Lecture 2:
Paper and paperboard based packaging
Overview of different types of materials

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After Lecture 2 you should be able to

• Describe different types of wood fibre based packaging materials and their basic usage in different applications
• Describe and define different types of paperboard and some of their basic end-use properties
• Describe and define different types of corrugated board (corrugated packaging) and some of their basic end-use properties
Literature

• Lecture notes
• *Paperboard Reference Manual* - Pages 11-36, 51-57
• *Cartons, Crates and Corrugated Board – Handbook of Paper and Wood Packaging Technology* - Chapter 7
• *Pulp and Paper Chemistry and Technology - Volume 4*, Paper Products Physics and Technology - Chapters 1, 10

World paper and board production in millions of tonnes

- Graphic 89,3 M (30 %)
- Other 9,9 M (3 %)
- Newsprint 36 M (12 %)
- Tissue 18,6 M (6 %)
- Packaging 145,1 M (49 %)

CEPI, 1998
### Paperboard Packaging’s 2009 Box Buyer Survey

<table>
<thead>
<tr>
<th>Substrate Demand, 2009 compared to 2007</th>
<th>Other Packaging Materials, 2009 compared to 2007</th>
</tr>
</thead>
<tbody>
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</table>

### Paper and Paperboard Packaging

- Exists at all levels of packaging
  - Sales or primary packaging
  - Grouped or secondary packaging
  - Transport or tertiary packaging
Paper and Paperboard Packaging

Paperboard based composites

1. Polyethylene
2. Paperboard
3. Polyethylene
4. Aluminum foil
5. Polyethylene
6. Polyethylene
Wood fibre based packaging

+ wood packaging!

Paper
Definition

• Matted or felted sheet usually composed of plant fibres
• Paper has been commercially made from such fibre sources as
  – rags (linen)
  – bagasse (sugar cane)
  – cotton
  – straw
• Modern paper is almost exclusively made from “cellulose fibres” derived from wood
**Terminology**

**Introduction**

- Paperboard = boxboard = cardboard = carton board describes a heavier paper stock
- Paper and paperboard are non-specific terms that can be related to either material caliper (thickness) or grammage (basis weight)
- ISO (International Standards Organisation)
  - Paperboard = paper with a basis weight > 250 g/m²
- General U.S. practice
  - Paperboard = paper with thickness > 300 μm

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**Fibre sources**

- Spruce fibre – long and flat
- Birch fibre – short and cylindrical
- Pine fibre – long and flat
- Mixed fibres of spruce, pine and birch
Fibre source and length

- Most important fibre characteristics is fibre length

<table>
<thead>
<tr>
<th>Fiber Source</th>
<th>Typical Fiber Length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Sources</strong></td>
<td></td>
</tr>
<tr>
<td>Hardwood (e.g., poplar, aspen, maple)</td>
<td>2 mm/0.08 in.</td>
</tr>
<tr>
<td>Softwood (e.g., pine, spruce, hemlock)</td>
<td>4 mm/0.16 in.</td>
</tr>
<tr>
<td><strong>Other Sources</strong></td>
<td></td>
</tr>
<tr>
<td>Straw, bagasse</td>
<td>&lt; 2 mm/0.08 in.</td>
</tr>
<tr>
<td>Bast (e.g., linen, cotton)</td>
<td>&gt; 2 mm/0.5 in.</td>
</tr>
<tr>
<td>Recycled paper</td>
<td>varies depending on source</td>
</tr>
</tbody>
</table>

Main Sources
- Hardwood (eucalyptus) 1-1.5 mm

Long fibres produces paper with

- proportionately higher
  - tensile strength
    - tear strength
    - fold strength
    - puncture strength
- a rougher surface texture
- variations in density due to poor formation that can lead to
  - uneven ink adsorption during printing
  - erratic adhesive bonding
Short fibres produces paper with

• a smoother surface, and
• significantly reduced physical properties compared to long fibres

Recycled fibres will have properties

• inherited from the original fibres source, but
• with the provision that every re-pulping process degrades and reduces fibre length, thus
• significantly reduced physical properties compared to long fibres, and
• affected by extraneous contaminants such as
  – water insoluble adhesives
  – plastic debris
  – non-removable printing inks
## Pulping methods

- **Mechanical pulping**
  - mechanical separation of fibres in refiners

- **Chemical pulping**
  - chemical separation of fibres
  - alkali sulphate extraction (kraft pulp)

- **Combined processes**
  - semi-chemical (chemicals before refining, NSSC)
  - thermo-mechanical (wood softened by heating before mechanical refining)
  - chemical-thermo-mechanical pulp (CTMP)

## Pulp characteristics

### Mechanical pulp

- High yield from the timber
- The presence of lignin makes the fibres hard and rigid.
- Limited degree of consolidation
  - Paper with high bulk (low density), bending stiffness and dimensional stability
- A sheet made solely of mechanical pulp is relatively weak but relatively stiff
**Pulp characteristics**

Chemical pulp

- Preserves fibre length
- Develops a high degree of consolidation
  - High density
- Flexible and soft fibres
  - Good creasing, embossing and cutting properties *(needs to be discussed)*
- High whiteness, brightness and light stability properties
- High purity yields good odour and taint protection

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**Final paper properties affected by**

- Beating of the pulp
- Forming of the fibre network
- Wet-pressing
- Drying and drying constraints
- Post-drying operations such as
  - Size pressing (starch solution)
  - Surface coating
  - Calendering
Representative paper machines

• Fourdrinier Machines

Representative paper machines

• Twin-wire Machines
Material directions

Depositing a fibre-water suspension onto a moving wire belt tends to align fibres in the direction of the web travel.

Paper can to a good approximation be considered as an orthotropic material.

Orthotropic material

- Three mutually perpendicular symmetry planes, i.e.
- Three perpendicular principal material directions
- Why only approximately orthotropic?
  - Principal directions do not necessarily coincide with MD, CD and ZD everywhere in the web.
- Why bother?

**Tensile stiffness index vs. shrinkage**

Reference: T. Wahlström
Shrinkage in CD

Position across the paper web, CD / m

Reference: T. Wahlström

Stiffness in the sheet at different drying strategies
To summarize:
Different shrinkage at the edges will make the sheet only approximately orthotropic across the web

Why bother?

• Non-uniform effects are typically located at the edges of the web, but streaks can also occur in the web.
• Edge effects create runnability problems in converting and end-use, particularly in
  – printing operations, and
  – manufacturing of paper bags and sacks
Large deformation bending of plates and its influence on deflection of paper and board

- Large deflection is typically larger than the sheet thickness!
- Double-curved surfaces in general possible only for very small deflections!

(Nordström et al. 1998)

PAPERBOARD FOR PACKAGING APPLICATIONS
The paperboard process

How to choose paperboard
Some related properties and features
How to choose paperboard
Promotion of products

- Physical protection needs
- Possibilities and contradictions
- Limitations due to the laws of nature
- Competitive economy
- Consistency in manufacturing
To select paperboard - I

<table>
<thead>
<tr>
<th>Paperboard manufacturing</th>
<th>Paperboard properties</th>
<th>From paperboard to product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Marketing</strong></td>
<td><strong>Shape</strong></td>
<td></td>
</tr>
<tr>
<td>Primary fibre</td>
<td>Strength and toughness</td>
<td>Design</td>
</tr>
<tr>
<td>Multiply forming</td>
<td>Stiffness</td>
<td>Die-cutting and creasing</td>
</tr>
<tr>
<td>Coating components</td>
<td>Creasability and foldability</td>
<td>Gluing and sealing</td>
</tr>
<tr>
<td></td>
<td>Gluability and sealability</td>
<td>Deep drawing</td>
</tr>
<tr>
<td>**Graphical reprodu-</td>
<td>Whiteness</td>
<td></td>
</tr>
<tr>
<td>cability**</td>
<td>Surface structure and</td>
<td>Design</td>
</tr>
<tr>
<td></td>
<td>smoothness</td>
<td>Extrusion coating</td>
</tr>
<tr>
<td></td>
<td>Flatness and dimensional</td>
<td>and lamination</td>
</tr>
<tr>
<td></td>
<td>stability</td>
<td>Printability and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>varnishability</td>
</tr>
<tr>
<td></td>
<td>Absorption and drying</td>
<td>Clean edges and surface</td>
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</tbody>
</table>

To select paperboard - II

<table>
<thead>
<tr>
<th>Paperboard manufacturing</th>
<th>Paperboard properties</th>
<th>From paperboard to product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protection</strong></td>
<td><strong>Physical protection</strong></td>
<td></td>
</tr>
<tr>
<td>Primary fibre</td>
<td>Strength and toughness</td>
<td>Design</td>
</tr>
<tr>
<td>Multiply forming</td>
<td>Stiffness</td>
<td>Extrusion coating</td>
</tr>
<tr>
<td>Coating components</td>
<td>Box compression strength</td>
<td>and lamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Die-cutting and creasing</td>
</tr>
<tr>
<td><strong>Product safety</strong></td>
<td>Taint and odour neutrality</td>
<td>Design</td>
</tr>
<tr>
<td>Primary fibre</td>
<td></td>
<td>Extrusion coating</td>
</tr>
<tr>
<td>Coating components</td>
<td></td>
<td>and lamination</td>
</tr>
<tr>
<td></td>
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<td>Printing and varnishing</td>
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</tbody>
</table>
## To select paperboard - III

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<thead>
<tr>
<th>Paperboard manufacturing</th>
<th>Paperboard properties</th>
<th>From paperboard to product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converting and recycling properties</td>
<td>Runnability</td>
<td>Primary fibre</td>
</tr>
<tr>
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<td></td>
<td>Multiply forming</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating components</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution and end-use</td>
<td></td>
<td>Primary fibre</td>
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</tbody>
</table>

Design
Extrusion coating and lamination
Printing and varnishing
Die-cutting and creasing
Embossing and hot foil stamping
Glueing and sealing

## Single-ply and multi-ply paperboard

**ply = layer**

Multi-ply paperboard is a LAMINATE structure
Solid Box Board (SBB)

Solid Bleached Board
(aroma and flavour sensitive products)

Solid Unbleached Board
(carrier sleeves, liquid packaging)

Folding Box Board (FBB)

Low density material with high stiffness

The I-beam principle
White Lined Chipboard (WLC)

- Wide range of different qualities
- Used in general packaging
CORRUGATED BOARD BOXES

- The corrugated fibreboard box is by far the most common form of transport packaging.
- Not very many years ago corrugated board packaging was still not considered (and accepted) as a transport packaging giving sufficient product protection.
  - Conveyance of goods was carried out in non-covered trucks and goods wagons exhibiting the packaging to severe climates.

Different types of corrugated board
Price per unit area as function of specific stiffness

![Graph showing price per unit area as function of specific stiffness]


Corrugated board containers/boxes

Main features

- Versatility
  - materials possessing a wide range of properties
  - flat sheets with a large range of structural and decorative properties
  - minimum space before erected
- High strength and low weight characteristics
  - structural sandwich with a low density core (long before it was introduced in the fibre reinforced plastics industry)
- Ready adaptation
  - suitable for a wide range of production techniques
- Production containment and protection features
  - contains and protects from producer to customer
- Low set up and tooling costs
  - many styles of boxes can be made by conventional converting equipment
Corrugated board boxes
Main features

- Low storage and handling costs
- Quick change characteristics
  - changes in style, graphics etc. can readily be made to suit changes in need
- Suitable for graphics design
  - “smooth” easily printed surface (Washboarding is a problem.)
- Use of renewable resources and suitability for recycling
  - made of wood fibres
- Contribution to the effectiveness of all handling and storage operations
  - smooth snag free surfaces
  - closely tolerated dimensions
  - secure closure methods
  - “good” graphics
  - easy design modification

Corrugated board - a sandwich structure

- Facing density 0.7 g/cm³
- Core density 0.07 g/cm³
- Low density core
- Strong relatively high density facings
- Honeycomb core
- Reboard
Notation used for corrugated board

Definitions of different types of corrugated board

<table>
<thead>
<tr>
<th>Flute type</th>
<th>Flute spacing (mm)</th>
<th>Flutes per meter</th>
<th>Flute height (mm)</th>
<th>Take-up factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.3–10</td>
<td>110 ± 10</td>
<td>4.67</td>
<td>1.54</td>
</tr>
<tr>
<td>C</td>
<td>7.1–8.3</td>
<td>130 ± 10</td>
<td>3.61</td>
<td>1.43</td>
</tr>
<tr>
<td>B</td>
<td>6.1–6.9</td>
<td>165 ± 10</td>
<td>2.46</td>
<td>1.32</td>
</tr>
<tr>
<td>E</td>
<td>3.2–3.6</td>
<td>295 ± 15</td>
<td>1.15</td>
<td>1.27</td>
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<td>1.27</td>
</tr>
<tr>
<td>F</td>
<td>2.3–2.5</td>
<td>422 ± 15</td>
<td>0.76</td>
<td>1.25</td>
</tr>
<tr>
<td>G</td>
<td>1.6–1.8</td>
<td>504 ± 25</td>
<td>0.53</td>
<td>1.2</td>
</tr>
<tr>
<td>N</td>
<td>1.8</td>
<td>555 ± 25</td>
<td>0.40</td>
<td>1.2</td>
</tr>
</tbody>
</table>
Usage of different types of liner and fluting in corrugated board

- Natural kraft linerboard
  - Mainly unbleached kraft fibre, some recycled content allowed
- White top linerboard
  - Bleached top layer on an unbleached base layer
- Testliner
  - Top layer and base layer made from 100% recycled fibres
- Other recycled liner
  - Mainly kraft top layer, which is a natural kraft layer on a recycled base layer
- Recycled medium
  - 100% recycled fibre furnish
- Semi-chemical medium
  - Contains mostly NSSC hardwood and/or softwood (NSSC= Neutral Sulphite Semi-Chemical pulp. Produced by defibration in a disc refiner.)

European market 1999

Different structural levels of corrugated board packaging

Liner

Corrugated board

Fibre network

Fluting

Container
Testing of corrugated board packaging structures and materials can be carried out at different structural levels.

Today, typically, component testing is carried out by paper “people” and box testing by “packaging” people. This should be changed since box and components properties of course are STRONGLY linked.

Different types of containers
Regular Slotted Container (RSC)

Special purpose packaging
Special purpose packaging

Die cut box

Wrap around box (IKEA)
Stacking of boxes on pallets

- Column stack
- Interlocking 2 top layers only

Interlocking layers of boxes

Interlock stack patterns has 37% less potential strength than column stacks.

P. G. Wright, P.R. McKinlay, E.Y.N. Shaw

Influence of stacking pattern on strength of pallets

- 3 tier vertically aligned no overhang: -45%
- 3 tier vertically aligned no overhang: -32%
- 3 tier horizontally aligned no overhang: ?
- 3 tier horizontally aligned 1" overhang: ?

31
Securing the pallet

angular corner pieces with twine or strap

shrink and stretch film

adhesive tapes ties

tension net

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