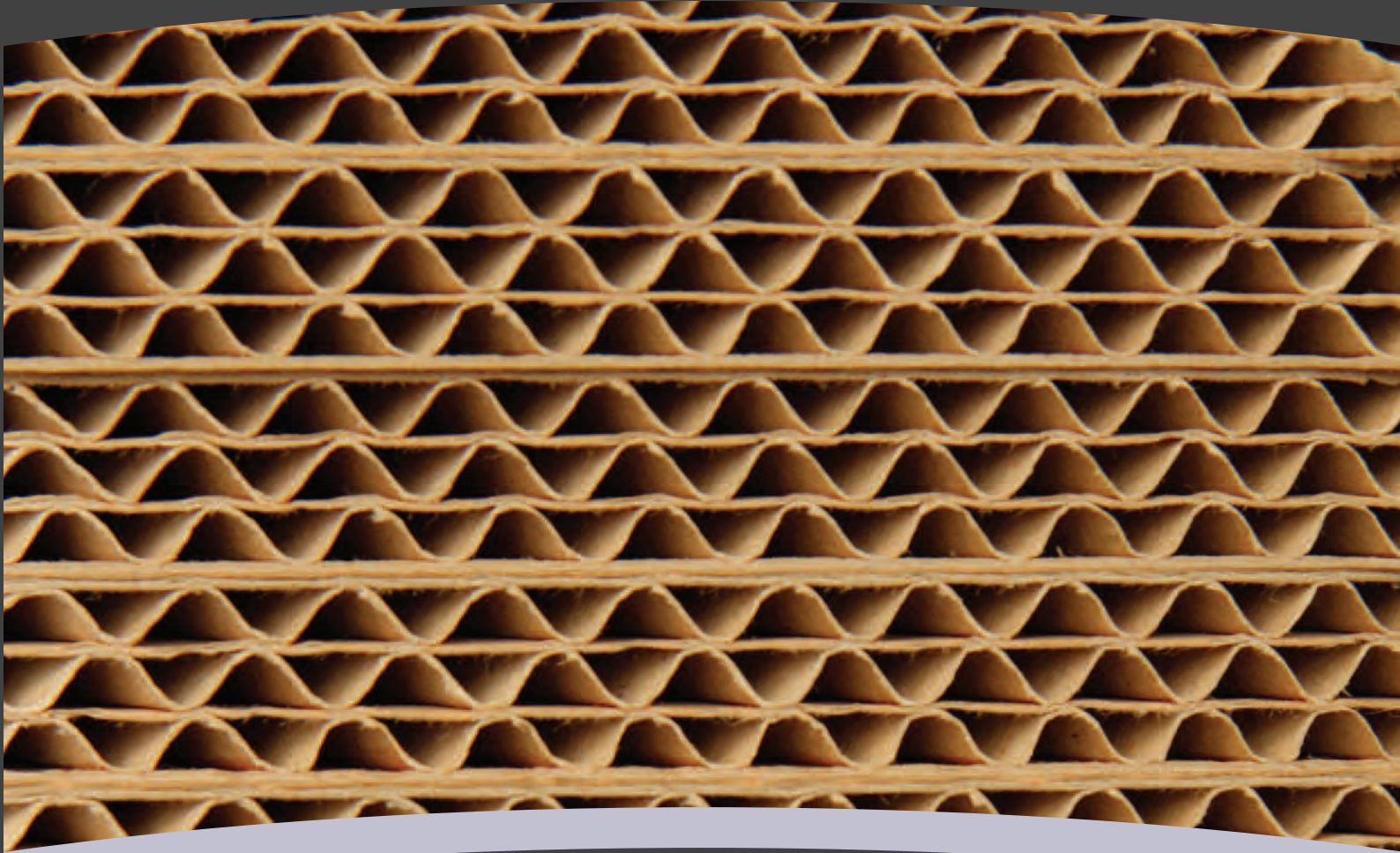


# Weedon



Group



## Corrugated Board Made Simple

A guide to papers used in corrugated packaging in the 21st century

The type of paper used to make the corrugated board used in packaging is a key factor in determining the performance of that packaging. Of course it is not the only factor. For example, it is important that the box-maker has installed modern conversion equipment with a kiss touch, which does not crush or weaken the board. And structural design – an area in which the Weedon Group has particular expertise – is also crucial.

In the old days, it was simple – it was all a matter of weight. The heavier the paper, the stronger the box produced from it. Today, with the development of paper-making, the type of paper can make a significant difference to performance too. Nowadays, lighter papers can – and do – perform as well and even better than heavier papers – with less damage to both budget and the environment!

The environment is another issue to consider when specifying paper. Is corrugated packaging a good choice in terms of the welfare of our planet? Does recycled board perform as well as board made from virgin fibres?

This guide charts the evolution of corrugated packaging board, and introduces the different types of paper used to make corrugated board today and their characteristics. The glossary at the end explains some of the jargon.

Choosing the right board for packaging today is not simple. But we in the Weedon Group have the specialists who can advise you and we are always happy to help. We even have our own in-house testing facility so we can try out proposed materials and prove a design will deliver before we go into production.

### **Paper – some interesting facts**

- Paper is a versatile material. As well as the obvious uses, such as writing, printing and packaging, it can even be an ingredient in food – particularly in Asian cultures.
- Paper, and the pulp paper-making process, were said to be developed in China during the early 2nd century AD, possibly as early as the year 105 AD by the Han court eunuch, Cai Lun, although the earliest archaeological fragments of paper derive from the 2nd century BC.
- The modern pulp and paper industry is global, with China leading world production.



### **Let's start with the basics**

#### **What is paper?**

Paper is usually produced by pressing together the moist fibres of cellulose pulp derived from wood, and drying them into thin, flexible sheets. The type of fibre used determines the performance of the paper produced.

Paperboard is generally thicker than paper (usually over 220 gsm). It can be single- or multi-ply. Sometimes it is referred to as cardboard, which is a generic, lay term used to refer to any heavy paper pulp-based board. The type of paper used determines the performance of the board.

#### **What is corrugated board?**

Corrugated board consists of one or more sheets of fluted paper (the corrugating medium) stuck between flat sheets of paper or board (the liners or linerboard). Because of its construction, it is stronger than flat board.

# I A Brief History of Corrugated Board in Packaging

## The early days

The history of corrugated board used in packaging goes back further than you might have expected. When it was first launched, Victoria was on the throne, the first cricket Test match was being played in England and Britain was fighting the Boer War!

In the 1880s the first corrugated packaging boards emerged, but they used materials produced for other types of packaging: bag papers for liners and strawboard for fluting. And they were mostly produced on machines built to manufacture other grades of paper such as writing papers or newsprint. The raw materials used were usually virgin fibre, unbleached wood pulps and straw pulp.

## The introduction of corrugated board into packaging

- **1817** – the first paperboard carton was produced in England
- **1860s** – folding cartons first emerged and were shipped flat to save space
- **1879** – the development of mechanical die cutting and creasing of blanks
- **1880s** – establishment of commercial operations producing corrugated board and packaging by Thompson and Norris, the emergence of corrugated board for packaging
- **1950s** – UK production of corrugated packaging board passed a quarter of a million tonnes
- **1980s** – UK production passed 1.5 million tonnes
- **Mid-1990s** – UK production passed 2 million tonnes
- **2001** – UK production passed 2.3 million tonnes

## The growth of recycled corrugated packaging board

During World War II, increasing quantities of waste paper were used to make corrugated board (recycling is not new!), but the results were of poor quality. After the War, new large pulp and paper mills were built specifically to produce Kraft liner and Semi Chemical fluting for the corrugating industry. However, waste paper had gained a foothold that it has never lost. During the 1950s, waste paper consumption started to increase in Europe, mainly due to developments which enabled starch to be incorporated in the papers to improve strength and stiffness.

In the 1970s, the fuel crisis, with a consequent rise in energy prices, and growing environmental legislation pushed up the price of Kraft liners and Semi Chemical fluting. This led to a further growth in the use of substitute materials using recycled fibre products – Waste-based fluting and Test-liners.

Over the next couple of decades, progress in corrugated board manufacture included the introduction of chemical additives, waste paper pulping equipment and paper-making machines with multi-ply forming. By the turn of the millennium, 85-90% of corrugated packaging board used in Europe was produced using recycled fibres. Some parts of the world now use almost 100% recycled fibres.

Of the fibres used to make paper in the UK, over 70% now come from paper collected for recycling by households and businesses. The rest come mainly from virgin wood fibre from trees grown in sustainably managed and certified forests. Paper fibres can only be recycled up to about seven times as they eventually degrade in the recycling process, losing their paper-making qualities. The degraded fibres are replaced with new virgin fibres, either from trees or more often from recovered paper that has not previously been recycled.





## II The Different Types of Corrugated Case Materials

	Virgin fibres	Secondary (recovered) fibres
For liner board	Kraft liner	Test-liner
For fluting	Semi Chemical fluting	Waste-based fluting

### 1 Virgin fibre products

**Virgin fibre** – wood fibre that has never been used before to make pulp, paper or board, ie it does not include any recycled fibres.

By the 1950s, corrugated packaging production was a major industry and was consuming increasing amounts of paper. The paper industry around the world – particularly in the USA and Scandinavia – responded by ramping up production of corrugated board from wood pulp. Probably for the first time, new pulp and paper mills were designed and built specifically to produce virgin fibre-based corrugated board products.

**Stiffness** – one of the most important properties of paperboard, as it affects both the runnability of the board during manufacture of the cartons and also the ability of cartons to run smoothly through the machine that erects, fills and closes them. Stiffness also gives strength and reduces the likelihood of a carton bulging under the weight of its contents.

Although most paper strength properties increase with increasing sheet density, stiffness does not. Other factors which affect board stiffness include coatings and moisture content.

There are two types of virgin fibre product used in the manufacture of corrugated board:

- **Kraft liner** – is a virgin fibre product made from softwood pulp, produced by a process known as Kraft pulping. This process uses sodium sulphate to treat softwoods, principally pine, to dissolve the bonding compound in the wood (lignin). This allows the cellulose fibres to be separated to form a wood pulp with little mechanical effort. These fibres are relatively long because the original wood is softwood, so the resulting paper is fairly stiff and has good tear and bursting strength. This makes it ideal for liners on corrugated board.
- **Semi Chemical fluting** – is produced from a hardwood pulp, ie where the cellulose fibres are

relatively short. It is produced by a sulphite bonding process which only partly dissolves the bonding material, lignin, so a significant amount is retained. This produces fibres with low flexibility and a dense paper which is very stiff and has a high compression strength. In addition, when passed through a corrugator, heat reacts on the lignin which sets very rigidly when it cools in the formed flute, bonding the fibres together to produce a very rigid board with good crush resistance.

### 2 Secondary fibre products

**Secondary fibre** – Fibre that has been used before, eg recovered paper.

As well as increased demand, several factors have driven the growth of secondary fibres in corrugated board including:

- Their low cost as a raw material
- Environmental issues such as the reduction in pollution and the potential for recycling
- The widespread availability of waste paper
- A lower capital cost for the construction of plant to produce waste paper pulp
- Lower energy costs for their operation

There are basically two categories of recovered paper used in corrugated packaging, each with different characteristics: Waste-based fluting (WBF) and Test-liners.

- **Waste-based fluting** – Starch is added to improve the stiffness of Waste-based fluting. Starch performs the same function as lignin in Semi Chemical fluting.
- **Test-liners** – Used as the outer layer of corrugated board, made partly from chemical pulp and partly from waste paper.

Today there are two grades: Test-liner 2 (partly recycled liner paper) and Test-liner 3 (fully recycled liner). In the main, Test-liner 2 matches Kraft liner in all respects except bursting strength, so is now widely used as an outside liner on board for corrugated cases where puncture and water resistance is not a key requirement.

# III The Characteristics of Corrugated Board

## 1 Virgin v. recovered fibre boards – how do they compare?

### Fluting:

- At the lower grammage levels, Waste-based fluting has been developed to a level close to Semi Chemical fluting. Above 150 gsm, Semi Chemical performs better.

### Liner:

- Kraft liner has a superior bursting strength, with Test-liner 2 achieving about 70% of the Kraft liner level.
- When it comes to compression strength, Test-liner 2 achieves about 90% of Kraft liner levels and Test-liner 3 about 50%.

- The internal fibre bonding strength of Test-liners is very similar to Kraft liner and at a level which meets industry requirements.
- The smoothness of Test-liner 2 is almost as good as Kraft liner and within the range needed to print on brown liners.

## 2 The different fluting profiles

**Fluting** – the corrugating medium that is covered on one or both sides by flat papers (or liners) to make corrugated board.

Corrugated board is available in many different widths with varying paper weights and finishes. Fluting ranges in terms of the number of corrugations (the waves or arches) per unit length and height.

### Flute ‘profiles’ (sizes)

Flute profile	Fluting height	Characteristics and uses
<b>B-flute</b>	3mm	Good puncture resistance. Most common type of fluting. Seen in all types of applications including die-cut and regular cases, gives a good all-round performance.
<b>C-flute</b>	4mm	Very common grade. Offers greater compression strength than B-flute, with slightly better stacking strength for lighter products. It can be prone to more crushing if used in the wrong application.
<b>E-flute</b>	1.8mm	Light-weight fine flute (it is one quarter the thickness of C-flute). Provides a flat surface for high quality printing. Excellent crush resistance and compression strength. Most commonly used in smaller cartons and die-cut applications.
<b>F-flute</b>	0.75mm	Extra thin. Commonly used for packaging of luxury products, which is to be litho-laminated.
<b>Less-flute</b> Weedon’s own range of environmentally friendly, economical board grades. Also known elsewhere as R-flute, S-flute or X-flute.	2mm	Particularly suited to the Retail Ready Packaging market. The board is thinner – without forfeiting strength – and therefore more efficient in production and reduces supply chain costs. It also offers a better surface for printing.

### Double wall combinations

Liners and fluting medium can be combined to produce single wall board, double wall board or even triple wall board:

- Single Wall Board – 2 liners and single flute
- Double Wall Board – 3 liners and double flutes
- Triple Wall Board – 4 liners and three flutes

The fluting of double wall board can be made of different paperboards, giving rise to combinations such as:

- BC double wall – 7mm in thickness, gives excellent all round performances, most often seen in shipping cases where a high protection level is required.
- EB double wall – 4.8mm in thickness, gives excellent performance in both print finish and impact protection.
- LE double wall (Less-flute combined with E-flute) – 3.8mm in thickness, offers the Point of Sale display market a fully recycled display board grade, which is also more space-efficient than the traditional EB option.

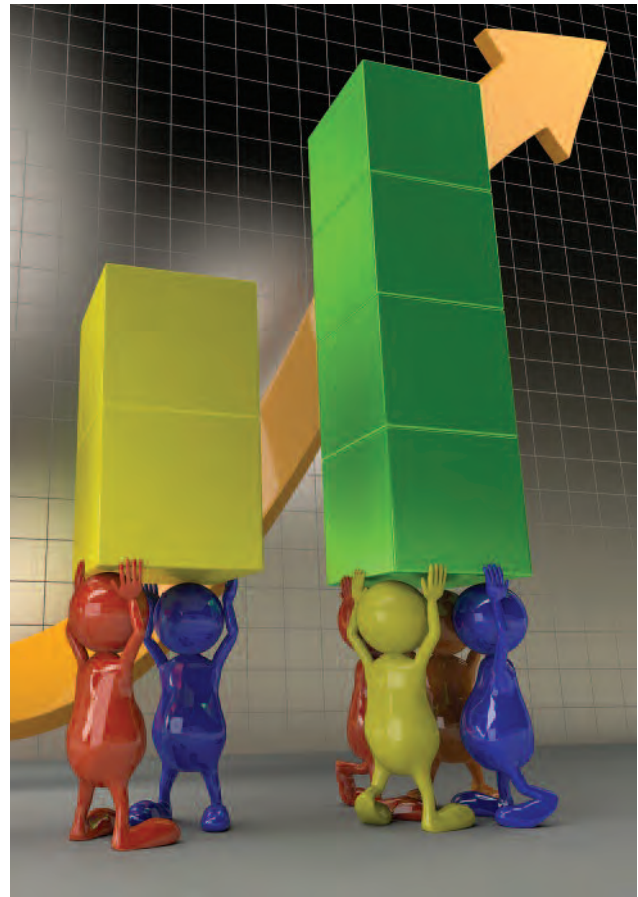
### 3 Measuring the performance of corrugated boards

Determining the strength of corrugated board is now no longer simply a matter of judging its weight or its thickness. A better indicator of potential strength is the bendability of the linerboard.

#### It's all a matter of science!

Research at the Institute of Paper Science and Technology in Atlanta, GA, has shown that crush resistance is not significantly affected by the weight of the board.

The introduction of more advanced conversion machinery is producing corresponding progress in the development of new boards. Today's high-performance, light-weight boards have relatively low bending stiffness and thus less tendency to collapse under pressure. As a result, a thinner board may now offer the same or even better strength and protection than a heavier board. The implications for materials usage and supply chain costs are significant.



Tests which measure the performance of paperboard are therefore increasingly important. A battery of tests is now available:

#### For flutings

- Concora Medium Test (CMT) – a stiffness test that measures the crush resistance of the fluting
- Ring Crush Test (RCT) – a stiffness test to identify what the fluting contributes to the compression strength of the board (ie how much load it can withstand before it collapses)
- Short Span Compression Test (SCT) – a more modern form of RCT

#### For liners

- Bursting strength test (how much pressure paper can tolerate before it ruptures)
- RCT and SCT – to indicate the liner's contribution to the compression strength of the board
- Cobb test – to measure water absorbency of the top surface, which affects printability. On the back surface the same test indicates how well the liner will adhere to the fluting
- The top surface is also tested for smoothness and shade level, which affect printability
- Tests for substance and moisture consistency and the ability to fold without cracking

## IV Environmental Considerations

### Why choose corrugated packaging?

Contrary to popular opinion, corrugated packaging is widely recognised in professional circles as the most environmentally friendly form of packaging available today.

For example, some believe that the world's forests are being decimated to make paper.

**FACT:** The virgin fibres for corrugated board mostly come from sustainably managed forests that exist solely for the materials they provide, though paper-making also provides a convenient outlet for low-grade wood resulting from essential forest management.

**FACT:** New forests are being planted rather than destroyed. For every tree cut down, three to four are replanted, and it is estimated that there are 25% more trees in the developed world today than there were in 1901.

**FACT:** The production of recycled corrugated board consumes not only recycled packaging waste but also conveniently disposes of other types of waste paper. Recovered paper (used paper) represented over 70% of the fibre used to manufacture paper and board in the UK in 2013.

This figure will never achieve 100% for two main reasons:

- Waste corrugated can only be recycled seven times before its fibre becomes too weak for further use (but even these unusable fibres are fully biodegradable).
- Paper and cardboard is lost when used, for example, in books or wallpaper, when destroyed in use or contaminated (think cleaning materials and toilet paper!).

All cardboard can be reused and recycled. Recycled corrugated cardboard can be used to make more cardboard boxes. This means that less resources are used in the future, and re-use of boxes ensures the maximum lifespan of the original materials.

Corrugated cardboard has a recycling rate of 84% in the UK – the highest recycling rate of any type of packaging. Every four months, an area the size of Greater London is saved from landfill by recycling corrugated cardboard alone!

### Other reasons to consider recycled board:

- Recycled materials generally cost less than virgin materials.
- Many consumers now base their purchasing habits on how eco-friendly a product and its packaging appear to be.



## V The Future?

Paper and board technology is improving all the time. One of the key trends likely to develop in coming years is the growth of 'light-weighting' – the move towards ever lower grammage corrugated board, possibly as low as 70-80 gsm.

Minimising the use of raw materials in this way will help sustain corrugated board as a packaging material. It will drive down prices to the customer and help address growing environmental concerns.

The key is the achievement of the same strength and protection from thinner boards – and we are already seeing this today with the introduction of a new generation of light-weight boards such as our own Less-flute.

If buyers only know one fact about choosing the right board for a job, it is that they should now be considering strength and performance rather than simply 'weight'.





## VI Appendix – Glossary

Terminology and classifications of paperboard are not always uniform. Differences occur depending on specific industry, geographical location and personal choice. However, the following terms are often used:

**Bleaching** – pulp used in the manufacture of paperboard can be bleached to decrease colour and increase purity. Virgin fibre pulp is naturally brown in colour. Recycled paperboard may contain traces of inks, bonding agents and other residue which colour it grey. Although bleaching is not necessary for all end-uses, it is vital for many graphical and packaging purposes.

**Bursting strength** – how much pressure paper can tolerate before it ruptures.

**Compression strength** – how much load paper can withstand before it collapses.

**Conversion equipment** – the machinery which converts corrugated board into boxes.

**Corrugated board** – consists of fluted paper (or ‘corrugating medium’) stuck to one or two flat sheets of paper or board (called liner or linerboard). Single face corrugated is where one sheet of fluting is stuck to one liner board; double face corrugated board is made up of a sheet of fluting stuck between two sheets of liner. Since corrugated board is made mainly out of natural unbleached wood fibres, it is generally brown, although its shade may vary depending on the type of wood, pulping process, recycling rate and impurities content. For certain boxes that demand good presentation, white bleached pulp or coating is used on the top ply of the linerboard that goes on the outside of the box.

**Corrugating medium** – the paper used to form the fluted part of corrugated board.

**Corrugator** – the machine that makes corrugated board from fluting and liner papers.

**Die-cut** – stamping out a box shape using steel rule dies (like cutting out biscuits with a pastry cutter!).

**Double wall board** – corrugated board comprising liner/flute/liner/flute/liner.

**Flute** – a single ridge (arch) in the fluting medium.

**Fluting** – the corrugating medium that is covered on one or both sides by flat sheets (or liners) to make corrugated board.

**Grammage** – mass per unit in gsm (grams per square metre), a measure of paper density. Although

technically paper is measured by its thickness, people still talk (inaccurately) about its ‘weight’.

**Hardwood** – eg birch, which has short fibres (approx. 1.3mm in length). Generally more difficult to work with, it provides higher tensile strength, but lower tear and other strength properties. Although its fibres are not as long and strong as those in softwood, they make for a stiffer product. Hardwood fibres fill the sheet better and therefore make a smoother paper that is more opaque and better for printing. Hardwood makes an excellent corrugating medium for fluting.

**Kraft liner** – is made from virgin fibre from softwood pulp, produced by a process known as Kraft pulping. This process uses sodium sulphate to treat softwoods, principally pine, to dissolve the bonding compound in the wood (lignin), allowing the cellulose fibres to be separated to form a wood pulp with little mechanical effort. These fibres are relatively long because the original wood is softwood, so the resulting paper is fairly stiff and has good tear and bursting strength, making it ideal for liners on corrugated board.

**Lignin** – found in plants, acts as a binding agent or cement between the fibres in wood and other plants, making them rigid.

**Liners/Linerboard** – in corrugated board, a strong stiff board covering one or both sides of the corrugating medium (fluting). The liner provides the puncture and tearing strength requirement, to protect the contents of the corrugated case. Special coatings may be applied for specific usage including moisture-repelling and anti-static.

**Multi-ply** – made from a number of layers of pulped fibres. Multi-ply paperboard generally creases and folds better than single-ply.

**Paper** – a thin material produced by pressing together moist fibres (typically cellulose pulp derived from wood, rags or grasses) and drying them into flexible sheets.

**Paperboard** – a thick paper-based material. While there is no rigid differentiation between paper and paperboard, paperboard is generally thicker. According to ISO standards, paperboard is a paper that is heavier than 224 gsm, but there are exceptions. Paperboard can be single- or multi-ply. Sometimes it is referred to as cardboard, which is a generic, lay term used to refer to any heavy paper pulp-based board.

**Pulp** – a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibres from wood, fibre crops or waste paper.

**Pulping** – extracting fibres from their sources.

**Recycled paper** – paper made from extracting used paper fibre.

**Runnability** – how well a paper performs on press. Considerations of a paper's runnability include a variety of structural and surface properties, such as cleanliness of the surface, how well particles of fillers and coatings remain bonded to the paper, how well a paper maintains its dimensional stability (changes in size due to changes in moisture content can affect not only the quality of the printed image, but also cause feeding problems), and other factors such as curling, wavy edges and chemical composition.

**Secondary fibre** – fibre that has been used before, eg recovered paper.

**Semi Chemical fluting** – produced from a hardwood pulp, ie where the cellulose fibres are relatively short. A significant amount of the bonding material, lignin, is retained. This produces a very stiff paper with high compression strength. In addition, when passed through a corrugator, heat reacts on the lignin which sets rigidly when it cools in the formed flute, bonding the fibres together to produce a very rigid board with good crush resistance.

**Sheet plant** – a corrugated box manufacturer that converts sheet board into packaging.

**Single face** – one piece of corrugated fluting glued to one liner.

**Single wall** – corrugated board comprising liner/flute/liner.

**Smoothness** – the flatness of the surface. It can determine whether or not the paper can be successfully printed.

**Softwood** – eg pine and spruce, which have typically long fibres (approx. 3.3mm in length) and make superior paperboard for use where strength is important. Softwood makes excellent linerboard.

**Stiffness** – the measure of force required to bend a paper through a specified angle. This is one of the most important properties of paperboard as it affects the runnability of the board during manufacture of the cartons and also the ability of cartons to run smoothly through the machine that erects, fills and closes them. Stiffness also gives strength and reduces the likelihood of a carton bulging under the weight of its contents such as, for example, cereals settling in the box. Although most paper strength properties increase with increasing sheet density, stiffness does not. Other factors which affect board stiffness include coatings and moisture content.

**Straw pulp** – an alternative to wood pulp in the making of paper. Non-wood fibre sources account for about 5-10% of global pulp production.

**Tearing resistance/strength** – the ability of the paper to withstand a tearing force. Fibre length and inter-fibre bonding are both important factors in tearing strength. Longer fibres (from softwood) deliver greater tear strength.

**Tensile strength** – resistance to the force required to produce a rupture in a strip of paper or paperboard, affected by fibre strength, fibre bonding and fibre length.

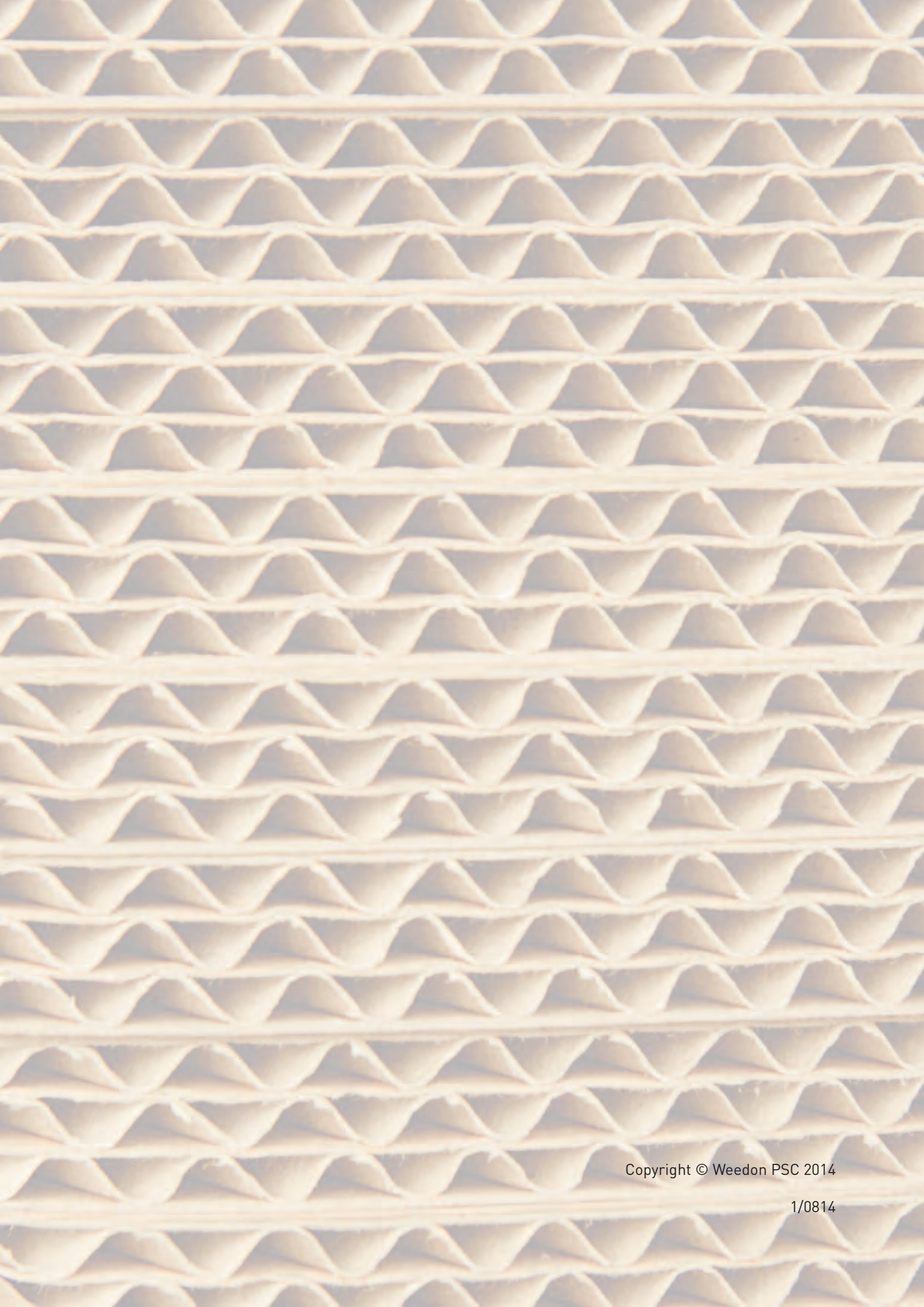
**Test-liners** – liners made partly from chemical pulp and partly from waste paper.

**Virgin fibre** – wood fibre that has never been used before to make pulp, paper or board, ie it does not include any recycled fibres.

**Waste-based fluting** – normally fluting made from 100% recycled paper. In the UK most WBF produced is in the lower board weights.

**Wet strength** – some grades of paper have to be strong enough to withstand tear, rupture or falling apart when saturated with water. To impart wet strength, the paper is treated chemically or the packaging is coated.

**Wood pulp** – wood fibre reduced chemically or mechanically to pulp and used in the manufacture of paper.





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