Surfboard Material Selection

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ME 4790

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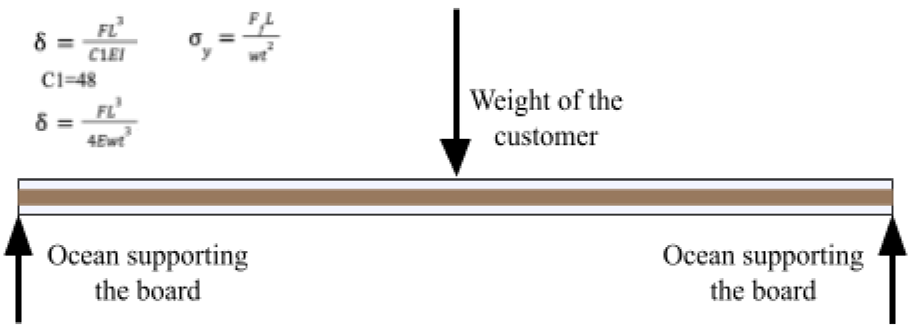
The objective of this study is to identify suitable materials for use in a surfboard. Surfboards must be stiff, strong, light, and relatively inexpensive. A surfboard that is too heavy will have issues with buoyancy and maneuverability. A surfboard should be able to accommodate a wide range of customer weights. The material should be non-porous so that it does not retain water or grow mold and it remains hygienic to use. Finally, the material should not degrade when exposed to UV radiation or salt water.

The most common surfboard materials are glassed wood, polyurethane, expanded polystyrene foam, or hybrid boards. Many wooden surfboards are made out of partially hollow wood (with the most common woods being paulownia, balsa, and cedar), that were then glassed (coated with a resin). The polyurethane or polystyrene foam boards are solid foams. The most common hybrid boards have an expanded polystyrene foam that is glassed with either an epoxy or polyester resin. Glassing of the surfboards is done with a resin, and a fiberglass cloth is sometimes set in the resin to add durability.

Translation Table

Function:	Strong-stiff-light-cheap panel
Constraints:	Specified length and width, thickness must be under 3 inches, specified force (weight of the person), max deflection specified, $\sigma < \sigma_f$, outer surface must be waterproof, corrosion resistant in a saltwater environment, and resistant to UV damage
Objective:	Minimize cost, minimize mass
Free variables:	Material selection, thickness

Since there are two objectives, and the panel has to be strong and stiff, there will be four performance and four material indices. The loading schematic illustrated below has been simplified to be a rectangular panel with a rectangular cross section that is loaded as shown above for the derivation of these indices. The weight of the person is modeled as a point load at the center of the load. The ocean that will support the person is modeled as two simple supports at either end of the board. This is a good way to model the surfboard because the board will be under the maximum stresses when the board is supported far away from where the person is standing. This situation is possible when the waves of the ocean form a concave shape beneath the board. This model shows the board when it is in the situation that will cause the maximum stresses.



The equation for the deflection of this panel is $\delta = \frac{FL^3}{C1EI}$. For this panel, C1=48. The panel is modeled with a rectangular cross section. The selected cross section has $I = \frac{wt^3}{12}$ where w is the width of the panel, L is the length of the panel, and t is the thickness of the panel. For this problem, $\delta = \frac{FL^3}{4Ewt^3}$.

The strength failure mode is to be defined as reaching the full plasticity failure mode. This can be defined as $F_f = \frac{CZ_p\sigma_y}{L}$. For this panel, C is 4, and $Z_p = \frac{wt^2}{4}$. So for this panel, $F_f = \frac{wt^2\sigma_y}{L}$ which can be rewritten as $\sigma_y = \frac{F_f L}{wt^2}$.

The equation for the cost of the panel is $Cost = C_m\rho Lwt$.

The equation for the mass of the panel is $m = \rho Lwt$.

The deflection equation can be rewritten as $t = L(\frac{F}{4Ew\delta})^{\frac{1}{3}}$.

The strength failure equation can be rewritten as $t = (\frac{F_f L}{w\sigma_y})^{\frac{1}{2}}$.

The performance equation for a light stiff panel is $m = \rho L^2 (\frac{F}{4Ew^4\delta})^{\frac{1}{3}}$.

The performance equation for a light strong panel is $m = \rho\, (\frac{F_f L^3 w}{\sigma_y})^{\frac{1}{2}}$.

The performance equation for a cheap stiff panel is $Cost = C_m \rho L^2 (\frac{F}{4Ew^4\delta})^{\frac{1}{3}}$.

The performance equation for a cheap strong panel is $Cost = C_m \rho\, (\frac{F_f L^3 w}{\sigma_y})^{\frac{1}{2}}$.

The material indices that each need to be minimized for those four types of panels are the following in their respective order:

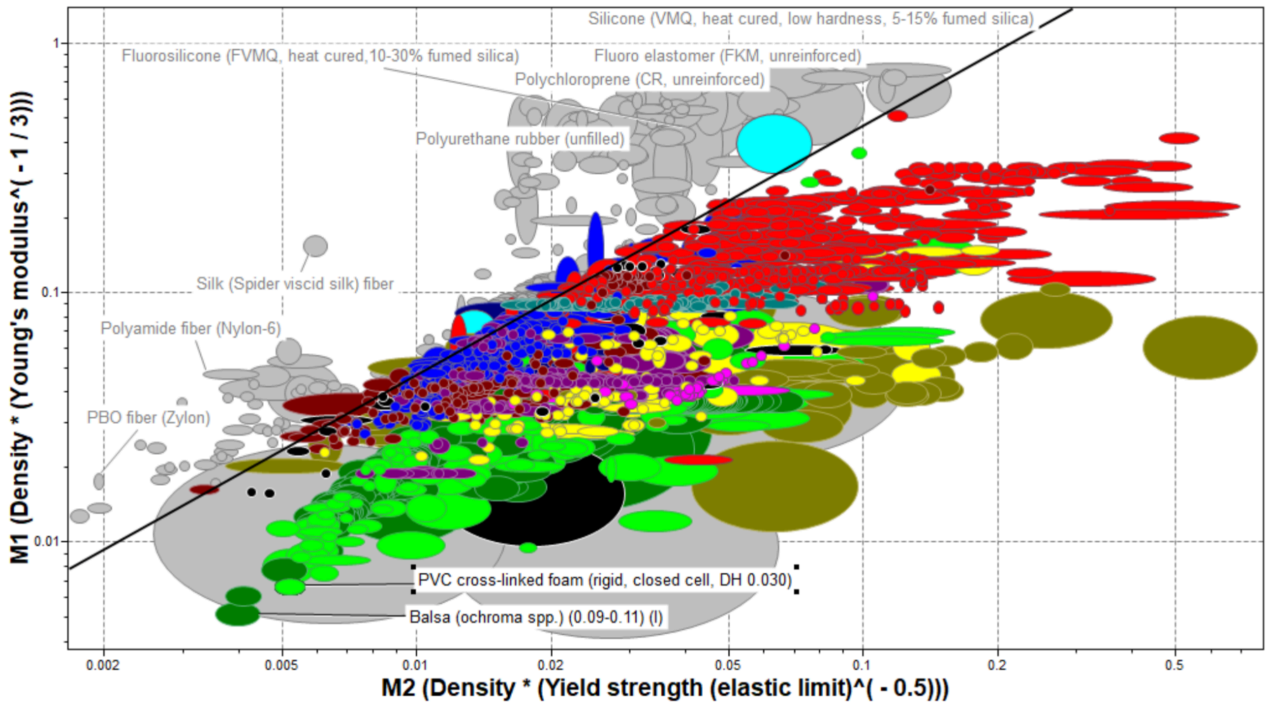
$M_1 = \rho E^{-\frac{1}{3}}$

$M_2 = \frac{\rho}{\sigma_y^{\frac{1}{2}}}$

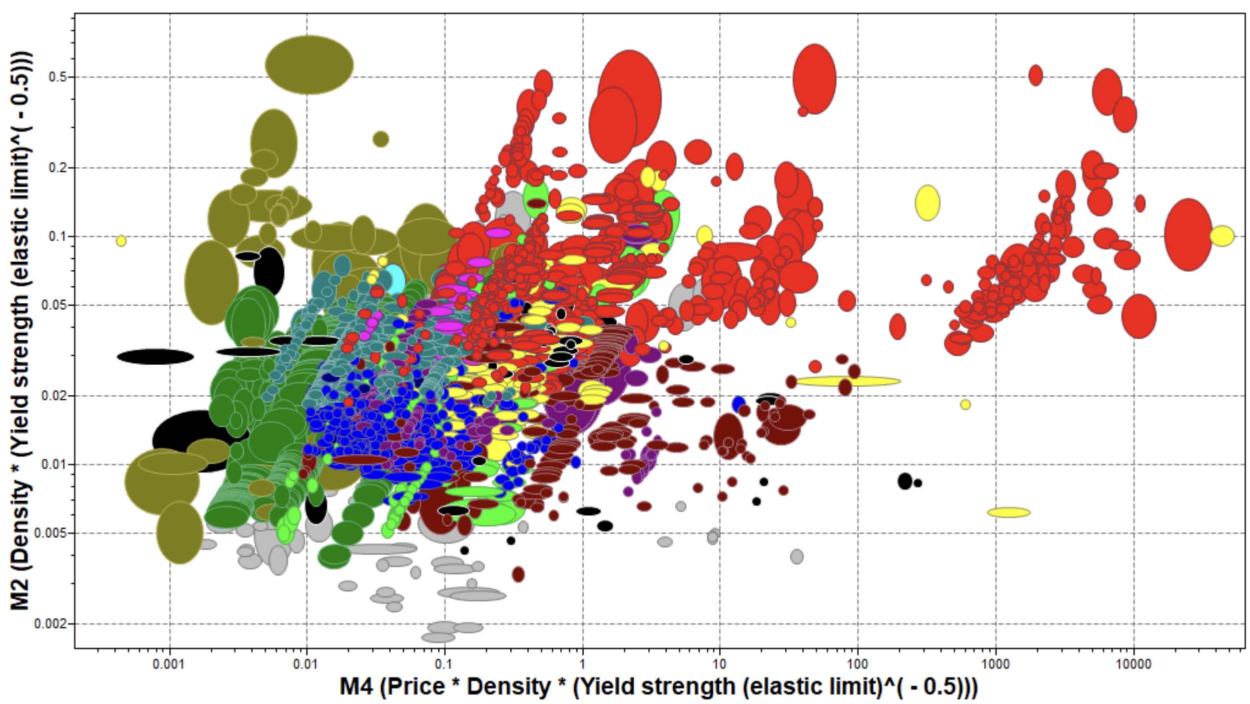
$M_3 = C_m \rho E^{-\frac{1}{3}}$

$M_4 = C_m \rho \frac{1}{\sigma_y^{\frac{1}{2}}}$

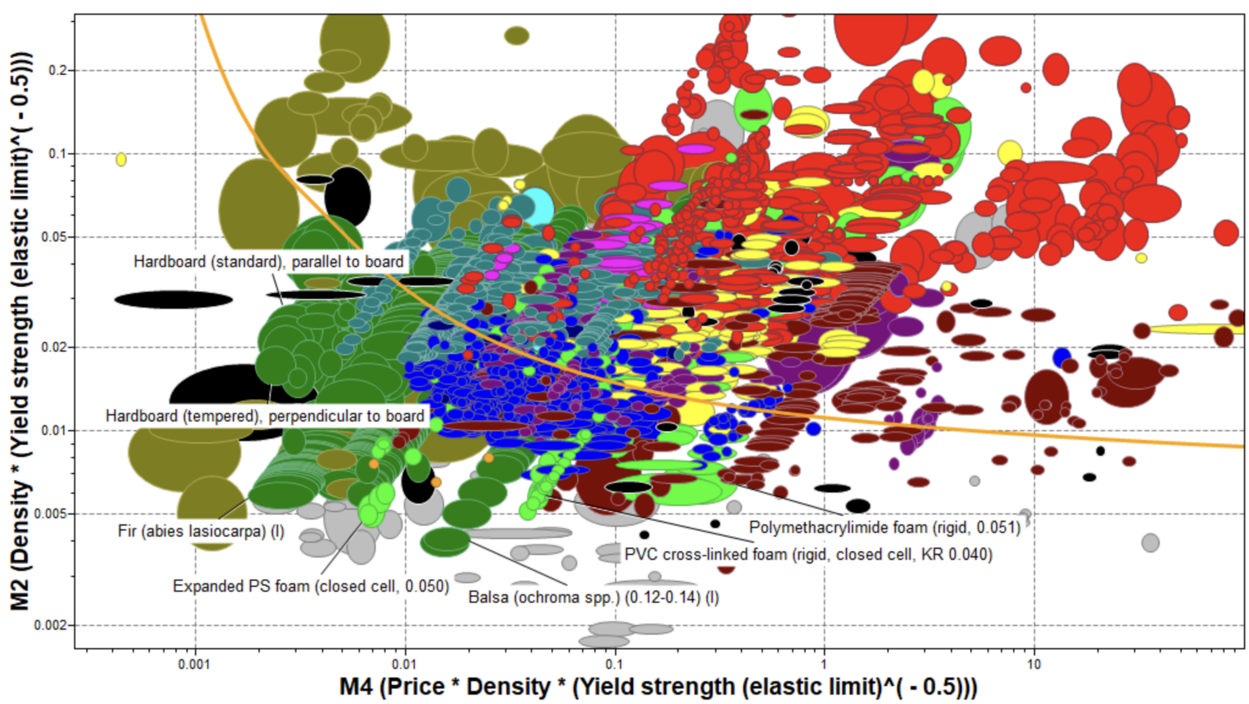
To compare potential core materials for layered panels, material indices 1 and 2 were plotted against each other with the objective of minimizing both of those. These indices contrast a light stiff panel with a light strong panel. Then the coupling line is plotted. As shown below, the majority of the materials are on the left of the coupling line, and the materials that are to the right of the coupling line are not feasible core materials for a surfboard. The material distribution signifies that the strength of the material is the dominant constraint, and that the stiffness is not. Notable materials are labeled on the graph.



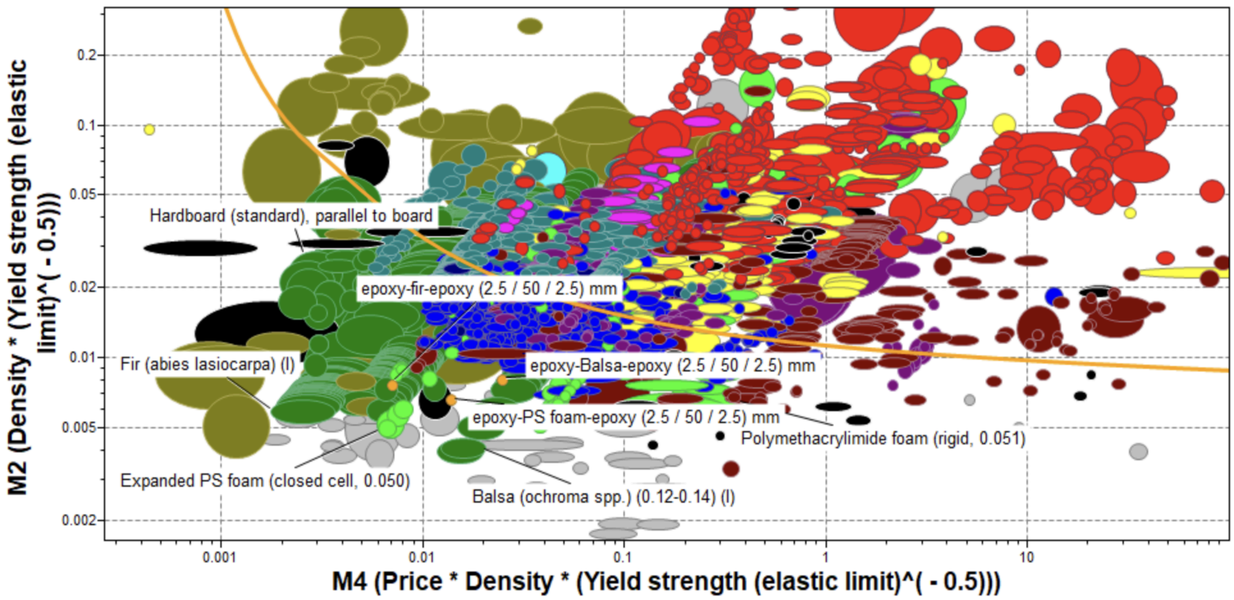
Material indices 2 and 4 were plotted against each other to compare cost and weight with the dominant constraint. As shown below, this plot contrasts a light strong and a cheap strong panel.



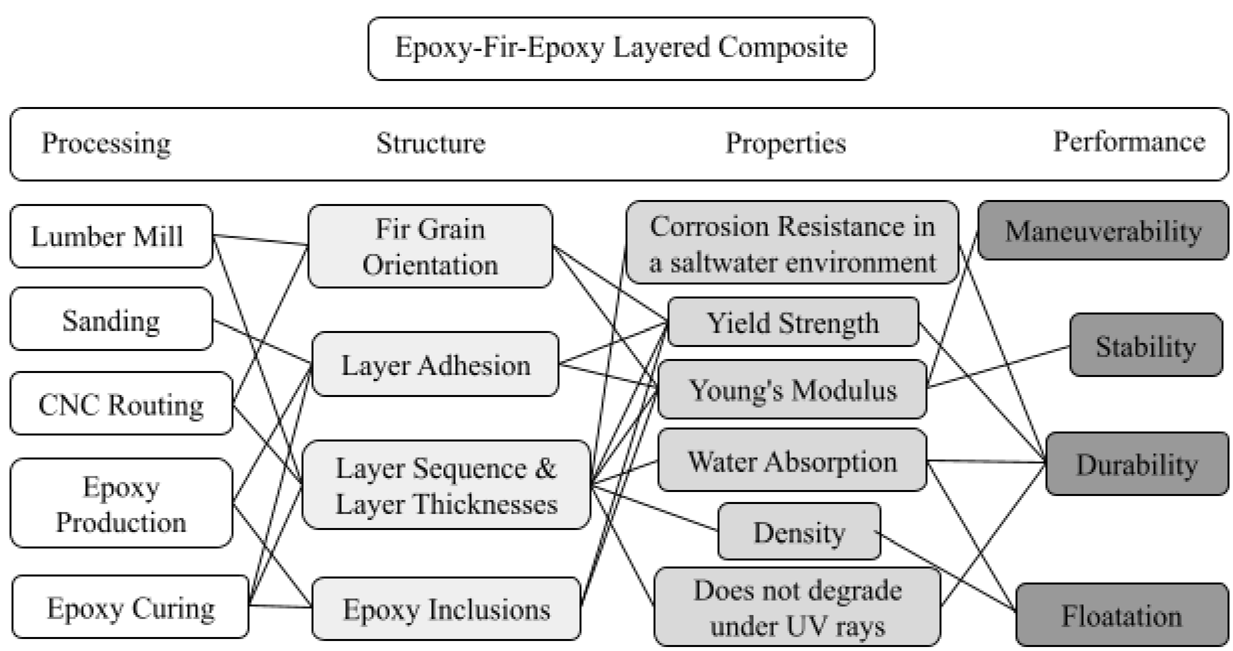
In the figure below, the M2 - M4 plot was magnified to expand the region of the graph in the lower left corner, and a trade off surface and material labels were applied. The magnification excludes materials that are too dense and materials that are too expensive. The region to the left of the trade off surface shows materials that are potential candidates for selection. There was significant overlap between materials that this chart showed as strong candidates, and materials that have traditionally been used in surfboards. As shown on the chart, balsa wood and expanded polystyrene are excellent choices for the material in a surfboard. The balsa, like many other wood materials, would require a surface treatment to be a feasible material for a surfboard because the wood's porous nature could allow it to retain moisture within the board. Some materials that are to the left of the trade off surface are not candidates for use in a layered surfboard due to other constraints (e.g. bone, powders, or spider silk are not practical surfboard layer materials).



The graph below has the same axes as above, but the below plot includes three additional synthesized hybrid layered materials that could be used for a surfboard. In the earlier figure, some of the materials that were to the left of the trade off surface would not withstand a saltwater environment. By coating them in epoxy, these otherwise unsuitable materials were transformed into options that would be feasible surfboards. Although balsa wood is significantly less dense and more expensive than fir, the balsa-epoxy-balsa sandwich structure is not notably lighter than the fir-epoxy-fir sandwich structure. The polystyrene hybrid was the lightest, and had a price point that was in between that of the balsa and the fir hybrids.



The following Processing-Structure-Properties-Performance map shown below highlights the steps involved in creating an epoxy-fir-epoxy sandwich structure, and how those steps impact the final product.



The optimal material to use for a surfboard is dependent on the intended customer base. Wealthy or professional surfers who are in the market for a stiff, lightweight option and are less concerned about the price point, may seek a layered structure involving PVC cross linked foam. For a consumer who is looking to balance cost with functionality, the epoxy-fir-epoxy structure is a material to be considered. Beginner surfers who do not want to make an extravagant purchase may find that expanded polystyrene boards are suitable for their needs. The aesthetics associated with different materials will also impact what material combination is most marketable to different customers. Wood is associated with high quality craftsmanship, and a board made from this material is likely to be perceived as a timeless item that will hold its value. A polystyrene board may be associated with a cheaper product that will depreciate. Identifying the target customer is necessary to create an optimized surfboard design.

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