Chipboard, oriented strand board (OSB) and structural composite lumber

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6.1 Introduction

Wood-based panel materials have been developed as a substitute for solid wood for the manufacture of panels and beams in buildings. It is usual for wood to be converted into chips or strands from small-dimension timber, sprayed with adhesive and hot pressed into boards or beams. The merits of wood-based materials are flexibility in determining panel size and minimising quality variation by dispersing defects in the wood. Hence, low-quality wood can be used for manufacturing wood-based panel materials derived from chips or strands.

The most common board material used to be plywood, which has become more expensive to manufacture because large diameter and good quality logs are increasingly in short supply, often for environmental reasons. Thin plywood veneer is peeled from steamed logs by rotation of the debarked log against a blade. The thin wood veneer is bonded together into plywood in a hot press. A thicker structural form of plywood is laminated veneer lumber (LVL), which is used for beams, walls and many other components in timber structures. Small-dimension, twisted and low-quality wood is not suitable for peeling wood into thin sheets. In contrast, wood-based materials reviewed in this chapter are able to use low-quality wood, fast-growing trees, for example, rubberwood and poplar, as raw materials and also recycled wood from factories and houses. Timber with low density and strength is a suitable raw materials for wood-based boards which contain different size elements according to the board type. Figure 6.1 displays the basic wood elements from largest to smallest. The wood elements which are intermediate in size between veneer and fibre bundles are described in this chapter. Veneer for plywood and fibre bundles for fibreboards such as medium density fibreboard (MDF) are described in Chapters 4 and 5, whereas this chapter is concerned with chips for chipboard and strands for oriented strand board (OSB) and structural composite lumber (SCL) also known as parallel strand products. Recently nano cellulose has been focused on future material (Philippe et al., 2011).

Applications for chipboard include interior panels for floors and walls and furniture. OSB is employed in more structural applications in construction including floors, walls, roofs and the webs of I-beams. As the element size becomes bigger, the strength of the board increases to the extent that beams such as parallel strand products may also be manufactured from strands. The various wood resources, and shapes and sizes of element are explained in this chapter. Figure 6.2 displays photographs of chipboard, OSB, plywood and SCL (LVL, parallel strand lumber (PSL), laminated strand lumber
Wood Composites

Basic properties of chipboard, OSB, plywood, LVL and solid timber are compared in Table 6.1 (Cai and Ross, 2010). Properties of these materials vary in comparison with clear wood. Most wood-based materials are not as high as those clearwood, however, they provide consistent and uniform performance. Figure 6.3 shows the relationship

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific gravity</th>
<th>Modulus of elasticity (GPa)</th>
<th>Modulus of rupture (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear wood</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>White oak</td>
<td>0.68</td>
<td>12.27</td>
<td>104.80</td>
</tr>
<tr>
<td>Red maple</td>
<td>0.54</td>
<td>11.31</td>
<td>92.39</td>
</tr>
<tr>
<td>Douglas–fir</td>
<td>0.48</td>
<td>13.44</td>
<td>85.49</td>
</tr>
<tr>
<td>Western white pine</td>
<td>0.38</td>
<td>10.07</td>
<td>66.88</td>
</tr>
<tr>
<td>Longleaf pine</td>
<td>0.59</td>
<td>13.65</td>
<td>99.97</td>
</tr>
<tr>
<td>Panel products</td>
<td></td>
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</tr>
<tr>
<td>Hardboard</td>
<td>0.9–1.0</td>
<td>3.10–5.52</td>
<td>31.02–56.54</td>
</tr>
<tr>
<td>Medium density fibreboard</td>
<td>0.7–0.9</td>
<td>3.59</td>
<td>35.85</td>
</tr>
<tr>
<td>Particle board</td>
<td>0.6–0.8</td>
<td>2.76–4.14</td>
<td>15.17–24.13</td>
</tr>
<tr>
<td>Oriented strand board</td>
<td>0.5–0.8</td>
<td>4.41–6.28</td>
<td>21.80–34.70</td>
</tr>
<tr>
<td>Plywood</td>
<td>0.4–0.6</td>
<td>6.96–8.55</td>
<td>33.72–42.61</td>
</tr>
<tr>
<td>Structural composite lumber</td>
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<tr>
<td>Laminated veneer lumber</td>
<td>0.4–0.7</td>
<td>8.96–19.24</td>
<td>33.78–86.18</td>
</tr>
</tbody>
</table>
Figure 6.3 The relationship between MOR and MOE in bending of different types of wood-based materials.
between modulus of rupture (MOR) and modulus of elasticity (MOE) in bending of different types of wood-based materials. The properties of these materials depend on raw materials, adhesives and procedures for production so it is a broad guide for choosing these materials. From a cost point of view, wood-based composite materials become more expensive as the mechanical properties increase.

### 6.2 Chipboard

#### 6.2.1 History and applications of chipboard

Chipboard is composed of particles and thin slivers of wood which are made by cutting the wood feedstock with rotating knives and shearing the wood into small elements. The characteristics of chipboard are low cost, high thickness and the capability to manufacture large dimension boards. Plywood was developed in the nineteenth century and the plywood industry grew dramatically in the housing boom of the 1940s. At the same time, the wood resources for making veneer was beginning to run out. In 1942, the Swiss inventor Fred Fahrni used timber which was not suitable for manufacturing plywood to produce chipboard with the commercial name NOVOPAN (NOVO = new and PAN = panel). Wood particles were dried and then sprayed with adhesive. These particles were loosely accumulated into the panel shape and hot pressed to set as a board. At about the same time, the German inventor Max Himmelheber developed a machine for making particles and succeeded in mass producing a chipboard called Homogenholz. Applications of chipboard include roof, floor and wall sheathing, furniture and electrical appliances.

#### 6.2.2 Wood resources for chipboard

Small-diameter wood was originally used as the raw material for chipboard but nowadays the choice of raw materials is wider and includes wood waste from forests and factories, dismantled wood in construction, annual grasses and so on. In the United States, southern pine was the species of choice for manufacturing chipboard but the quality of young plantation trees is now too low, reflected in their low density, high micro fibril angle, high lignin content and low cellulose content which have an adverse effect on the properties of chipboard. The replacement of southern pine with sweetgum was investigated to solve the problem of inferior quality. Sweetgum particles are both smaller and larger particles than southern pine particles. The mechanical properties of sweet gum chipboard were equal or better than those of the pine. Hence hardwood species are feasible substitutes for pine in the southern U.S. as the demand for woody resources continues to grow (Atta-Obeng et al., 2012). Fast-growing trees such as Acacia saligna, Conocarpus erectus, Melia azedarach and Date palm midribs are sources of high-quality wood for chipboard. However, to achieve the same properties of conventional chipboard, fast-growing tree species are pressed to a density level of 750 kg/m³ which is 10–20% higher than conventional chipboard (Hegazy and Aref, 2014).
Since the 1950s, Japanese cedar and Japanese cypress have been planted to remedy the lack of timber construction materials in Japan. However, with time, imported wood resources have become cheaper and personnel expenses higher which mean that Japanese cedar and cypress have lost their market. The present situation is exacerbated because there are many mature tree resources with little infrastructure in the form of forest roads for cutting and transporting trees to the highway. Trees frequently grow on steep gradients which are difficult to access. The quality of these wood resources is quite low because the diameter of logs is small and many knots are present due to the lack of thinning. Many Japanese researchers are trying to develop chipboards from domestic trees (Kojima et al., 2009a,b). High bond quality and durability have been achieved by bonding wood particles with methylene diphenyl diisocyanate (MDI) resin. The mechanical properties of hinoki board were 2–3 times those of commercial chipboard. Agricultural fibres have also considered as a raw material for chipboard. Strawboard products are very attractive in regions or countries where wood resources are scarce and agricultural fibres are readily available (Bowyer and Stockmann, 2001). The residues from wheat and rice plants are lighter than wood and the bulk density of the mat is low. Therefore, it is very difficult to let the gas out of a mat during hot pressing process. These kinds of board are much more compressible and therefore require less platen pressure for pressing. Compared to wood particle, it is recommended that a slower press closing rate and longer press opening time should be employed to manufacture board products from these resources (Dai et al., 2004).

6.2.3 Manufacture of chipboard

A process flow diagram for chipboard manufacture is shown in Figure 6.4.

Milling and screening/classifying: Chips are manufactured with a ring flaker and a variety of wood shapes and waste wood may be used as raw materials. Hammer mills are used for milling waste veneers. Milled chips include a range of chip sizes from small to large which are classified by screening. Chipboard usually has a three layer structure where the surface layer contains small chips and the core layer is comprised of large chip. The surface layer must be smooth for bonding on films and painting. Particles are classified by size by physical screening and air shifting.

Drying: The rotary drum dryer is the main method for drying because the problem of raising dust is avoided. The moisture content of chips should be between 5% and 8% for the surface layer and about 3% for the core layer to prevent steam explosion and reducing the press time during hot pressing.

Blending with resin: Urea formaldehyde, melamine formaldehyde, phenol formaldehyde (PF) and isocyanate resins are adhesives used for the manufacture of chipboard. Water resistance and mechanical properties depend on the type of resin. The resin content of chips is 6–12% for the surface layer and 4–8% for the core layer. Less than 1% paraffin wax is added to improve short time water resistance. The components are blended by loading chips into a rotate drum with internal ‘wings’ and a resin mist is sprayed onto the chips. The resin is deposited on the chip surface as small dots which minimises the use of resin and determines the mechanical properties and cost of the chipboard.
**Forming:** A three layer pre-board may be formed from an initial layer of small chips followed by a second layer of large chips and finally a third layer of small chips. Single layer and five layer boards may also be formed. Some manufacturers cold press the pre-board to reduce the height of the pre-board and to increase stability to prevent the collapse of pre-board during hot pressing.

**Hot pressing:** A multilayer press or continuous press is used for hot pressing. The basic key features of pressing are common to all processes. Pressing is divided into three stages. The first stage is to press until the required thickness is reached. In the second stage the press is maintained at maximum pressure. During the third stage the pressure is gradually released which eases internal stresses in the board. Minimising pressing time reduces process costs accordingly. If the press pressure is released before internal stresses are reduced the chipboard may collapse by puncturing. The temperature of the hot press is 150–160°C for urea formaldehyde resin and 180–200°C for PF resin. Three factors strongly influence the quality, productivity and cost of chipboard, namely the control of temperature for drying chips, pressure levels for hot pressing and time management.

**Sanding and trimming:** Manufactured chipboard is cut to standard sizes (2440 mm × 1220 mm or 3050 mm × 1220 mm). It is important to reduce cutting operations to minimise costs. Saw blades with tungsten carbide tips are used for trimming.
and the surface of chipboard is sanded after trimming. Manufactured board is left to cool and cure before packaging allowing the release of volatile compounds and stabilising moisture content.

### 6.2.4 Structure-related properties of chipboard

According to BS EN 312 (2003), chipboards are classified into seven types of boards as follows:

- **P1** General-purpose boards for use in dry conditions
- **P2** Boards for interior fitments (including furniture) for use in dry conditions
- **P3** Non load-bearing boards for use in humid conditions
- **P4** Load-bearing boards for use in dry conditions
- **P5** Load-bearing boards for use in humid conditions
- **P6** Heavy duty load-bearing boards for use in dry conditions
- **P7** Heavy duty load-bearing boards for use in humid conditions

Mechanical properties of chipboard are strongly related to the bonding strength between chips. When the density of chips is low, adhesive properties improve. However, low density chips are less strong so it is important to achieve a balance between adhesion and chip density. Achieving an optimum density profile in the thickness direction of the board is essential because when the surface density of the board is higher, the bending properties improve. Figure 6.5 shows the mechanism for achieving this density profile. During hot pressing, the surface chips of the board contact the hot press surface first. The surface chips have a higher moisture content compared to the core layer chips. When the pressing speed is fast, the surface chips are pressed before the core layer is plasticised by heating ensuring that the board has a high density surface layer and low density core layer. The mechanical properties of chipboard are strongly related to the board manufacturing process and the properties of the raw materials. Ingress of moisture will cause swelling when the internal stresses from through-thickness pressing are relieved. Such thickness swelling can be avoided by the use of water proof adhesives such as isocyanate and PF resins. In general, urea formaldehyde resins possess low water proofing qualities but are suitable for adhesively bonding chipboards such as P1 grade.

### 6.2.5 Future development of chipboard

Although changes in the way that chipboard is used are unlikely to be significant improvements can be made to utilise wood resources more efficiently and reduce environmental impact. As well as the use of small-diameter logs, recent developments include manufacturing with low-quality wood, wasted wood and other resources besides...
wood. Bark has traditionally been burnt as a source of energy after its removal in the saw mill. Martin et al. (2008) and Gireesh et al. (2011) have trialled the use of bark as a raw material for chipboard. The bending strength, young modulus in bending and internal bond strength (IB) decreased and linear expansion increased with increase in bark contents (Martin et al., 2008).

However, bark board possesses good dimensional stability in water with no formaldehyde emission (Anon., 1999). The properties of bark board may be improved by removing the extractive content of bark by hot-water treatment (Martin et al., 2008). Binder-less board has been developed by utilising the adhesive properties of bark (Gireesh et al., 2011). In a report which compares chipboard with other materials, the most attractive point of chipboard is its low cost (Wong and Kozak, 2008). Improving the properties of chipboard using advanced techniques will inevitably raise cost, and will result in competition from panel products such as OSB, fibreboard and plywood. Hence the most important direction of research on chipboard is the expansion of the choice of raw materials which may be single component or mixed. When chipboard is manufactured from waste materials, chipboard has extra carbon offset value, making a sustainable contribution to the earth’s environment.

6.3 Oriented strand board

6.3.1 History and applications of OSB

OSB is an engineered, composite, wood-based panel product, designed as a structural replacement for sheathing grades of plywood. The quality and quantity of plywood has successively reduced in recent years. OSB is taking an increasingly higher share in the structural panel products market in applications such as walls and roof sheathing, I-beam webs and single layer flooring (Illston and Domone, 1994; Kubler, 1980).

OSB is characterised by its constituent strand elements which vary in size and aspect ratio and are larger than the chips from which chipboard is pressed. OSB strands have an aspect ratio (strand length divided by width) of at least three. Approximately strand sizes lie in the range 15–25 mm (width), 75–150 mm (length) and 0.3–0.7 mm (thickness). OSB is a wood strand board comprised of wooden strands where there is some degree of orientation with respect to the major board axis. It is usual for strands in the upper and lower faces to be roughly oriented along the major board axis, but in the core strands are disposed at approximately 90° to this direction. Strands in the faces are laid down by rotating disks whereas strands in the core are delivered via slots in a transverse rotating drum. Potentially the mechanical properties of OSB are superior to other wood-based panel products, due to the preferential orientation of the large strands (Geimer, 1976; Shaler, 1991).

OSB was developed in the United States in the 1960s and then in Europe in the 1970s. Initially OSB was termed wafer board and strands were not orientated. Strand lay-up was subsequently controlled to improve properties along the board axis and OSB was established in its present form. The properties of OSB are similar to those of plywood for use in construction and a variety of wood resources can be used to make
OSB which is very attractive from a cost point of view. The cost of plywood was higher in the 1980s because the cost of wood resources was higher. In the 1980s, OSB constituted 1% of the production volume of structural panels whereas today currently OSB has a 75% market share (APA Homepage, 2014: http://osbpanel.org/about_osb.php).

OSB is divided into four types in relation to application under EN 300 (BS EN 300, 2006):

- **OSB/1** General-purpose boards and boards for interior fitments (including furniture) for use in dry conditions
- **OSB/2** Load-bearing boards for use in dry conditions
- **OSB/3** Load-bearing boards for use in humid conditions
- **OSB/4** Heavy-duty load-bearing boards for use in humid conditions

### 6.3.2 Manufacture of OSB and quality control techniques

Raw materials for OSB do not include waste wood employed in the manufacture of chipboard. However, there is no need to use high-quality mature wood peeled into veneer for plywood. For OSB the preference is for young fast-growing trees such as pine or aspen from plantation thinnings in the United States. Other countries have investigated the use of domestic natural resources for OSB in order to utilise resources efficiently. For example, bamboo and poplar have been used for OSB in Malaysia (Mulik and Fauzi, 2013; Jorn and Gerhard, 2013). These species are fast growing, so they are effective resources which can be used sustainably. Furthermore, small-diameter logs for pulp have been evaluated for the manufacture of OSB (Henrik et al., 2004). Figure 6.6 shows the manufacturing process for OSB. The process is fundamentally the same as that for manufacturing chipboard. Debarked logs are stranded with a disk flaker or ring flaker. The flake angle and the temperature of the wood strongly influence the quality of the strands so it is very much important to control these two factors for efficient strand production (Paul et al., 2006).

An investigation of strand thickness in six factories (Timothy et al., 2009) reported that the distribution of wood strand thickness was non-normal. Best-fit distributions varied and included log–logistic, largest extreme value, log–normal and Weibull distributions. The mean and median strand thicknesses for all mills were 0.0322 in (0.8179 mm) and 0.0310 in (0.7874 mm), respectively. The coefficient of variation for all mills was 39.1%. The size of strands is larger than chips which is why the quality of strands directly affects board properties.

Strands have to be dried more than chip because overlapped strands prevent the release of gas from the board during hot press. The core and surface strands are dried to approximately 2 and 3% moisture content, respectively, before resin and wax are added. Normally, PF or diphenylmethane diisocyanate (MDI) adhesives are sprayed onto strands. The surface area of strands in OSB is smaller than the area of chips in chipboard which is why the adhesive content of the surface layer is only 3–6% and the core layer is 4–8%, less than chipboard. Recently MDI adhesive has been employed in the core layer and PF in the surface layer because MDI possesses good bonding strength which makes the panel more waterproof and also reduces the curing temperature in comparison with PF. However, MDI bonds strongly to metal so it is not a good idea to use MDI at the surface because of contact with the steel platens of the press.
The orientation of strands on the forming mat is influenced by the height of the falling strands and the shape of strands, both of which are strongly connected to the mechanical properties of OSB. Nishimura et al. (2004) employed the technique of image analysis to assess the quality of model OSB panels by investigating the relationships between the shape and size of strands, the distribution of strands and bending properties. A batch of commercial strands was analysed by image analysis and the distribution of the shape and size of strands was quantified. The strands were categorised into five strand types as a function of size and aspect ratio. Figure 6.7 shows examples of each strand type. In general, the strand shapes were observed to be mostly rectangular and there was a wide variation in strand dimensions in commercial material. Bigger area strands had lower aspect ratios and small strands had higher aspect ratios. Half of the commercial strands were longer than 100 mm. Model OSB panels were manufactured in the laboratory by hot pressing strand mats formed from each of the five strand types. Strands were laid up by hand into the forming mat and following pressing the orientation and shape of strands was evaluated by image analysis and
the panels were tested in a three point bending. Large area (type 3) strands with high aspect ratios produced model panels with optimum strand orientation and mechanical properties. Type 3 panels were also fabricated from strands dropped through a slotted forming device in order to simulate the delivery of strands to the forming line under factory conditions. As the height of strand delivery increased from 0 to 100–200 mm the disorientation of strands in the pressed panels progressively increased and as a result, mechanical properties in bending were reduced. Hence strand orientation depends on strand size, strand shape and the height of strand formation. If the orientation of strands on the forming line can be checked as a function of time, it is possible to correct the strand shape and forming process during the manufacture of OSB.

The image analysis technique was used to analyse strands orientation (Nishimura et al., 2001, 2002a,b, 2004; Chen et al., 2008). In Figure 6.8, the surface of OSB (a) is imaged with a CCD camera. The digital image is progressively filtered (b–f) to enhance features or remove image noise from. An ellipse is then fitted to each portion of white line in the filtered image and the angle between the major axis of the ellipse and horizontal line of the images is measured. The fibre orientation lies in the range $-90^\circ$ to $+90^\circ$ where the orientation $0^\circ$ is the direction of the moving production line. Strand orientation on the forming mat was measured using image analysis technique. Figure 6.9 shows the relationship between relative intensity and fibre orientation of OSB specimens made from different strand type. In the papers by Nishimura et al., the technique was called filtered image analysis (FIA). FIA allows the strand pattern of OSB to be monitored as a function of time, improving the consistency of engineered wood by linking strand pattern data to the manufacturing process and the forming process of strands.

In the hot pressing process, there is a major difference between the height of the forming mat in OSB and chipboard because the OSB strands are bigger and drier than chips. The height-induced pressing pressure is higher for OSB which means that internal stress in the pressed board is higher, so moisture-induced expansion is greater. Density variations in OSBs are higher than chipboard and MDF due to the larger element size (Wang et al., 2007). Screw withdrawal, head pull-through and lateral resistance should be evaluated because of density variation. Ideally, OSB should be formed from a homogeneous mat and pressing pressure should be minimised.
Figure 6.8 Progressive modification of images with image analysis to measure the orientation of OSB strands.

Figure 6.9 The relationship between relative intensity and fibre orientation of OSB specimens made from different strand types.
6.3.3 Structure-related properties of OSB

The fundamental properties of OSB are reported in a paper on the relationship between OSB properties and board density (Chen et al., 2010). The board density relates to MOR, MOE, IB, thickness swelling (TS), water absorption (WA) and rolling shear (RS). Increasing the density of OSB has a positive effect on MOR, MOE, IB and RS. However, there is not a linear relationship with density because there is damage caused to strands at high pressure during hot pressing. The TS and WA of low density board is low because the bond strength between strands is weak and in high density boards the swell thickness of the heavily compressed strands is high following exposure to water. The balance of bonding strength and pressed strand stress must be optimised to minimise WA and panel swelling. For that reason, resins such as MDI which are waterproof and possess high bonding strength are used and wax is added to improve water resistance. In a new approach, hot water extraction of hemicellulose from strands has been investigated to improve water resistance of OSB (Paredes et al., 2008, 2010; Zhang et al., 2011; Hosseinaei et al., 2011). The extract can be used for the generation of bio-energy and residues are used for the manufacture of improved water proof OSB. This treatment method for strands adds one more process to conventional OSB manufacturing which increases costs. However, if there is a market for hemicellulose, it is a potential method for improving the water resistance of OSB.

As an alternative material to replace structural plywood, OSB has a relatively short history so the assessment of long-term durability is necessary to establish the long-term performance. Bouffard et al. (2010) reported on the long-term durability of OSB for wood flooring and found that the long-term performance of OSB bonded with MDI is the same as structural plywood. Grandmont et al. (2010) examined the mechanical properties of OSB webs in the I-joist webs of OSB. A finite element method was employed to determine which properties of OSB have the highest impact on I-joist shear strain and deflection. The finite element I-joist model was mainly sensitive to the shear modulus of the OSB web plane.

OSB properties were measured by Garay et al. (2009) at 40°C and 95% relative humidity for a period of up to 800h. There were fluctuations in weight and mechanical properties which lay within the ranges determined by the quality standards. The physical properties of OSB were superior to plywood. Kojima et al. (2009a,b) evaluated the durability of wood-based panels comparing TS results from five laboratory-accelerated aging tests with the TS results from panels that had experienced two years of outdoor exposure. The TS of PF resin-bonded panels was higher than that of isocyanate resin diphenylmethane diisocyanate (MDI) bonded panels.

6.3.4 Environmental impact of OSB

Since the birth of OSB the product has expanded rapidly in the marketplace because the lack of good quality forest resources and deforestation. The weakest point of OSB is thickness swelling due to moisture uptake which can be remedied.
by using water resistant adhesives and by removing hemicellulose from strands. From a production point of view, techniques such as image analysis can be used to measure strand orientation on the production line, providing feedback to enhance the reliability and stability of engineered OSB. Today OSB is used not only for structural applications in buildings but also for interiors and Figure 6.10 shows an example of an OSB finished ceiling. OSB should be seen as an environmental friendly material which reduces waste and makes the best use of natural resources.

### 6.4 Structural composite lumber

SCL is historically classed as re-engineered wood, developed as a substitute for high-quality wood. SCL products include LVL, LSL, PSL and OSL. Either layers of wood veneer or wood strands are laminated together with adhesive to create a multi-layer structure with structural dimensions.
6.4.1 Manufacture of SCL

Veneers or strands are bonded together to form a panel or beam in a hot press. Unlike lumber, major defects such as knots and splits are absent because SCL is material reconstructed from small elements. As a result, dimensional stability and mechanical properties are often better than lumber.

*LVL* is the most common SCL. Veneers are peeled from wood, in the same way as plywood veneer is manufactured, and cut into standard lengths and dried. Veneers are bonded together mainly with phenolic resin and the grain of each veneer is oriented in the same direction. LVL is manufactured by hot pressing veneers followed by cooling and trimming. The quality of veneer determines the properties of the final laminated product which is inspected non-destructively (*DeVallance et al., 2011*) with visual grading and ultrasonic techniques. Low grade veneers are used for core layers and high-grade veneer for surface layers to improve strength and appearance.

*PSL* is a U.S. product marketed as Parallam, which is a trade mark. The raw material is veneer from Southern pine and Douglas fir which is clipped into strands to a width of approximately 19 mm, bonded with phenolic resin and consolidated in a hot press at high pressure with the grain oriented along the major axis of the lumber.

*LSL* is comprised of strands of about 300 mm length which are cut from the log with a rotating knife and dried. MDI resin is sprayed onto strands in a rotating drum and the strands are formed into a lumber shape which is up to 2.4 m (8 ft) wide, 140 mm (5.5 in.) thick, and 15 m (48 ft) long and then hot pressed. After pressing it is sawn and sanded to the net lumber size. In contrast to PSL, where strands are derived from veneer, LSL uses wood resources more effectively because cut strands are used.

*OSL* is nearly the same as OSB and LSL but strands are shorter. OSL can be produced using the same facility as OSB which is an attractive feature of OSL but the annual production of OSL is much smaller. The size of OSL products is bigger than any other SCL so during pressing of thick sections steam is formed which increases the internal pressure in the mat. OSB is used flatwise with high density at the surface and low density in the board core whereas OSL is mainly used edge wise so a homogeneous density profile is preferred. Overall, OSL is weaker than LVL and PSL because strands are shorter.

6.4.2 Recent advances in the production of SCL

Erdil *et al.* (2009) report that LVL has the same properties as the solid wood from which the LVL veneer is peeled. LVL properties also depend on the quality of the solid wood and the properties of the adhesive. Low-quality wood can also be used to make LVL and research has concentrated on the best utilisation of low-quality wood resources for the manufacture of LVL. For example, Wang and Chui (2012) investigated the properties of LVL made from lodgepole pine (*Pinus contorta*) which had been degraded by mountain pine beetle infestation. They treated each veneer by dipping into PF resin or using a vacuum pressure method to improve the mechanical properties of LVL. Dimensional stability, shear strength and flatwise bending MOE of LVL were improved, but cost is an important consideration.
Dundar et al. (2009) assessed the fire resistance of LVL made from beech wood (*Fagus orientalis* L.) veneer chemically treated with fire retardant. Although fire performance was improved, the veneer surface was roughened during the drying process after the fire retardant treatment, interfering with the bond strength between veneers in the LVL. Drying at 140°C rather than 160°C improved the surface finish of the treated veneer. The LVL can be used in building applications, but the cost of the fire retardant treatment of the veneers is an issue.

In order to utilise low-quality wood resources, Wang and Wharton (2008) conducted pilot plant tests and mill trials to benchmark mountain pine beetle (*Dendroctonus ponderosae*)-attacked lodgepole pine (*P. contorta* Dougl.) veneers against interior Douglas-fir (*Pseudotsuga menziesii* var. glauca) veneers and normal spruce-lodgepole pine-alpine fir (SPF) veneers for plywood and LVL products. The dry veneer quality of the MPB veneer in terms of thickness and roughness was no different to the SPF control veneer and overall the mechanical properties of the plywood and LVL were similar.

In comparison to LVL PSL and LSL, OSL uses small strand elements, which is an effective way to use low-quality wood resource. Beck et al. (2009) demonstrated the possibility of manufacturing OSL with the same properties as LSL by the optimisation of strand thickness, strand length, slenderness ratio and specific surface area. In future, under-utilised wood resources can be used to manufacture OSL, and it will also be possible to use an OSB manufacturing line, which is expected to reduce costs.

### 6.4.3 Future developments for SCL

SCL products have been reviewed in comparison with sawn timber. SCL products are generally more expensive because of the many processes which include cutting/peeling, bonding and pressing. Life cycle assessment indicates that SCL uses much more energy than sawn timber during manufacture (Puettmann and Wilson, 2005). Overall, the manufacturing life-cycle stage consumes the most energy when the manufacture of resin is considered part of the production process. Extraction of log resources and transportation of raw materials for production has the least environmental impact. However, there are significant advantages in producing SCL including consistent quality and flexibility in selecting raw materials. In future, efforts will be made to reduce the cost of manufacturing SCL and adding value by improving properties. SCL is expected to improve manufacturing process technically and effectively in order to reduce both cost and manufacturing energy.

Rice et al. (2006) and Jonsson et al. (2008) reported on customer reaction to wood-based materials which is important for product development and marketing. The aim of these studies was to identify attributes and associations that people use to describe different types of wood materials and to explore how they relate to preferences. The appearance of SCL is completely different to solid wood – for example, the LVL beams seen in Figure 6.11. The modern appearance of SCL makes a positive impact on customers.
Figure 6.11  The appearance of LVL beams.
The design by Eureka, Architectural Design & Engineering Japan. ‘Dragon Court Village’
won the best residential building prize at Japan Youth Lumbermen’s Association 17th Wood
Design Award: http://www.eurk.jp.

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