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Effect of outdoor storage conditions of wood chip pile on the technological properties of wood-based panel

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ABSTRACT

Effect of outdoor storage conditions of wood chip pile on the physical and mechanical properties of wood-based panel, high density fiberboard (HDF), was investigated in this study. The chip pile of Southern pine wood without bark was stored for 6 months at woodyard of a commercial fiberboard manufacturer. The HDFs with dimensions of 2632 mm × 2081 mm × 8 mm were commercially produced from the chips with dimensions of 23–25 mm × 20–22 mm × 3–4 mm at 15, 30, 45, 60, 90, 120, and 180 days of the storage. Some physical and mechanical properties of the HDF panels were determined according to European Norms. The thickness swelling and surface absorption of panels increased as the storage time increased from 15 to 180 days. The modulus of rupture values decreased noticeably after 60 days of the chip storage while this decrement was observed for the modulus of elasticity values after 90 days. The formaldehyde emission values of the panels increased from 8.0 to 9.6 mg per 100 g of absolutely dry panel as the storage time increased. In particular, the internal bond strength significantly decreased (1.71–1.04 N mm^{-1}) as the storage duration reached to 180 days. This was mainly caused by a combination of accelerated resin cure and thermal/biological decomposition of the wood chips. Based on the findings obtained from the present study, it can be said that outdoor storage duration of pine chip piles used in the manufacture of HDF panels should not be more than 30 days.

1. Introduction

When wood is chipped and placed in a pile, the living cells in the wood rays (also called parenchyma) respire in what amounts to an attempt to heal the tree. Oxygen is consumed and heat is released. This heat generation provides good growth conditions for bacteria, which feed on the extractives in the wood. At the end of 7–14 day period, it is not unusual to find that temperature in a chip pile has reached average 65 °C [1]. The acid, in large quantities causes deterioration of wood by attacking the cellulose chain molecules. This can result in yield and strength losses when the wood is pulped [2,3]. Volatile Fatty Acids (VFA) – lower order (short carbon chain) fatty acids like acetic, lactic, propionic, and butyric that are volatile at ambient temperatures. They have characteristic strong astringent smells. At 65 °C it is hot enough for acetyl groups attached to the cellulose to be split from the chain to form

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acetic acid. In short rotation coppice bacterial interaction with sugars may also have produced other VFAs. The production of VFA (esp acetic) appears to be a natural part of decomposition of outside chip storage. Higher soluble carbohydrates and increased cellulose break down under low pH could assist this [4]. Fermentation and microbial decay processes of chip pile cause increases in temperature. The increased heat, of course, drives this reaction even faster if it is not dissipated, releasing more acid [1,3].

The ones of most interest concerning storage of wood chips are actinomycetes. Bacteria can tolerate a wider temperature range than the fungi. Some of them can tolerate temperatures up to 75 °C but the variation between species is large. The chemical processes slowly takes over as the dominating heat producing mechanism starting with temperature above 40 °C and at a temperature of 50 °C it is the most important one [5]. Mainly fungi are responsible for the decrease in wood quality during storage. Generally, brown rot fungi depolymerize cellulose, which results in decreased fiber strength, while white rot fungi degrade lignin with fewer effects on the strength. Both types of rot degrade hemicellulose and decrease wood pile yield [6,7].

Growing demand for wood-based panels in many countries has led to continuous efforts to find new resources for wood material. The substantial increase in the raw material requirement for the wood-based panel industry in Europe, Turkey, China, Japan, and other countries has resulted in development of the international wood chip market. Turkey has recently imported 70–80% of total wood material used in the manufacture of fiberboard and particleboard from overseas countries such as USA and Canada by ships. Since Turkish wood-based panel manufacturers supply of large amounts of Southern Yellow Pine chips for 5–10 year contracts by ships (about 40 kt for each shipment), the chips are stored outside in large piles for several months. Previous studies showed that chip quality was significantly affected by the outdoor chip storage conditions [1,4,6,7]. Wood chips stored in outside piles are subject to microbiological and chemical attack that causes losses in wood substance. It is well know that physical and mechanical properties of wood-based panels such as fiberboard and particleboard are significantly affected by chip quality [8].

There is a limited study about the effect of the chip storage conditions on the properties of wood-based panels [9,10]. In this study we aimed to determine effect chip pile storage conditions on the physical and mechanical properties of dry process fiberboard, which was high density fiberboard (HDF). As the effect of outdoor storage conditions of chip pile on the properties of fiberboard is known, wood losses can be minimized caused by storage period.

2. Materials and methods

2.1. Materials

Southern yellow pine (*Pinus palustris*, commonly known as the longleaf pine) chips without bark used in the manufacture of experimental panels were imported from the United States. The trees were planted for commercial production in the Southeastern Georgia, the United States. The age of pine plantation certified by the Forest Stewardship Council (FSC) ranged from 13 to 18, with a mean age of 15 years. The wood chips were derived from the tree trunks using a chipper at seaport and then shipped to Turkey by containers in 45 days. Their method of storage and processing along the chain of custody from forest or field to the mill complied with all the FSC's principles and criteria. The wood chips were stored outside in a large pile for durations of 1 day, 15 days, 30 days, 45 days, 60 days, 120 days, and 180 days. The dimensions of chips were 23–25 mm in length, 20–22 mm in width, and 3–4 mm in thickness. Dry process HDF panels were manufactured from the chips stored at different durations. The mixture of inner and outer layers of the chip pile was used in the manufacture of HDF panels. The moisture content and pH of the chips were measured at each storage duration before the HDF panel manufacture.

The E1 class urea–formaldehyde (UF) resin was used in the manufacture of HDF panels. The specifications of the UF resin is as follows; density: 1.249 g cm^{-3}, solid content: 58 wt%, viscosity 113 cP, formaldehyde/urea content: 1.15, pH: 8, free formaldehyde (max.): 32.

2.2. Manufacture of HDF panels

The HDF panels were manufactured at Kastamonu Integrated Wood Company in Gebze, Turkey. The wood chips were converted into fiber furnish in an Asplund defibrator using a steam pressure of 7.3 bar at a temperature of 170 °C for 3.5 min. The following were added to the fiber furnish: 1.5% paraffin, 0.8% NH_4Cl as hardener, and 15% UF resin. The mats with an average moisture content of 12% were pressed at a temperature of 218 °C for 4 min at a maximum pressure of 208–210 N cm^{-2} (specific press factor: 8.33 sn mm^{-1}). The HDF panels were sanded with a sequence of 150, 180, and 200 grit sizes following the cooling process. A total of 16 panels, two for each type of treatment, were tested. The experimental design is presented in Table 1.

2.3. Determination of pH and moisture content of chip pile

The pH of wood chips was determined using the method proposed by Johns and Niazi [11]. Aqueous wood extract solutions were prepared by refluxing 25 g of ground wood at 100 °C for 20 min. After the extraction aqueous solutions

Table 1 – Experimental design.

HDF panel type	Outdoor storage time of chip pile (day/date)	HDF panel dimensions (mm)	Panel replications
1	0 (16.11.2011)	2632 × 2081 × 8	2
2	15 (01.12.2011		2
3	30 (16.12.2011)		2
4	45 (01.01.2012)		2
5	60 (16.01.2012)		2
6	90 (16.02.2012)		2
7	120 (16.03.2012)		2
8	180 (16.05.2012)		2