A Simulation of Moisture Diffusion Process in Furniture-Grade Medium Density Fiberboard

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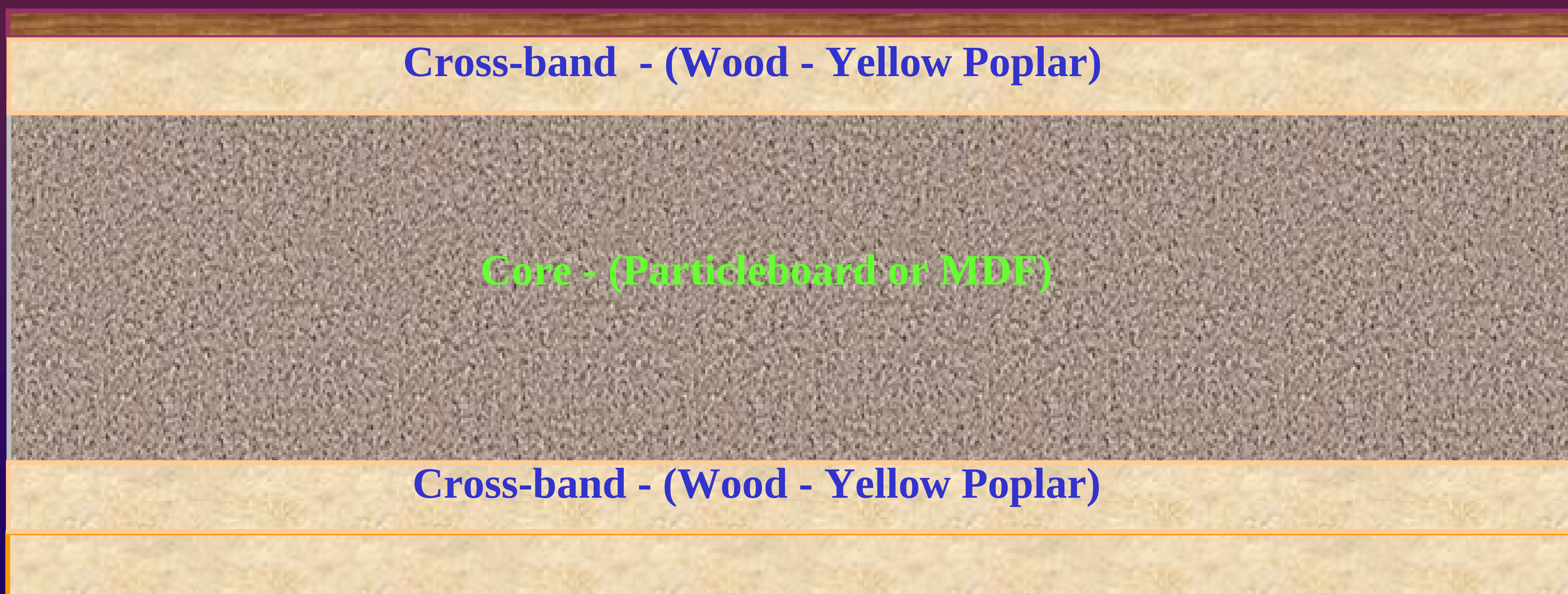
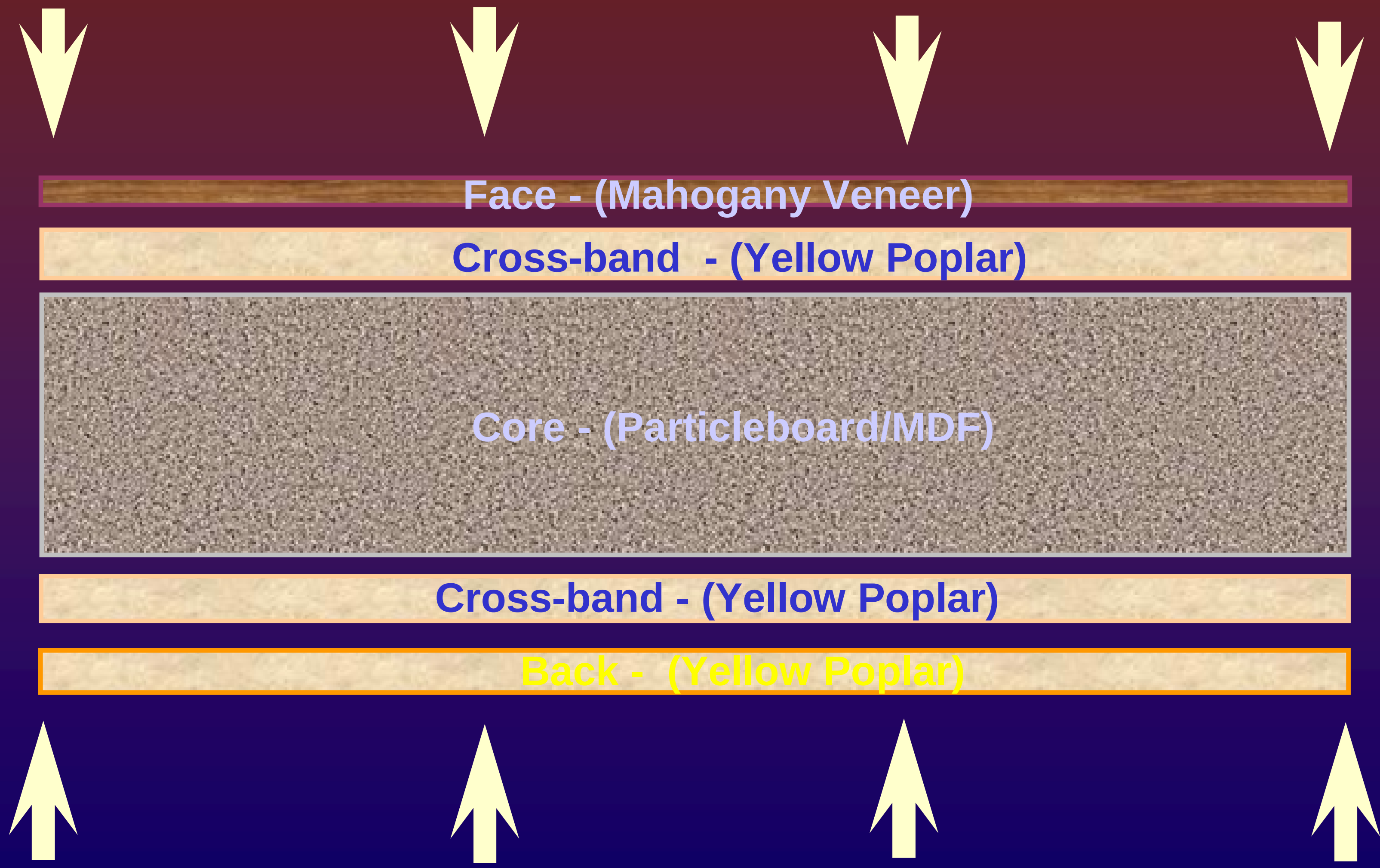
Typical 5-ply Veneered Furniture Panel

Face (Wood Veneer - Mahogany)

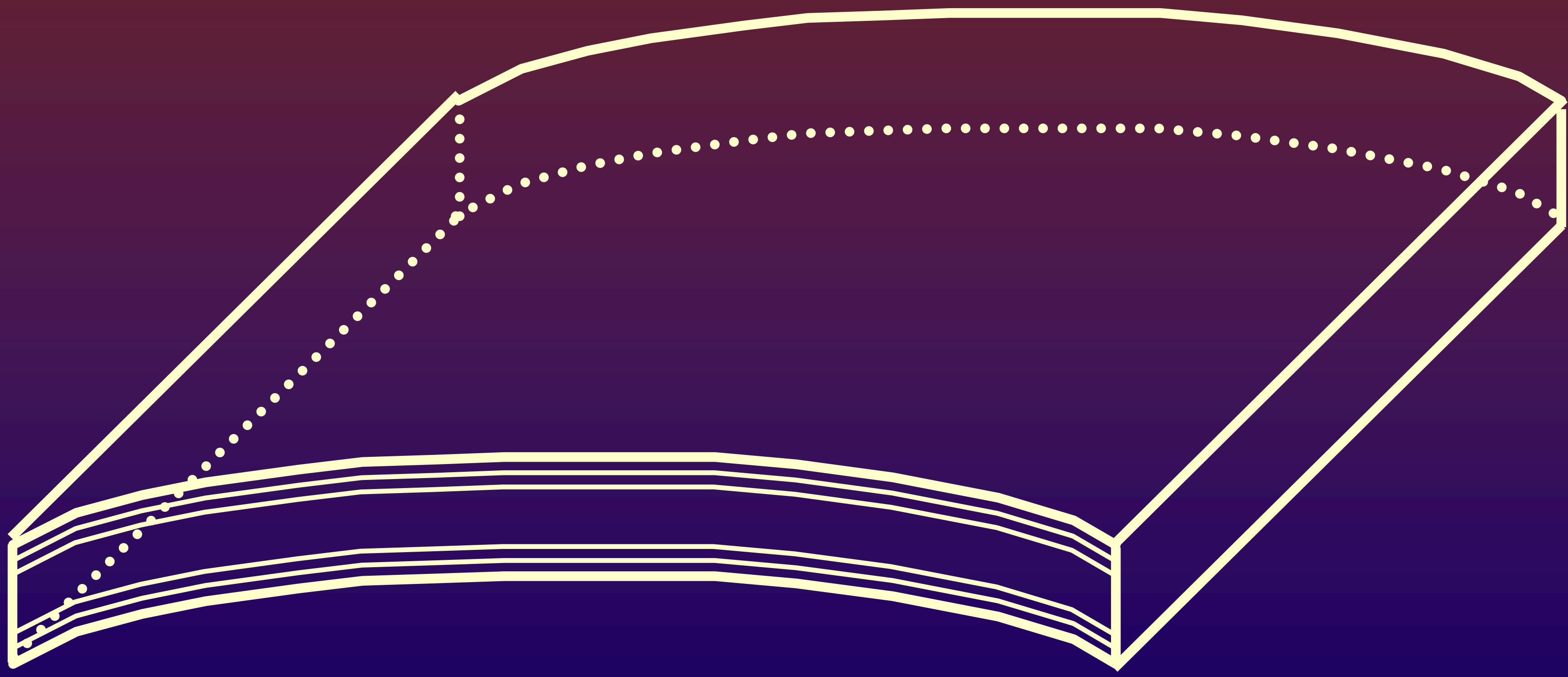


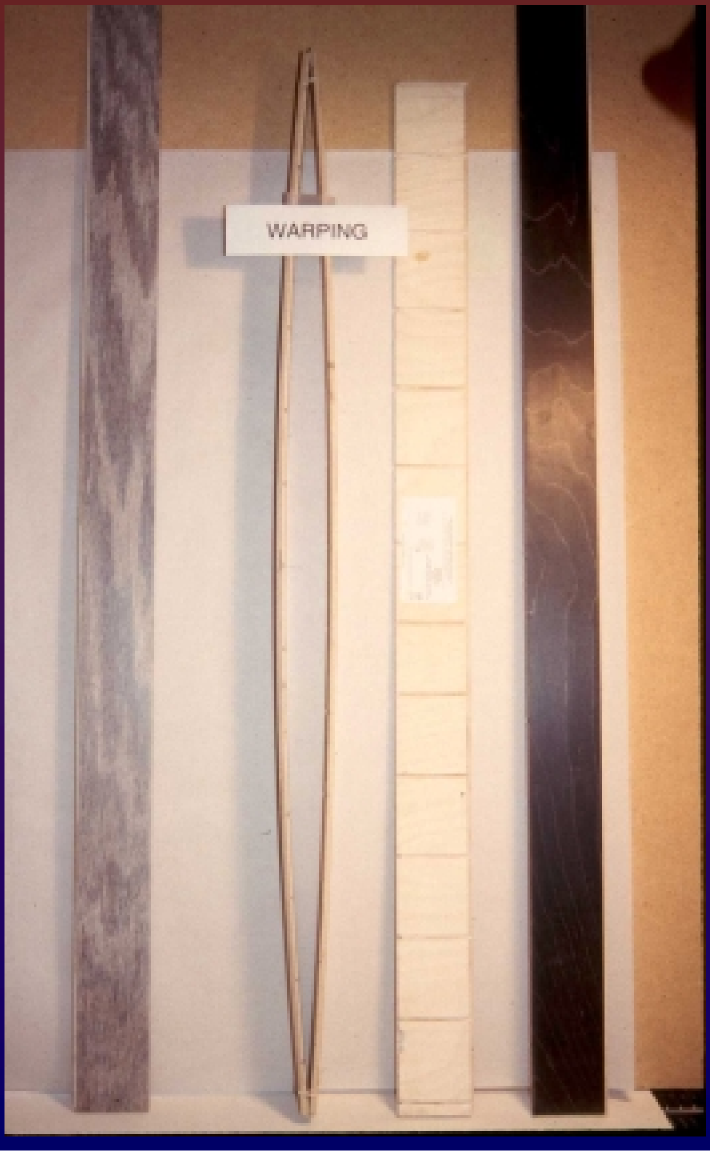
Back - (Wood - Yellow Poplar)

Laminating Operation

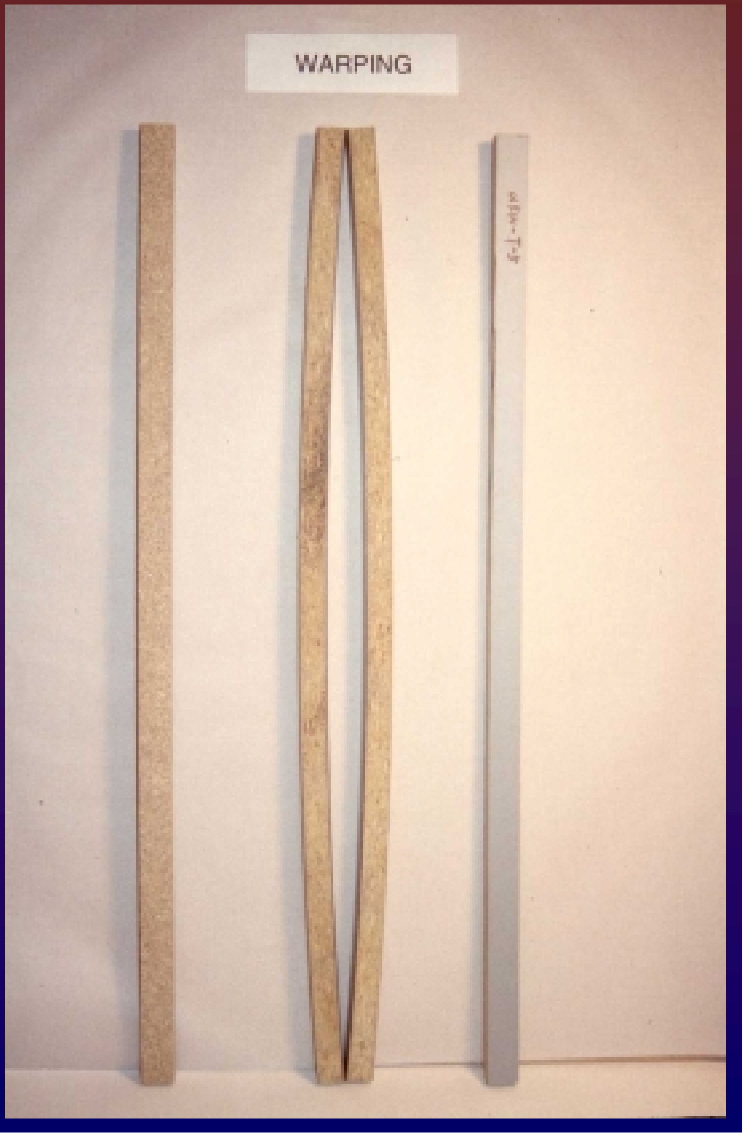


Panel Warping





Practical Warp Examples



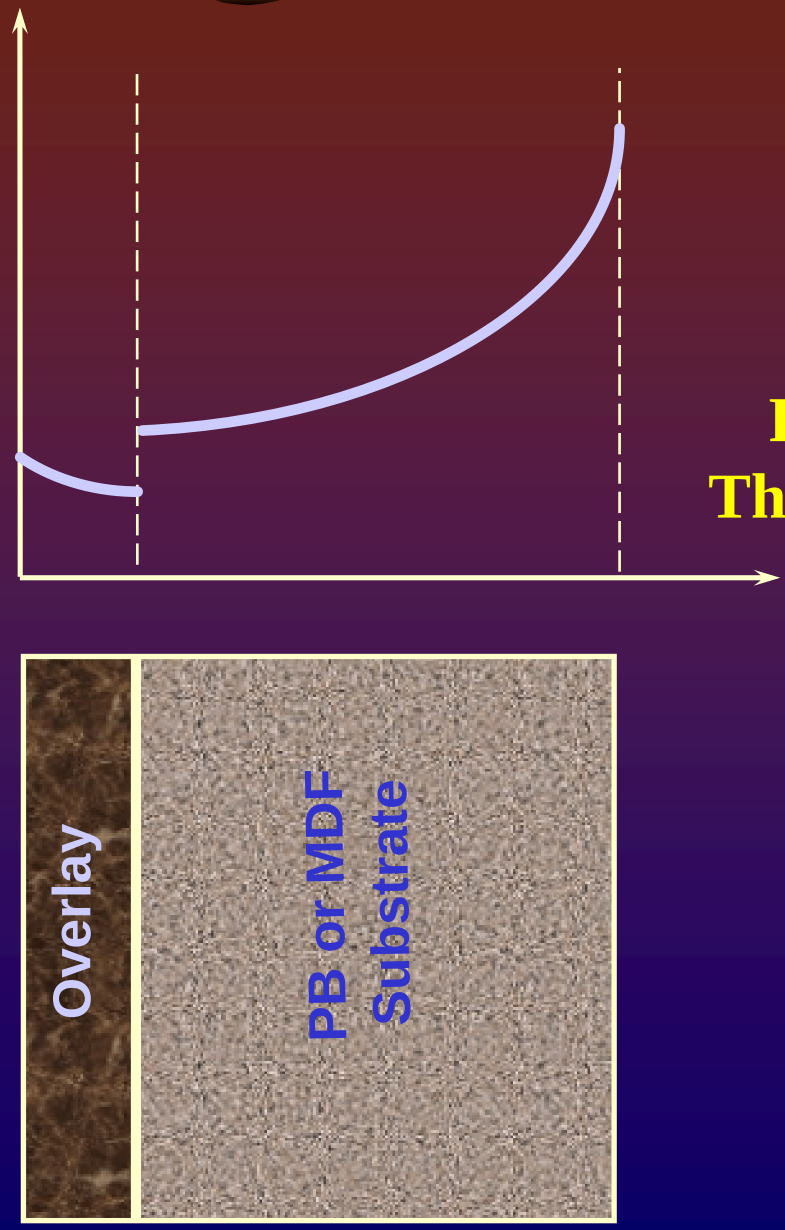
Factors That Affect Panel Warping

- Material Properties - MOE, LE
- Geometric Configuration - TK, OR
- Panel Construction
- Internal Moisture Gradient

Moisture Distribution

Panel Thickness

2-ply Laminate



Moisture Diffusion Process in Wood and Wood Composite Panels

- Extensive studies made for solid wood along the three principal directions
- Partial vapor pressure – the most proper driving force for moisture transfer
- Limited study made for particleboard (e.g., Cai and Dek 1993, Wu and Suschland 1996)

Medium Density Fiberboard (MDF)

- Popular laminating material
- Fine internal structure
- No moisture diffusion study made

Objectives

(a) To measure layer density, EMC and diffusion coefficients as a function of position across panel thickness in commercial MDF,

(b) To develop a simulation model for the moisture diffusion process through MDF using partial vapor pressure as the driving force, and

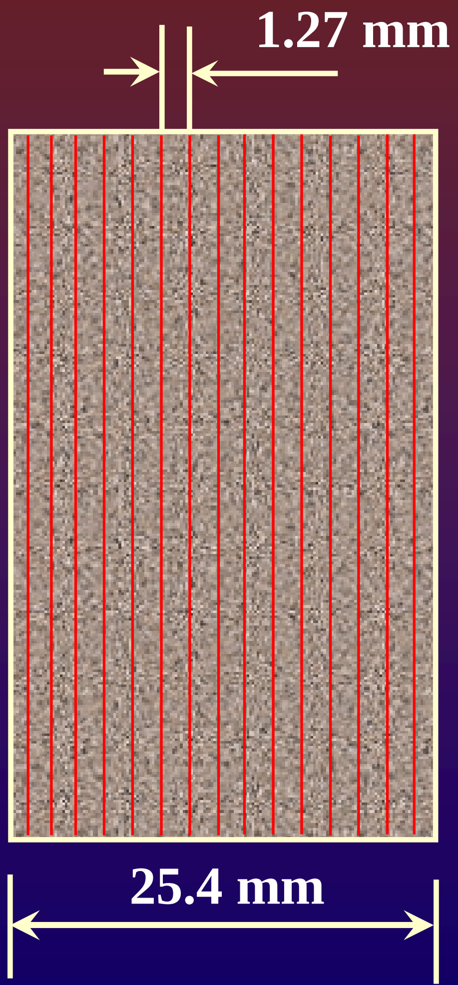
(c) To compare the model's prediction with measurements from the MDF panel.

Materials

- **25.4-mm Commercial MDF**
- **Density/EMC/Diffusion Coefficient**

  20 “continuous” layers (1.27-mm thick) across panel thickness)
- **Moisture Distribution**

  25.4-mm thick samples



Diffusion Coefficient

Diffusion Cell

RH Steps:

47%->20%
66%->47%
75%->66%
81%->75%
86%->81%
93%->86%

$$J = K \frac{dP}{dX}$$

J = diffusion rate (g/cm^2/hr)
K = diffusion coefficient (g/cm/mmHg/Hr)
P = partial vapor pressure (mmHg)
X = dimension coordinate (cm)

Moisture Diffusion Model

$$D\,C_{MC}\frac{\partial P}{\partial t} = \frac{\partial}{\partial X}\left(K\frac{\partial P}{\partial X}\right)$$

D is density (g/cm^3)
C_{MC} is specific MC (%/mmHg)
P is partial vapor pressure (mmHg)
t is time (hour)
X is distance across thickness (cm)
K is diffusion coefficient (g/cm/mmHg/hour).

Solution Method- Diffusion Model

Diffusion Model

$$DC_{MC}\frac{\partial P}{\partial t}=\frac{\partial K}{\partial X}\,\frac{\partial P}{\partial X}+K\,\frac{\partial^2 P}{\partial X^2}$$

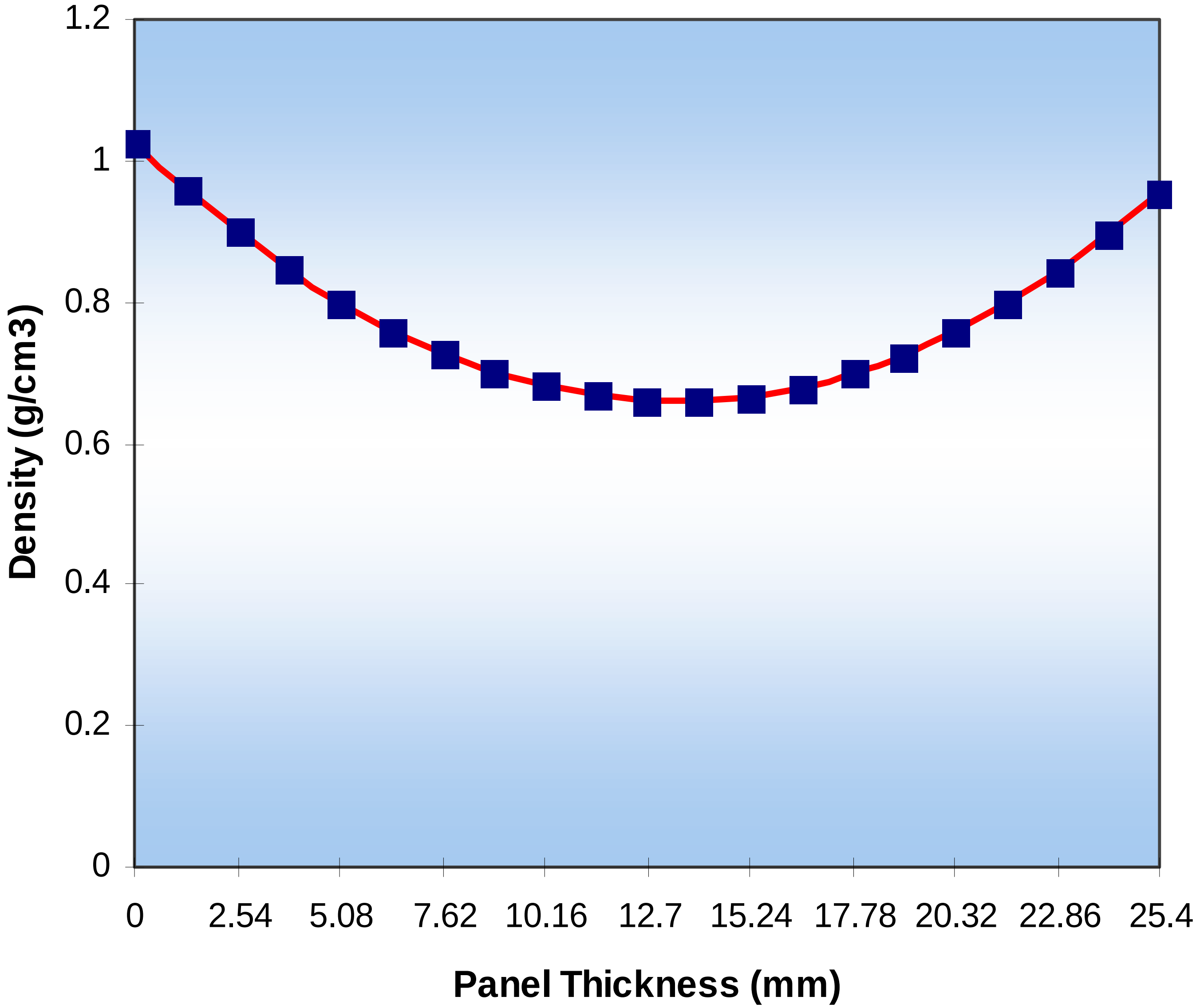
Finite Difference Approximation

$$\frac{\partial P}{\partial t}=\frac{P_{i,n+1}-P_{i,n}}{\Delta t}\;; \qquad \frac{\partial P}{\partial X}=\frac{P_{i+1,j}-P_{i-1,j}}{2\Delta X}\;; \qquad \frac{\partial^2 P}{\partial X^2}=\frac{P_{i-1,j}-2P_{i,j}+P_{i+1,j}}{(\Delta X)^2}$$

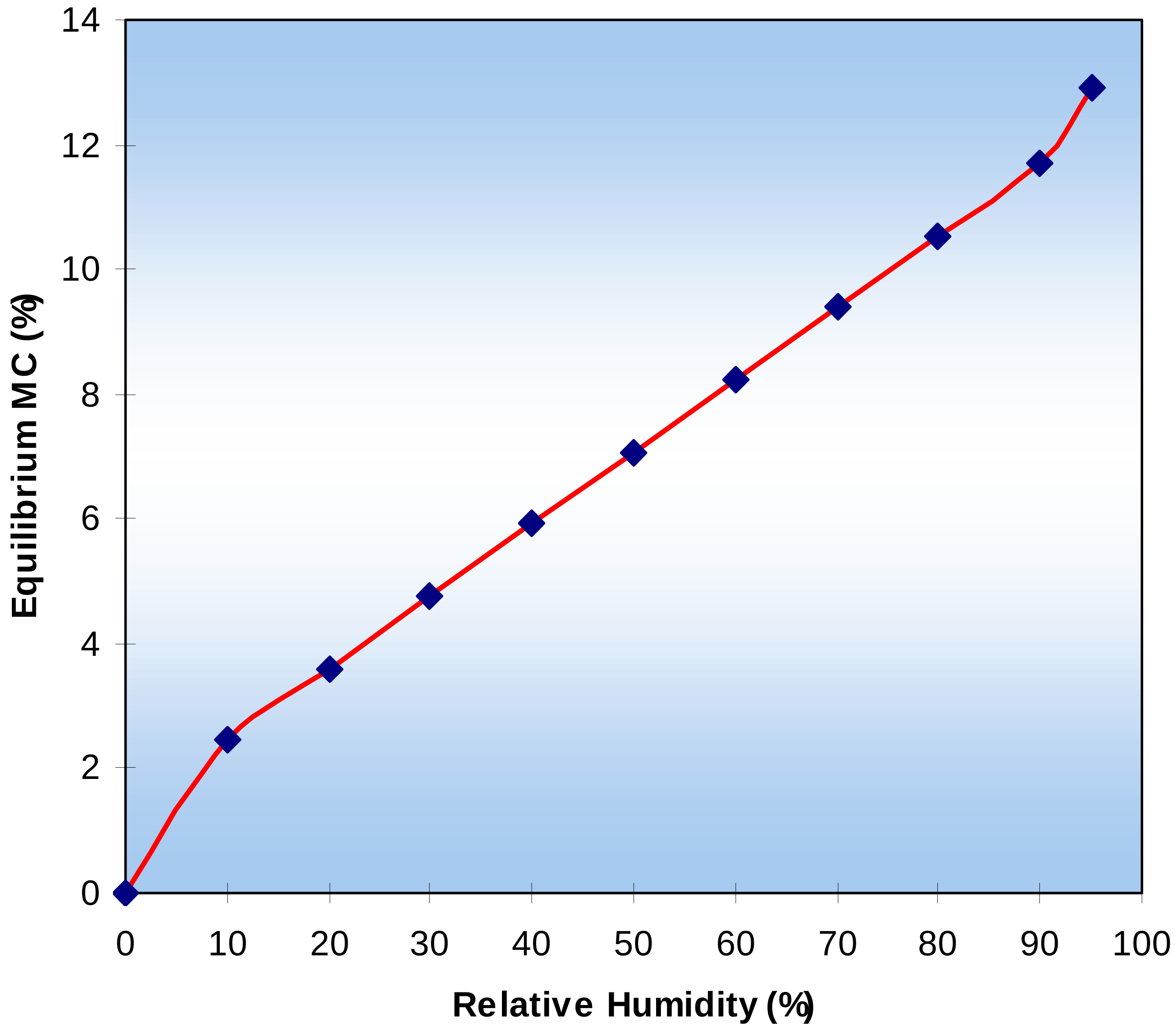
$$\frac{\partial K}{\partial X}=\frac{\partial}{\partial X}(\alpha_0+\alpha_1 P+\alpha_2 X+\alpha_3 P^2+\alpha_4 X^2+\alpha_5 PX)=\alpha_2+2\alpha_4 X+\alpha_5 P$$

RESULTS AND DISCUSSION

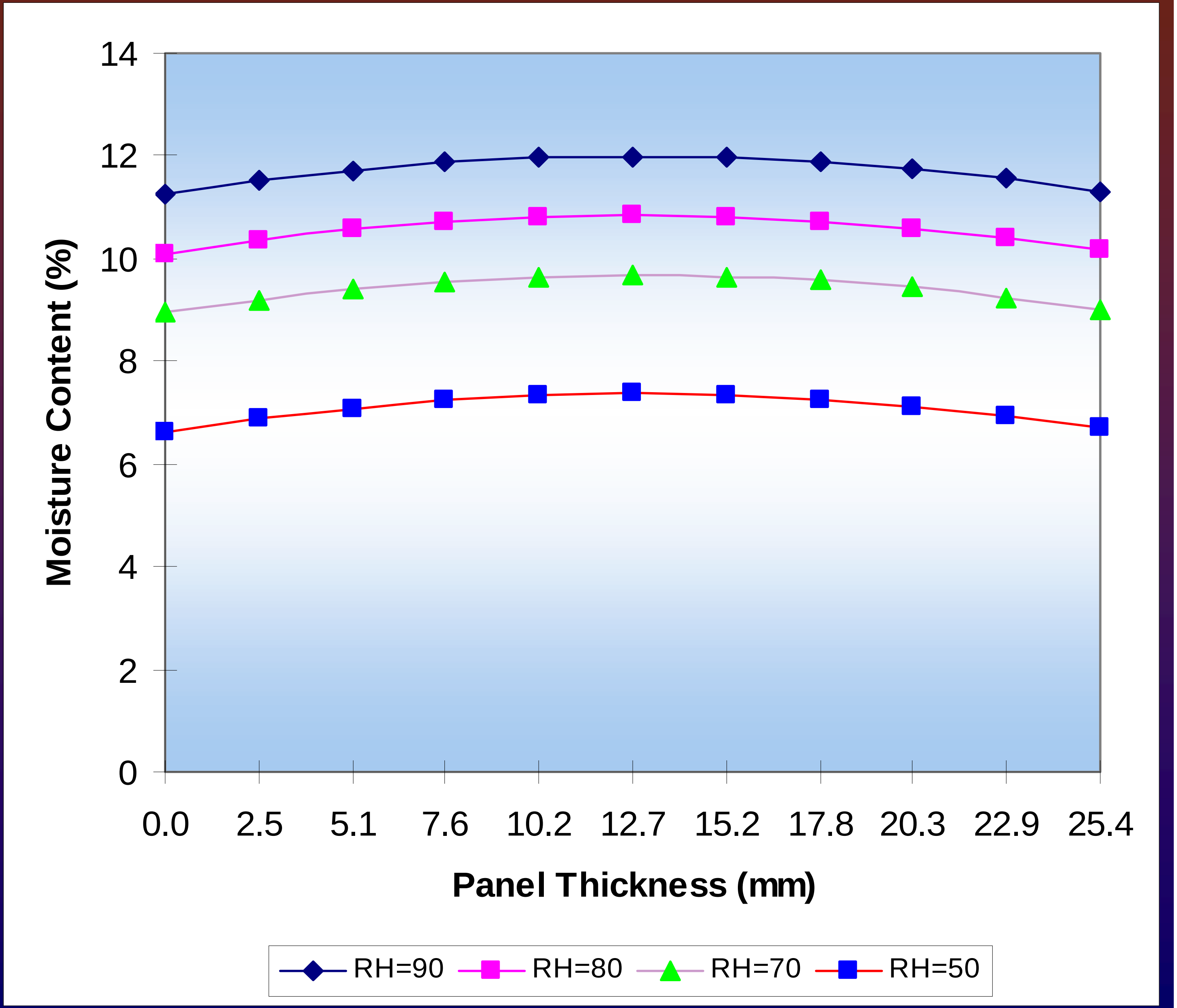
Typical Density Profile Across Panel Thickness for 25.4-mm Thick MDF



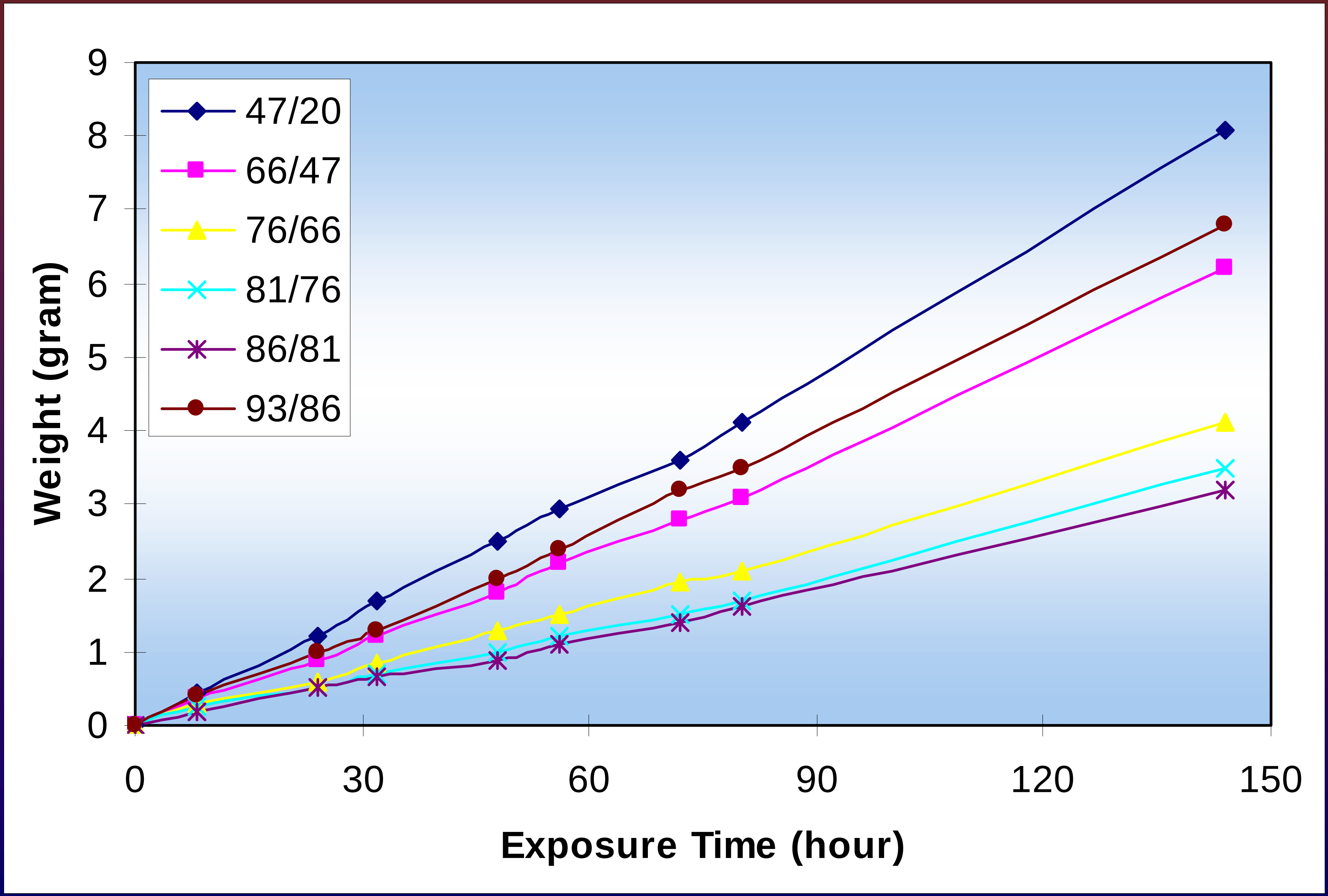
Mean EMC As a function of Relative Humidity for 25.4-mm Thick MDF



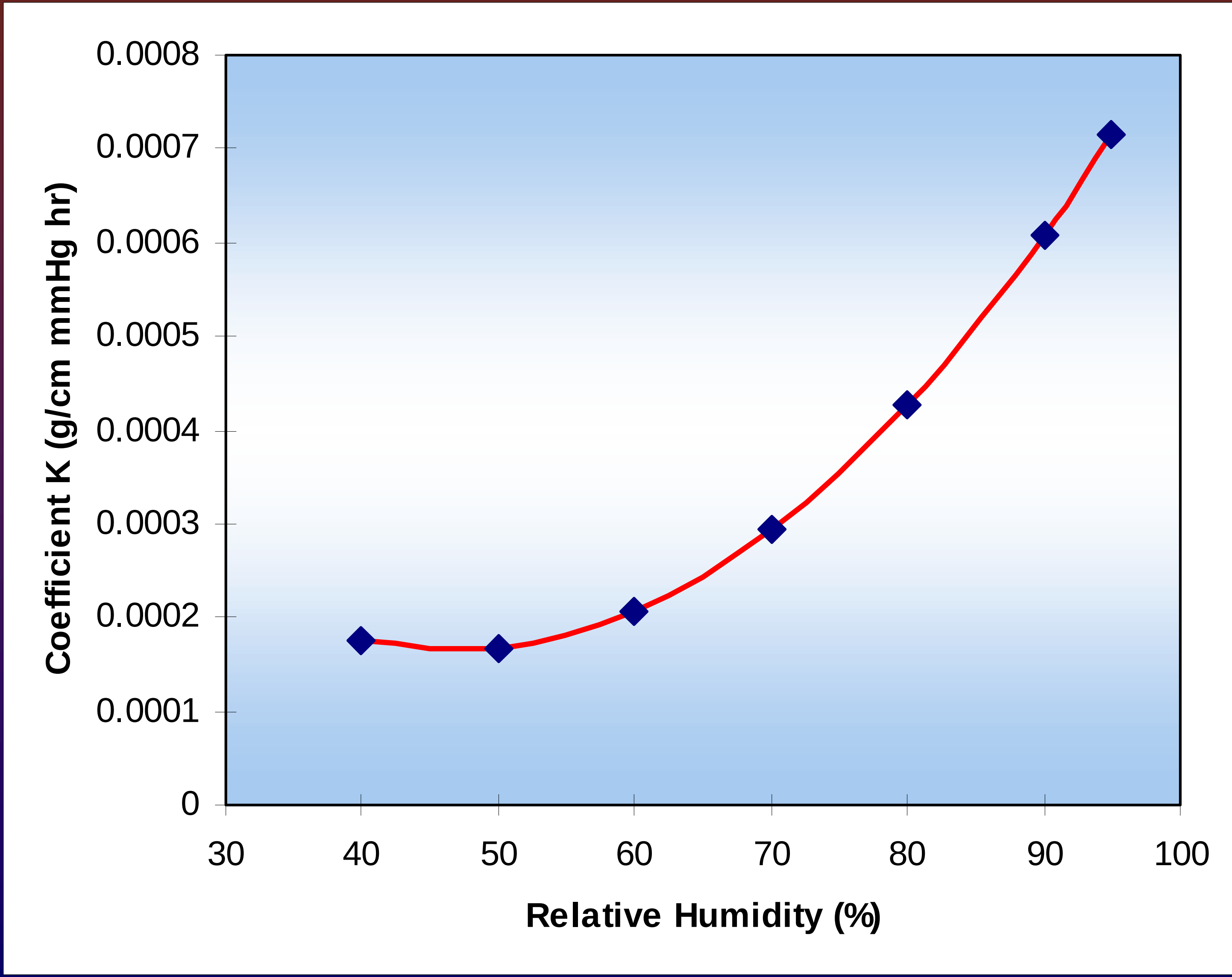
EMC Distribution Across Panel Thickness for 25.4-mm Thick MDF



Sample weight change as a function of exposure time for diffusion coefficient measurements



Coefficient k as a function of RH level



Material Property Models

Density-Thickness Relation

$$D\,(g\,/\,cm^{3}) = 1.0258 - 1.3917X + 1.3205\,X^{2}$$

EMC-Position-Vapor Pressure Relation

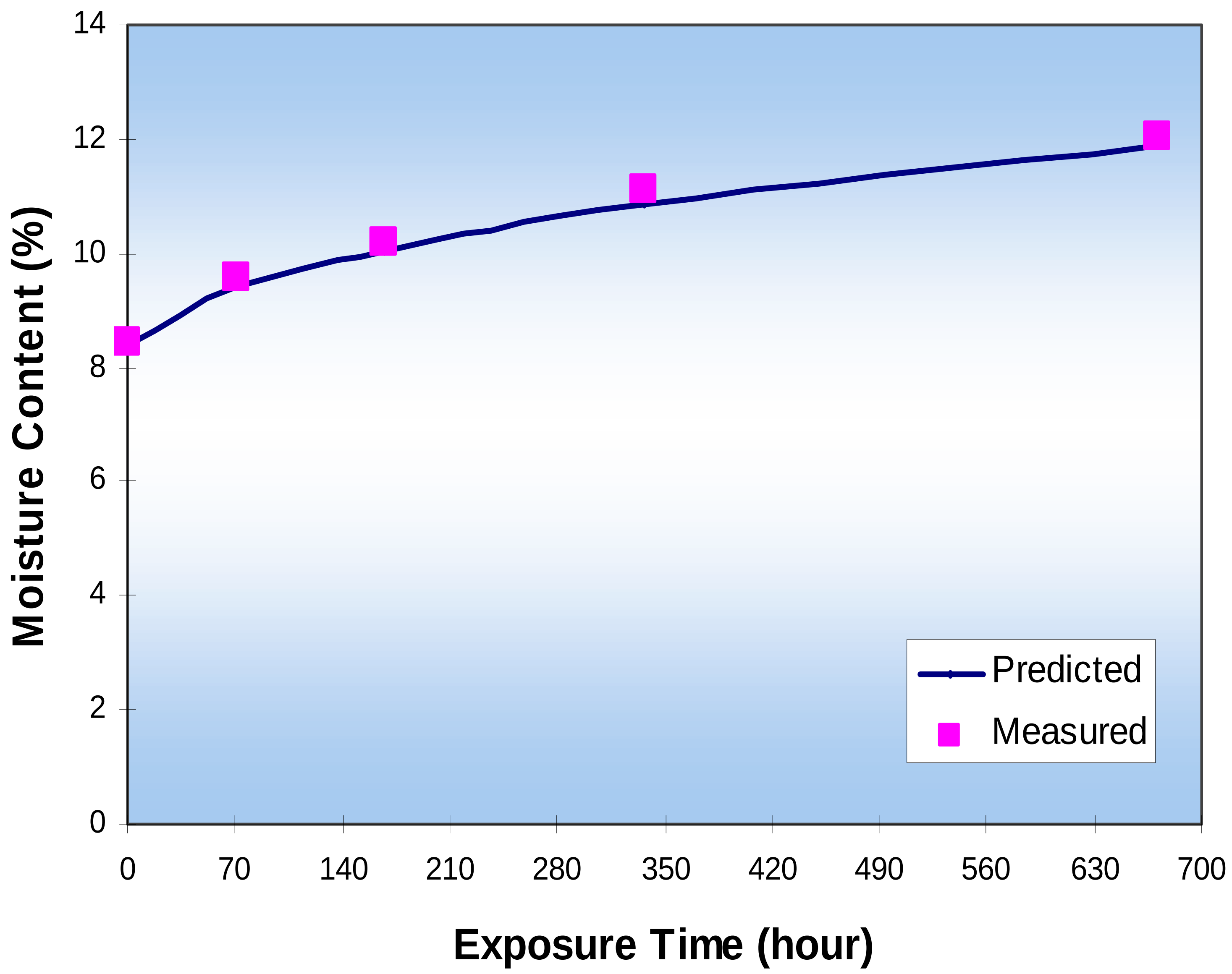
$$\mathrm{EMC}\,(\%) = (0.0084 + 0.0517\,\mathrm{P} + 0.0289\,\mathrm{X} + 0.0283\,\mathrm{X}^{2})*100\%$$

Diffusion Coefficient-Position-Vapor Pressure Relation

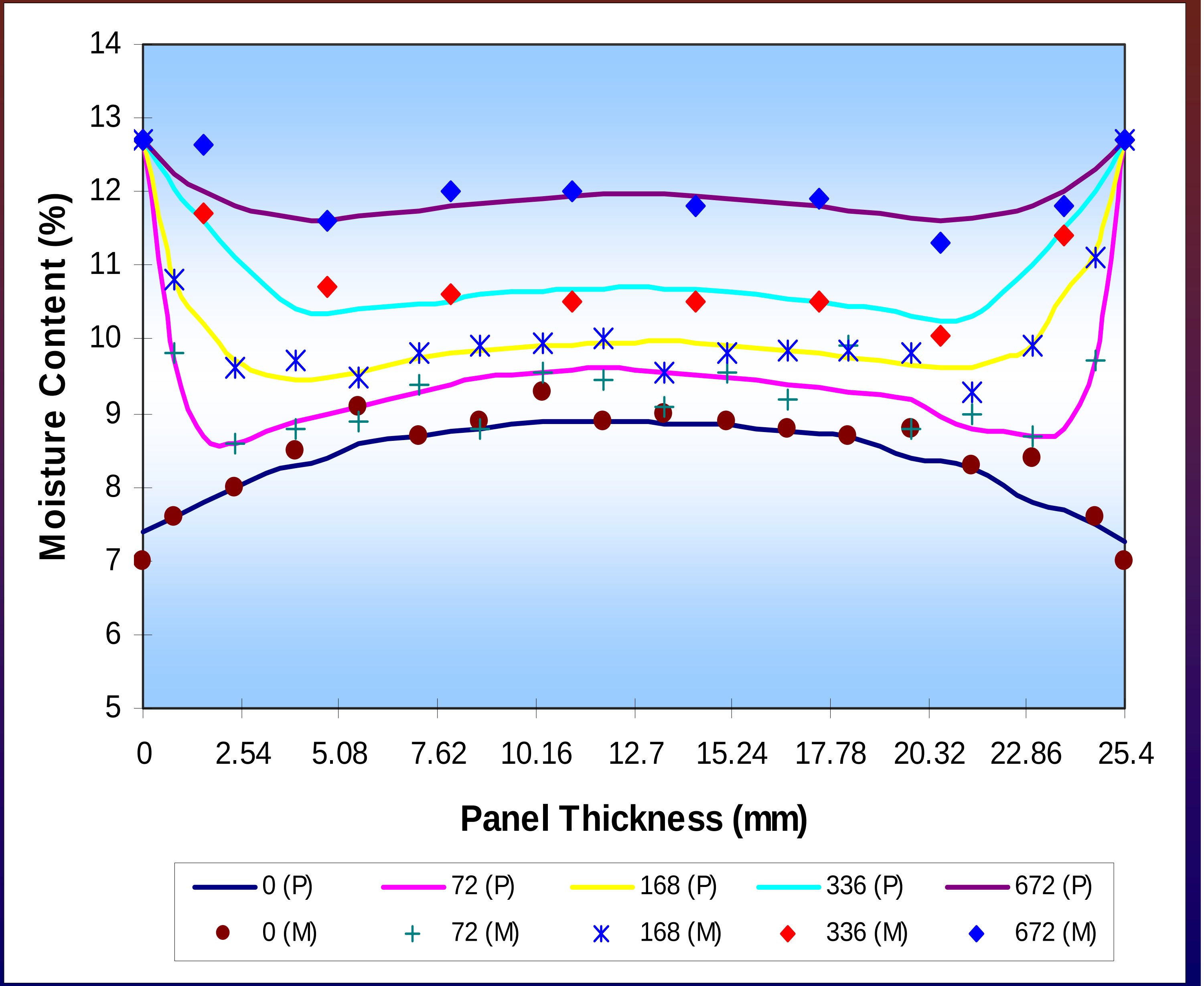
$$\mathrm{K}\,(\mathrm{g/cm/mmHg/Hour})$$

$$= 0.000431 - 0.00107\,\mathrm{P} + 0.00192\,\mathrm{X} + 0.0005\mathrm{P}^{2} - 0.00192\,X^{2} + 0.000206\,\mathrm{XP})$$

Predicted Mean Moisture Content of MDF As a Function of Exposure Time



Predicted Moisture Distribution of MDF as a Function of Exposure Time



Conclusions

(a) The densities of MDF varied across the board thickness with higher values near the board surface and lower values near the center.

(b) The EMC of MDF at a given RH level was higher near the board center than the surface.

(c) The diffusion coefficient of the MDF varied with both location over the board thickness and MC level.

(d) The moisture diffusion process in MDF can be simulated theoretically by using Fick's second law and finite difference method.