A NOVEL RESIN SYSTEM FOR COLOURLESS OSB PRODUCTION

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SUMMARY

There is a growing demand for binders for the OSB industry in Europe. Current solutions are based on the use of phenolic resins or their combinations with PMDI. Associated problems include dark colour, sticking and increased cost. A revolutionary resin system was developed for the production of OSB type of panels with no dark colour. The system avoids the use of isocyanate binders by employing an efficient melamine-urea-phenol-formaldehyde resin and additives adapted to the special needs of this product.

OSB – COMPOSITE OF THE FUTURE

Oriented Strand Board, also known as OSB, is the second generation of waferboard. The main differences between the two products are, firstly, the size of the wafers or strands, which are shorter in waferboard, roughly 40mm by 40mm and more elongated in OSB, approximately 25mm wide by 80 to 150mm long. Secondly, the manner in which the mat is formed. In waferboard the wafers are randomly laid up in the forming process into one homogeneous layer or mat, whereas in OSB the mat is formed in several layers of strands, which are cross aligned and typically oriented in the machine direction in the outer surface layers.

OSB is an engineered wood structural panel that is rapidly gaining popularity with builders, architects, engineers and renovators for use in construction applications where panels are required. This popularity has encouraged significant growth in the OSB industry in both the U.S. and Canada, commencing in the 1980's. Last year, over 500 million standard size panels were used in construction and for industrial purposes (EPF Annual Report, 1999-2000). In recent years the industry has expanded, with new mills being built in Canada, the U.S. and Europe. More specifically, worldwide OSB production has almost doubled during the last decade (Figure 1).

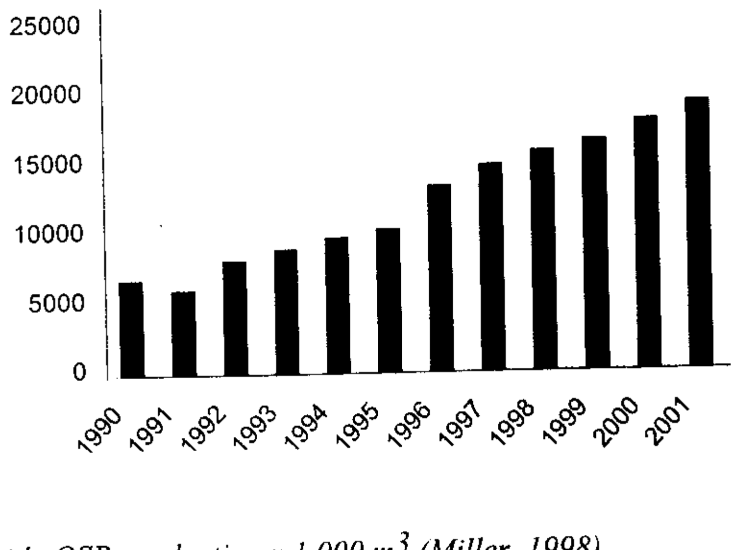

Figure 1: Worldwide OSB production x 1,000 m³ (Miller, 1998).

In 1999, the total world output of OSB rose to an aggregate figure of almost 19.7 million m^3, of which 10 million and 7.5 million m^3 were produced in the U.S.A. and Canada respectively, while the aggregated capacity in Europe slightly exceeded one million m^3. North America still represents the major market for OSB, with an impressive relative share of about 93.5% of the global consumption. Europe ranks second, with a share of 5.1 %. Within Europe, the United Kingdom has a dominant position with almost 30% of the overall consumption. The third major consumer of OSB is Japan, accounting for another 1.1% of the global consumption.

Since 1994, when the commercial production of OSB started in Europe in earnest, production has grown at an impressive rate (Figure 2). The 1999 European production of OSB of around one million m^3 represents an increase of 25% over the previous year. This increase was wholly due to higher output from existing plants, since no new capacity has come on stream. Across Europe, there are currently six plants operating in five different countries (France, Ireland, Luxembourg, Poland and the UK) and one plant in Germany is at the start up phase. Thus, during the year 2000, the aggregated European OSB production capacity is expected to rise by 66% (EPF Annual Report, 1999-2000). For the years 2001 and beyond, an expansion of some 140% has already been announced. This would result in a capacity of some 4.3 million m^3 by the year 2004.

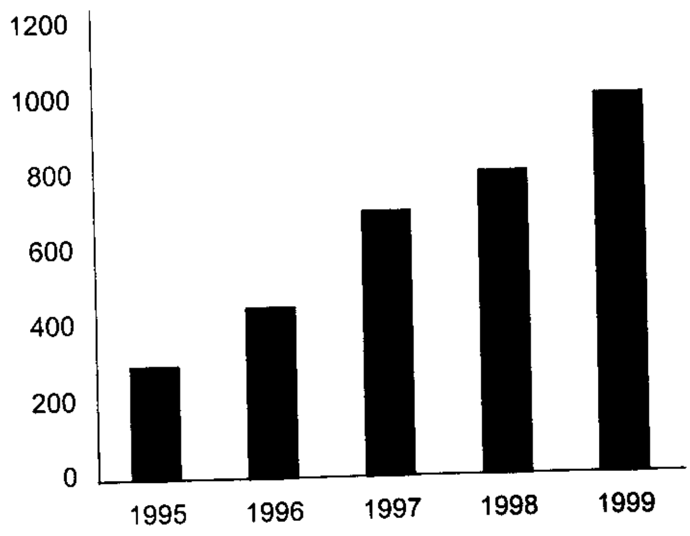

Figure 2: Overall European OSB production x 1,000 m^3, 1995-1999 (EPF Annual Report, 1999-2000).

The structure of North American wood-based panels market has been developed very differently compared to that in Europe. Structural panels, softwood plywood and OSB dominate in North America, accounting for almost two thirds of total demand (Figure 3). By contrast, particleboard is the dominant panel in Europe and there is also a much higher consumption of MDF compared to North America. The high consumption of softwood plywood and OSB in North America is driven by a tradition of wooden housing construction that uses large volumes of panels in structural applications, such as walls, flooring and roofing.

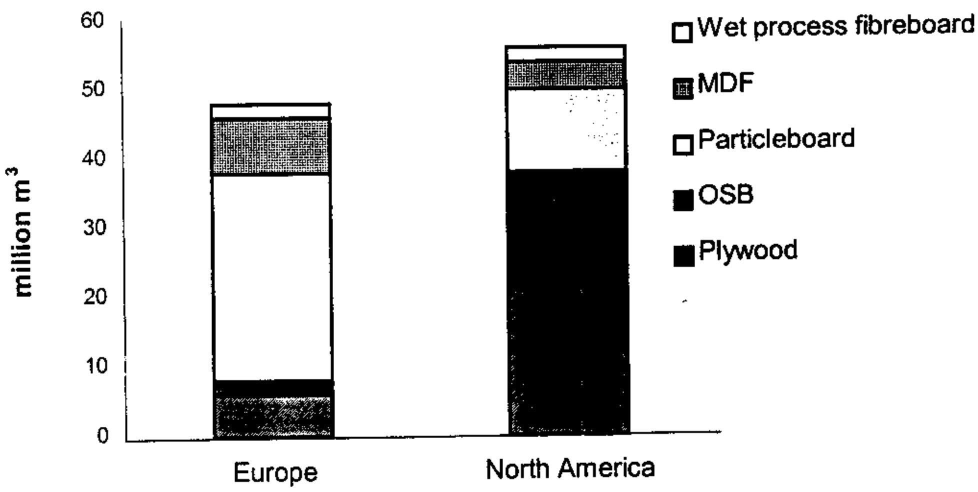

Figure 3: Consumption of wood-based panels in Europe and North America, 1999 (EPF Annual Report, 1999-2000).

The relative position of OSB in the group of wood-based panels can be pictured as in the following:

- Timber boards, beams, solid wood panels
- Blockboard, glulam
- Plywood
- OSB
- Particleboard
- MDF/Fibreboard

From its properties, OSB is ranked between plywood and chipboard (particleboard), which are also used for decorative purposes. OSB panels are, in principle, manufactured in the same way as particleboard, but due to their composition (strands), have different properties across different directions of the boards, eg bending characteristics. Originally, OSB was seen as an alternative to plywood and sawn timber, and it can be used for almost all the uses of both particleboard and plywood. As it is made from lower cost logs in highly automated plants, it is less costly to produce than plywood even though it uses the same type of resin binders as exterior grade plywood. The increasing trend of forest protection and environmentalism has led to the shortage and increased cost of softwood timber, the raw material for plywood. This has helped to reduce the demand for plywood in favour of OSB (in North America, in the mid 1980s, softwood plywood accounted for almost 85% of structural panel demand, but by 1999 the share had fallen to just under 50%, with the rest being satisfied by OSB). There is hence a clear trend towards the use of OSB, which has demonstrated that it can compete with plywood on strength, appearance, versatility and cost. It can be supplied in a wide range of sizes to meet specific end use requirements and is machinable (it can be easily sawn, nailed, drilled, planed, sanded and painted).

In 1978 the first OSB was used and this was recognised by the American Plywood Association as having equivalent performance to plywood for similar uses. It was included in APA's performance standard APA PRP108, followed shortly afterwards by TECO PRP133 and, in 1985, by the Canadian CSA 0437 - Waferboard and Strandboard. Further performance standards were developed: in 1988 the Canadian CSA 0325 - Construction Sheathing, in 1992 the US DOC PS2-92 – Performance Standard for Wood-Based Structural-Use Panels, and in 1994 the Canadian CSA 0452 - Design Rated OSB. In Japan, OSB is now regulated through the JAS standard - Structural Panels, and in Europe through the recently promulgated EN 300 - Oriented Strand Boards - Definitions, classification and specifications. OSB today has full building code acceptance in North America through the national model building codes, and is gaining widespread acceptance in Japan and Europe. In Latin America the acceptance will most likely occur on a national level, in compliance with the U.S. or Canadian standards.

One cannot directly compare the North American and European standards for OSB, since the test conditions employed are not the same. Nevertheless, in Table 1 the main property values required by CSA 0437 and EN 300 are presented and compared. CSA classifies two thickness ranges (<12.7mm and >12.7mm) and three orientation grades (random R, orientation O1 and O2). The European standard classifies three thickness ranges (6-10mm, >10-18mm, and >18-25mm) and four board types: OSB/1 (general purpose boards and boards for interior use), OSB/2 (load-bearing boards for use in dry conditions), OSB/3 (load-bearing boards for use in humid conditions) and OSB/4 (heavy duty load-bearing boards for use in humid conditions). A main difference amongst the two standards lies in the expression of durability performance: after 2hr boiling of the test samples, the bending strength (MOR) is determined in the Canadian standard, whereas the tensile strength (IB) is measured in the European standard (V100 test). This difference may lead to the choice of different required adhesive performances.

Basically, OSB can be manufactured with all resins used in the chipboard industry: phenol-formaldehyde resins (PF), polymeric diphenyl methane diisocyanate (PMDI), melamine-formaldehyde (MF), melamine-urea-formaldehyde (MUF) and urea-formaldehyde (UF) resins. Uniform gluing of the large-area strands of OSB with small amounts of conventional liquid PF resin is difficult and for this reason PF, in powder form, was the adhesive used in the early stages of OSB production in North America. Although the cost of this adhesive is higher, the low quantities employed (2 to 3% by weight based on dry strands) made its use acceptable. The liquid PF resins on the other hand, react faster and facilitate a higher moisture content in the finished board. By improving elements of the manufacturing process, it was possible to reduce the amount of liquid resin needed. Thus, 3.5-4% of liquid resin loading are required to obtain the same board quality as that obtained with 2-2.5% powder resin. Liquid phenolic resins also allow a higher resin loading where special applications require higher strength; this is not feasible with powder resins since typically not more than 3% (by mass on wood) will adhere to the strands.

Table 1: OSB properties required by North American and European Standards

Standard	CSA 0437			EN 300			
Classification within the standard	**R1**	**O1**	**O2**	**OSB/1**	**OSB/2**	**OSB/3**	**OSB/4**
Thickness range, mm	>12.7	>12.7	>12.7	>10-18	>10-18	>10-18	>10-18
MOR parallel to the orientation, N/mm^2	17.2	23.4	29.0	18.0	20.0	20.0	28.0
MOR perpendicular to the orientation, N/mm^2	17.2	9.6	12.4	9.0	10.0	10.0	15.0
MOR parallel to the orientation 2h boil test, N/mm^2	8.6	11.7	14.5	-	-	-	-
MOR perpendicular to the orientation 2h boil test, N/mm^2	8.6	4.8	6.2	-	-	-	-
MOR parallel to the orientation after humid cycle test, N/mm^2	-	-	-	-	-	8.0	14.0
MOE parallel to the orientation, N/mm^2	3.100	4.500	5.500	2.500	3.500	3.500	4.800
MOE perpendicular to the orientation, N/mm^2	3.100	1.300	1.500	1.200	1.400	1.400	1.900
Internal Bond (IB), N/mm^2	0.3	0.3	0.3	0.28	0.32	0.32	0.45
IB after humid cycle test, N/mm^2	-	-	-	-	-	0.15	0.17
IB after 2h boil test, N/mm^2	-	-	-	-	-	0.13	0.15
Thickness swelling 24h, % *	10.0	10.0	10.0	25.0	20.0	15.0	12.0
Linear Expansion o.d. – saturated, %	0.40	0.40	0.40	-	-	-	-
Linear Expansion 50–90 r.h., %	0.20	0.20	0.20	-	-	-	-

* In CSA 0437 the test samples are of 15 x 15 cm size, while in EN 300 the sample size is 5 x 5 cm.

PMDI adhesives were promoted to overcome the dimensional instability of OSB panels after exposure of their edges to high moisture. These binders are more reactive than PF resins and help to achieve shorter press cycles (increased productivity). However, they have the disadvantage of sticking readily to the hot press platens; the release agents developed to avoid this problem have not been fully successful. This is why the isocyanate binders are normally used in the core layer of OSB together with phenolic resins, which are applied in the surface layers. The reactivity (cure factor) of the latter has been increased considerably over the last years; however it is still low compared to UF, MUF and PMDI.

MUF and UF resins have also been employed in OSB production, though at levels higher than the previous adhesives (higher than 8% by weight based on dry strands). Straight MF resins are also commercially available for OSB, the current high price of melamine, however, makes them of no economic value to the OSB industry. Trials have also taken place with tannin resins, which are reactive and moisture resistant. More recently, MUPF resins have gained much attention in Europe due to their potential for achieving the more demanding standards at acceptable cost.

There is a difference between the resins employed in North America and Europe, which is mainly due to the different standards applied. In North America, OSB binders are either phenolic or PMDI based. Phenolic resins are supplied in either powdered (PPF) or liquid (LPF) form and PMDI is supplied in liquid form only. Combinations of these two binder types are often employed and most commonly PMDI is used in the core, while PF is used in the surface layers of the panel to avoid the problems of panels sticking to press platens. More specifically, in North America the levels of resin usage in commodity OSB panels are presented in Table 2, while Table 3 includes the estimated resins solids consumption for 1997. As the data of Table 3 indicate, the adhesives for bonding OSB in North America in 1997 were 86 % phenolic resins and 14% isocyanates.

Table 2: % levels of resin usage in OSB, in North America (Davis, 1998).

Year	PMDI	LPF	PPF
1996	1.8-2.2	2.8-3.5	1.4-2.2
1998	1.7-2.0	2.6-3.25	1.8-2.2

Table 3: Estimated resin solids consumption to produce OSB in North America in 1997 (Sellers, 1999).

Resin type	Resin solids, kt	Resin solids, %
Liquid PF	188	59
Powder PF	87	27
PMDI	46	14
Total	321	100

In Europe, apart from LPF, PPF and PMDI, melamine-urea-formaldehyde and melamine-urea-phenol-formaldehyde (MUPF) resins are also readily used. This difference in the OSB adhesives employed in North America and Europe is caused by the need to satisfy the stringent V100 test of EN 300. This cannot be achieved with PPF, while economically unacceptable levels of LPF or PMDI are needed. Furthermore, increasing the phenolic resin level results in boards with dark colour. Table 4 presents the estimated resin solids consumption for 1999. It is seen that MUPF counts for 50% of the binder consumption, being used mainly in the surface layers with a tendency to replace PMDI usage in the core layers.

Table 4: Estimated resin solids consumption to produce OSB in Europe in 1999 (Boehme, 1999).

Resin type	Resin solids, %
Liquid PF	11.0
Powder PF	9.6
PMDI	29.4
MUPF	50.0
Total	100.0

EXPERIMENTAL

The stringent European regulations for OSB products have forced the wood adhesives industry to develop new highly sophisticated resin systems which will facilitate the production of OSB panels of the most demanding OSB/4 class. **A.C.M. Wood Chemicals plc** has proved that solving this problem is not a matter of changing the resin alone, but rather changing the resin system itself. It has hence developed a unique cost effective environmentally friendly resin system. This system relies on a combination of a melamine-urea-phenol-formaldehyde (MUPF) resin and a special cross-linking agent/hardener. The application of this system in the pilot scale production of OSB provided property values that satisfy the OSB/4 requirements of EN 300 and its successful performance is due to the synergistic action of its properly formulated components. Representative results of this pilot trial are given in Table 5, whereby:

- System 1 is a typical North American gluing system for forming OSB
- System 2 is a phenolic-based gluing system
- System 3 is a system currently employed in European OSB plants
- System 4 is the one proposed by A.C.M. Wood Chemicals plc

The target board density and thickness were 660kg/m^3 and 12mm respectively. Wax emulsion with 60% solids content was employed in both surface and core layers at a level of 1.5% w/w based on dry strands. The temperature of the press platens was 215°C and the press time applied was 10s/mm. The face/core ratio was 50/50 with random orientation.

The data in Table 5 indicate that it is not possible to satisfy the IB requirements after the 2hr boiling test (V100) of EN 300 by employing System 1 (MDI-LPF). Using System 2, which is based on liquid phenolic resin, necessitates an increase in the gluing factor above the 6% level, in order to achieve the V100 value. However, the boards obtained were of dark colour and the swelling value was well above the CSA 0437 and EN 300-OSB/4 limit.

Table 5: Pilot scale OSB production

	System 1	System 2	System 3	System 4
Resin type, %:				
Core	MDI, 2.5	LPF, 6	MDI, 4.5	MUPF, 10
Face	LPF, 5	LPF, 7.5	MUPF, 11	MUPF, 11
Density, kg/m^3	640	655	650	667
IB, N/mm^2	0.35	0.44	0.61	0.69
V100, N/mm^2	0.03	0.33	0.24	0.21
MOR, N/mm^2	32.8	29.9	29.0	29.7
24h swelling, %	10.9	16.2	10.5	11.1

The gluing system currently employed in the largest part of European OSB production (System 3, MDI-MUPF) seems to be able to overcome the problems of dark colour and increased thickness swelling. It relies, however, on the combination of two different resin types and the use of MDI requires special handling, which is non-conventional to the everyday board manufacture. When producing thicker boards, i.e. above 18mm thickness, a higher amount of MDI is required to satisfy the property values of the standards. This, combined with the already high cost of MDI binders, leads to a considerable cost increase.

The system proposed by A.C.M. Wood Chemicals plc is also able to satisfy the EN 300-OSB/4 standard requirements, avoiding dark colour and the use of two different resin types. **Never before has a resin system for OSB based on MUPF alone been proven to be able to compete with the performance of MDI-based systems and meet OSB/4 property levels.** It should be noted that the formaldehyde emission of the OSB panels produced in this trial was low even in the case of the straight MUPF system. This is because the A.C.M. system is properly formulated to meet the most stringent requirements and has the flexibility to attain the lowest formaldehyde emmission levels with the incorporation of a suitable formaldehyde catcher. The cost of such a system is not higher than the cost of an MDI-based system.

CONCLUSIONS

A.C.M. Wood Chemicals plc has recently developed a cost effective gluing system able to attain the stringent OSB/4 requirements, which is based on an efficient melamine-urea-phenol-formaldehyde resin and a hardener adapted to the special needs of this product. The system avoids the use of isocyanate binders, the dark colour given by phenolic resins and the need to employ two resin types together.

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