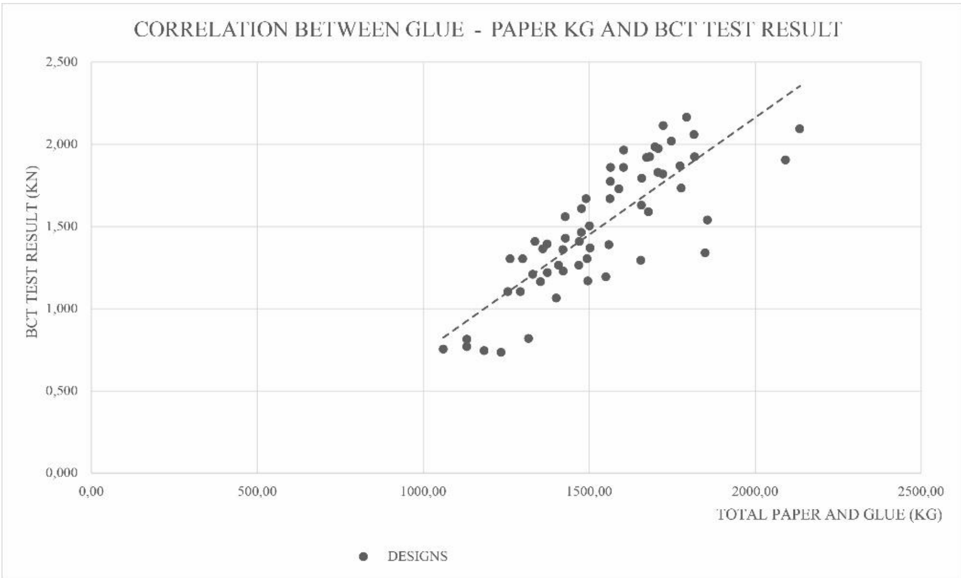


Figure 3.28 : Correlation of total kg and Box Compression Test results of all designs with inserts.

4. CONCLUSIONS

4.1 Introduction

The researcher executes the research on 24 different design styles with both automatic and slotted inserts made with E and B flute materials in total 60 packages, to view and exhibit that the decision on the design type plays a significant role on the outcomes. The data of the research is first inspected in four topic, which are; cost, strength, speed and environment. Although the choise and the order of importance of these four information depends on the customer itself, the converters mostly look for high strength and fast production. Here the designs are evaluated and interpreted with these four facts as equal.

The research dwells on tube style boxes with two different inserts, the results of these examples are not for generalizing the designs, but indicating the process with their hows and whys. Therefore, the research is a guide for what is possible for optimization in design step. The guide can be altered for different design brief or problem to keep track of the outcomes.

4.2 Conclusion and Guideline

Depending on the results of the specific research, some key points are aimed to find for the designers and customers. These key points are categorized again in four topics to make it easy to follow and then summarized (Figure 4.1).

To optimize the strength;

Where you need to fortify the box or the insert and if changing the design of the box or insert is not suitable or possible, using a corrugated which has a higher take up factor is the best and fastest solution. However, always check the necessity for using the durable one. For instance; using B flute instead of E flute for insert or box, changes also dimensions for both in and out of the box. If there is an important issue on restrictions; such as secondary package dimensions, pallet sizes, manufacturing capacities or already produced prints and parts, the situtation have to be taken into account.

If both are possible, automatic and slotted inserts are good solutions in multipacks, but choosing one of them can be tricky, as both of them have different diecut dimensions and setting processes. Observing their costs and adequate strength, and directly choosing the slotted inserts can guide the designer wrongly, as not all the slotted inserts can be set by the machine, thus resulting a waste of time. Automatic inserts are faster and more durable with a little higher cost. As always, the designer have to think about the production, filling and transporting processes.

Double walls especially in vertical flute direction and parallel to the height, help the box or inserts to gain high strength. For special occasions adapting them in boxes or inserts are advantageous, if also possible for the production line.

Undivided surfaces always have an advantage over the others. Without making unsuitable diecuts, and causing the dimensions getting too high, try to create surfaces which covers entirely. The crease lines, cuts and perforated lines which don't have a support, decrease the strength of the structure. This is also same for diagonal creases and perforated lines for auto erect boxes.

To compensate the lost strength because of a divided surface, using manufacturer's joint or increasing corner structures help. These are all supporting structures which give durability to boxes or inserts. Divided from corner or divided from middle of the surface both decrease the solidity however, leaving corners as one piece, and dividing from the surface in middle is much more better for strength.

Wider area generally means higher strength. This comes from the results of the research however, bigger area also means high cost and in some situations higher waste percentage. Keeping this information in mind and using it wisely helps to decide in some occasions between the designs.

Acknowledging your product to be packed, helps the beginning, the evalution and the result of the designs. Every decisions are taken for the product itself with its environment and conditions. Whenever an indecision occurs, the solution is in the product. For instance, the adequate strength is determined by the product and its transportation, overall apperance and dimensions of the package depend on the product's shape. This is also valid for environment, cost and speed topics.

To calculate BCT with the McKee formula use high safe factor, as the formula tends to measure the boxes and inserts a little higher than expected in some cases. To gain more approximate results, more detailed research or tests should be used as the formula neglect many criterias. While using the formula in full form also helps, the affect of the height shouldn't be ignored.

For a cost effective product;

Cost topic can change according to the manufacturer's policies of course, cost efficiency is important among the competitive sector, thus companies try to make new arrangements with other companies. Also companies can make agreements annually thus the cost effective become more significant for the converter. Checking the raw materials like paper and glue industry and following the technology bring advantage to the manufacturer. As it is seen in the results of the research, cost is mostly affected from the consumption of paper and glue.

Looking at the results of the cost and the correlation charts of strength and cost, it can be said that there is a connection however, it is also clear that cost effective doesn't mean low strength. Again by knowing the manufacturing process and the machine capacity, it is possible to produce a sturdy package without a high price. Moreover, the cost and strength increment angle is not same, which means, a little higher cost results much more durable product.

Without designing the final package it is hard to calculate the price of the production. As all the details are also an element of this calculation, one mm or a special paper choise, extra visual effects change the result entirely. Normally structural designer doesn't have to deal with some of these details. Still, every revision should be taken into account by the designer, if there is a possibility of change of the diecut dimensions.

For a faster manufacturing;

Rapid production is always desired by customer, in this rush, the designer makes the design in a very short time. However the operation in the production is another matter as there are restrictions of the machines and unfeasibilities of processes. The designers always have to find possible ways with the help of the engineers, but in this restricted times, they should find the most feasible and fastest ones. It is achievable only for the designer who knows the production line and the machines which will be used in the manufacturing of the package. The capacity and the restrictions of the factory and its machines reveal the manufacturing time, while the customer's facilities and resources reveal filling and setting time of the package.

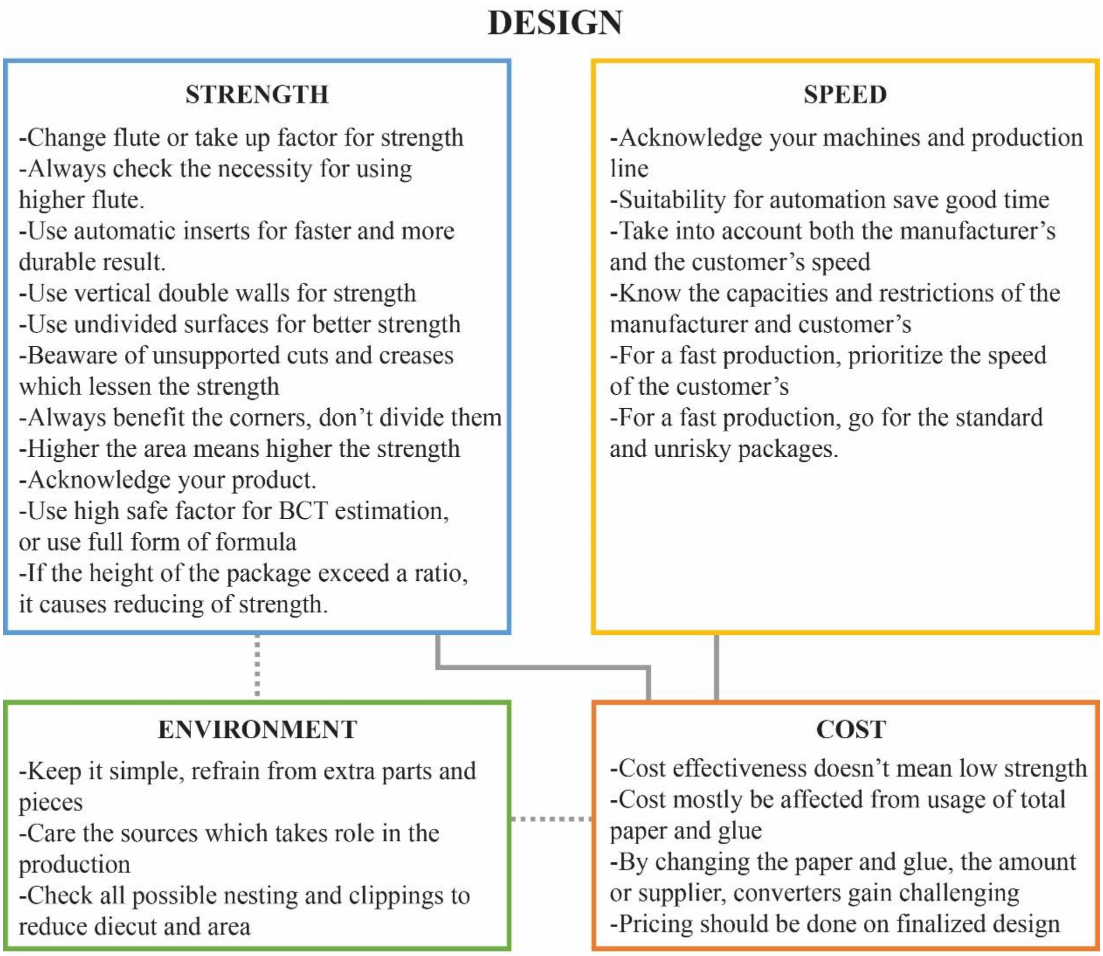


Figure 4.1 : Summary of the conclusion an their relations; line for direct proportion and dotted line for inverse proportion

If any manual operation is included in the process, removing and making possible machine adaptations gains good time nearly for every step. Especially for high order units, changing the designs toward to auto erect boxes such as ready glued boxes, glued inserts and trays is the right approach. Even the cost of these boxes are higher, this becomes a low priority under rapid demand.

Similar to the knowledge of the manufacturing, being aware of the customer is also a need as it has been mentioned before. The designer have to take a comprehensive brief from the customer, for instance; customer glued boxes are complicated designs, both designing and testing processes takes time. Generally they have to be produced as trial production for machine setting, but once the setting is done, the filling goes smoothly and fast.

Standardization of the packages and production is another key for acceleration in manufacturing. Possible encounters and arrangements will be known by both the designer, engineers and the employees. In case of a fast demand, persuasion on customers in these packages will clear any unexpected misfortunes.

The result of the research reveals that manual filling and setting times takes more time than the manufacturing time. Correspondingly, without going too far from a standard production for converter's, giving priority to the customer's fast production is more significant. Again, the urgency leaves the other criterias less conspicious.

For an environmentally friend production;

All of the produced packages become a burden for the environment, thus disposal of all the unnecessary and extra parts, extensions and pieces should be the designer's aim. Apart from the amount of the glue and paper, the time and the energy also depends on the volume of the production, keeping simple and away from the risky packages decrease the waste of the sources in many ways.

Waste percentage and volume highly depends on the nesting and arrangement of the diecut design. Not always the design of the diecut managed by the designer, that's why possible alternative arrays or clippings to decrease the diecut dimension should be thought again after the design is approved by the customer. This can be occur for suitability of manufacturing line or paper sizes or removing blank areas, increasing flaps and at the same reducing the waste.

Both over and under packaging is a damage for the environment. Finding the optimum design not just for the cost and customer, but also a duty of designer for our world.

To display all these findings on the designs Figure 4.2 highlights the highs and lows in their categorizes. Topics are in color codes; red for cost, blue for strength, yellow for speed and green for environment. The up pointing triangles mean the results are the highest and down pointing triangles display the lowest ones. Thus, the fastest design is glued insert bottom with lock tuck top, while the slowest is slotted bottom with customer lock top. Even the glued insert bottom takes a little more time in converter's plant, the setting and filling is fast by the customer. On the other hand, slotted bottom needs a process with duct tape and an extra insert placing inside the box. Customer lock top also requires time to be adjusted to be locked and closed. The most enduring design is interlocked bottom with customer lock top with an extra insert and glued insert bottom and slotted insert top is the weakest design. Eventhough the self insert boxes are advantageous for cost, speed and environment, extra inserts are strengthening pieces for the boxes. Moreover, the double walls of the box make a difference among the other designs. The unsupported designs are mentioned before that they reduces the durability of the boxes. Thus the disconnecting self inserts become weakness for the design. The slotted bottom and slotted insert top design is both economic and environmental design while the lock tuck bottom with customer lock top is the most expensive design with high consumption of resources. Both these outcomes are affected from paper and glue usage with the box units per diecut. Thus the results of them shows the same designs for the high and the low ones for environment and cost. Slotted insert top enables a smaller area while the lock tuck bottom and customer lock becomes larger with extra insert needing.

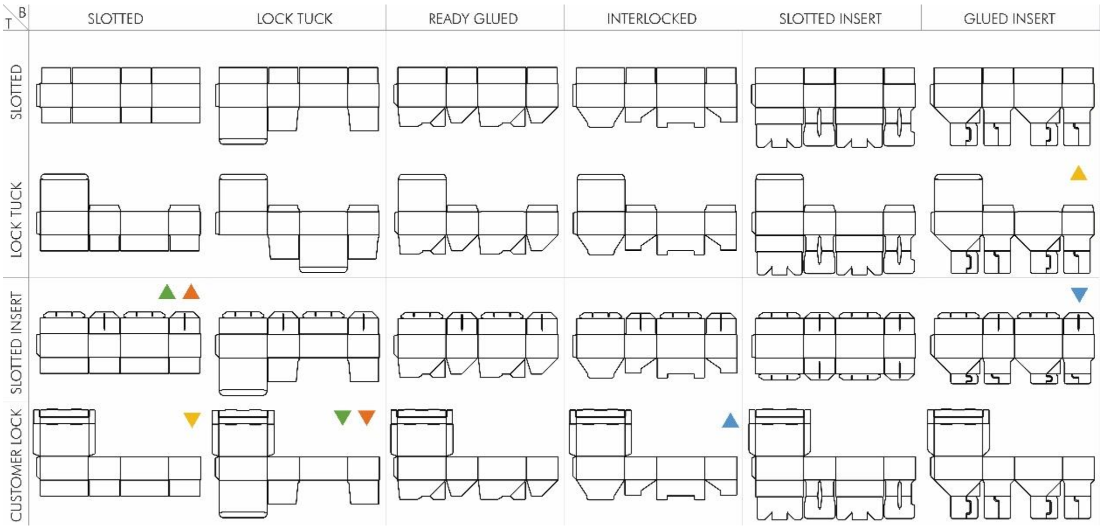


Figure 4.2 : Highest and lowest designs in strength, cost, environment and speed. Designs also include their inserts.

This study is tried to be useful for the customers and package designers in their projects. The dissertation demonstrates that packages having duties of containing, protecting and promoting. Moreover they are designed objects and entail a series of important design decisions through its production. With the need of the package, the design and manufacturing of the package take place and this process have so many points which interact with each other. These points generate the cost and the duration, and it becomes significant to control and develop them. Without effecting the desired strength, to change and make decisions on the design, it guides the customer and designer when a contradiction occurs. With all this guiding and optimization possibilities, the design can be done with less source and waste, which maybe is the most critical factor for our world. As a result, this research has brought the package designing and technical data together with their findings.

The research can also be useful for other sectors whose material is corrugated cardboard such as; exhibition, furniture, lightining, transporting, stage design and visual art along with the packaging sector. Furthermore, corrugated cardboard material is known as one of the most environmentally friendly material with lightweight and insulating construction, therefore other sectors can also find new opportunities in it. For instance, insulator and padding material for civil engineering, architecture and interior design. Especially the findings on strength and differentiation of the designs can raise the awareness of the behaviour of corrugated cardboard and creating new designs.

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APPENDICES

APPENDIX A: Designs
APPENDIX B: Samples

APPENDIX A DESIGNS

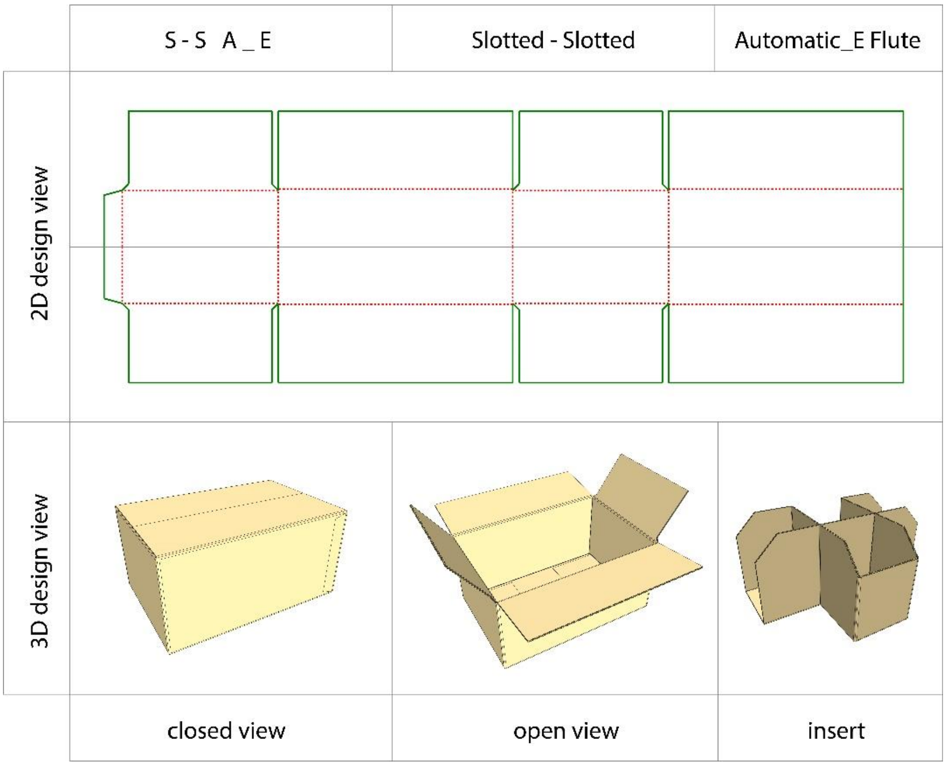


Figure A.1 : S-S A_E Slotted – Slotted _ Automatic Insert – E Flute

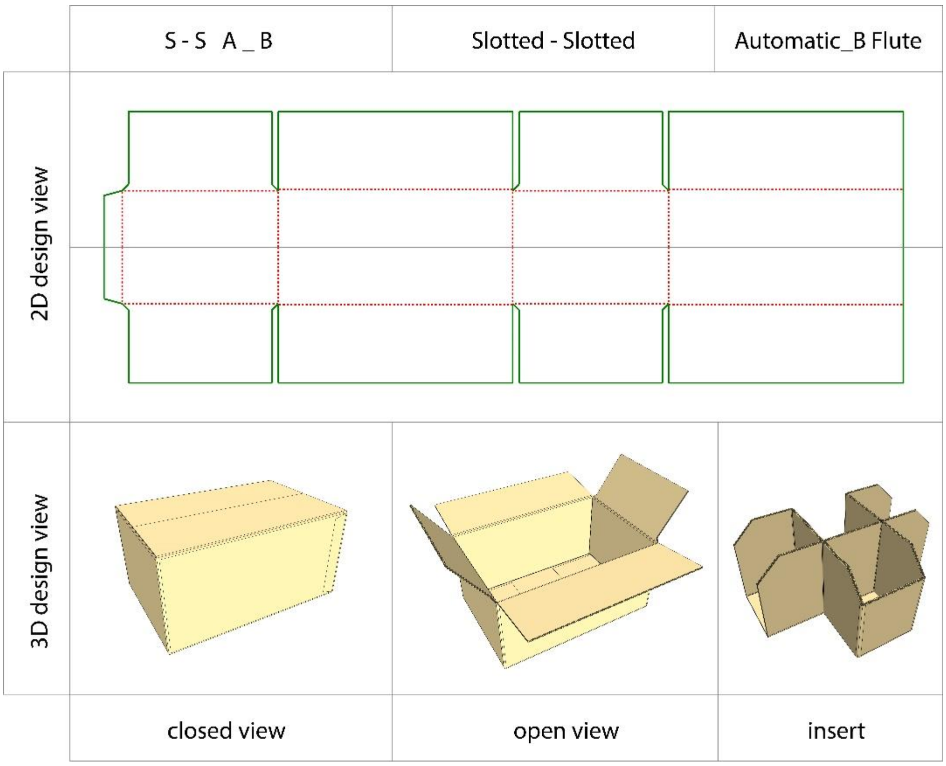


Figure A.2 : S-S A_B Slotted – Slotted _ Automatic Insert – B Flute

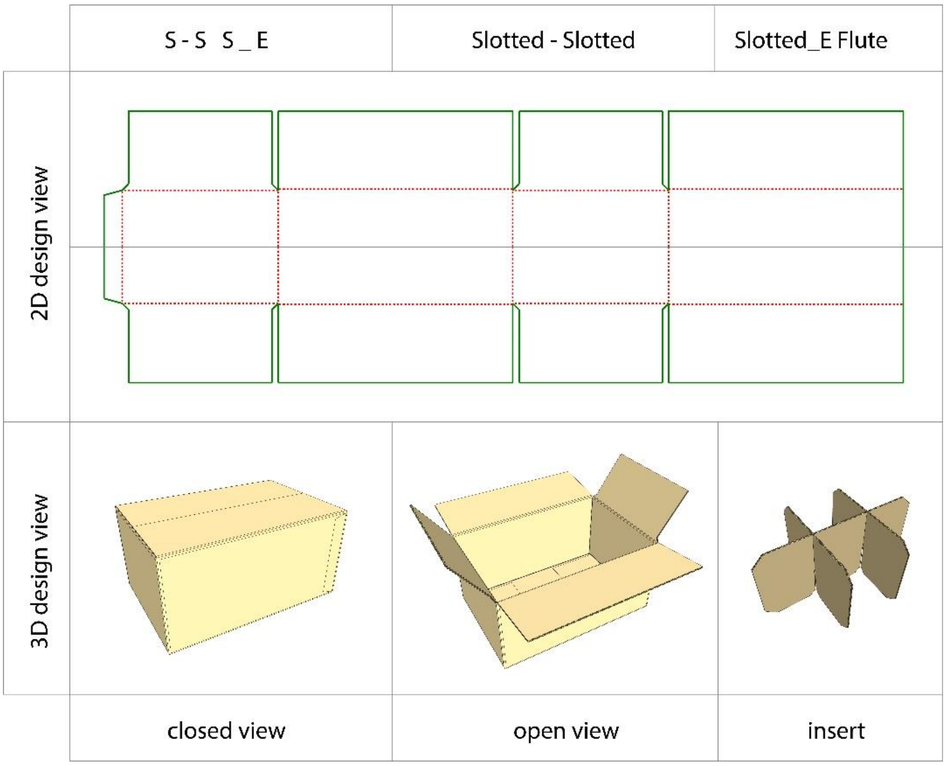


Figure A.3 : S-S S_E Slotted – Slotted _ Slotted Insert – E Flute

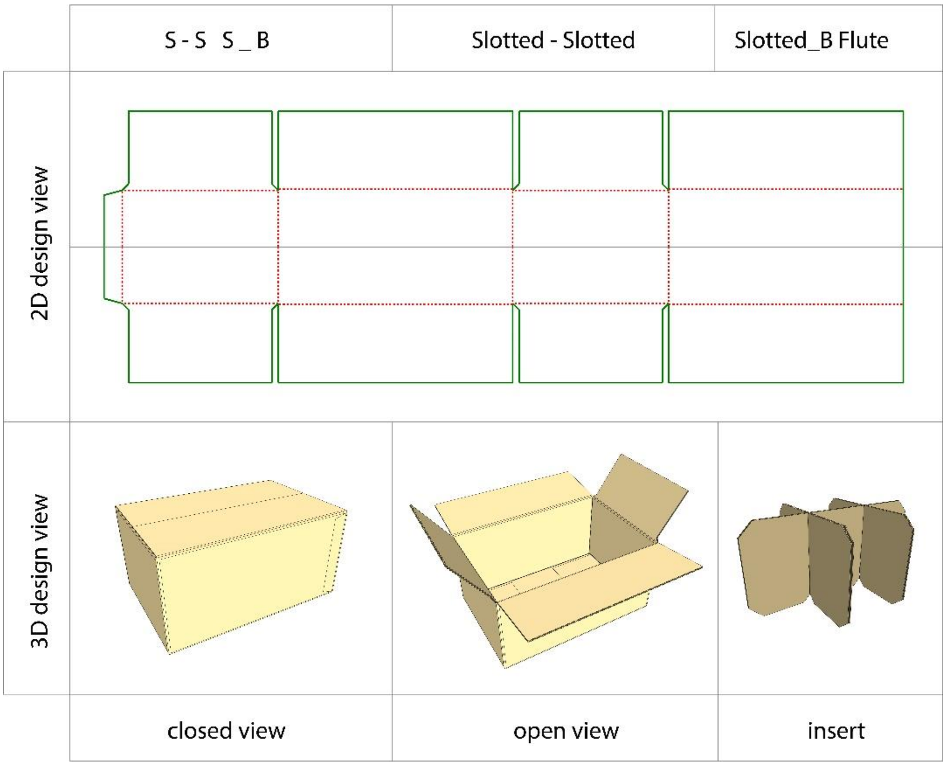


Figure A.4 : S-S S_B Slotted – Slotted _ Slotted Insert – B Flute

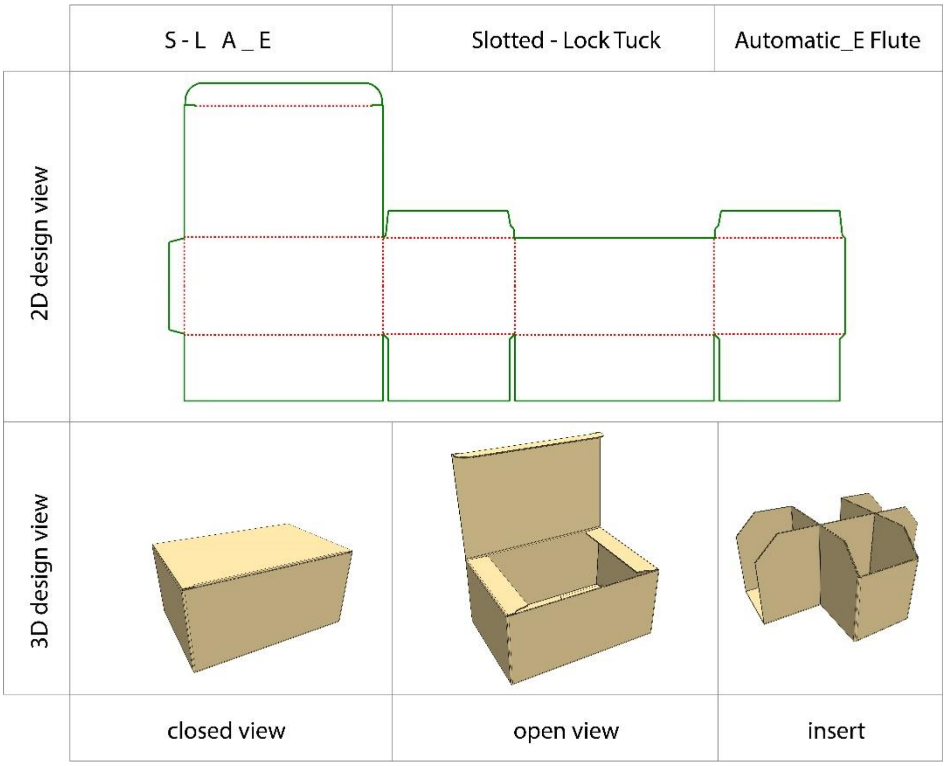
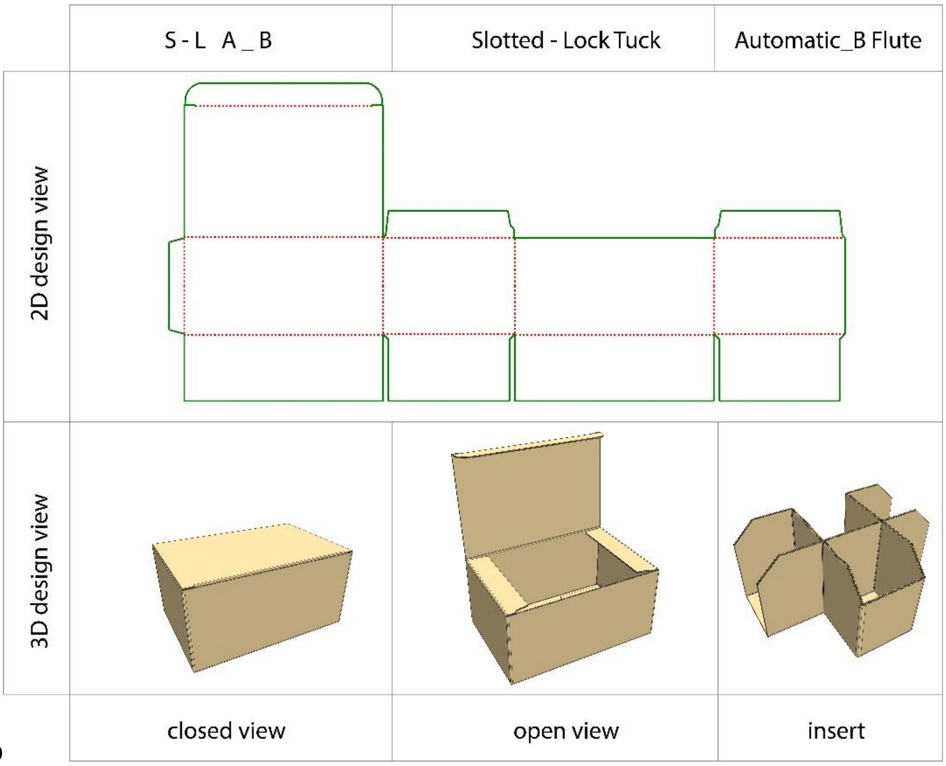


Figure A.5 : S-L A_E Slotted – Lock Tuck _ Automatic Insert – E Flute



no

Figure A.6 : S-L-A_B Slotted – Lock Tuck _ Automatic Insert – E Flute

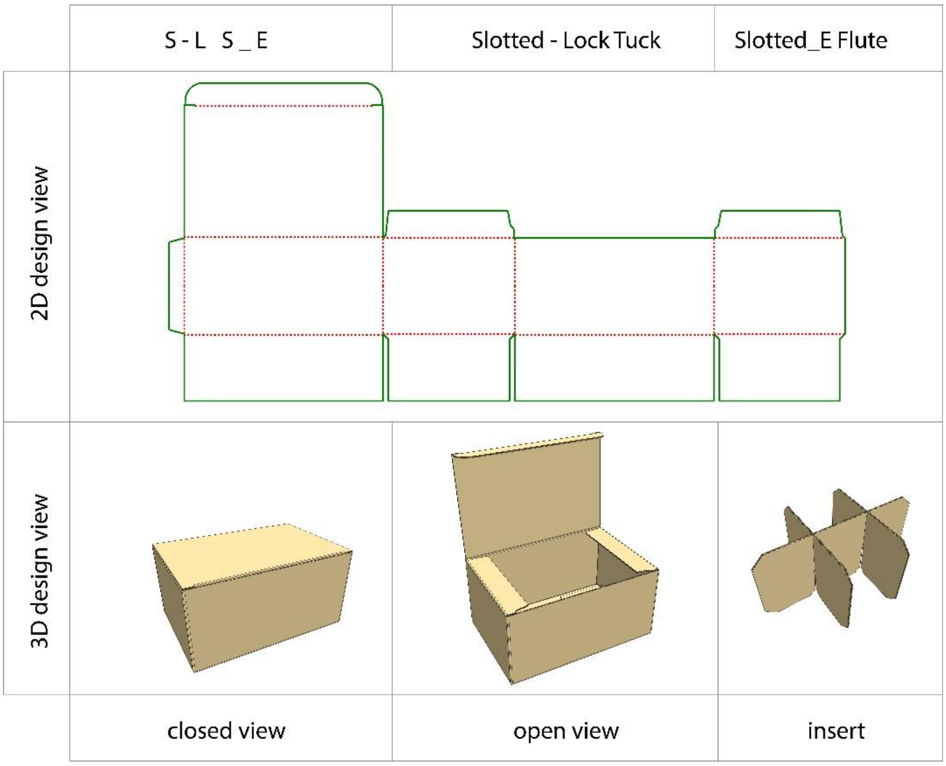


Figure A.7 : S-L S_E Slotted – Lock Tuck _ Slotted Insert – E Flute

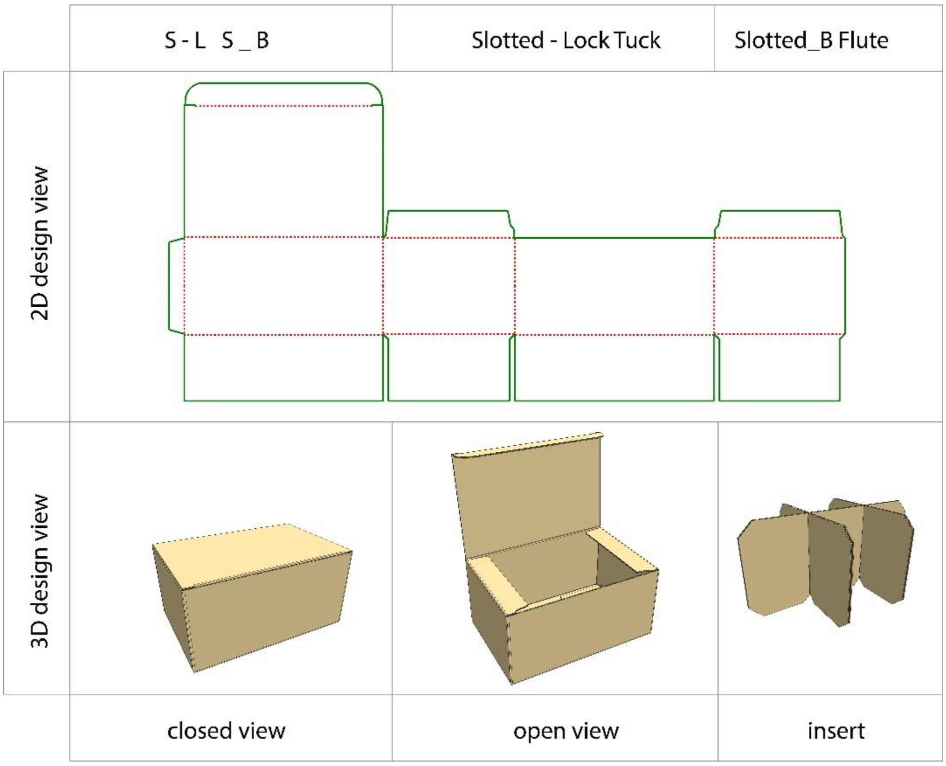


Figure A.8 : S-L S_B Slotted – Lock Tuck _ Slotted Insert – B Flute

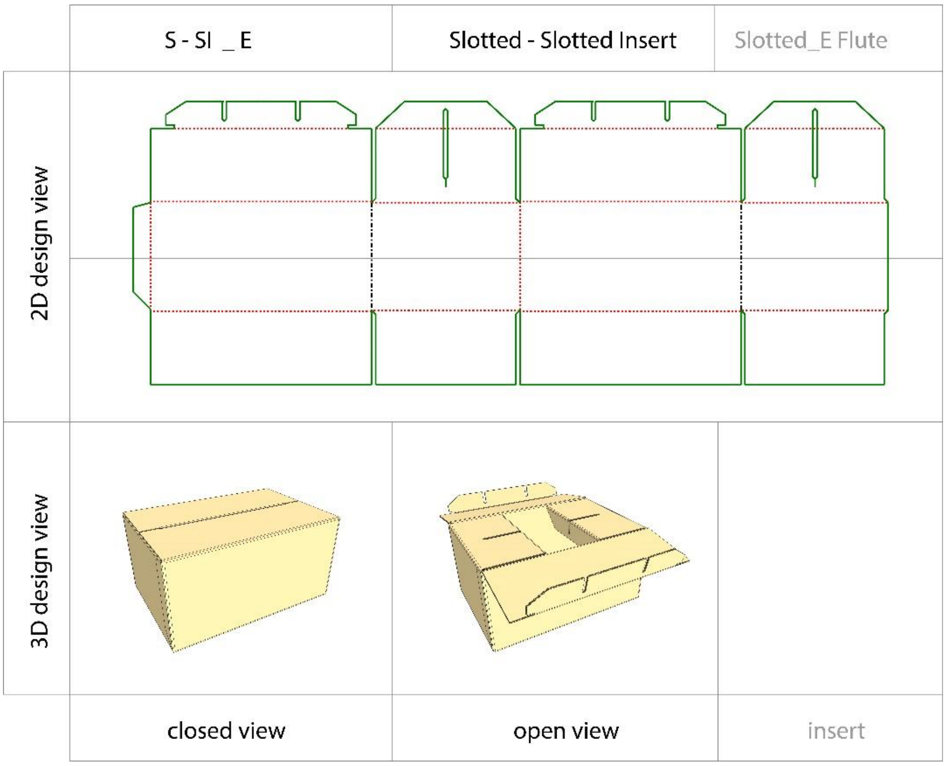


Figure A.9 : S-SI_E Slotted – Slotted Insert _ E Flute

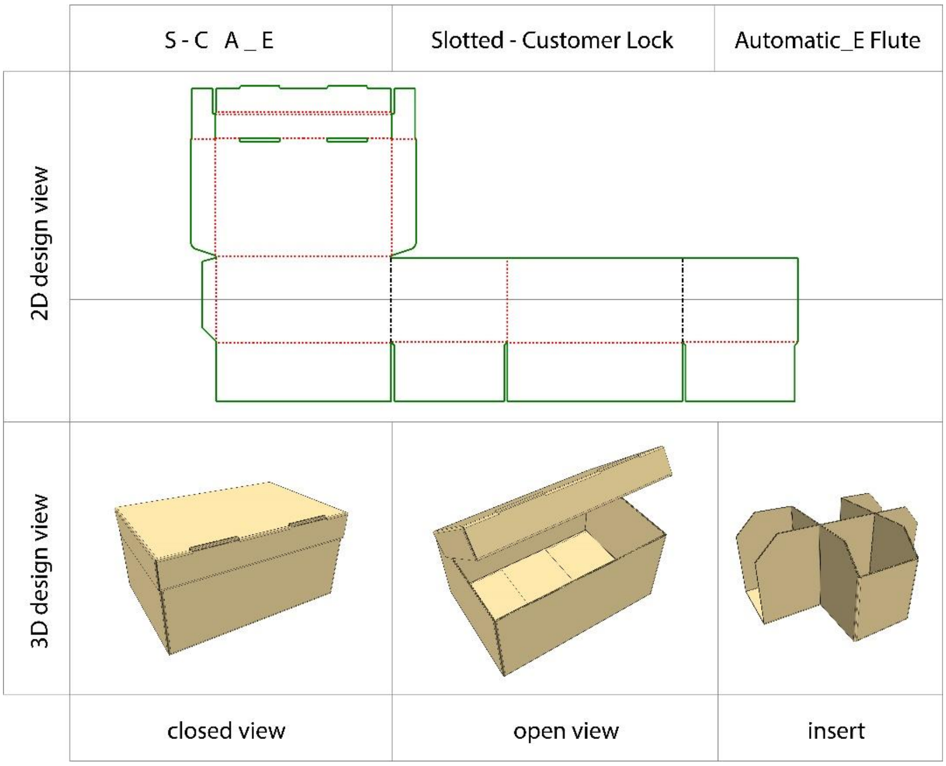


Figure A.10 : S-C A_E Slotted – Customer Lock _ Automatic Insert – E Flute

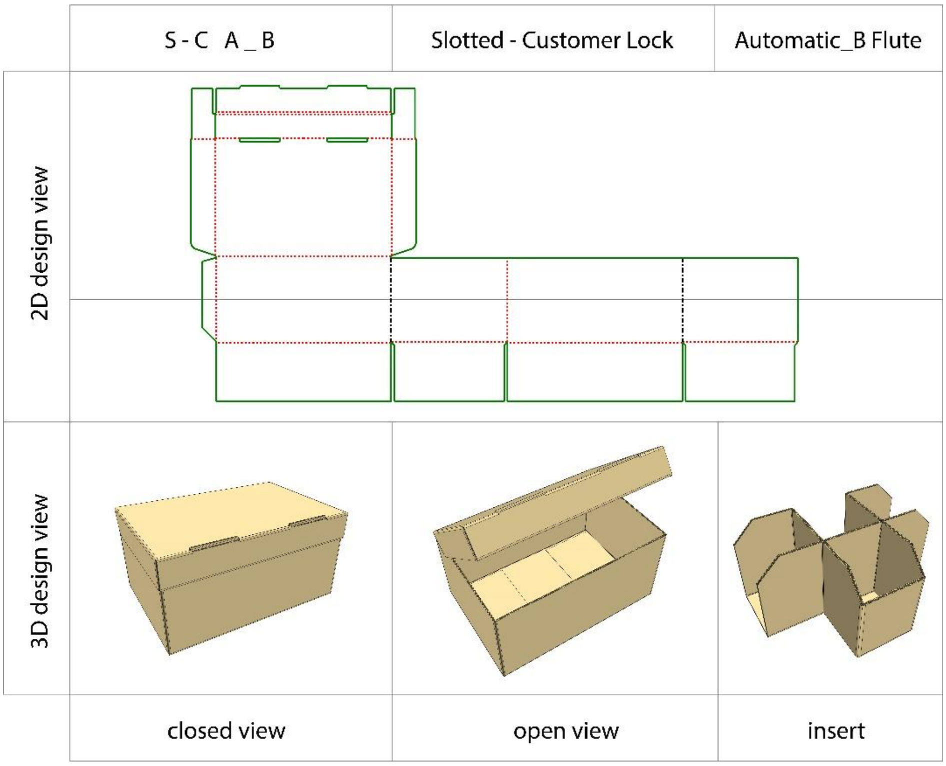


Figure A.11 : S-C A_B Slotted – Customer Lock _ Automatic Insert – B Flute

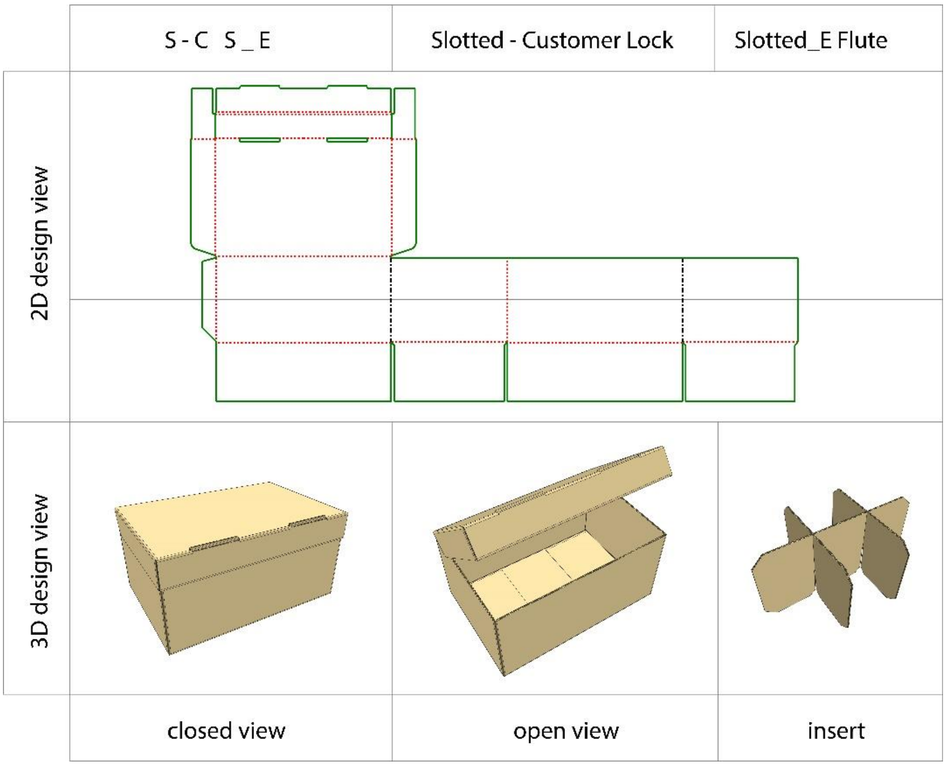


Figure A.12 : S-C S_E Slotted – Customer Lock _ Slotted Insert – E Flute

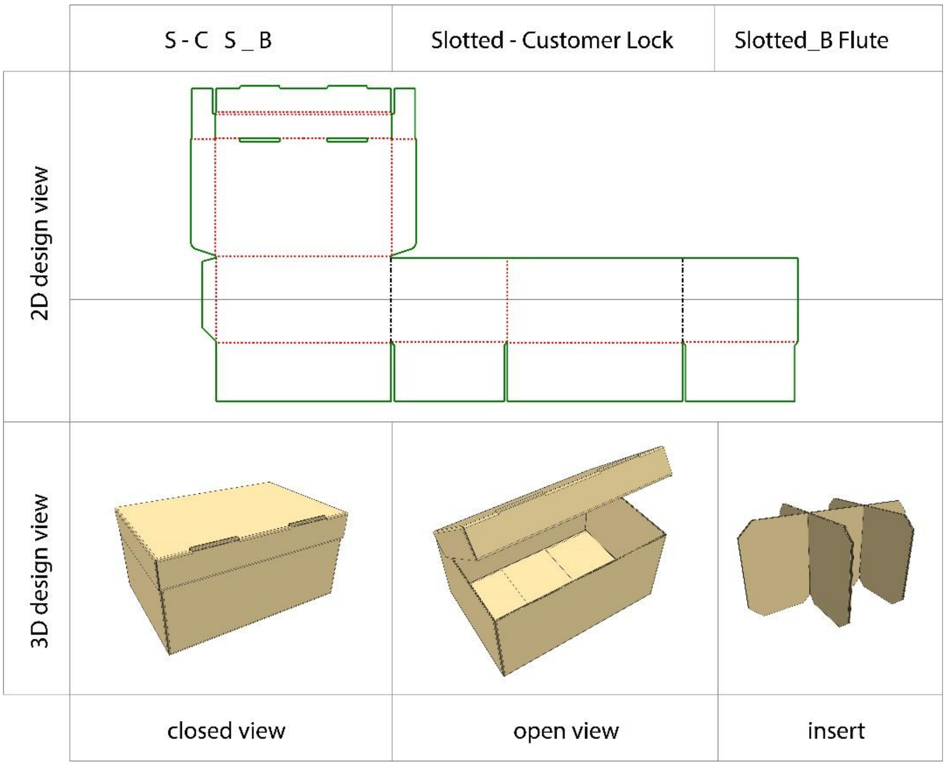


Figure A.13 : S-C S_B Slotted – Customer Lock _ Slotted Insert – B Flute

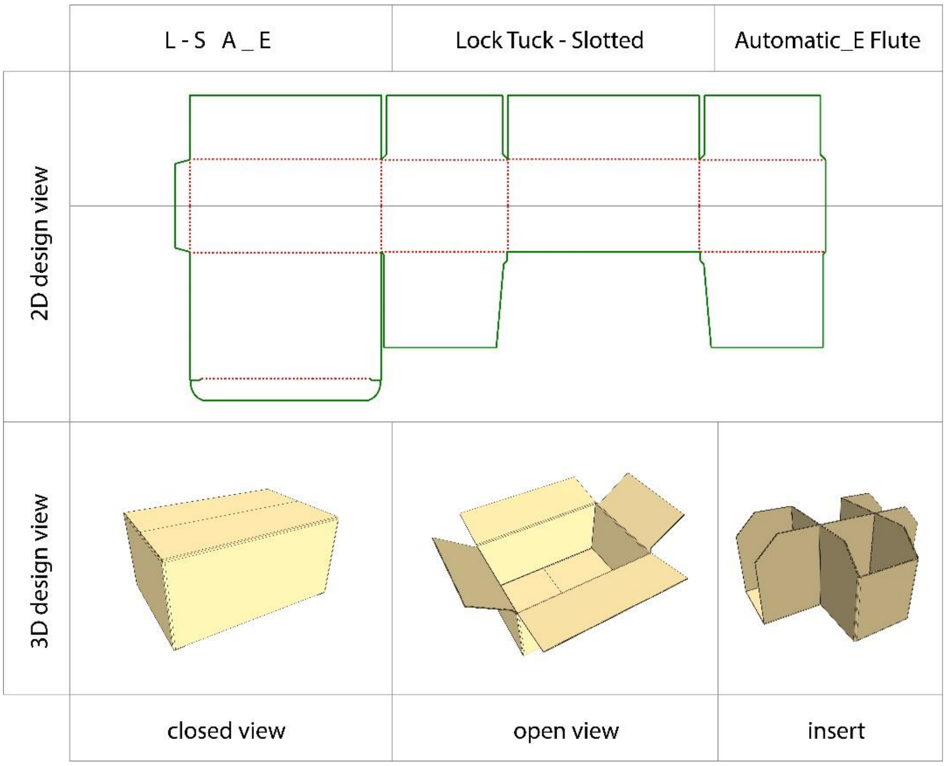


Figure A.14 : L-S A_E Lock Tuck – Slotted _ Automatic Insert E Flute

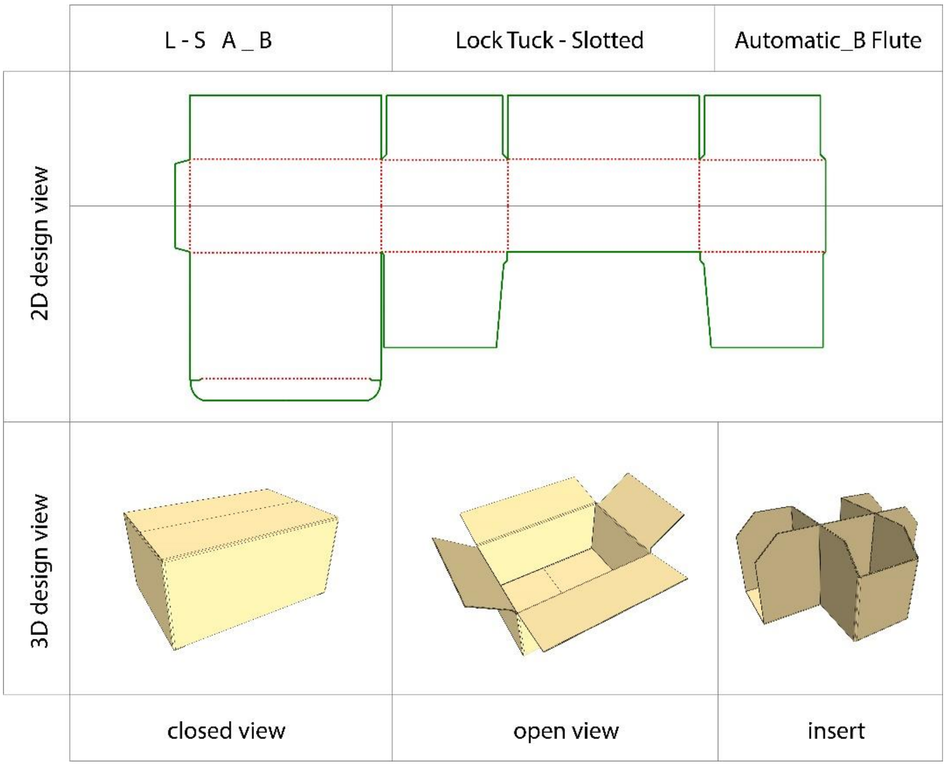


Figure A.15 : L-S A_B Lock Tuck – Slotted _ Automatic Insert B Flute

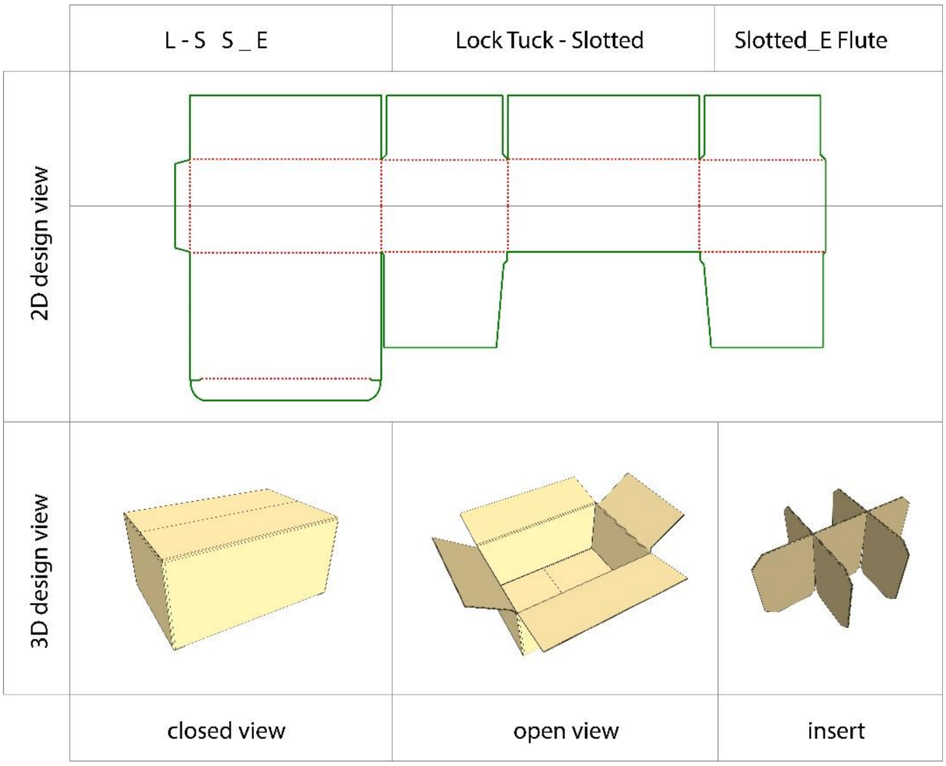


Figure A.16 : L-S S_E Lock Tuck – Slotted _ Slotted Insert E Flute

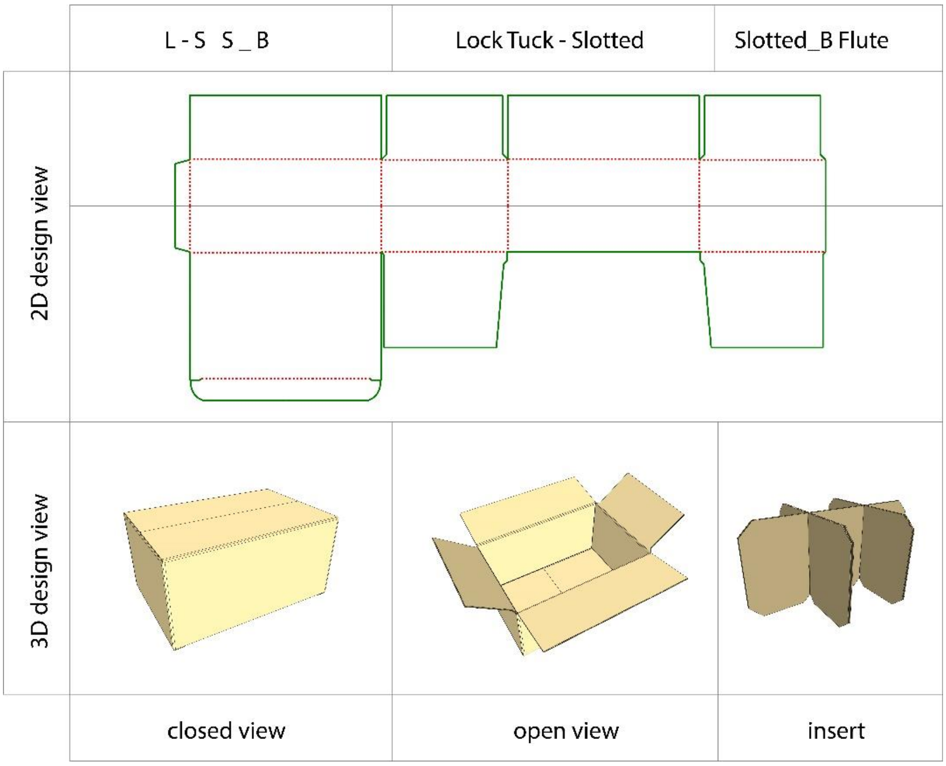


Figure A.17 : L-S S_B Lock Tuck – Slotted _ Slotted Insert B Flute

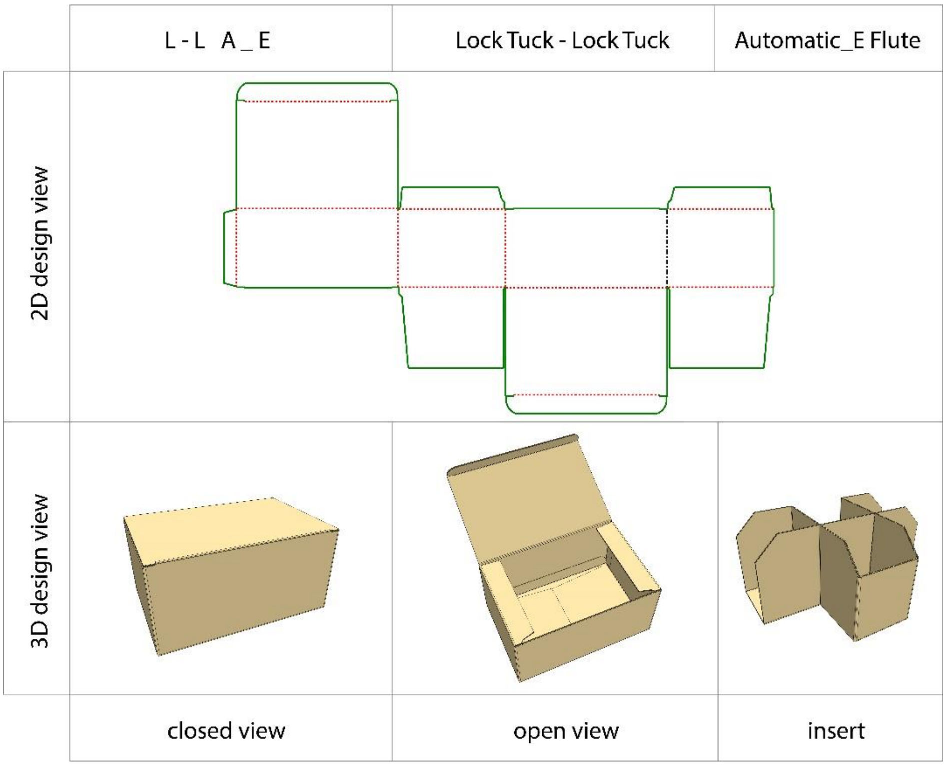


Figure A.18 : L-L A_E Lock Tuck – Lock Tuck _ Automatic Insert E Flute

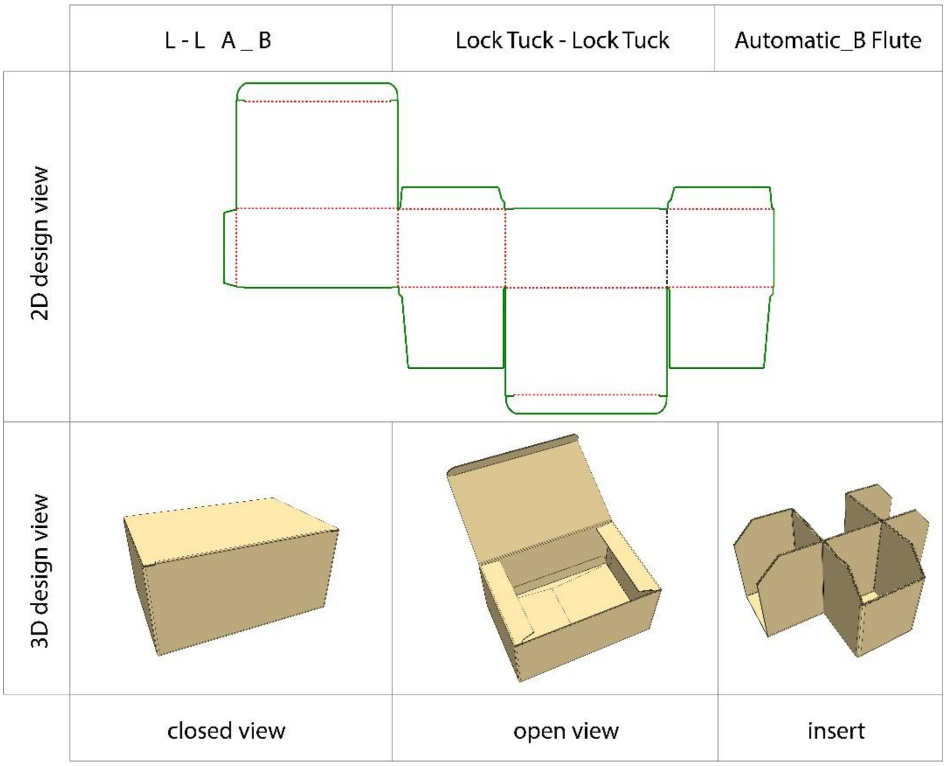


Figure A.19 : L-L A_B Lock Tuck – Lock Tuck _ Automatic Insert B Flute

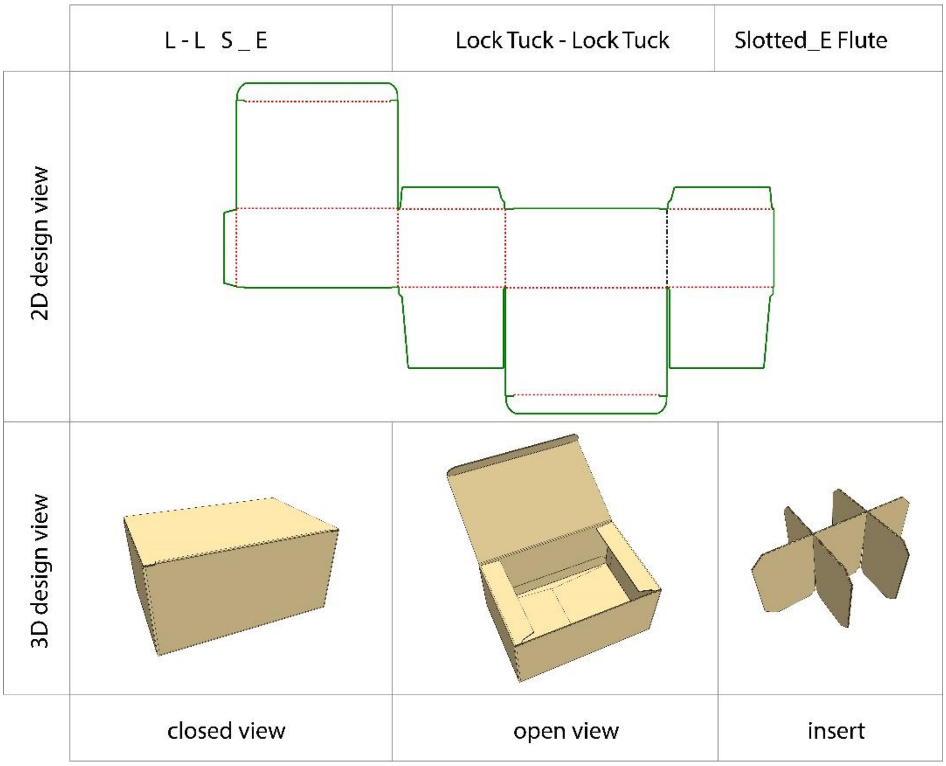


Figure A.20 : L-L S_E Lock Tuck – Lock Tuck _ Slotted Insert E Flute

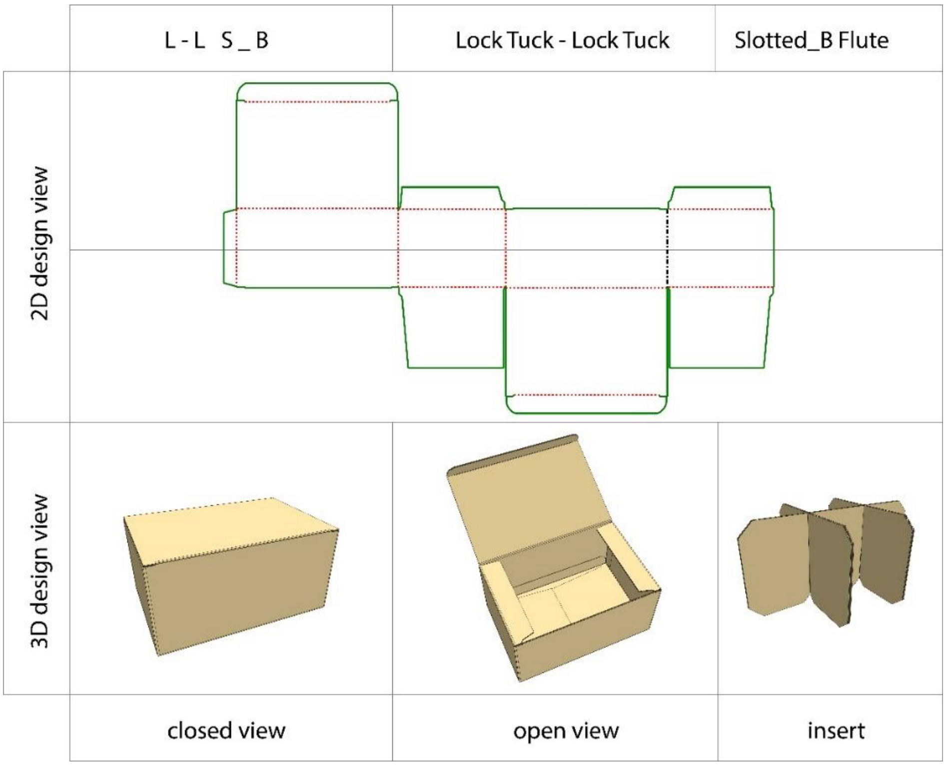


Figure A.21 : L-L S_B Lock Tuck – Lock Tuck _ Slotted Insert B Flute

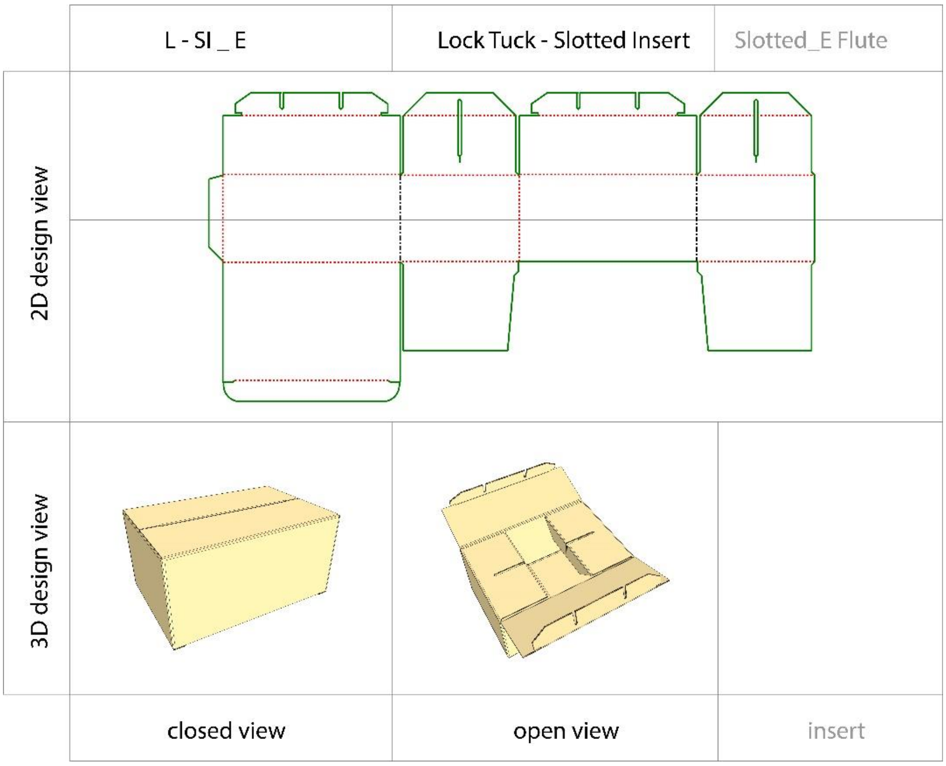


Figure A.22 : L-SI_E Lock Tuck – Slotted Insert _ E Flute

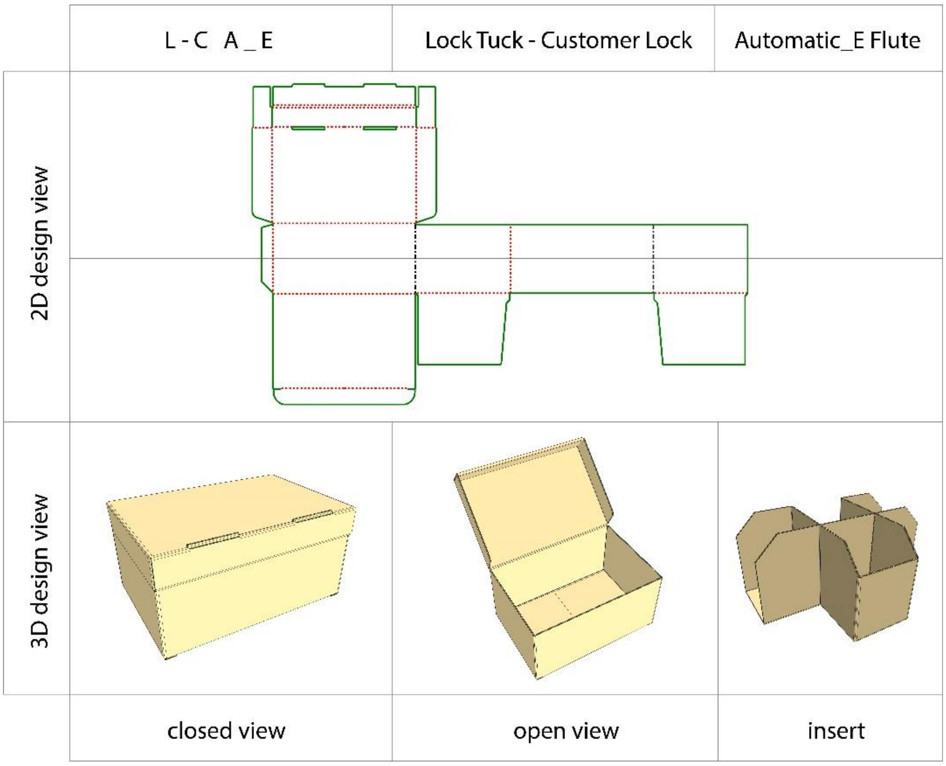


Figure A.23 : L-C A_E Lock Tuck – Customer Lock _ Automatic Insert E Flute

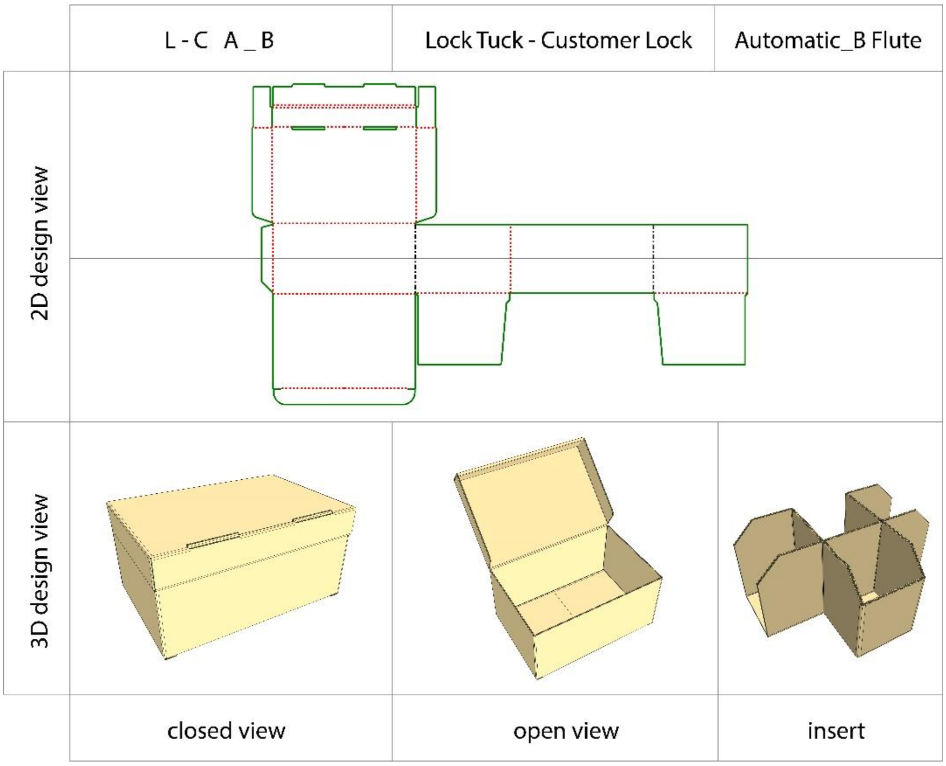


Figure A.24 : L-C A_B Lock Tuck – Customer Lock _ Automatic Insert B Flute

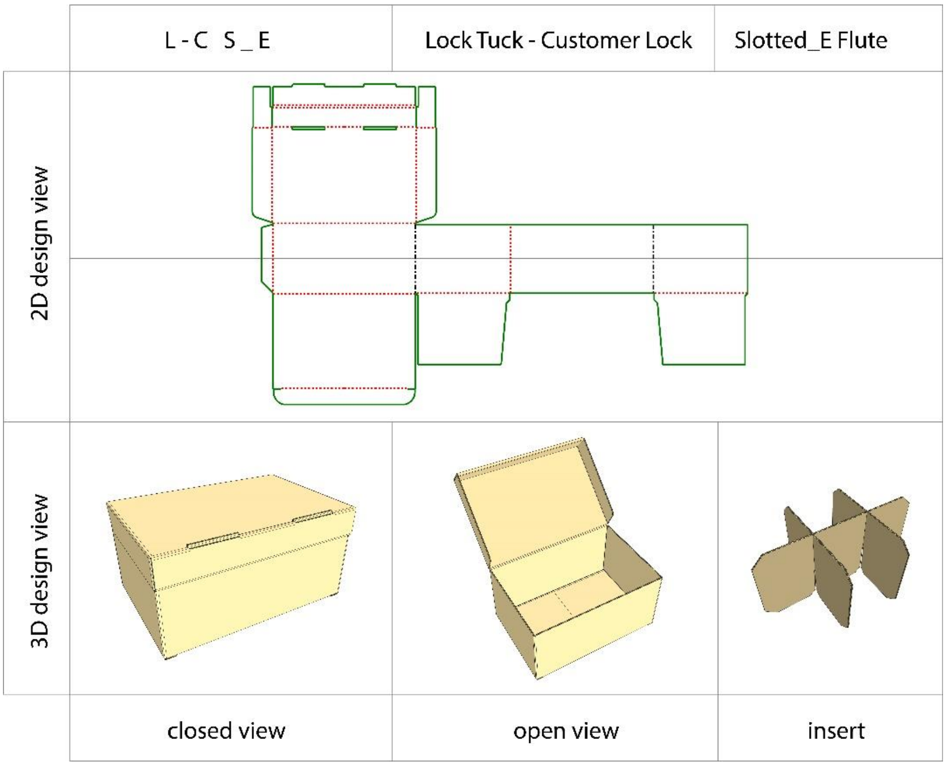


Figure A.25 : L-C S_E Lock Tuck – Customer Lock _ Slotted Insert E Flute

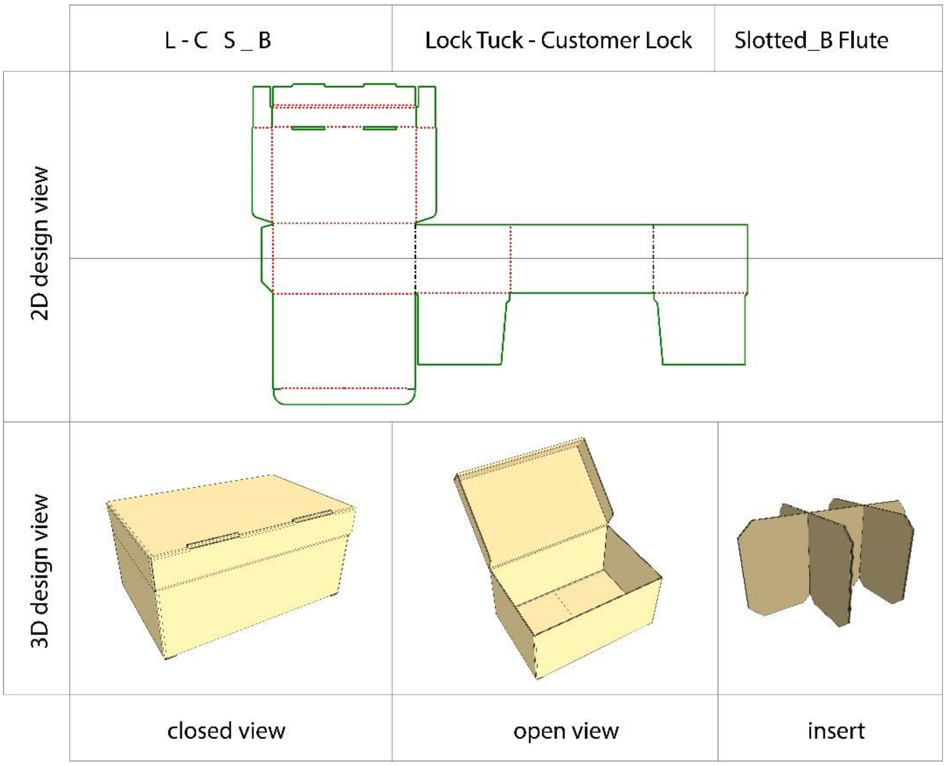


Figure A.26 : L-C S_B Lock Tuck – Customer Lock _ Slotted Insert B Flute

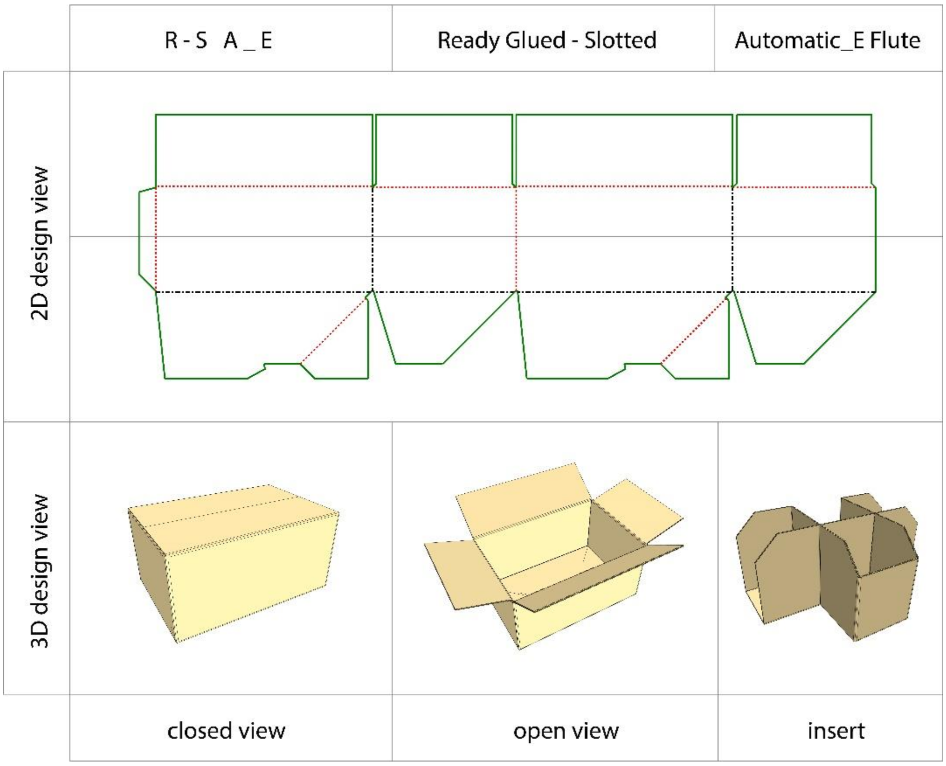


Figure A.27 : R-S A_E Ready Glued – Slotted _ Automatic Insert E Flute

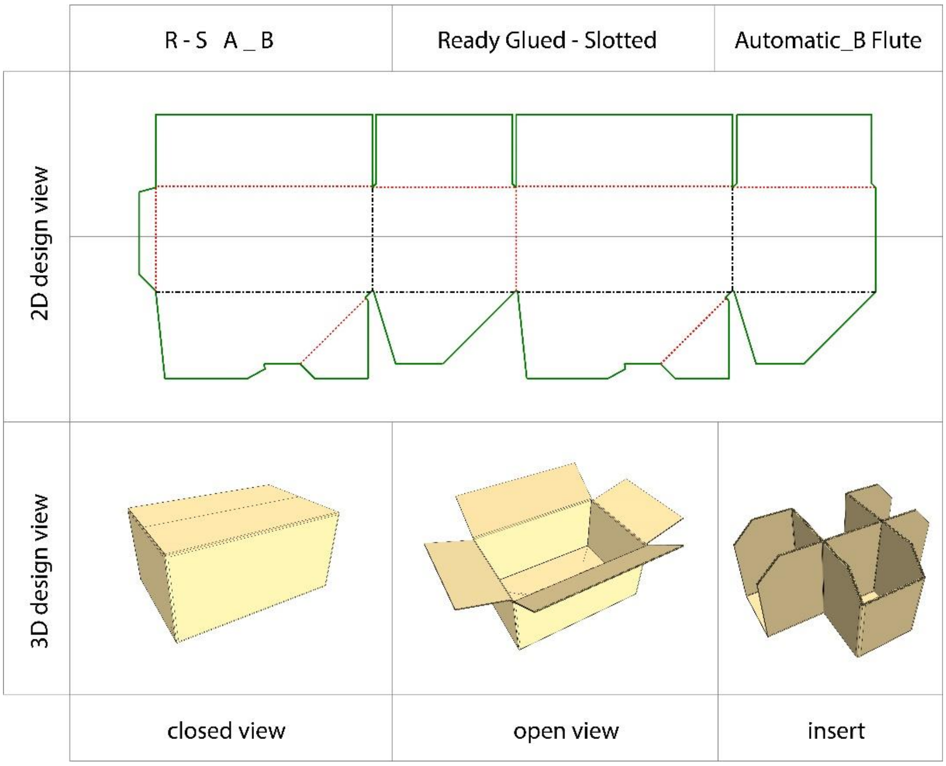


Figure A.28 : R-S A_B Ready Glued – Slotted _ Automatic Insert B Flute

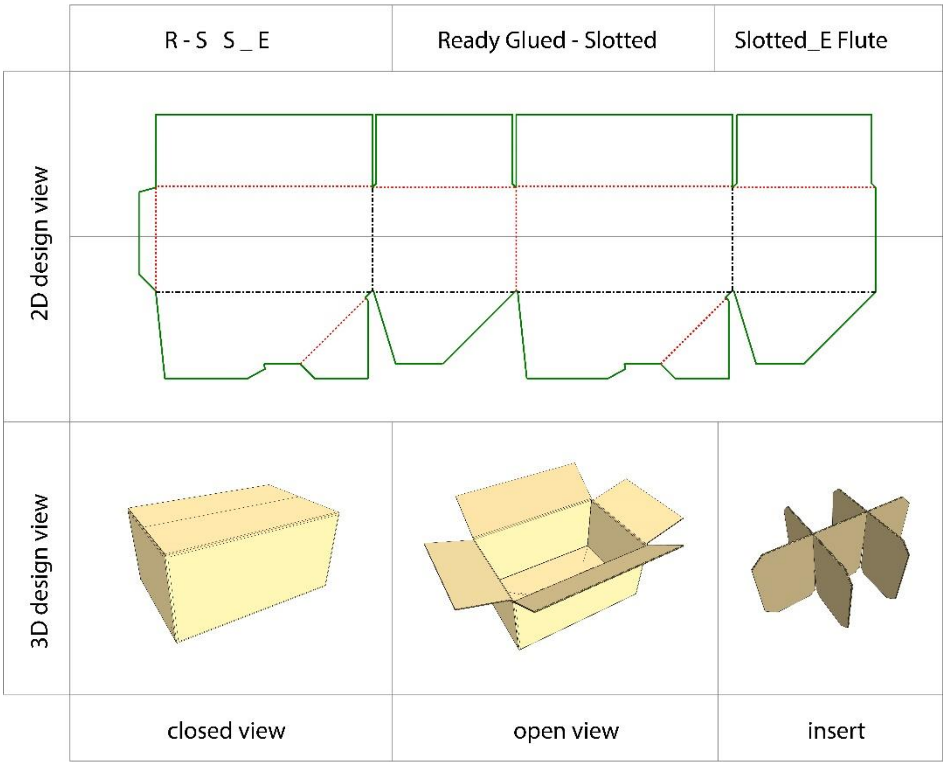


Figure A.29 : R-S S_E Ready Glued – Slotted _ Slotted Insert E Flute

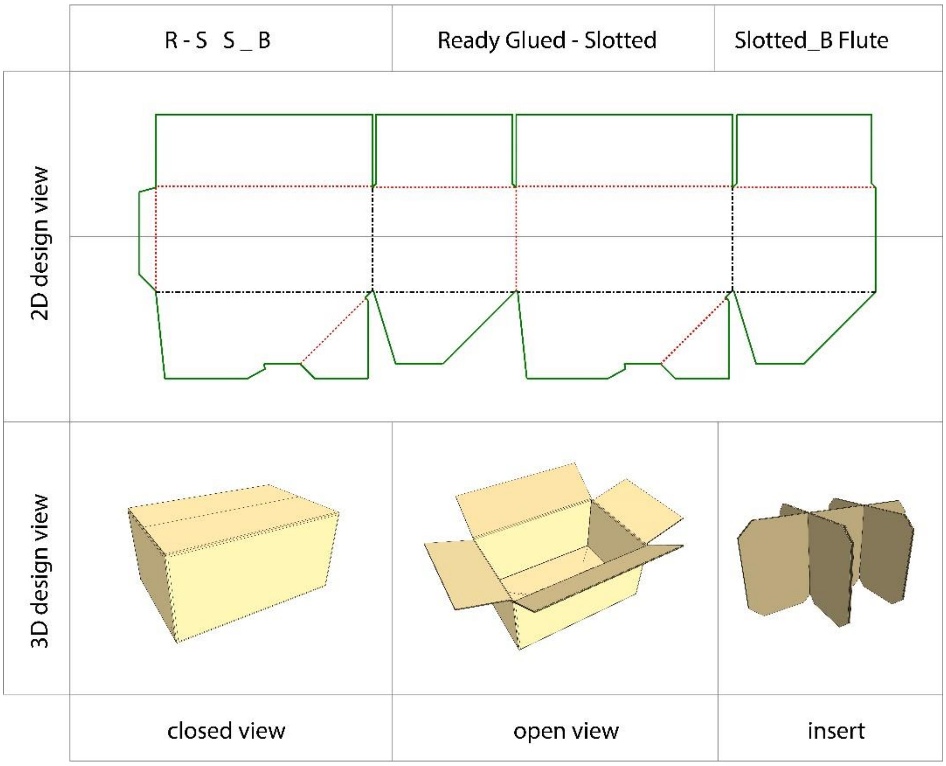


Figure A.30 : R-S S_B Ready Glued – Slotted _ Slotted Insert B Flute

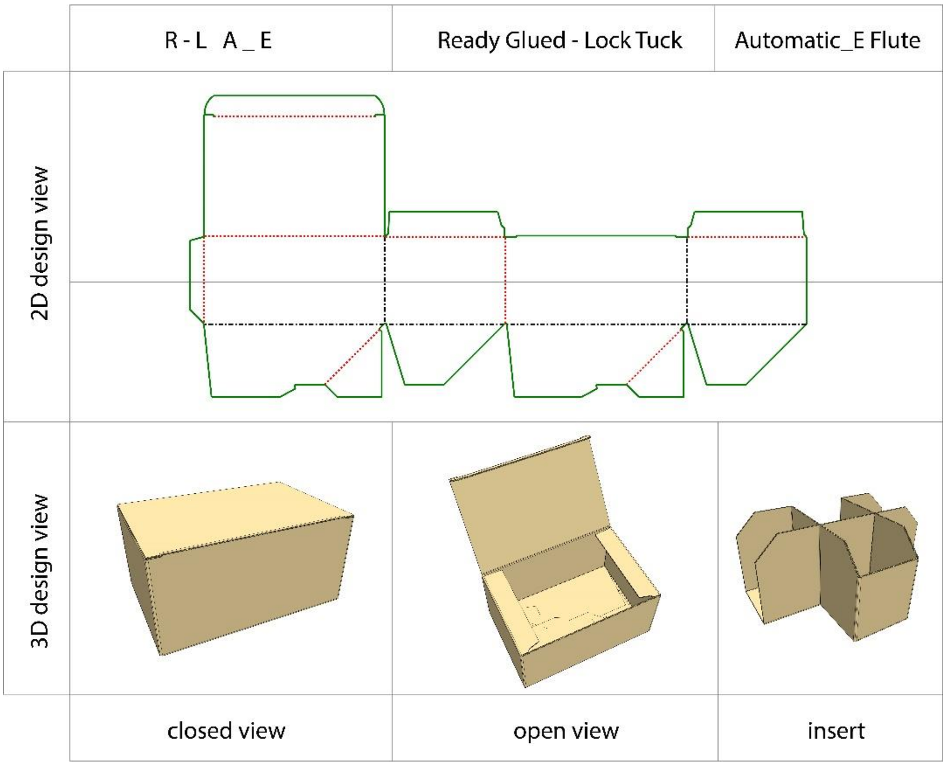


Figure A.31 : R-L A_E Ready Glued – Lock Tuck _ Automatic Insert E Flute

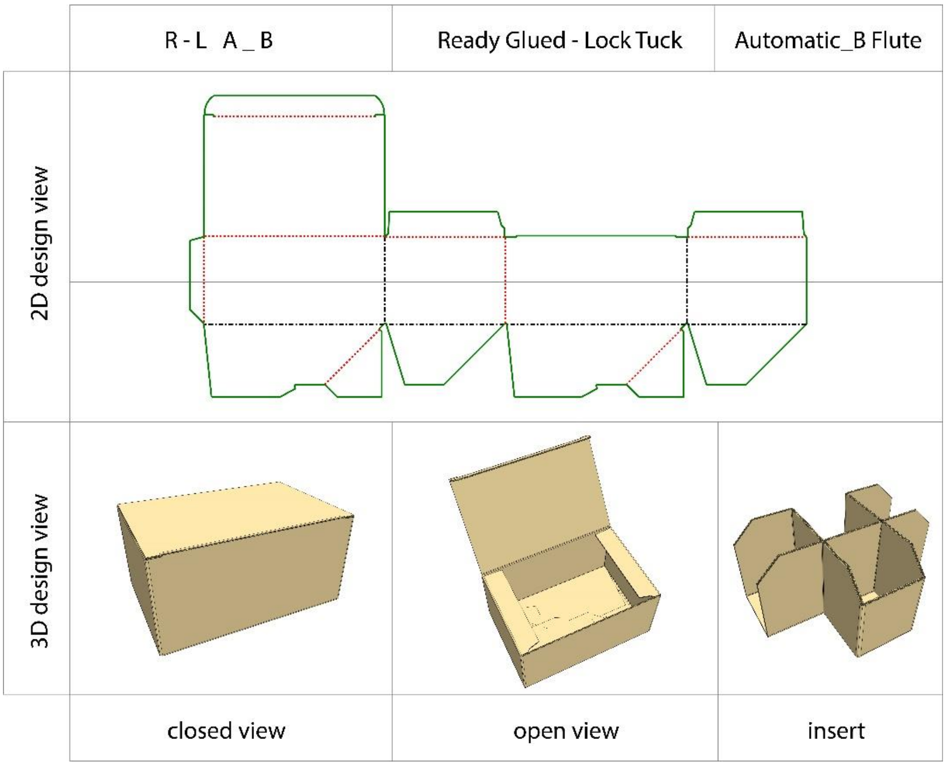


Figure A.32 : R-L A_B Ready Glued – Lock Tuck _ Automatic Insert B Flute

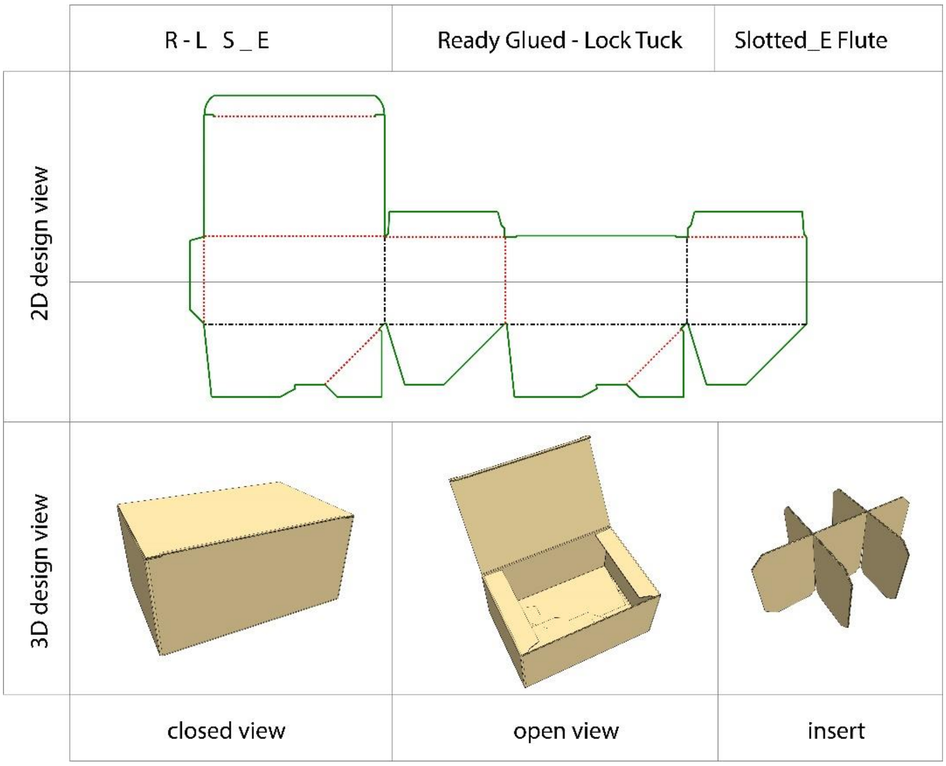


Figure A.33 : R-L S_E Ready Glued – Lock Tuck _ Slotted Insert E Flute

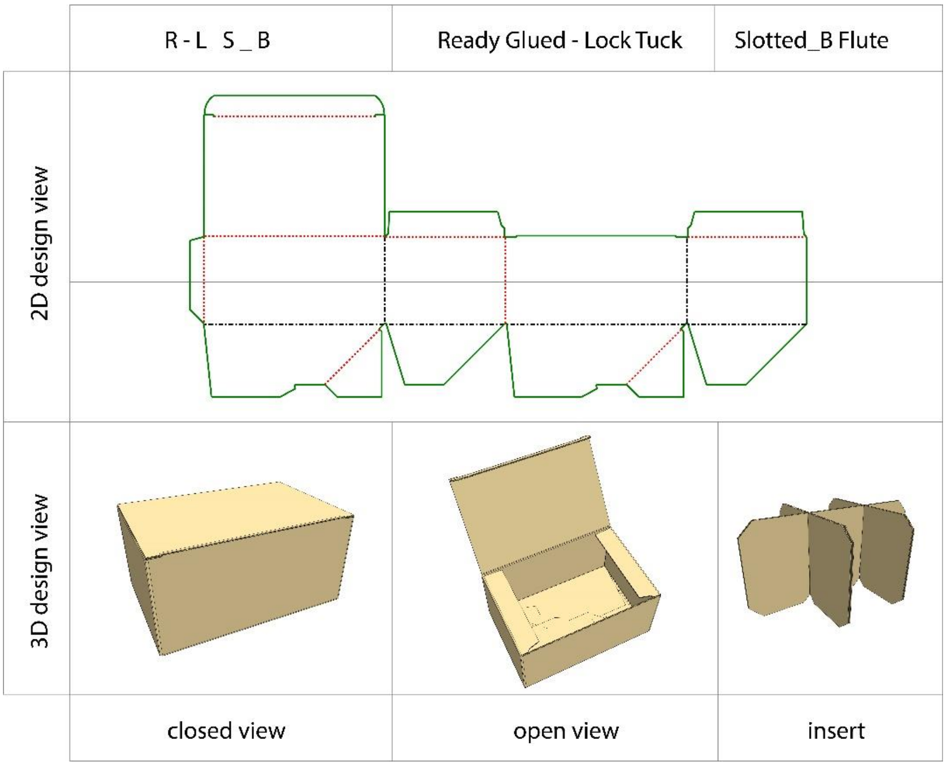


Figure A.34 : R-L S_B Ready Glued – Lock Tuck _ Slotted Insert B Flute

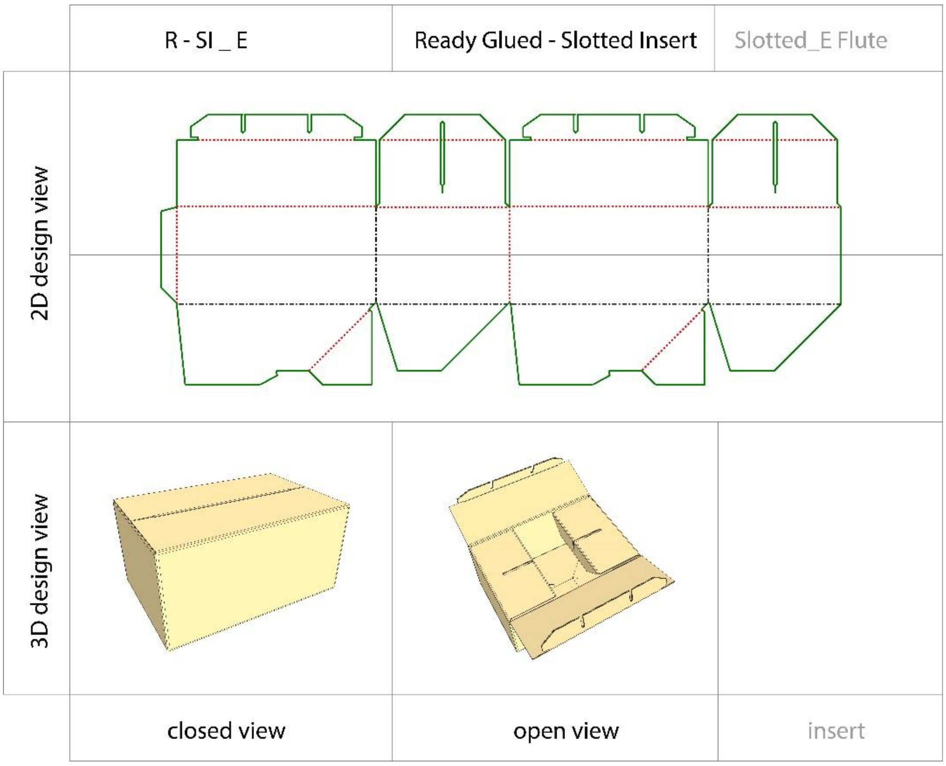


Figure A.35 : R-SI _ E Ready Glued – Slotted Insert _ E Flute

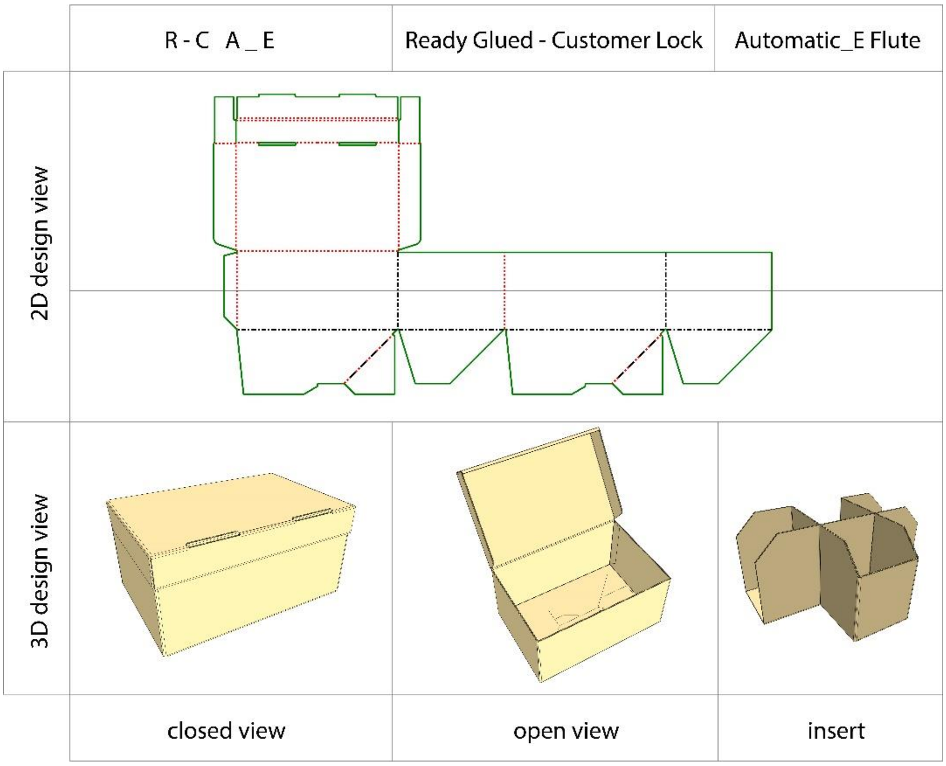


Figure A.36 : R-C A_E Ready Glued – Customer Lock _ Automatic Insert E Flute

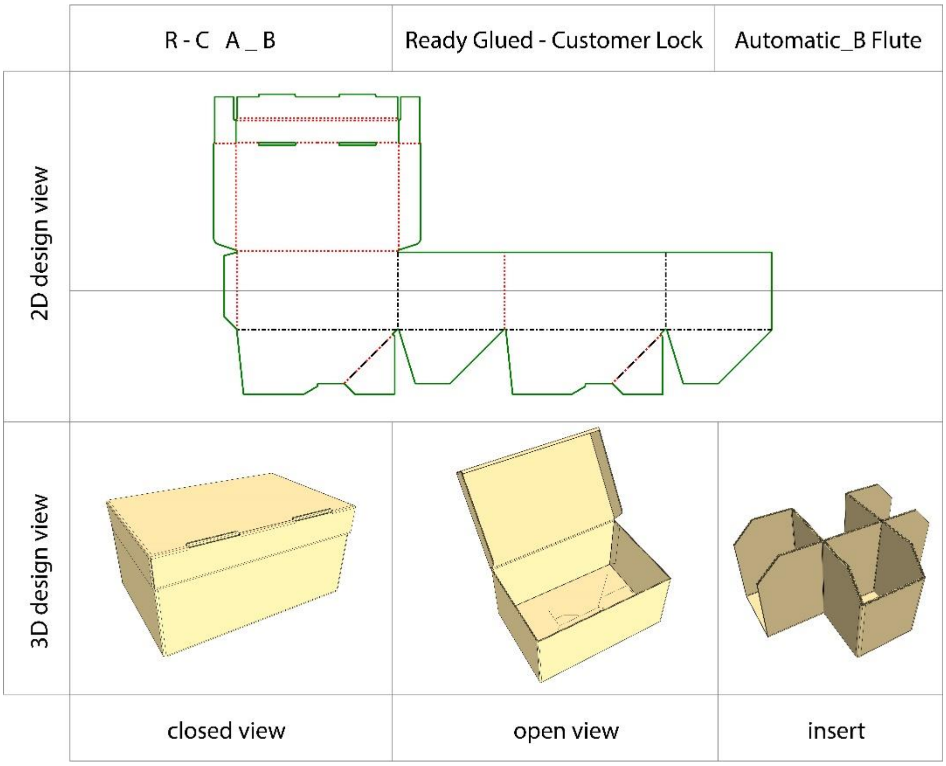


Figure A.37 : R-C A_B Ready Glued – Customer Lock _ Automatic Insert B Flute

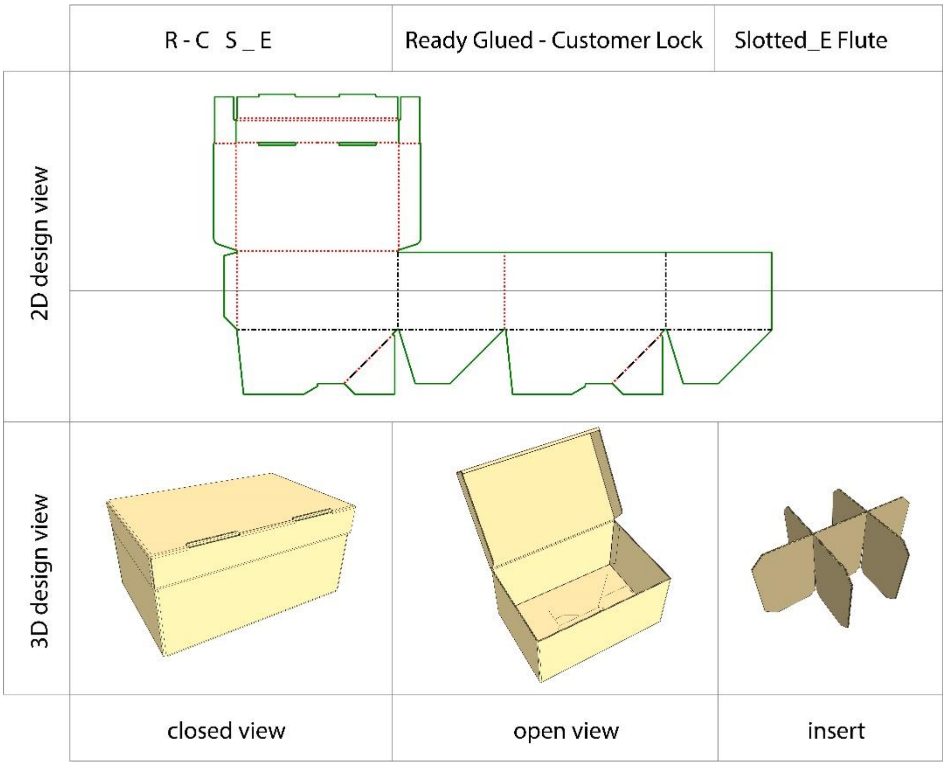


Figure A.38 : R-C S_E Ready Glued – Customer Lock _ Slotted Insert E Flute

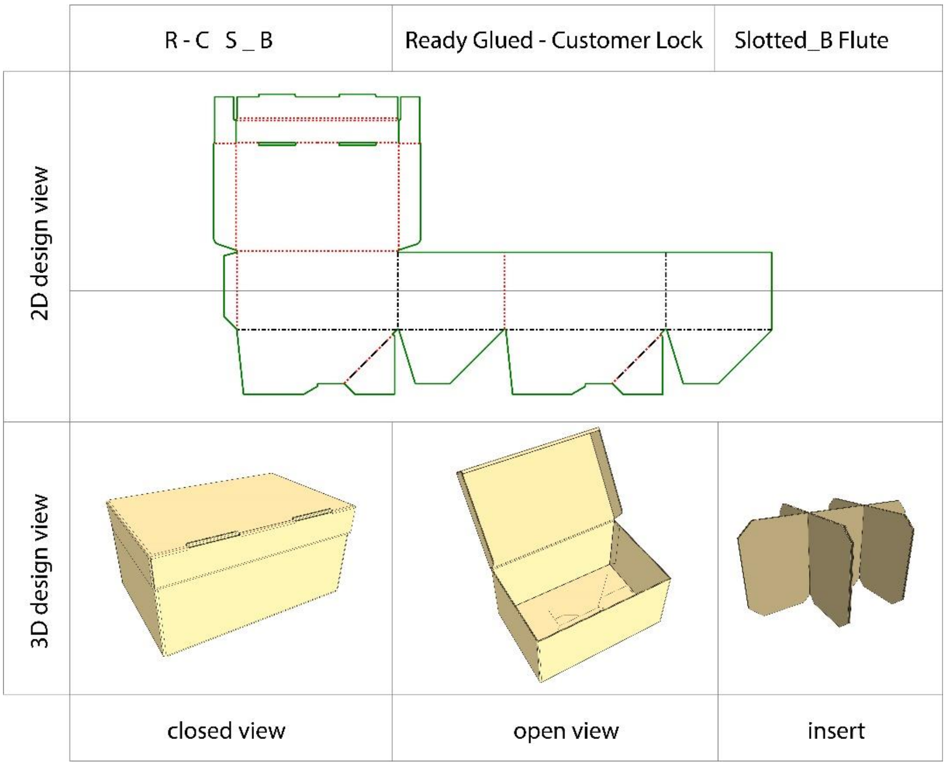


Figure A.39 : R-C S_B Ready Glued – Customer Lock _ Slotted Insert B Flute

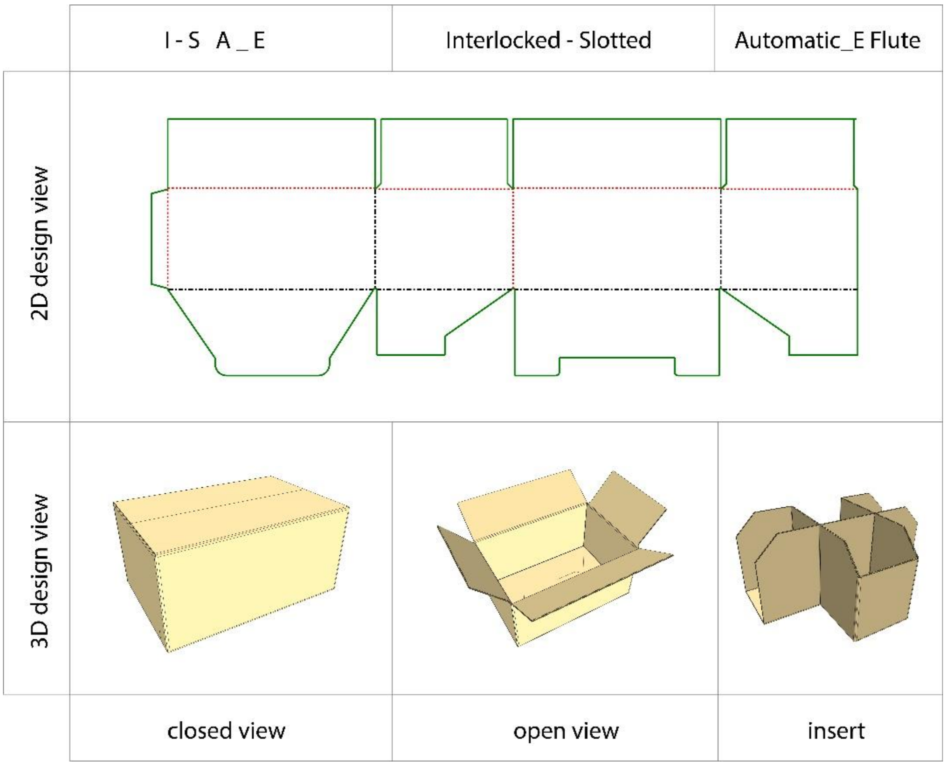


Figure A.40 : I-S A_E Interlocked – Slotted _ Automatic Insert E Flute

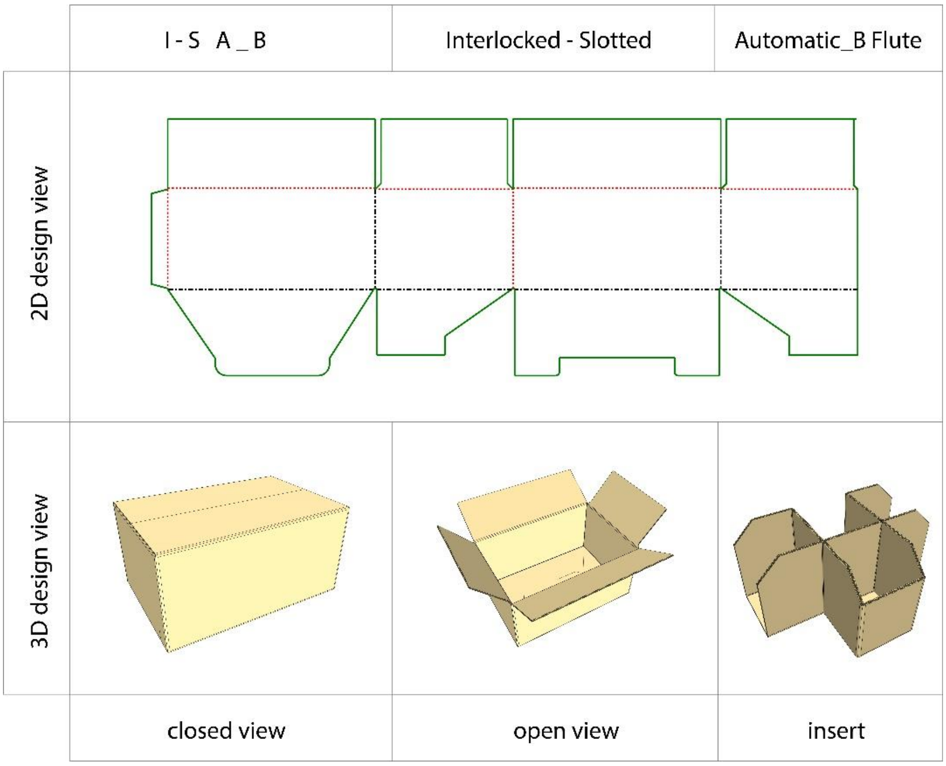


Figure A.41 : I-S A_B Interlocked – Slotted _ Automatic Insert B Flute

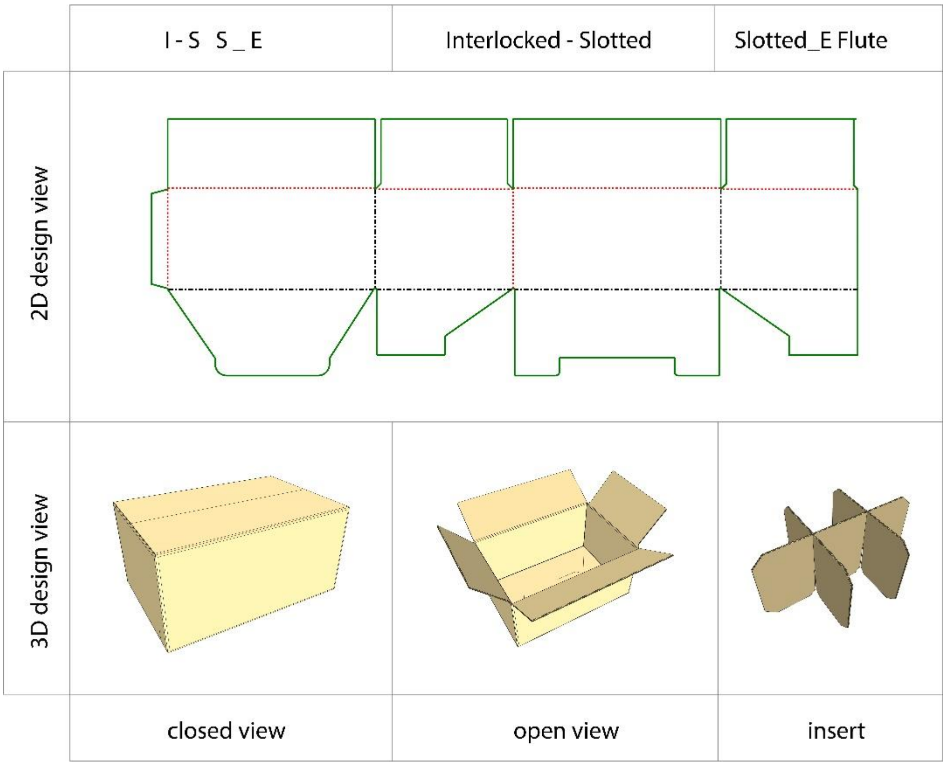


Figure A.42 : I-S S_E Interlocked – Slotted _ Slotted Insert E Flute

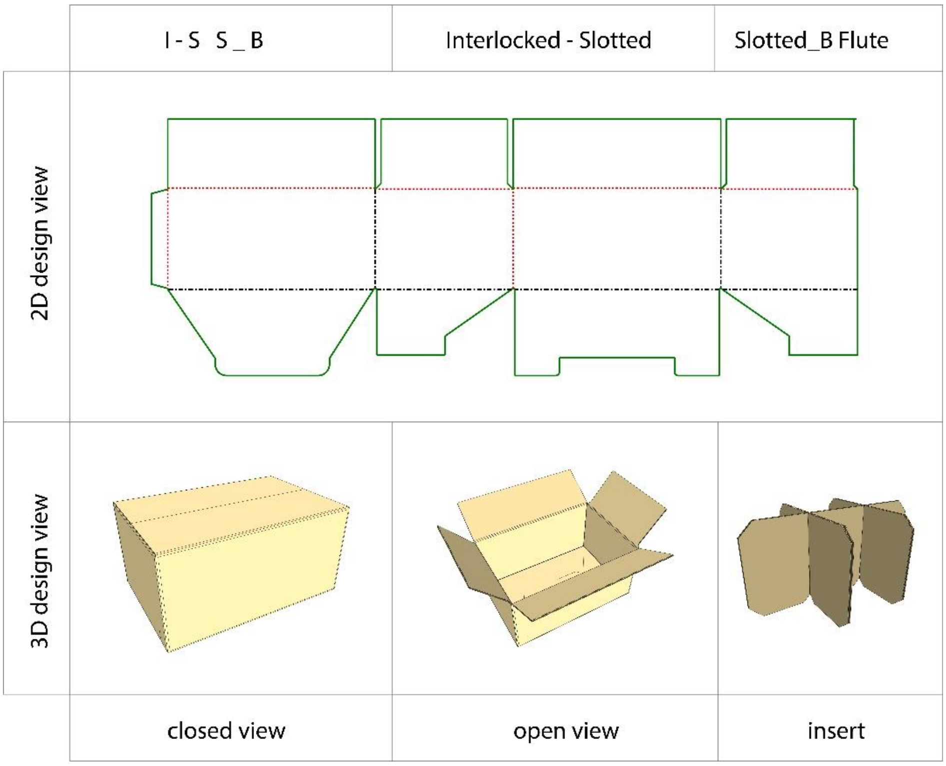


Figure A.43 : I-S S_B Interlocked – Slotted _ Slotted Insert B Flute

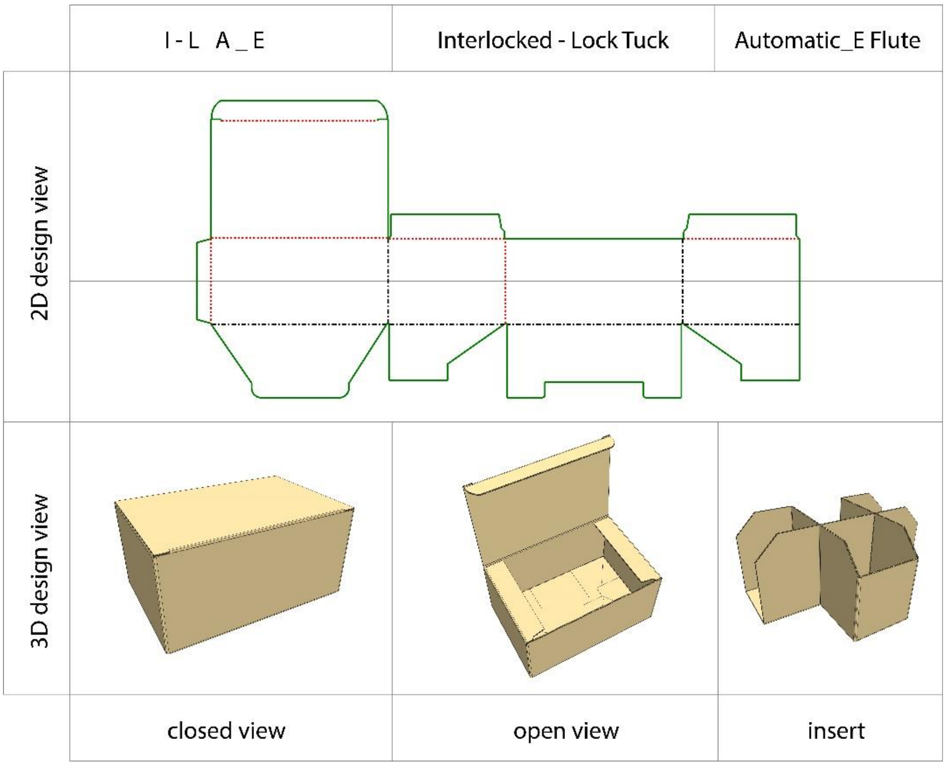


Figure A.44 : I-L A_E Interlocked – Lock Tuck _ Automatic Insert E Flute

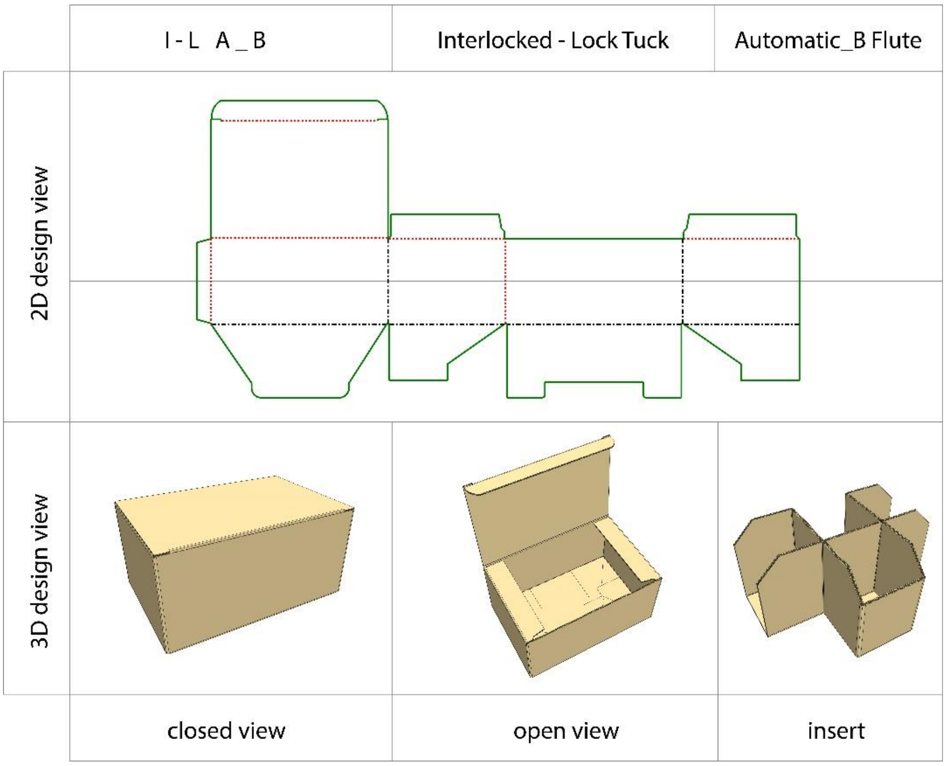


Figure A.45 : I-L A_B Interlocked – Lock Tuck _ Automatic Insert B Flute

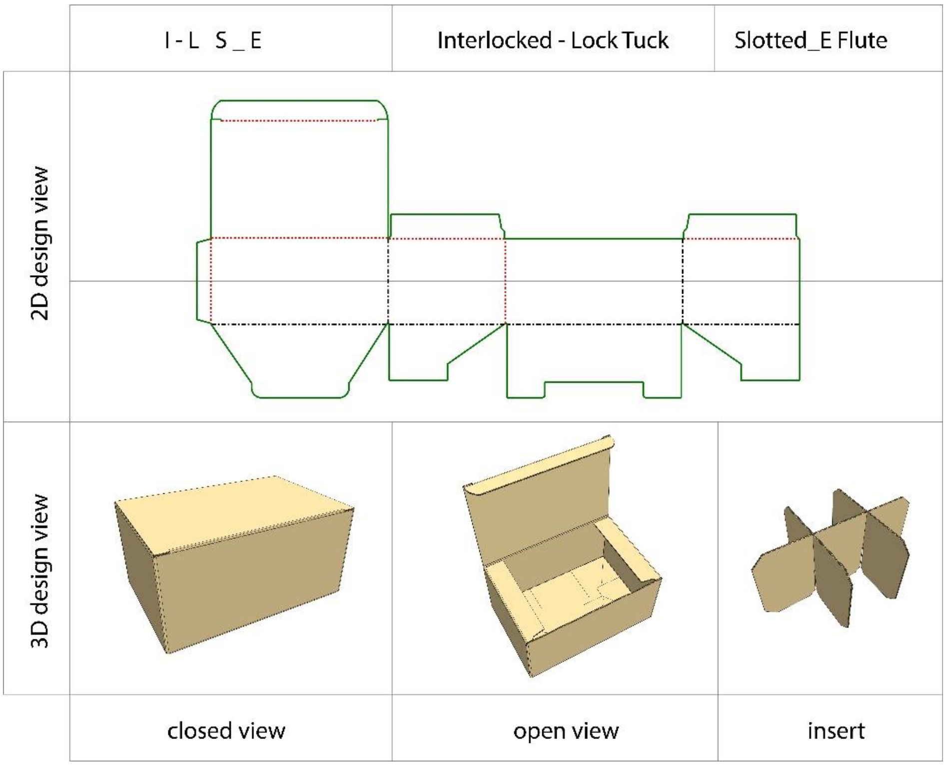


Figure A.46 : I-L S_E Interlocked – Lock Tuck _ Slotted Insert E Flute

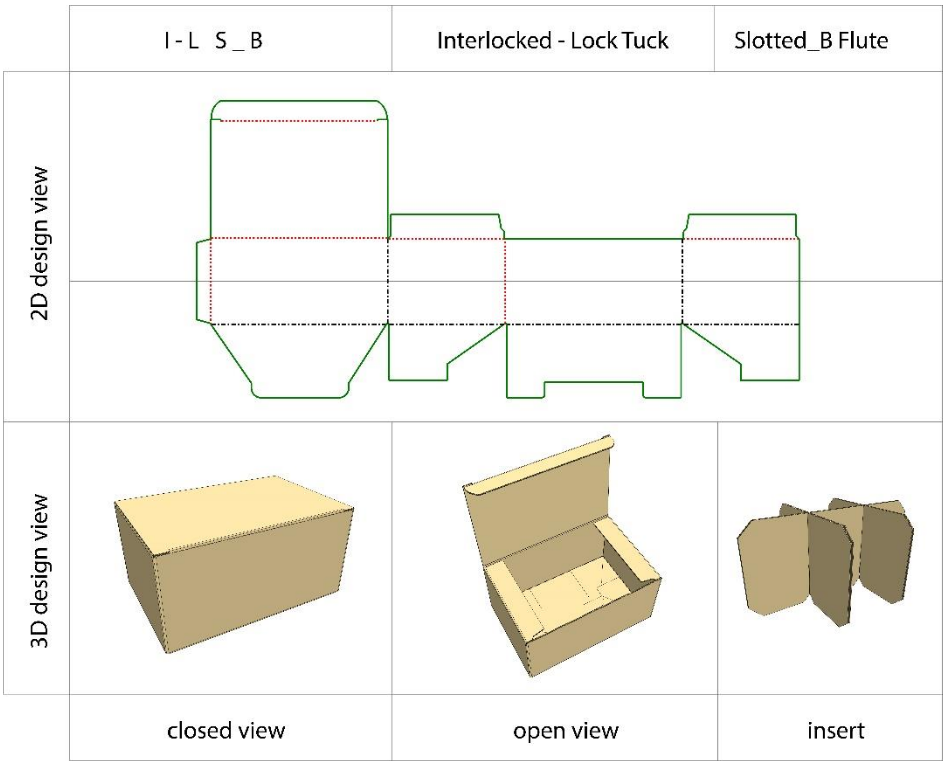


Figure A.47 : I-L S_B Interlocked – Lock Tuck _ Slotted Insert B Flute

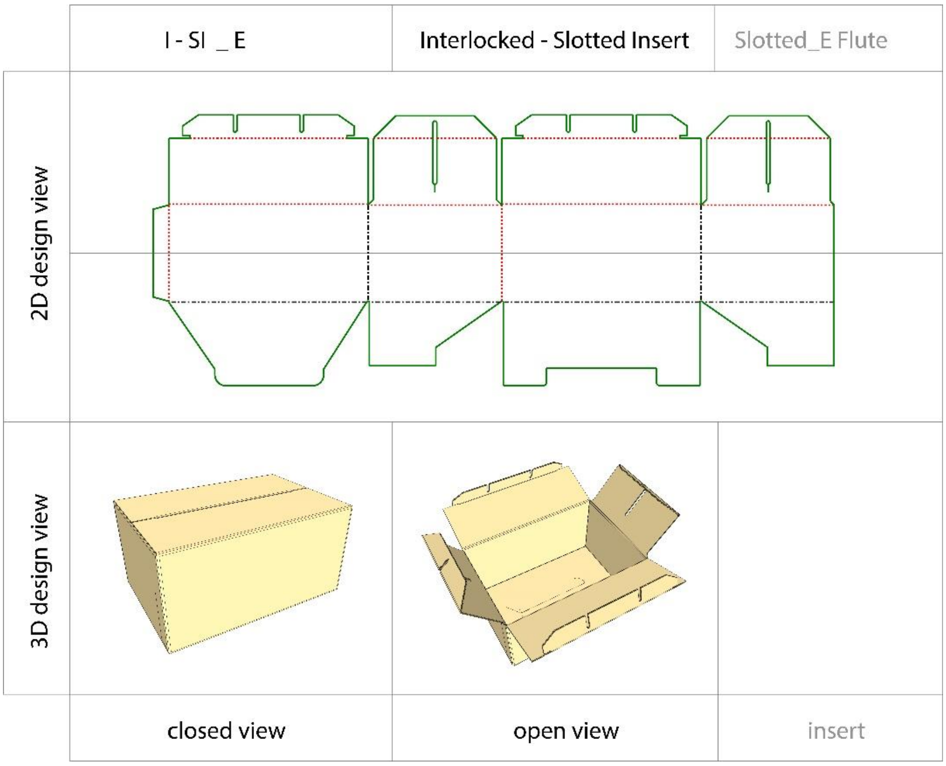


Figure A.48 : I-SI _E Interlocked – Slotted Insert _ E Flute

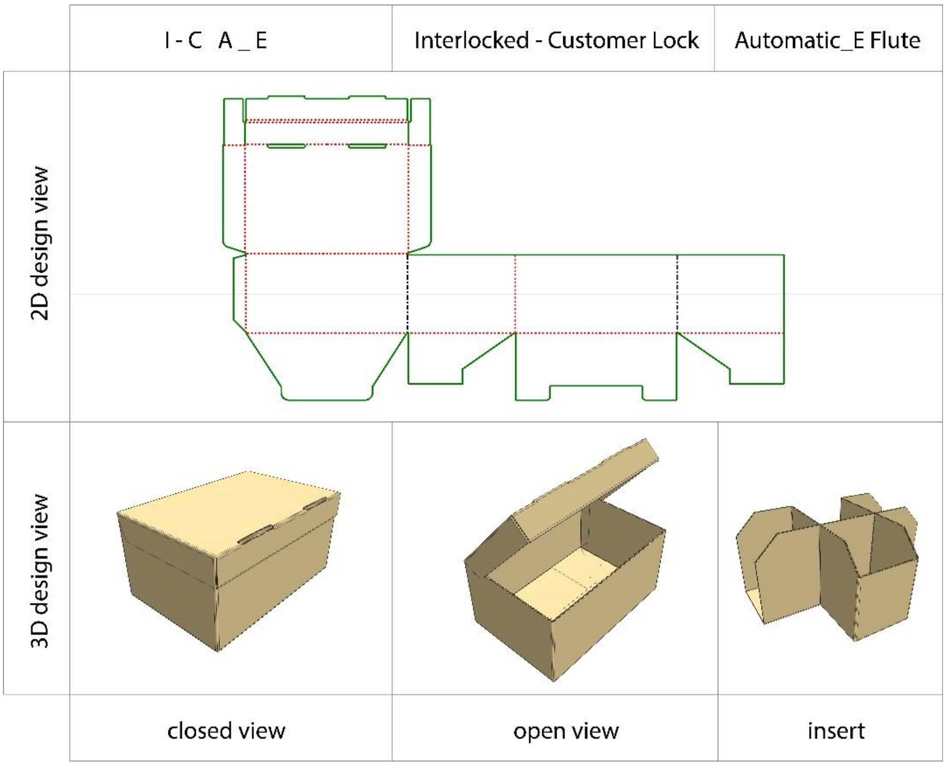


Figure A.49 : I-C A_E Interlocked – Customer Lock_ Automatic Insert E Flute

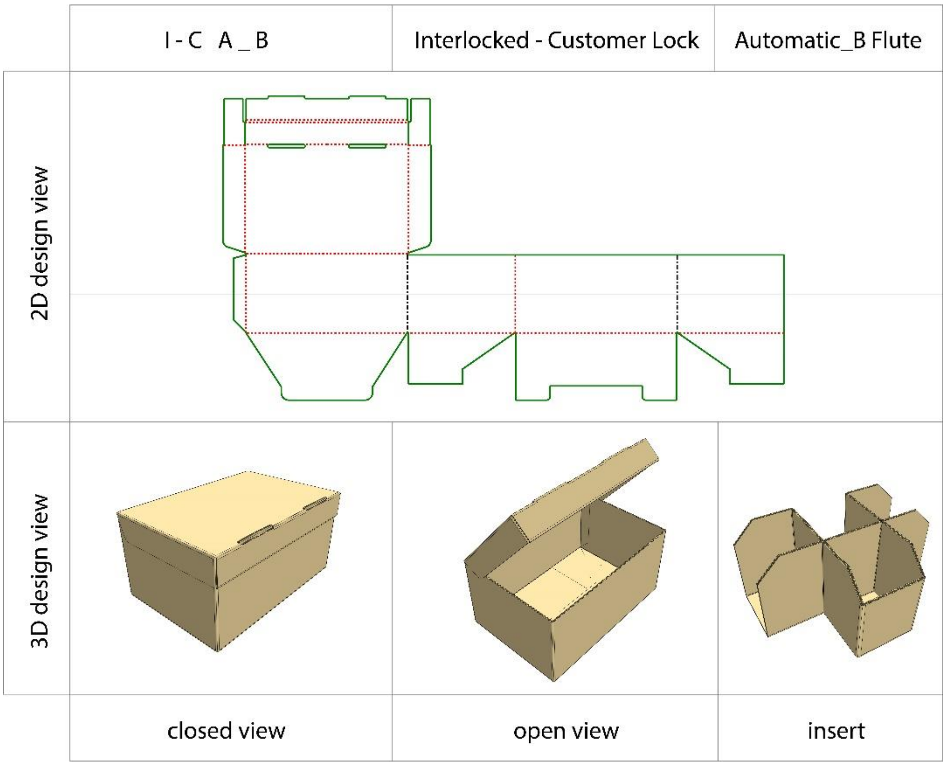


Figure A.50 : I-C A_B Interlocked – Customer Lock_ Automatic Insert B Flute

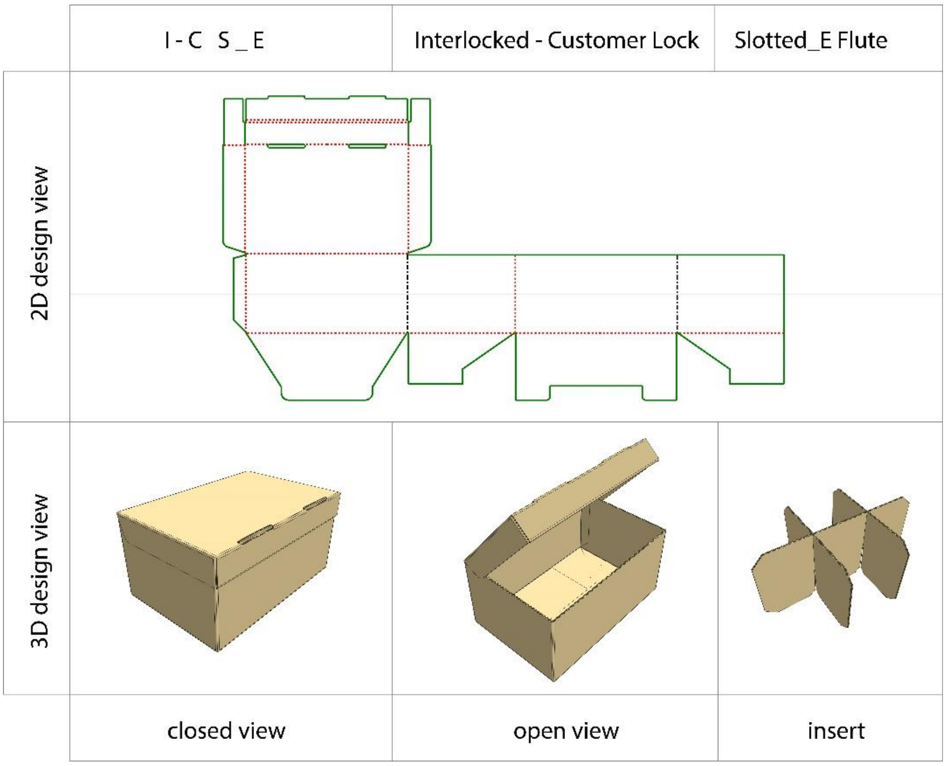


Figure A.51 : I-C S_E Interlocked – Customer Lock_ Slotted Insert E Flute

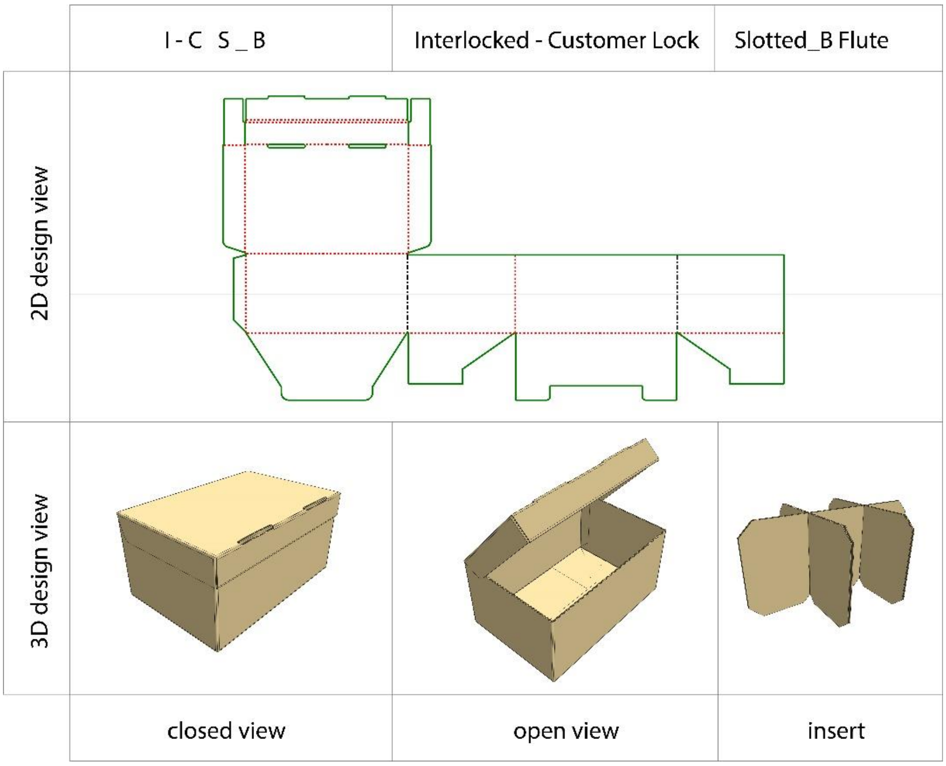


Figure A.52 : I-C S_B Interlocked – Customer Lock_ Slotted Insert B Flute

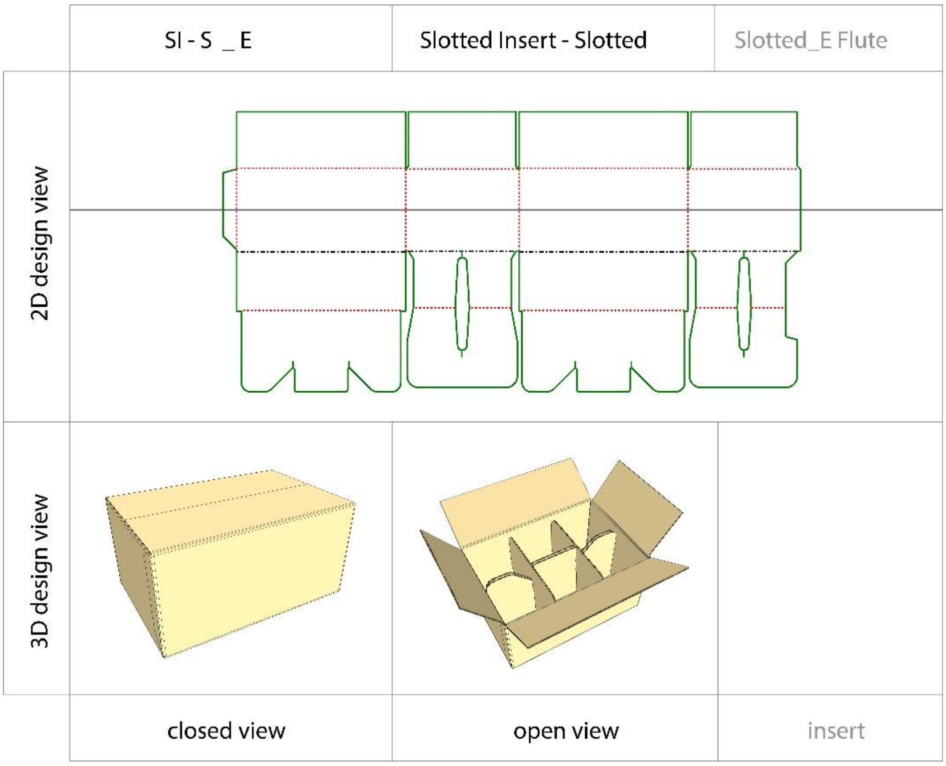


Figure A.53 : SI – S _ E Slotted Insert – Slotted _ E Flute

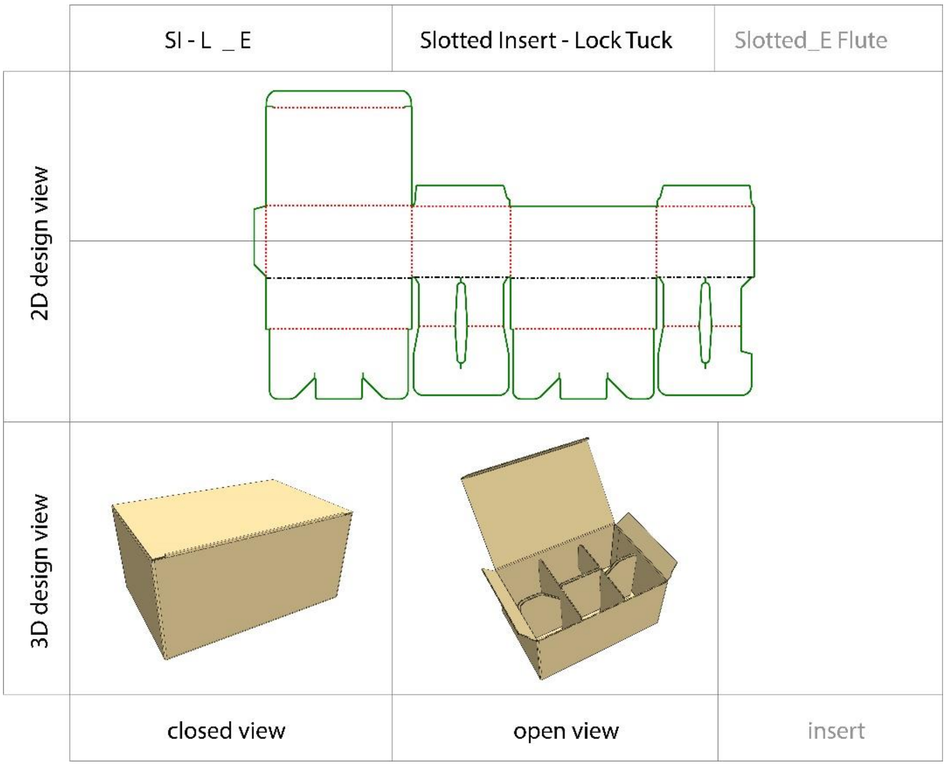


Figure A.54 : SI – L _ E Slotted Insert – Lock Tuck _ E Flute

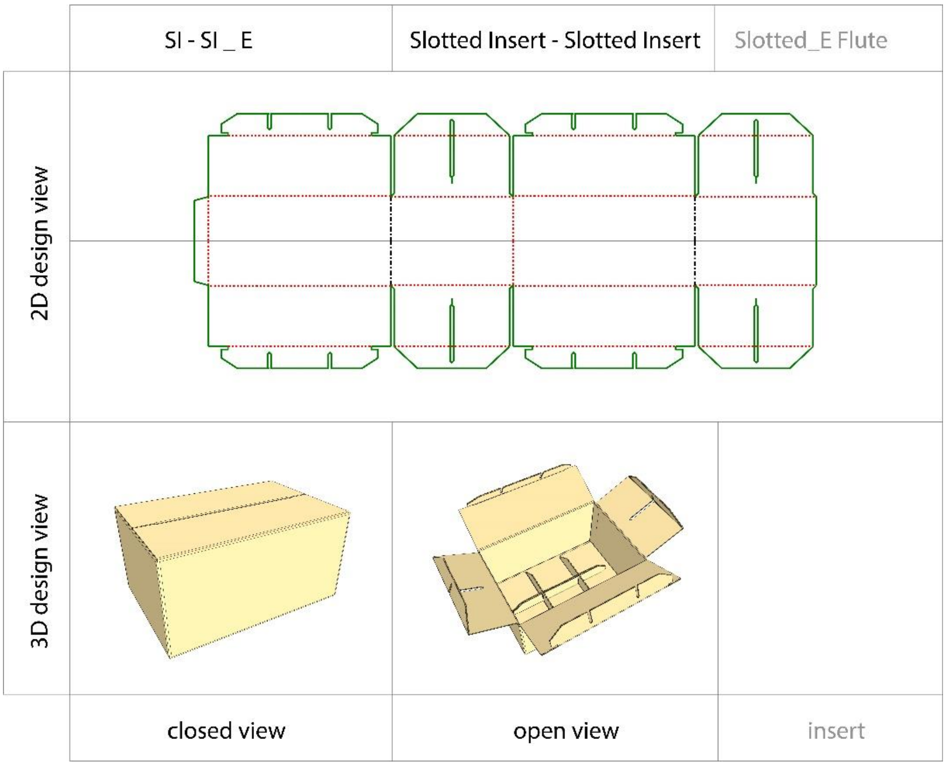


Figure A.55 : SI – SI _ E Slotted Insert – Slotted Insert _ E Flute

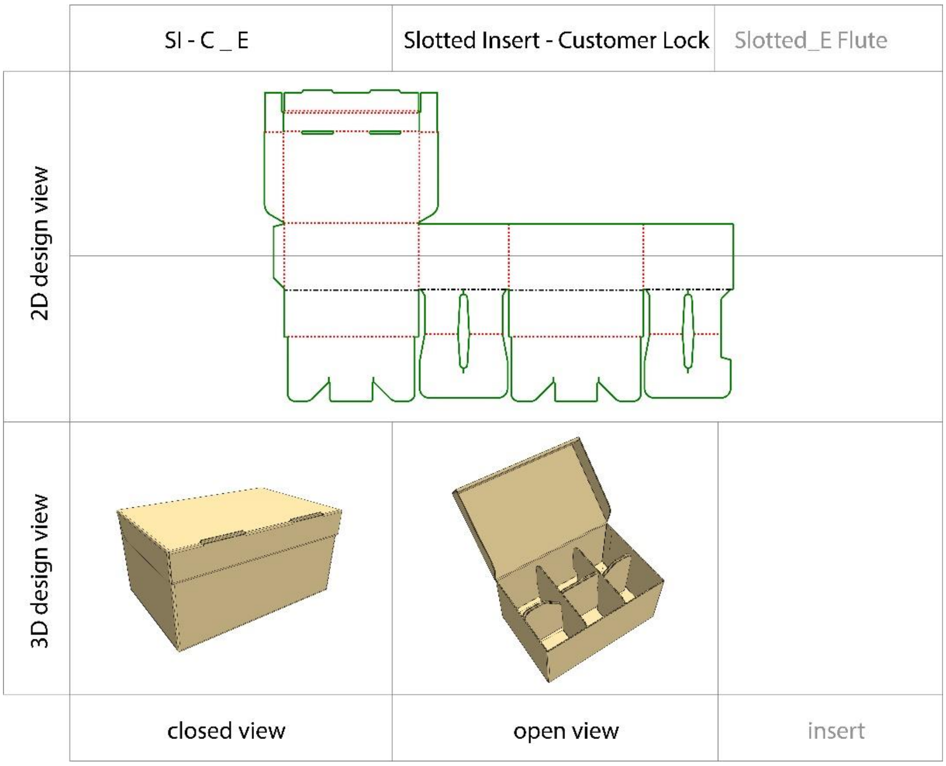


Figure A.56 : SI – C _ E Slotted Insert – Customer Lock _ E Flute

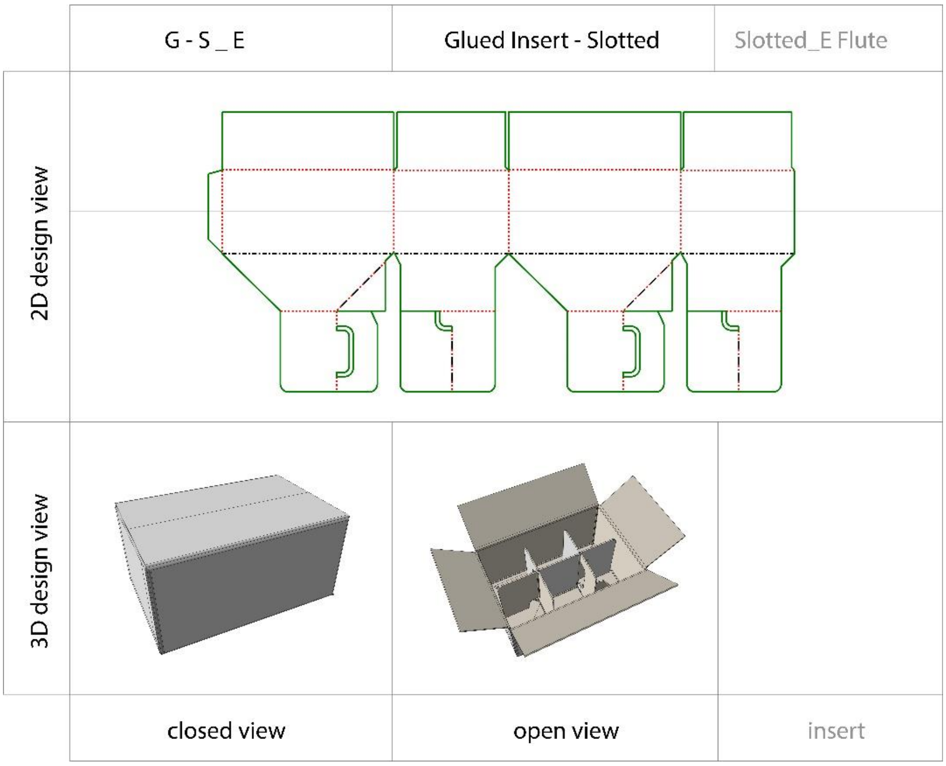


Figure A.57 : G – S _ E Glued Insert – Slotted _ E Flute

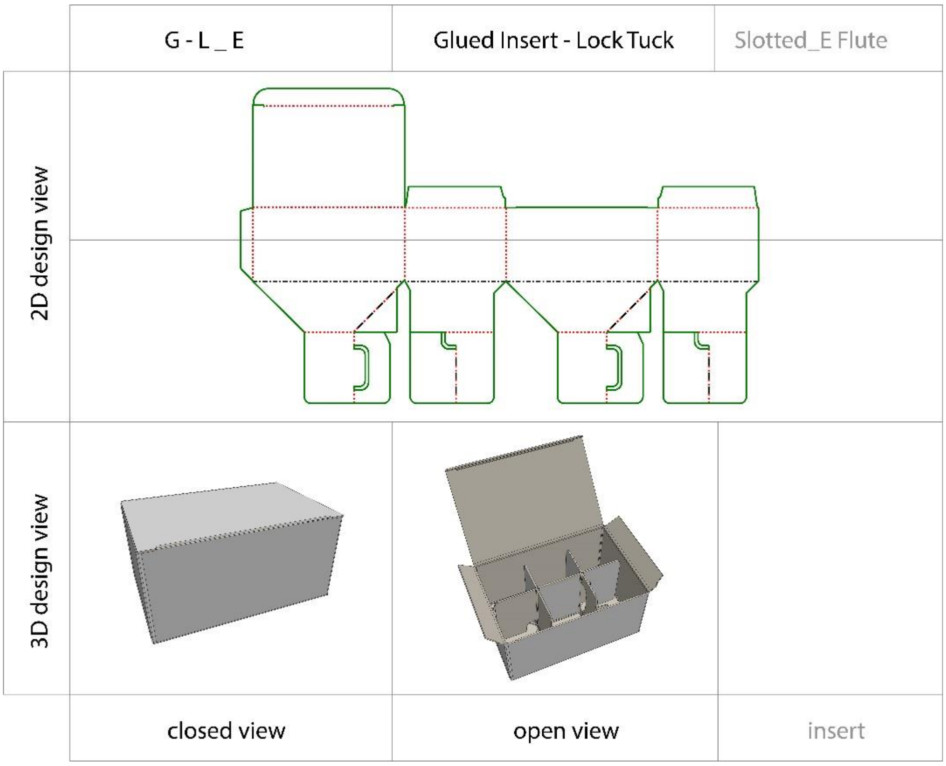


Figure A.58 : G – L _ E Glued Insert – Lock Tuck _ E Flute

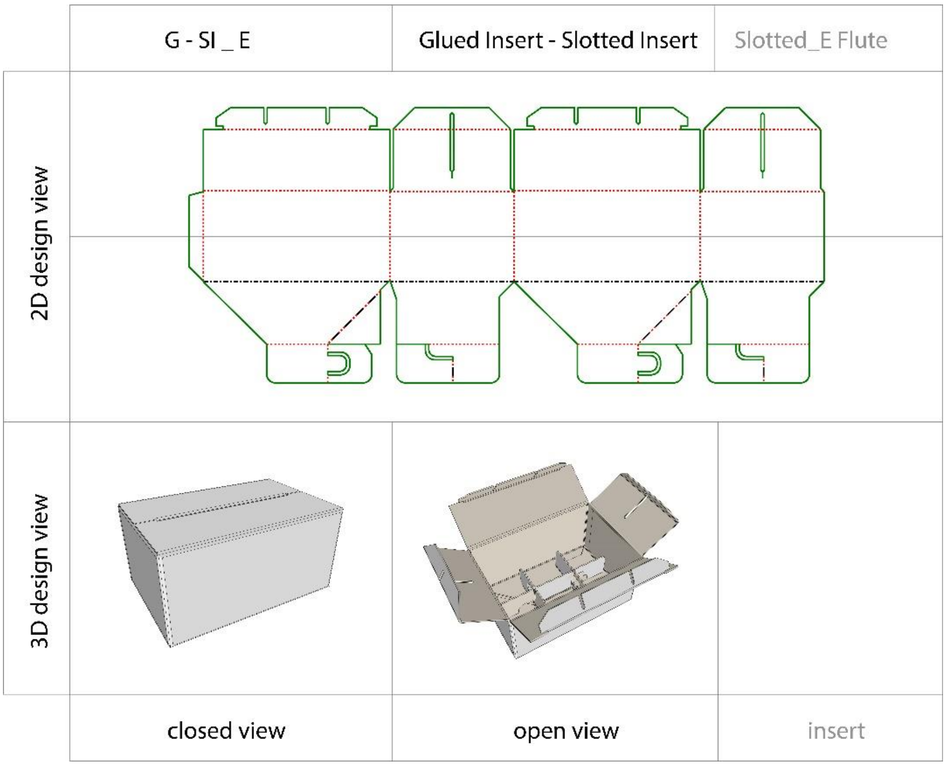


Figure A.59 : G – SI _ E Glued Insert – Slotted Insert _ E Flute

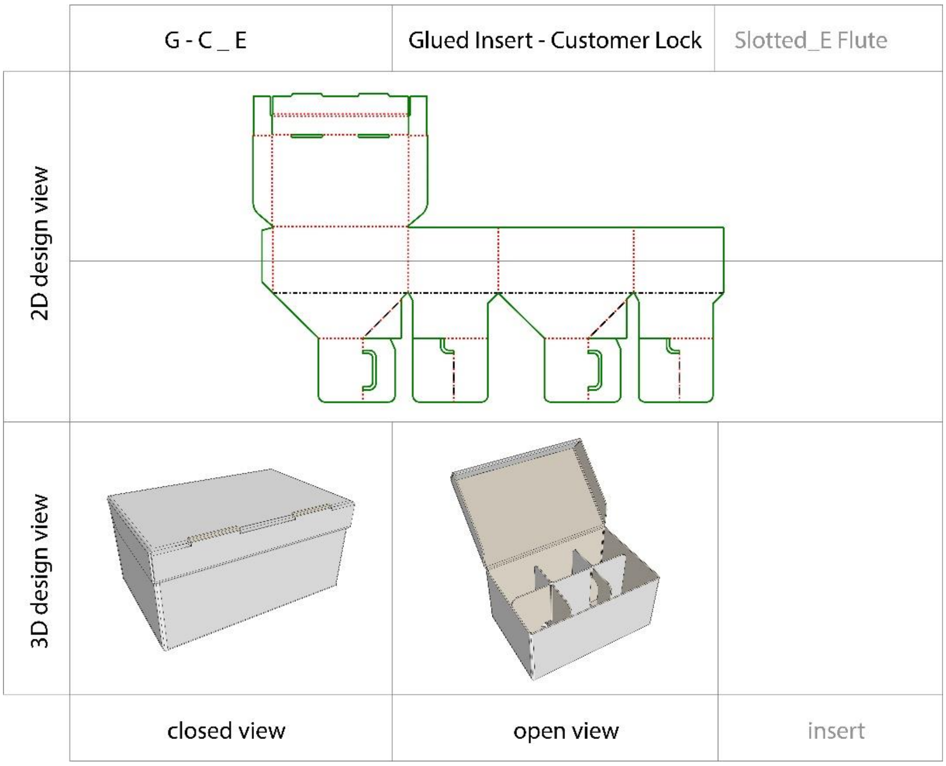


Figure A.60 : G – C _ E Glued Insert – Customer Lock _ E Flute

APPENDIX B SAMPLES

Figure B.1 : Sample photographs (a) Lock tuck top tupe style box closed. (b) Lock Tuck open. (c) Tray style box (d) Standard reverse double tuck. (e) One side open sleeve style. (f) Glued insert open top tube style

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