Modeling Formation and Bonding of Wood Composites

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Empirical Approach vs Modeling

Trial-and-Error Approach

Advantages:
- Simple
- Direct

Disadvantages:
- Time consuming
- Expensive
- Lack of fundamental understanding

Modeling offers a new approach to advancing the science of wood composites, by applying *mathematics*, *physics*, *mechanics* and *computer simulation* to the field of *wood science*.

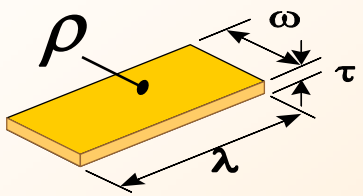
Objectives

To develop basic theories and models for wood composites, particularly:

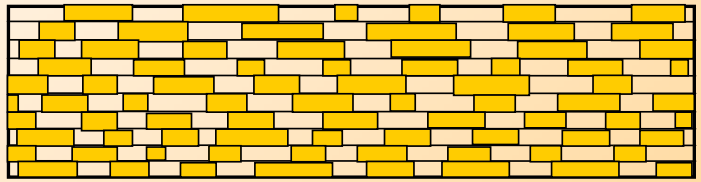
- Mat formation,
- Mat consolidation,
- Hot pressing, and
- Bonding.

Model Development: Theory and Methodology

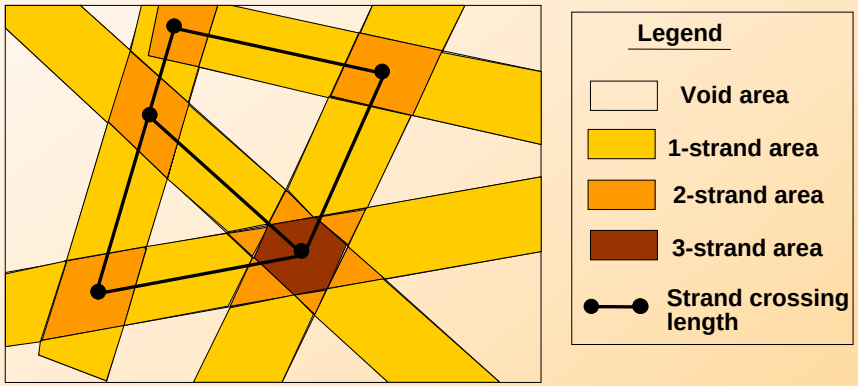
Mathematical Modeling



1. Rectangular Strand Shape



2. Layered Structure: *2D Model*



3. Random Formation

Theories: Geometric Probability and Statistics, Material Science, Physics, Mechanics and Thermal Dynamics.

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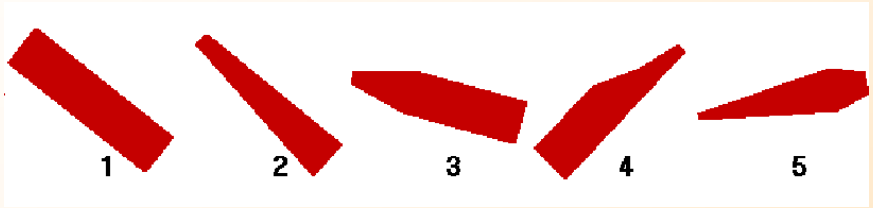
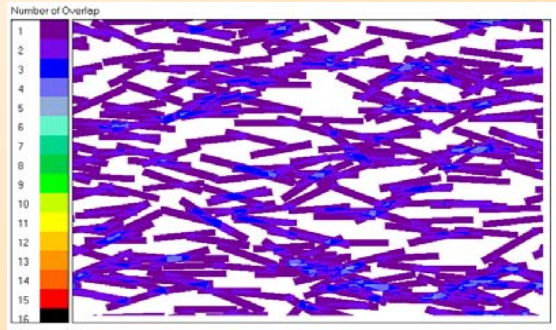
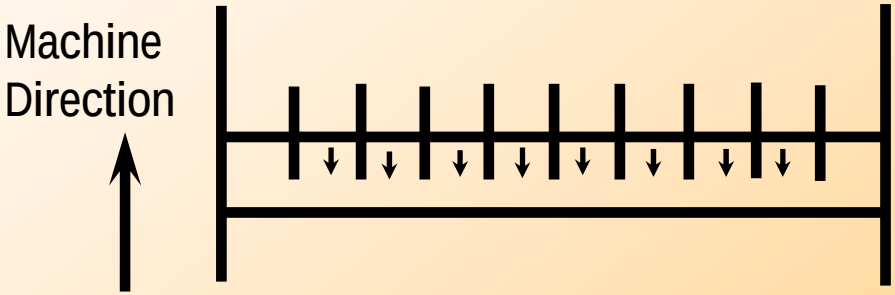
Computer Simulation



1. Irregularity of Strands



2. Strand Orientation

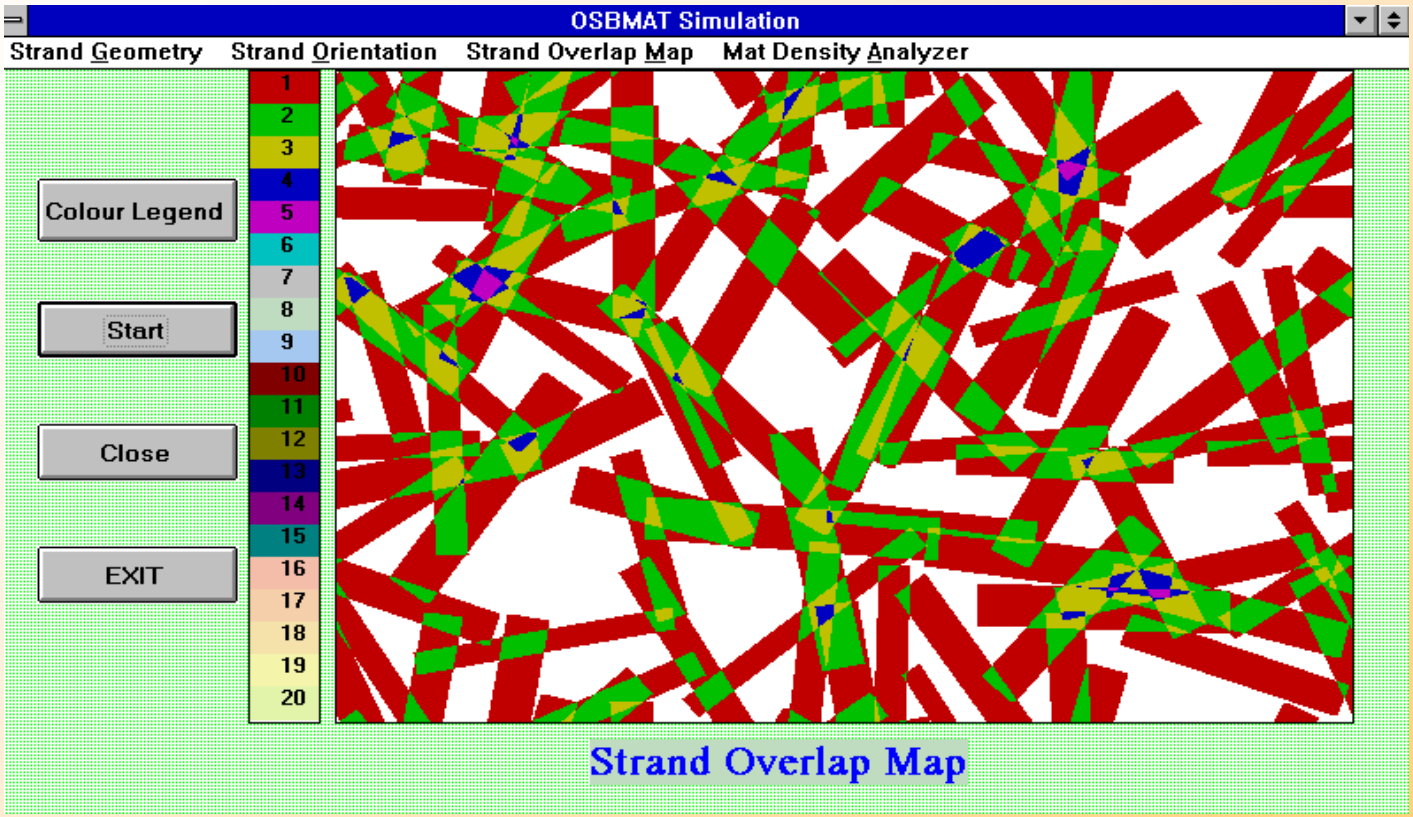


3. Machine Induced Non-Randomness

Methodology: Discrete Object Simulation, Monte Carlo Simulation, FD/FE Method, Computer Graphics and Programming

Key Results: Fundamentals of Composite Manufacturing

Mat Formation:
A Stochastic Network of Wood Strands



$$p(i) = \frac{a_i}{A} = \frac{e^{-n} n^i}{i!} \text{ and } n = C_r T_r$$

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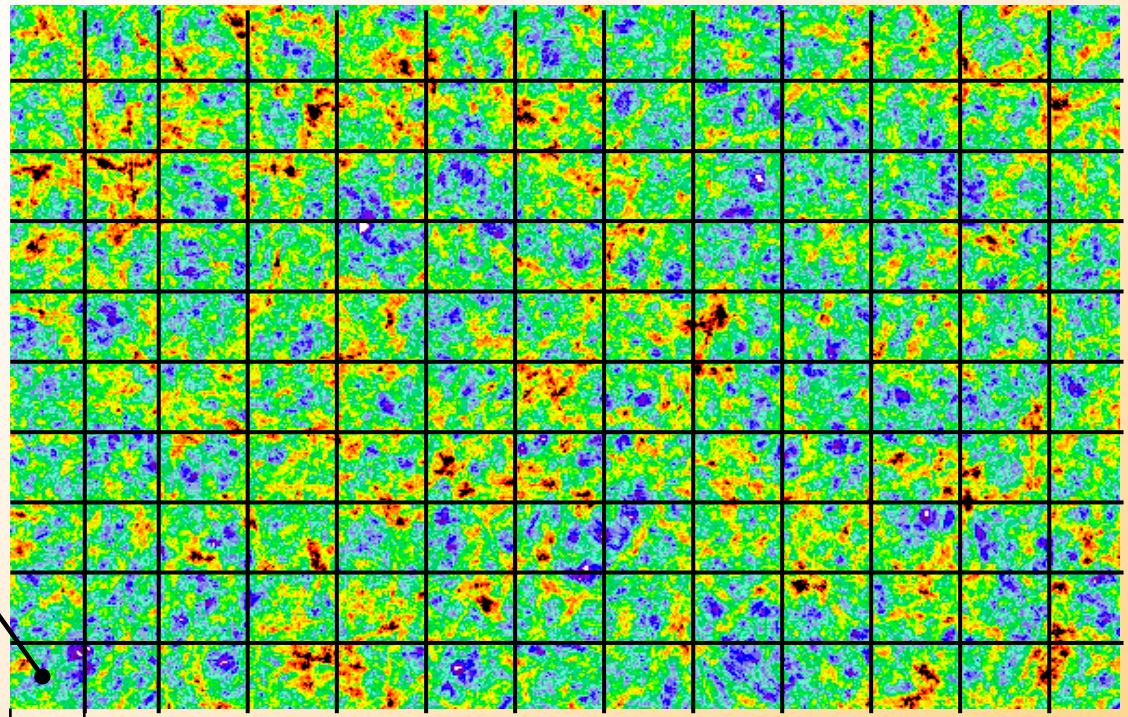
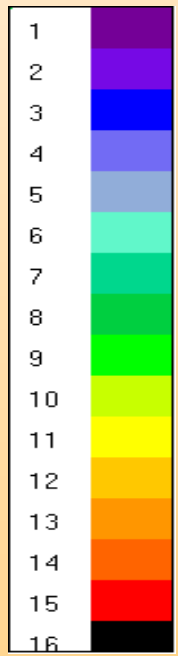
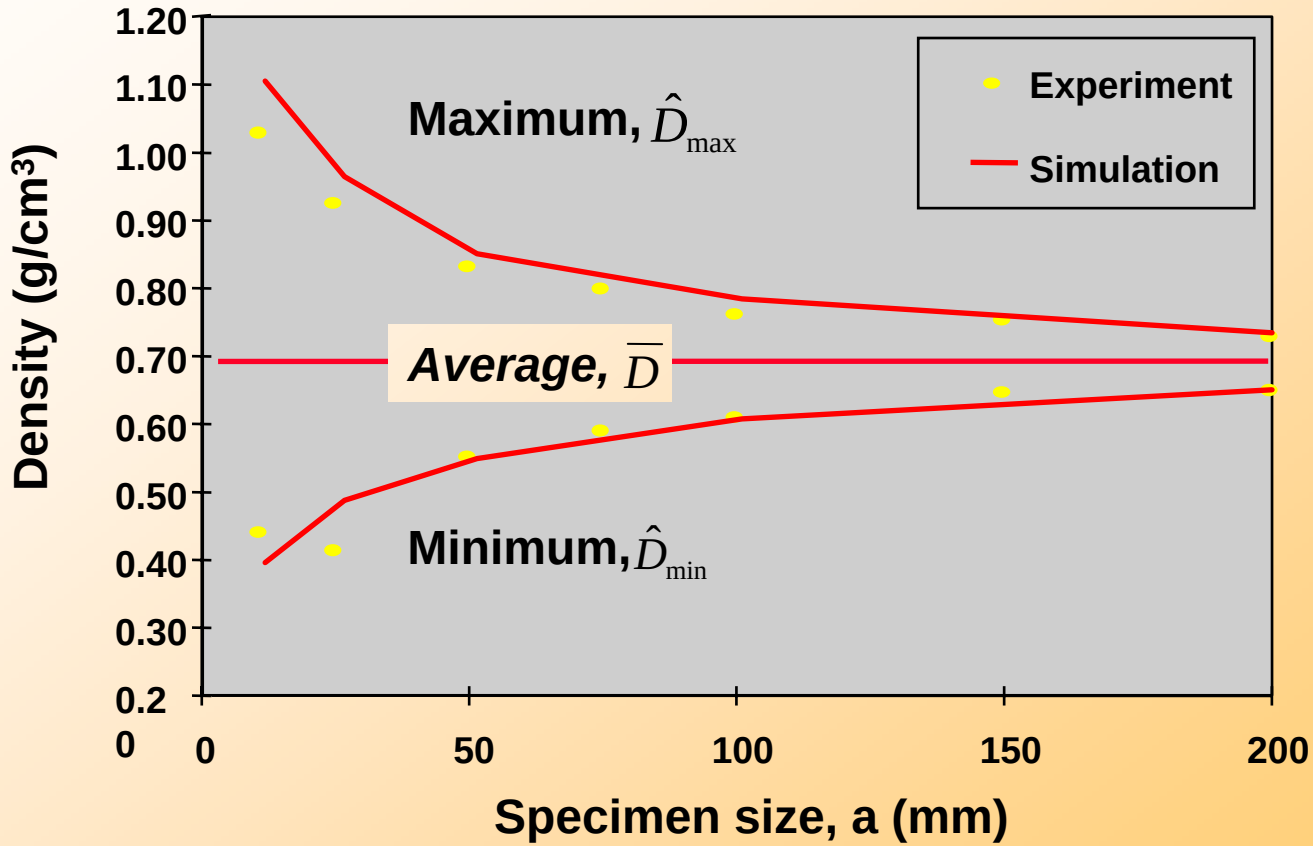
Mat Formation: Horizontal Density Distribution





$$Var(\hat{D}) = \frac{\overline{D}^2}{n} \int_0^{\sqrt{2}a} \eta(r;\lambda,\omega)\, p(r,a)\, dr$$

Mat Formation: Size Effect on Variability



Theoretical basis for analyzing mat formation uniformity

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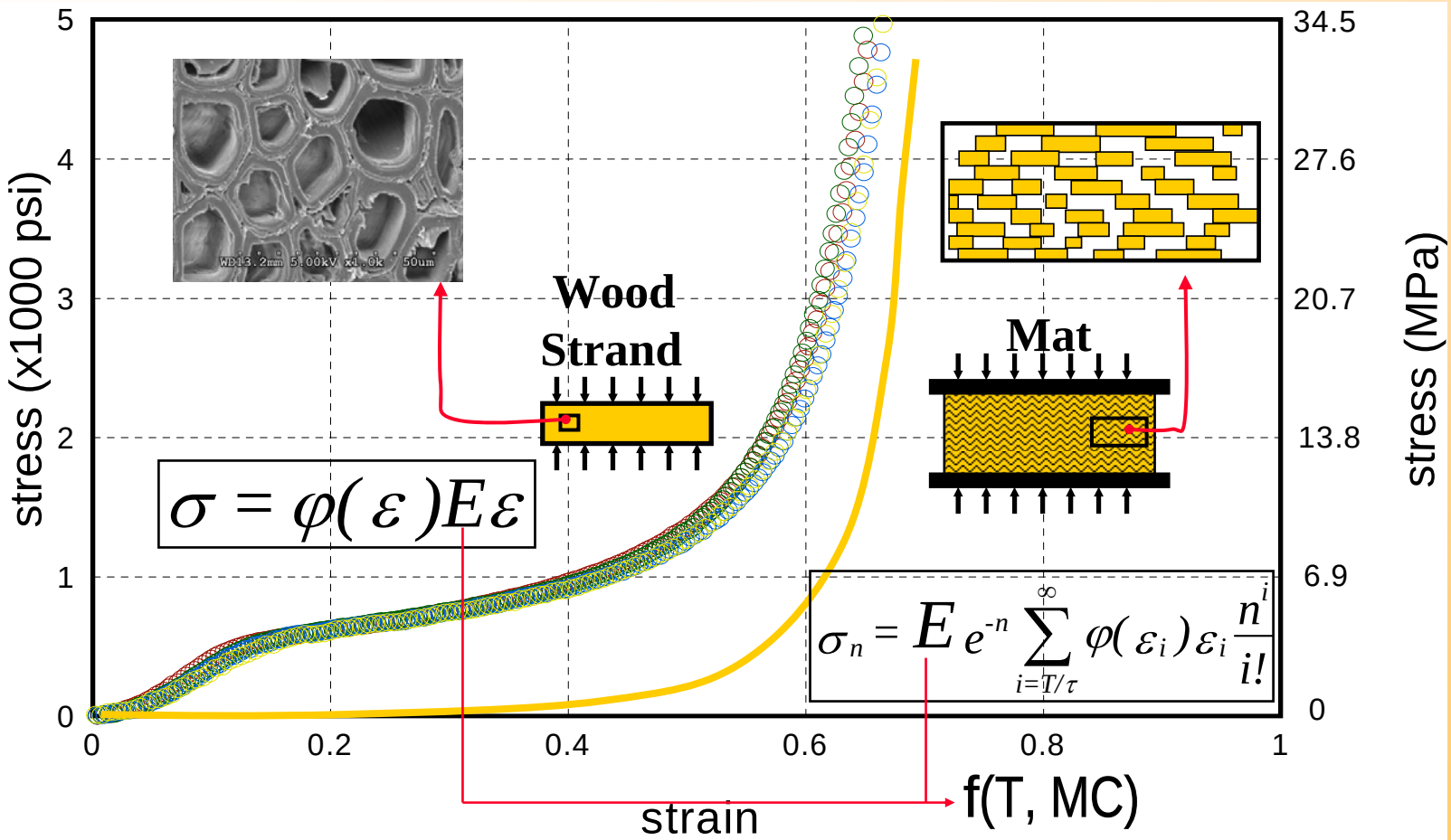
Mat Consolidation: Compression Mechanics of Wood and Porous Strand Structure



Theoretical basis for modeling pressing and vertical density profile

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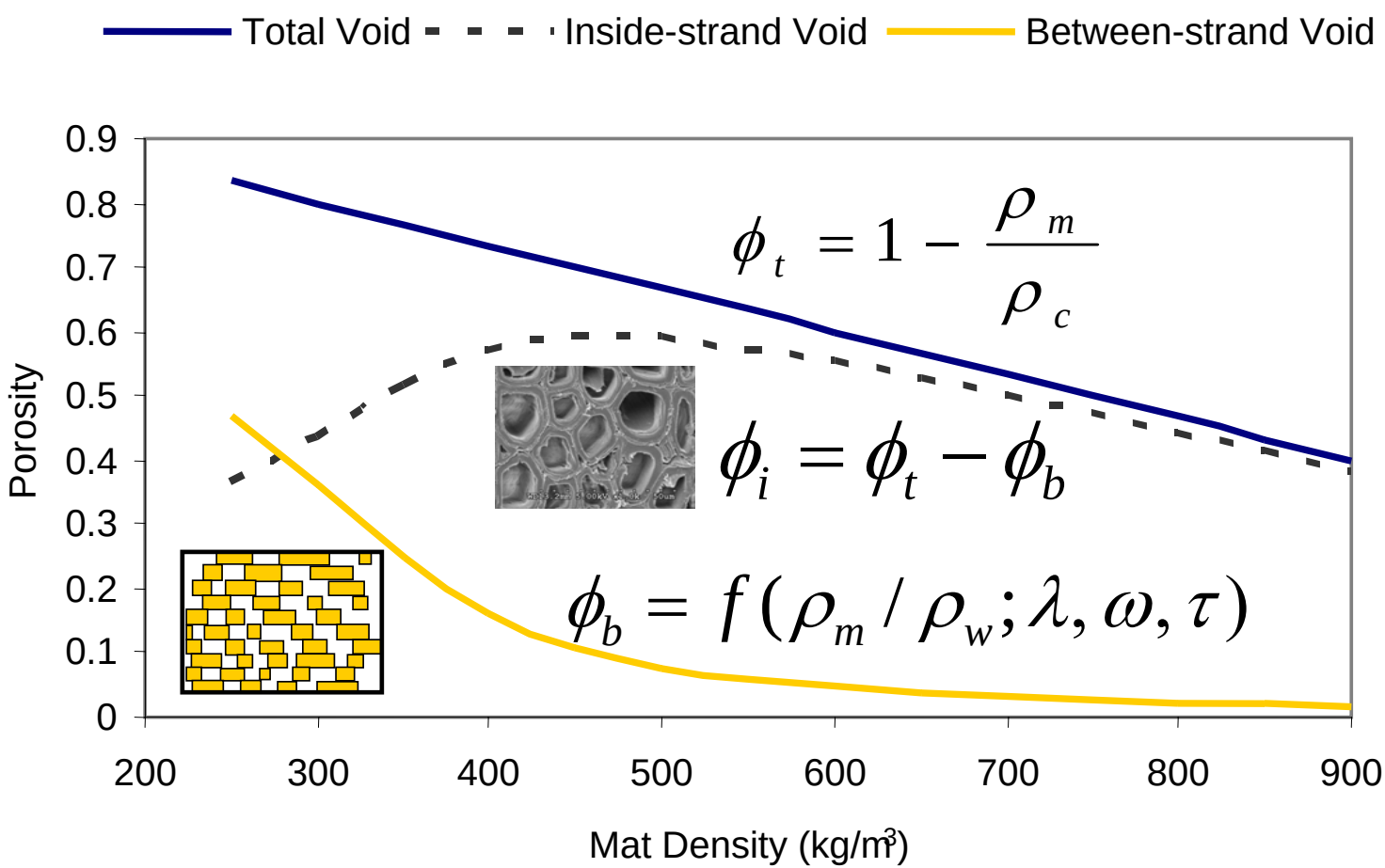
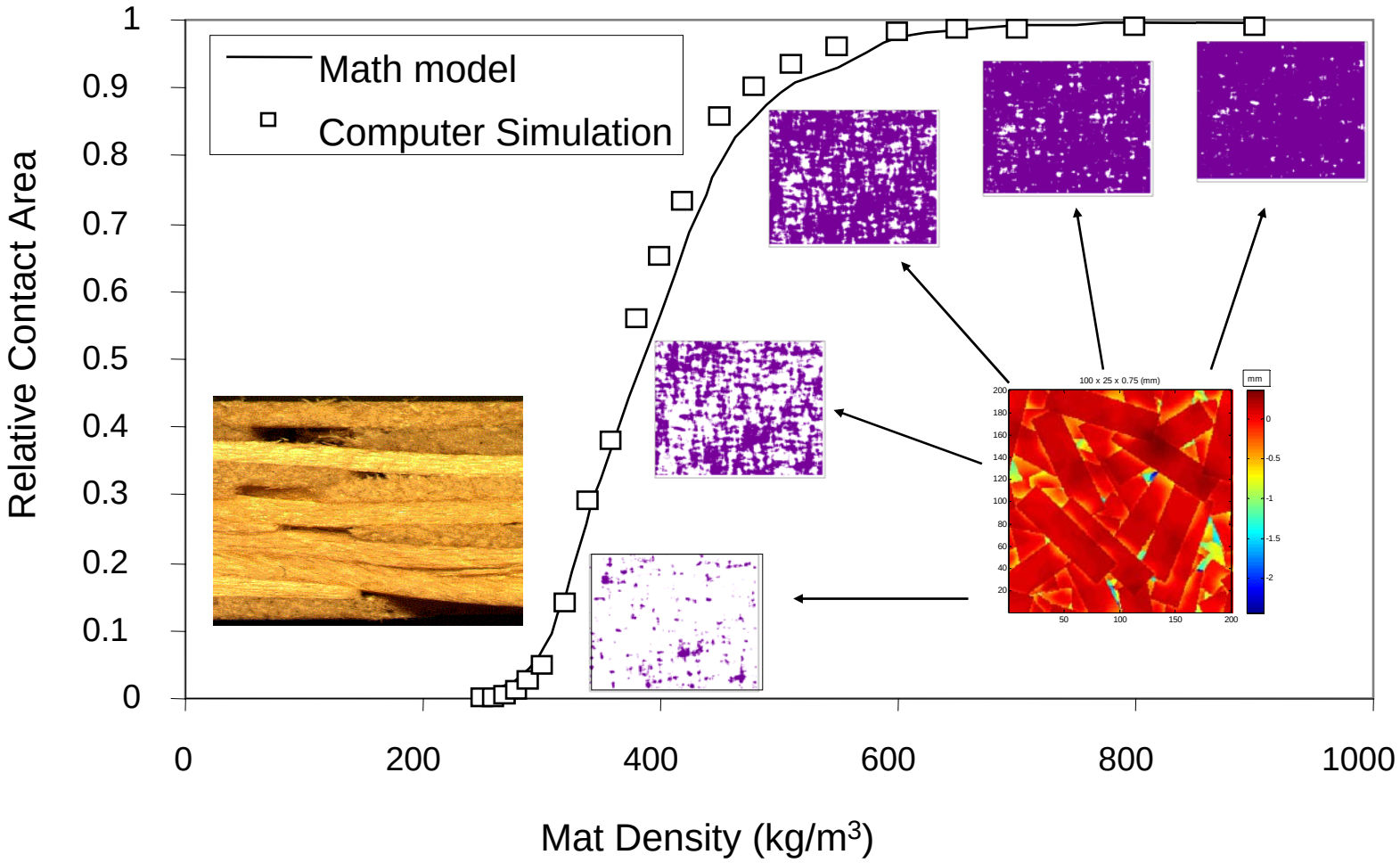
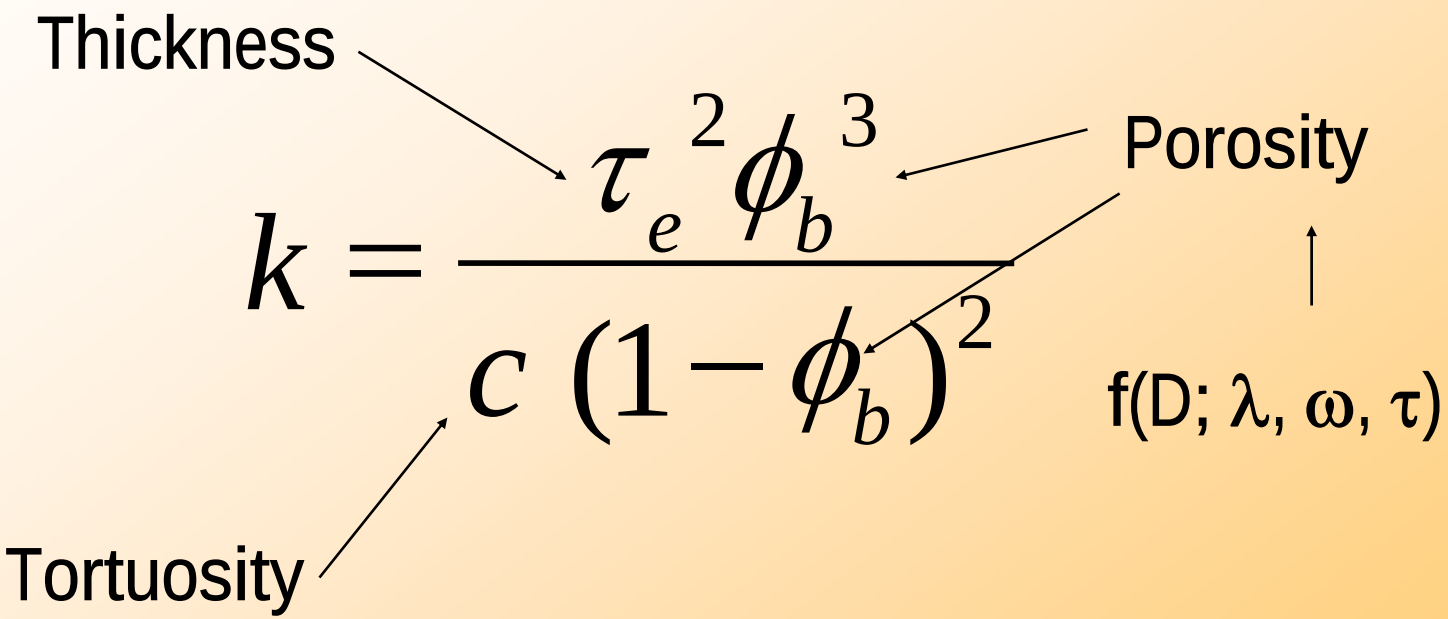
Mat Consolidation: Porosity Variations



Mat Consolidation: Inter-element Contact Development

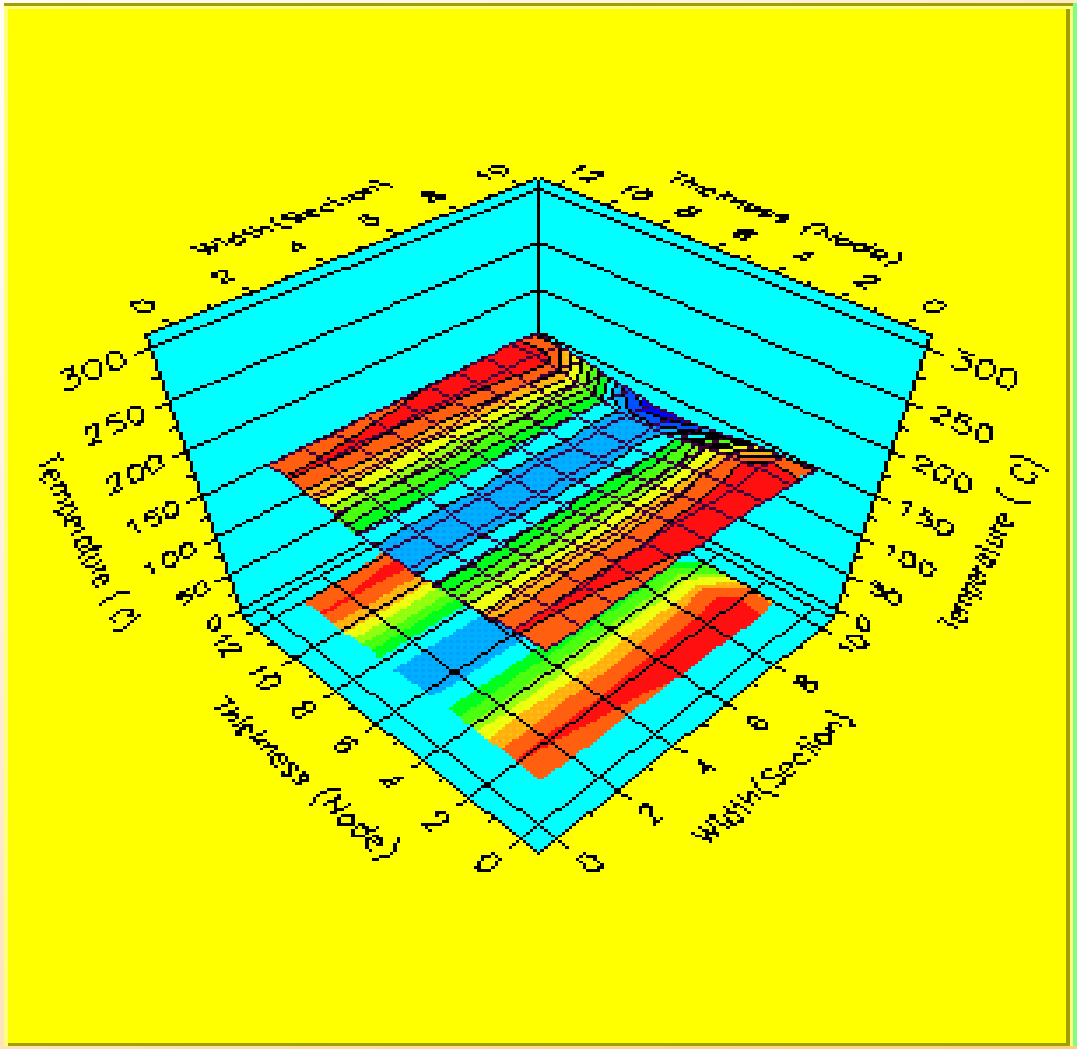


Mat Consolidation: Permeability (k)



Theoretical basis for linking strand dimensions to hot pressing

Computer Simulation of Hot Pressing: Temperature



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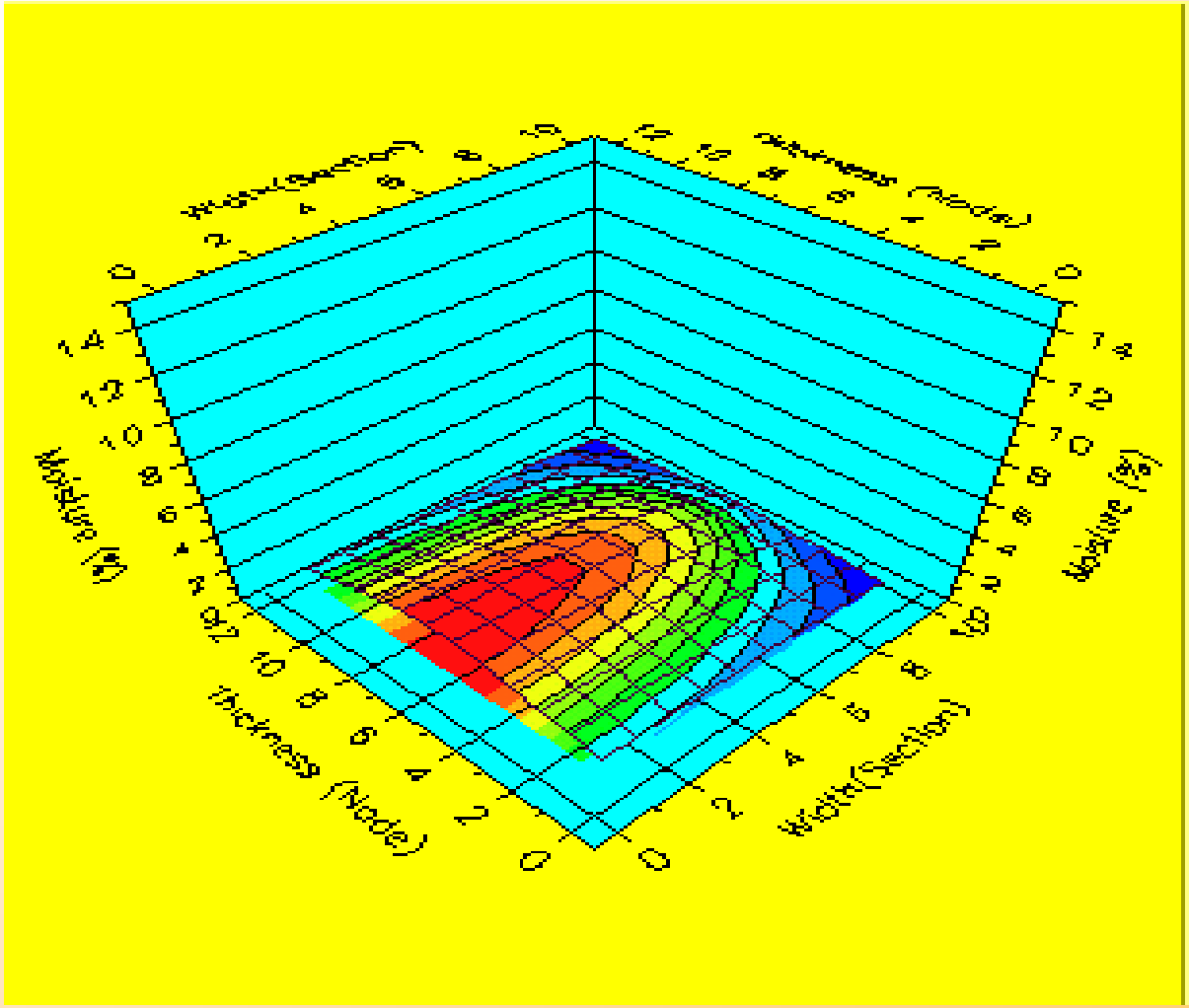
Computer Simulation of Hot Pressing: Moisture Content



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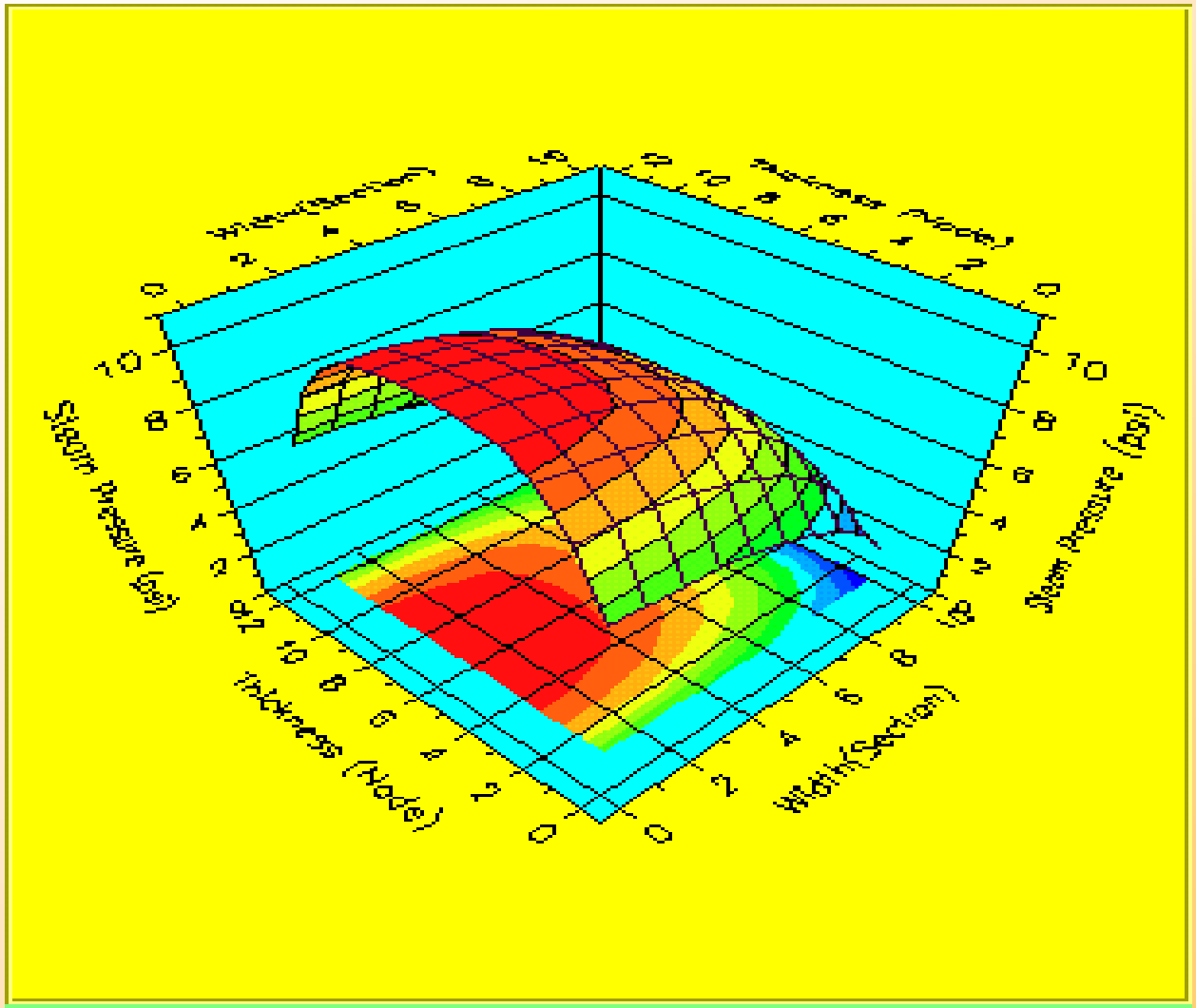
Computer Simulation of Hot Pressing: Gas Pressure



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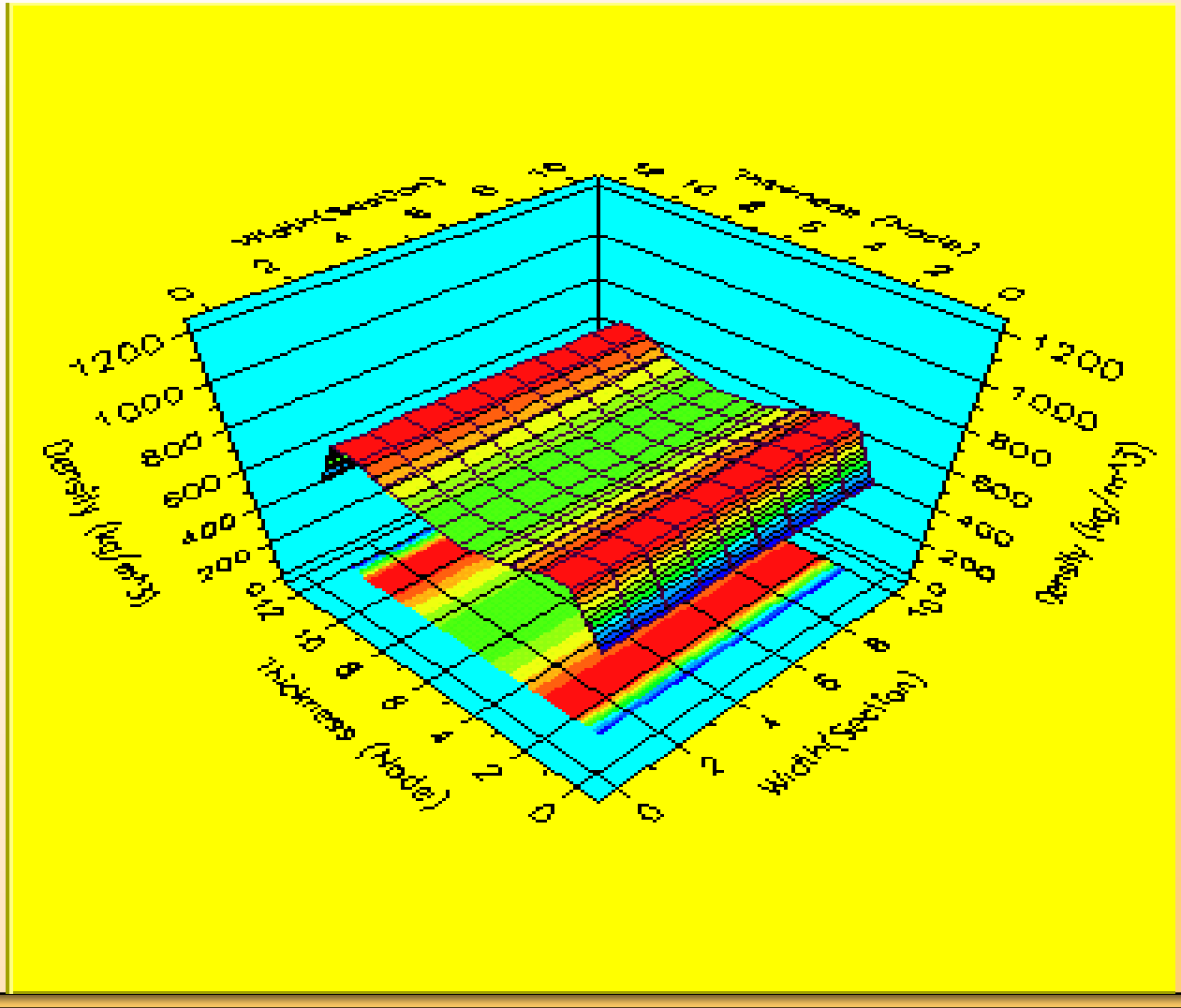
Computer Simulation of Hot Pressing: Vertical Density Profile



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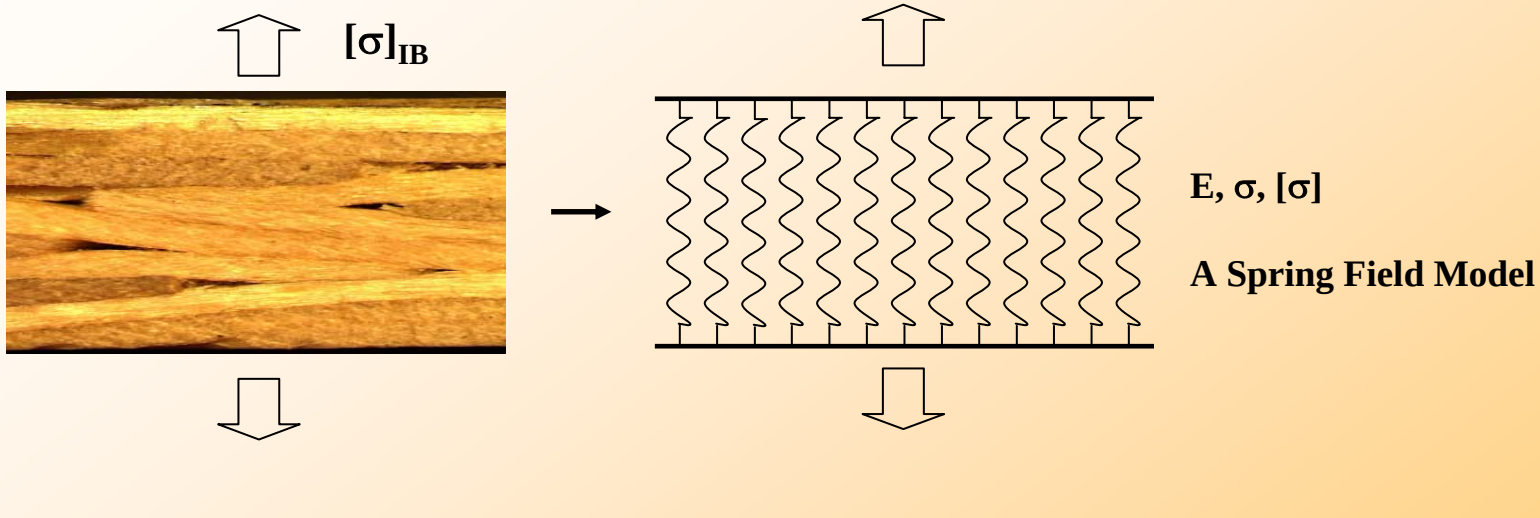
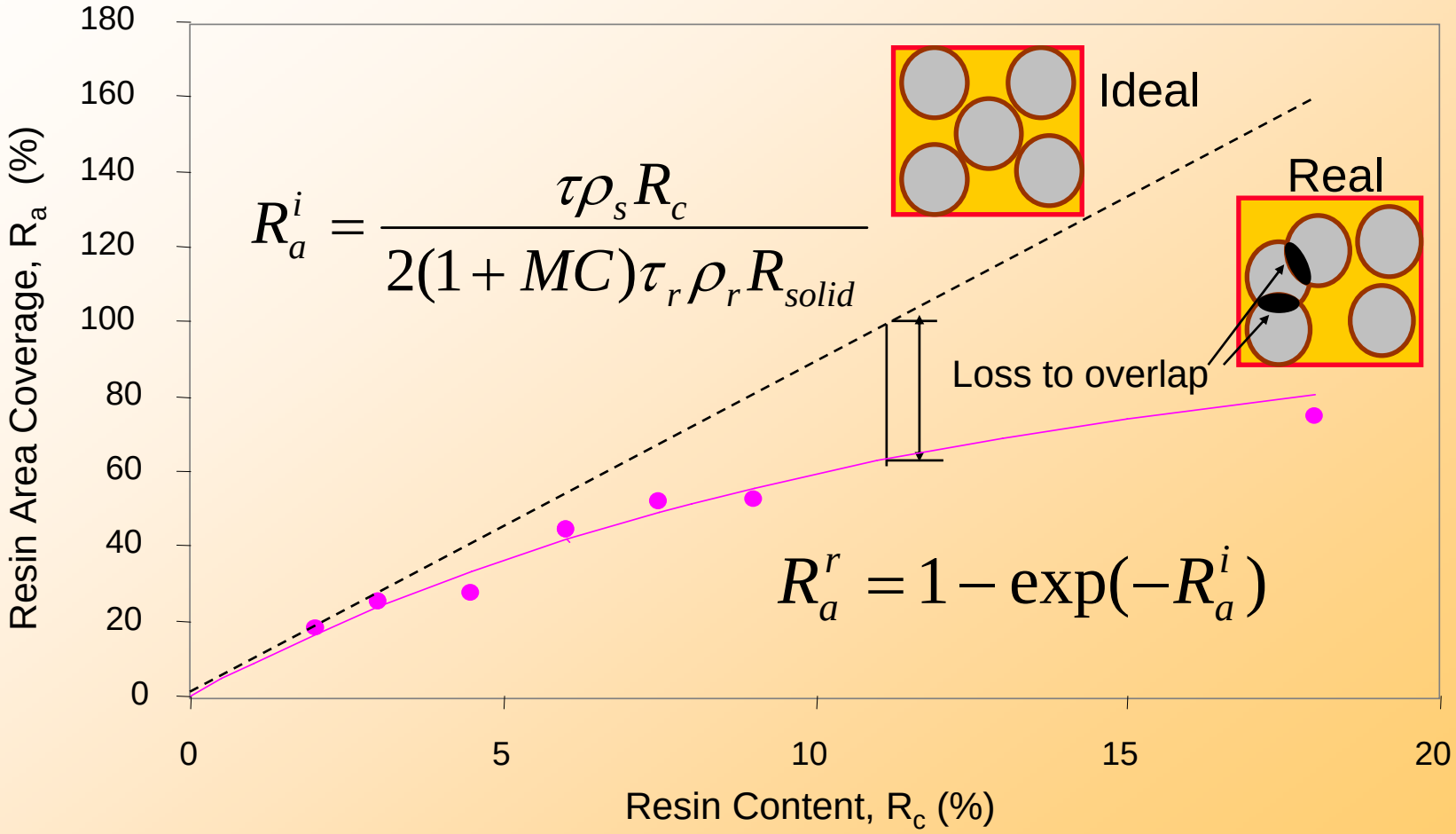
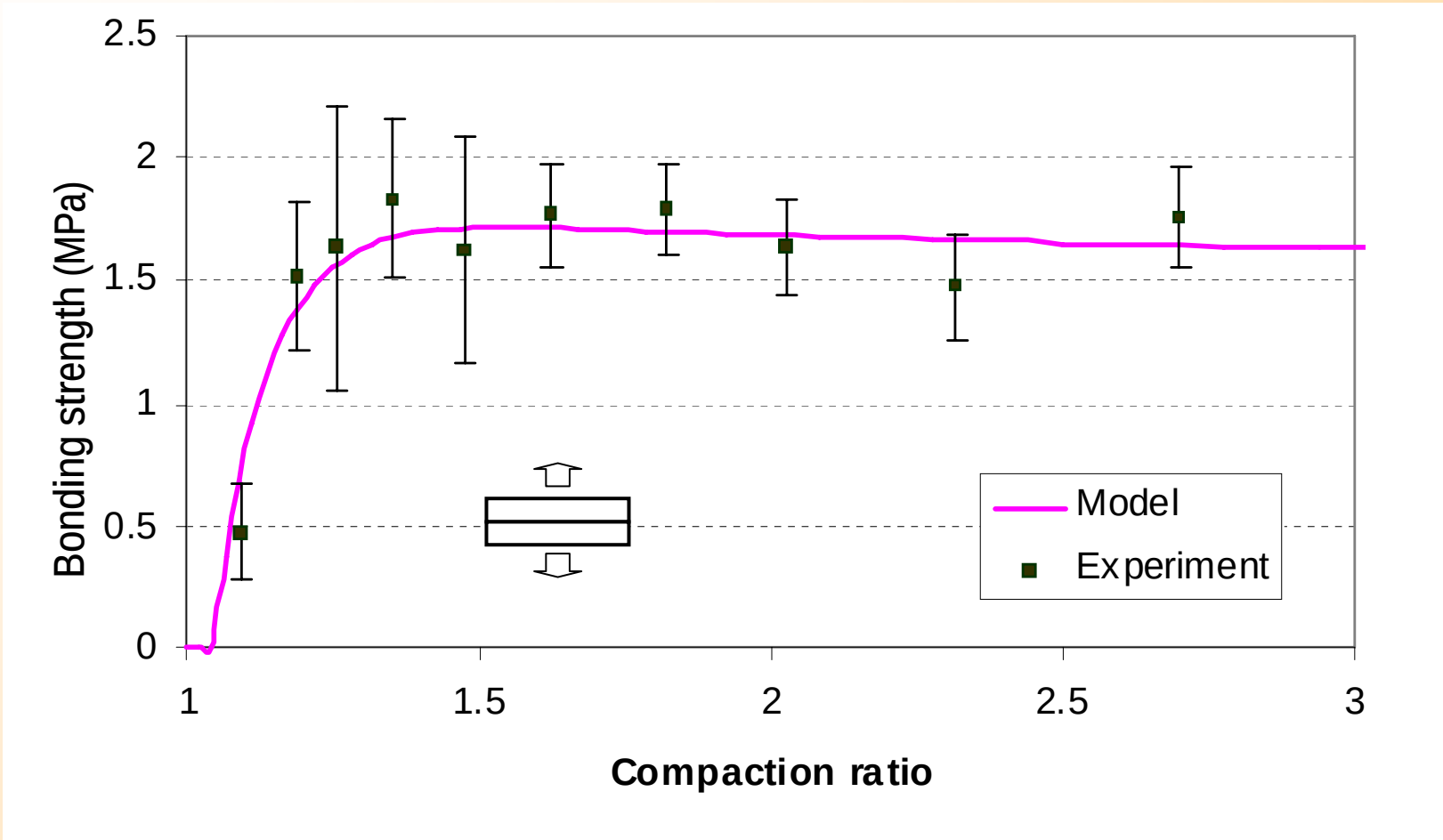
Modeling Wood Composite Bonding



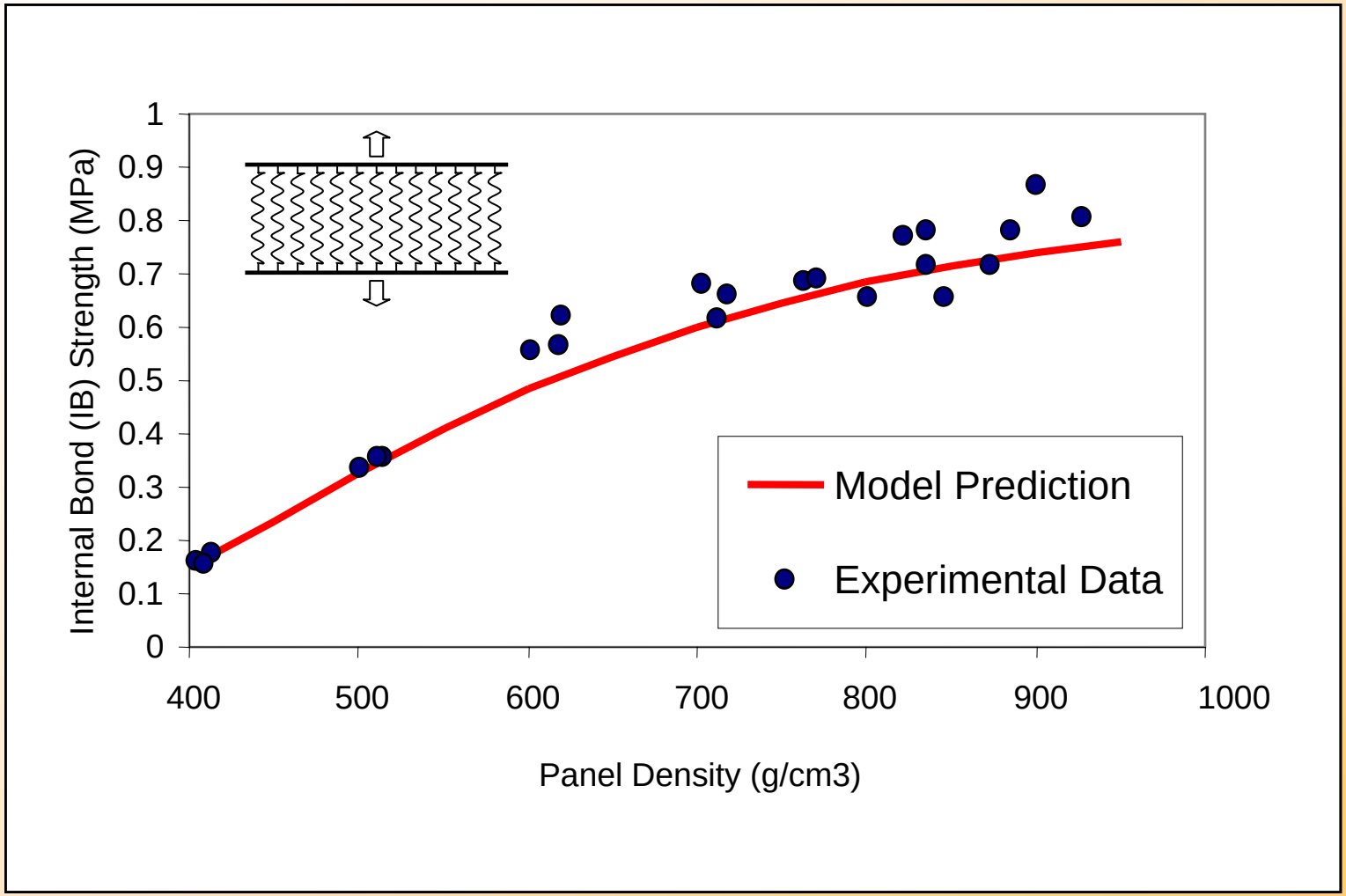
Resin Distribution: Resin Coverage – Content Relationship



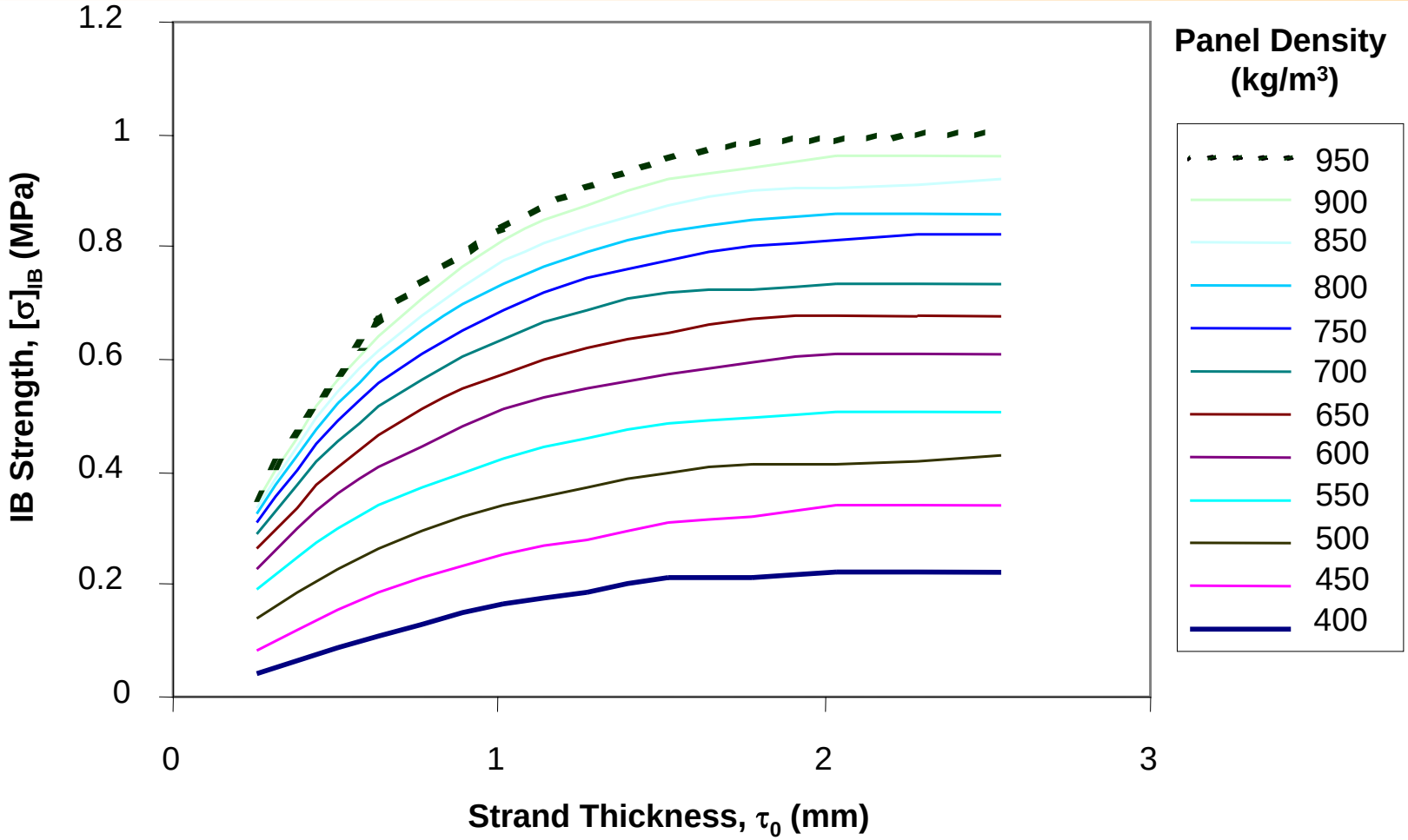
Bonding Strength between Two Wood Strands



Internal Bond (IB) Strength of OSB



Predicted Effect of Strand Thickness on IB



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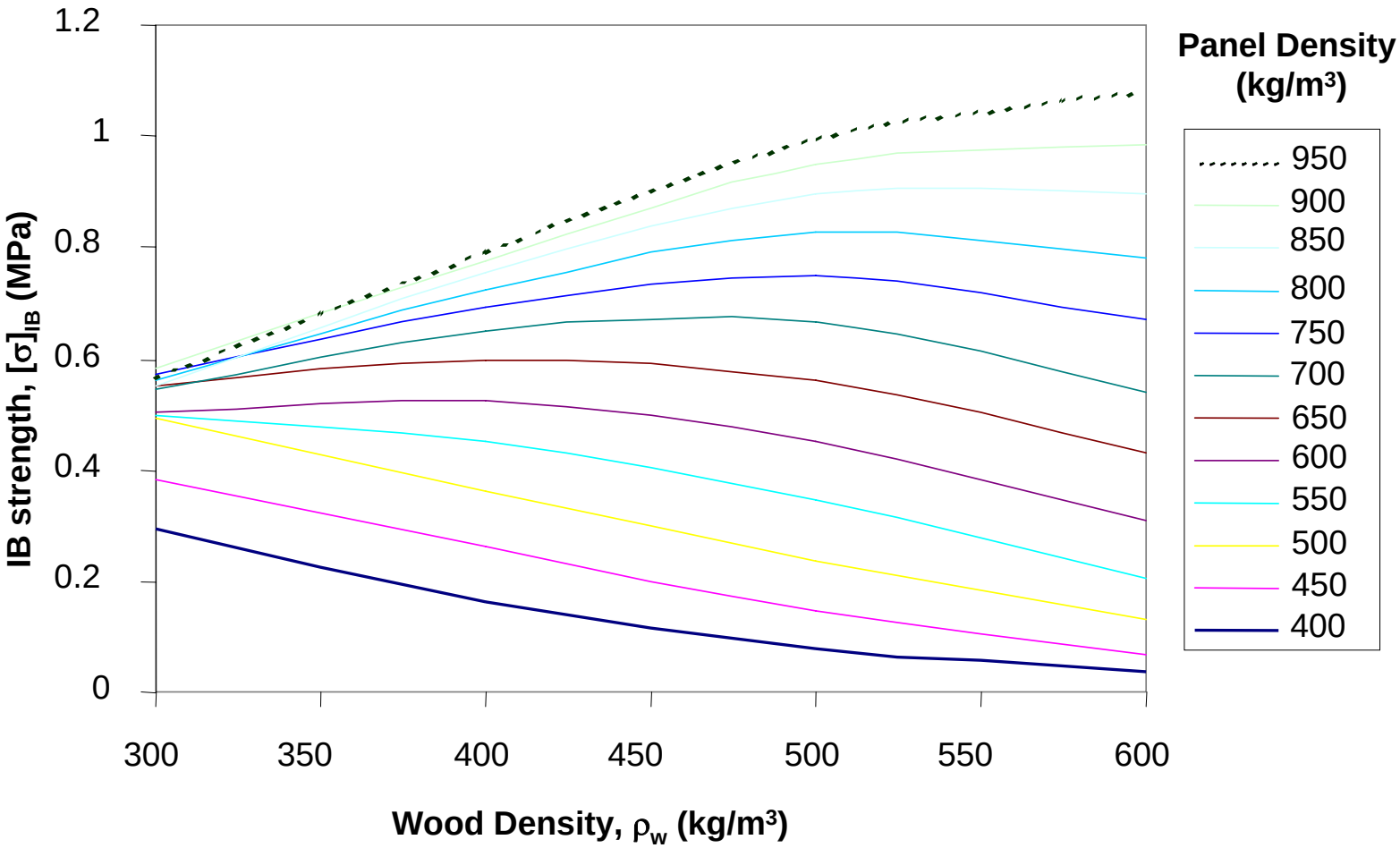
Predicted Effect of Wood Density on IB



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Summary

Analytical and computer simulation models are developed which can predict: mat formation, consolidation, hot pressing and bonding of wood composites.

The results improve the fundamental understanding of processing characteristics and performance of wood composites.

The proposed theories and methodologies open a new path for research and education in wood composites.

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