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# The manufacture of particleboards using mixture of reed (surface layer) and commercial species (middle layer)

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**Abstract** This research was conducted to investigate the suitability of reed (*Arundo donax*) as a substitute for wood in laboratory made 3-layer particleboard in order to supplement the supply of raw material for the Iranian particleboard industries. The ratio of the mixture of reed and wood particles were 20:80, 30:70, and 40:60, respectively, in the surface and middle layers. Press temperatures were chosen at two levels of 165 and 185 °C. Three levels of urea formaldehyde resin were selected for the surface layers, namely: 8, 10, and 12 percent. The experimental panels were tested for their mechanical strength including modulus of elasticity (MOE), modulus of rupture (MOR), internal bonding (IB) and physical properties (thickness swelling and water absorption) according to the procedure in DIN 68763. In general, the results show that reed has a positive effect on the mechanical and physical properties of boards. In this research, the treatment with 40% reed, 12% resin in the surface layers and a 185 °C press temperature has resulted in an optimum reed board product.

**Die Herstellung von Spanplatten aus einer Mischung von Schilfrohr (Deckschicht) und Handelsholzarten (Mittelschicht)**

**Zusammenfassung** In dieser Studie wird die Eignung von Schilfrohr (*Arundo donax*) als Holzersatz für die Herstellung von 3-schichtigen Laborspanplatten untersucht, um die Versorgung der iranischen Spanplattenindustrie mit Rohmaterial zu erweitern. Das Verhältnis von Schilfrohr in den Deckschichten und Holzspänen in den Mittelschichten betrug 20:80, 30:70 und 40:60 Masseprozent. Als Presstemperaturen wurden 165 und 185 °C gewählt. Die verwendeten Harnstoffformaldehydharzgehalte waren 8, 10 und 12 Prozent. Geprüft wurden der Elastizitätsmodul (MOE), die Biegefestigkeit (MOR) und die Querzugfestigkeit sowie die physikalischen Eigenschaften (Dickenquellung und Wasseraufnahme) gemäß dem Verfahren in DIN 68763. Insgesamt zeigen die Ergebnisse, dass Schilfrohr einen positiven Einfluss auf die mechanischen und physikalischen Eigenschaften der Platten hat. Im Rahmen dieser Untersuchung wurde eine optimale Schilfrohrplatte mit einem Mischungsverhältnis von 40:60 und 12 % Harz in den Deckschichten sowie einer Presstemperatur von 185 °C erzielt.

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## 1 Introduction

Approximately 95% of the lignocellulosic material available for particleboard production is wood. However, at the present time, decreasing availability of raw material and the need to conserve natural resources initiated research regarding the use of non-wood fibers in particleboard production.

Much research has been done on the use of various non-wood fibers for particleboard manufacturing. Among the raw materials studied are kiwi pruning (Nemli et al. 2003), almond shells (Gürü et al. 2006), flax shiv (Papadopoulos and Hague 2003), wheat straw and corn pith (Wang and Sun 2002), bark extracts (Nemli et al. 2004), durian peel and coconut coir (Khedari et al. 2004), vineyard pruning (Ntalos and Grigoriou 2002), sunflower stalks (Khristova et al. 1998), cotton stalks, bagasse, rice straw (Heslop

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1997), cotton carpel (Alma et al. 2005), cob and maize husk (Sampathrajan et al. 1992), bamboo (Rowell and Norimoto 1988), jute stalks (Kollmann 1966), bagasse (Youngquist et al. 1997), cotton stalks (Guler and Ozen 2004), kenaf stalks (Kalaycıoglu and Nemli 2006), hazelnut husk (Copur et al. 2007), bamboo chips (Papadopoulos et al. 2004), kenaf core (Xu et al. 2004), sunflower stalks (Bektas et al. 2005), eggplant stalks (Guntekin and Karakus 2008), and waste grass clippings (Nemli et al. 2009).

There are several particleboard factories in the north of Iran. However, limitations in forest area and available volume of trees make the provision of raw materials for the particleboard industries a special challenge in Iran. Hence, finding other sources of cellulosic material is one of the most important objectives of the Iranian government. There are some non-wood plants which may be considered including wheat and rice straw, bagasse and reed.

Iran, thanks to its special climate, possesses some areas where reed can be grown. So the aim of this study was to investigate the use of reed (*Arundo donax*) as a substitute for wood in the manufacture of laboratory made 3-layer particleboard to supplement raw materials for the Iranian particleboard industries.

A primary study conducted by Doost-Hosseini (1989) shows that, in Iran, reed is a lignocelluloses material which has favorable characteristics such as ease of regeneration, rapid growth rates, short term harvesting cycle, continuous availability, low cost and renewability. Reed has a low density, which may lead to better densification during pressing and better mechanical properties.

The negative effect of the high density of raw materials on the mechanical properties of particleboard was explained by Malony (1993) and Moslemi (1974). It is though that better mechanical properties can be achieved by utilization of reed in the surface layers in 3-layer particleboards. This is because of the higher slenderness ratio and lower density of reed particles which promote better adhesion and densification. This was the motivation for this study and the approach has already been successful for bamboo (Namaipoor 1995; Vital and Haselein 1988), for other panel products (Bucur et al. 1998) and for OSB (Nishimura et al. 2004). The studies showed that the adhesive level (Yin 1987; Ashori and Nourbakhsh 2008) and press temperature (Amir-Hosseini 2001) have a direct effect on the mechanical properties of panel made of reed. Hence, these factors were considered in making a three-layer particleboard with reed faces.

## 2 Materials and method

Three-layer particleboards were made in laboratory condition using reed (*Arundo donax*) in the surface layers and commercial wooden chips in the middle layer. Control samples were also made from wood particles only, under industrial production conditions (resin content in the surface layer: 12%, press temperature: 180 °C and shelling ratio: 40:60).

The reeds and wood were chopped up with an industrial Flaker by a local company. The average size of reed particles was 6.3 mm by 0.62 mm by 0.35 mm and wood particles averaged 11.4 mm by 2.7 mm by 0.87 mm. The ratio of the mixture of reed and wood particles were, 20:80, 30:70, 40:60, respectively, in the surface and middle layers. Press temperatures were chosen at two levels of 165 and 185 °C. Particles were bonded with urea formaldehyde resin in the proportion, based on raw material oven dried weight, of 7 percent for the middle layer. Three levels of resin were selected for the surface layers, namely 8, 10, and 12 percent. Target board density was 0.7 g/cm$^3$ and target board thickness 15 mm.

Each board was laid up by hand as a 3-layer mat with adhesive inside an iron frame. After pressing, the boards were conditioned at room temperature. The modulus of rupture (MOE), modulus of elasticity (MOE), internal bonding strength (IB), water absorption (WA), and thickness swelling (TS) after 24 hour water soaking of samples was measured according to DIN 68763 (1982).

Based on these variables 18 board formulations were manufactured with three boards of each type resulting in 54 boards in total. The effect of the variables on the properties of the boards was assessed by Variable Analysis in factorial design and Duncan Analysis was used for comparison of the average values. The comparison between the properties of the reed boards and the control samples was conducted by the LSD method.

## 3 Results and discussion

The average values of mechanical properties (modulus of elasticity, modulus of ruptures, internal bonding) and physical properties of panels (water absorption and thickness swelling after 24 h water soaking) are shown in Tables 1 and 2. Also, statistical comparisons between the value of these samples and the control samples are summarized in Tables 1 and 2.

It can be seen that the treatment with 40% reed, 12% resin in the surface layers and a 185 °C press temperature has resulted in an optimum reed board product.

The values of MOE and MOR are significantly improved by a factor of 19.2% and 14.71%, respectively, in comparison with the control sample. As mentioned before, the reason for this improvement can be related to the low density of reed particles which causes more densification at the surface. This in turn leads to better adhesion during hot pressing. The positive influence of temperature can also be seen in

**Table 1** Mechanical properties of samples made by different treatments and the control sample
**Tab. 1** Mechanische Eigenschaften der unterschiedlich hergestellten Prüfplatten und der Kontrollplatte

| Press Temp (°C) | Resin (%) | Mechanical properties at three mixer levels of reed: wooden chips | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 20:80 | | | 30:70 | | | 40:60 | | |
| | | MOE | MOR | IB | MOE | MOR | IB | MOE | MOR | IB |
| 165 | 8 | 1040[*](40.44) | 7.47[*](2.12) | 0.34[*](0.07) | 1378[*](48.91) | 9.13[*](3.27) | 0.35[*](0.04) | 1464[*](53.2) | 9.73[*](1.67) | 0.38[*](0.08) |
| | 10 | 1257[*](55.35) | 8.69[*](2.86) | 0.48[*](0.06) | 1551[*](65.24) | 10.29[*](1.81) | 0.49[*](0.05) | 1625[*](77.36) | 10.89[ns](2.39) | 0.46[*](0.05) |
| | 12 | 1303[*](37.22) | 9.05[*](1.85) | 0.51[*](0.08) | 1702[*](43.2) | 11.49[ns](2.65) | .05[*](0.05) | 1870[ns](39.24) | 12.2[ns](3.18) | 0.53[ns](0.04) |
| 185 | 8 | 1129[*](68.36) | 8.08[*](2.93) | 0.41[*](0.06) | 1473[*](48.96) | 10.09[*](2.93) | 0.39[*](0.05) | 1565[*](43.18) | 10.49[*](2.14) | 0.42[ns](0.05) |
| | 10 | 1375[*](58.31) | 9.49[*](1.14) | 0.59[ns](0.09) | 1658[*](41.25) | 11.08[*](1.66) | 0.56[ns](0.06) | 1764[ns](45.3) | 11.98[ns](2.91) | 0.56[ns](0.05) |
| | 12 | 1439[*](53.48) | 9.79[*](2.52) | 0.64[ns](0.04) | 1997[*](33.19) | 12.92[*](1.47) | 0.64[ns](0.08) | 2168[*](66.83) | 14.79[*](1.52) | 0.64[ns](0.06) |
| Control Sample MOE: 1849(48.68) MPa, MOR: 11.95(2.74) MPa, IB: 0.59(0.05) MPa | | | | | | | | | | |

The values shown are means from 12 samples

[*]Significant: 95%

[ns]Non-significant

**Table 2** Physical properties of samples made by different treatments and the control sample
**Tab. 2** Physikalische Eigenschaften der unterschiedlich hergestellten Prüfplatten und der Kontrollplatte

| Press Temp (°C) | Resin (%) | Physical properties at three mixing levels of reed:wooden chips | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20:80 | | 30:70 | | 40:60 | |
| | | WA | TS | WA | TS | WA | TS |
| 165 | 8 | 83.15[*](4.6) | 25[*](3.92) | 85.03[*](2.83) | 25.83[*](2.57) | 89.63[*](4.21) | 26.81[*](3.87) |
| | 10 | 78.09[*](3.88) | 23.75[*](4.18) | 70.64[*](4.57) | 21.48[*](3.46) | 65.68[*](3.76) | 19.79[*](4.61) |
| | 12 | 76.53[*](3.52) | 23.21[*](3.68) | 68.54[*](2.28) | 20.65[*](3.82) | 63.84[*](3.28) | 19.17[*](4.24) |
| 185 | 8 | 79.6[*](4.18) | 24.33[*](3.95) | 80.97[*](4.7) | 24.5[*](3.17) | 83.79[*](4.45) | 25.24[*](2.88) |
| | 10 | 75.98[*](4.92) | 23.35[*](4.56) | 63.03[*](4.91) | 18.95[*](4.45) | 54.47[ns](4.63) | 17.6 [ns](3.6) |
| | 12 | 74.56[*](4.36) | 22.88[*](2.67) | 61.23[*](3.16) | 18.46[ns](2.39) | 51.71[ns](3.25) | 16.52[ns](3.74) |
| Control Sample WA: 54.33(4.12)%, TS: 17.24(3.54)% | | | | | | | |

The values shown are means from 12 samples

[*]Significant: 95%

[ns]Non-significant

terms of improved mechanical and physical properties. The MOR, MOE, IB, and TS of the experimental particleboards increased significantly with an increase in press temperature and adhesive ratio ($p < 0:05$). This expected finding is due to the increasing bond between the particles and hardening of the resin efficiency during hot pressing. Similar results were determined in previous studies (Amir-Hosseini 2001; Ashori and Nourbakhsh 2008; Philippou et al. 1982; Au and Gertjejansen 1989).

In contrast, the IB value was not significantly higher than for the control samples. There is a reduction in the internal bonding values of samples as the reed level reduces from 40% towards 20%. This is probably a function of the moisture content in the surface layer which is related to the proportion of reed. It should be noted that the moisture content of the surface layer (12%) compared with the middle layer (8%) reduces as the reed level reduces. So, heat transfer from the surface layer to the middle layer and the pressing time influence the level of adhesive cure and thus the amount of internal bonding.

## 4 Conclusion

This study determined some of the mechanical and physical properties of experimental particleboard panels manufactured from reed (surface layer) and commercial species (middle layer). The results of this study indicate that reed

(*Arundo donax*) is a suitable raw material for three-layer particleboard manufacturing. In the research, the treatment with 40% reed, 12% resin in the surface layers and a 185 °C press temperature has resulted in an optimum reed board product.

Resin content and press temperature were the main parameters influencing the physical and mechanical properties of the panels. Increasing of press temperature and amount of resin improved significantly the surface quality, physical and mechanical properties of particleboards. This expected finding is due to the increasing bond between the particles and hardening of the resin efficiency during hot pressing.

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