Material Selection and Design Analysis of a Snowboard System

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Project completed as part of a team-based design study

Group Project Description

Figure 1: Snowboard in use, https://www.billjacksons.com/how-to-choose-your-first-snowboard-5-essential-qualities/

COMPONENT	PERSON RESPONSIBLE
(1) Board Core	Jessica Schubert
(2) Board Base	Camden Galen
(3) Foot Binding Straps	Kaitlyn Shtaih
(4) Top Sheet	Alexia Follett

Table 1: Component index

Purpose, Use, & Unique Characteristics

This design concept is for a snowboard capable of encompassing a variety of the most desired characteristics across the industry. This design implements aerodynamic features that help users navigate through the snow more effectively. Angular geometry and surface divots emphasize this. Furthermore, the idealization of material selections combined with this design allow for this board to be extremely lightweight, whilst maintaining enough structural elements to support riders alongside the flexion seen during riding. The lightweight feature is combined with a breathability intent when considering the bindings where riders place their boots on the board. When combined, these key traits create the highest performing snowboard on the market. The use case for this snowboard is that of any other snowboard - riding. It is designed to be a versatile piece of equipment that can combat most any terrain or riding condition a snowboarder might encounter. It is inferred that a typical customer for this design will most value the performance of the board. Due to its lightweight nature and aerodynamic capabilities, the responsiveness of the board should appeal greatly to the user. The tuned surface design and shaping emphasize how the board should behave. A typical customer would also appreciate a lighter board, which will minimize the rider's own fatigue from using the board and help with the overall maneuverability of the board.

Individual Component Description

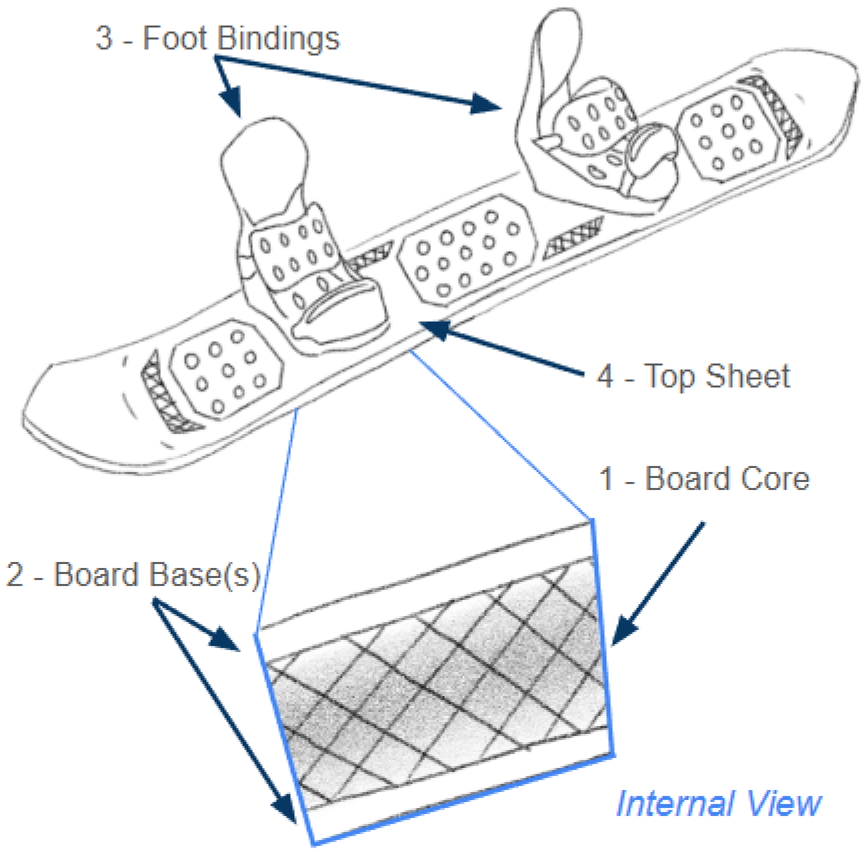

Figure 2: Overview of snowboard concept broken into sections

Simplified Geometry & Design Criteria

Board Core

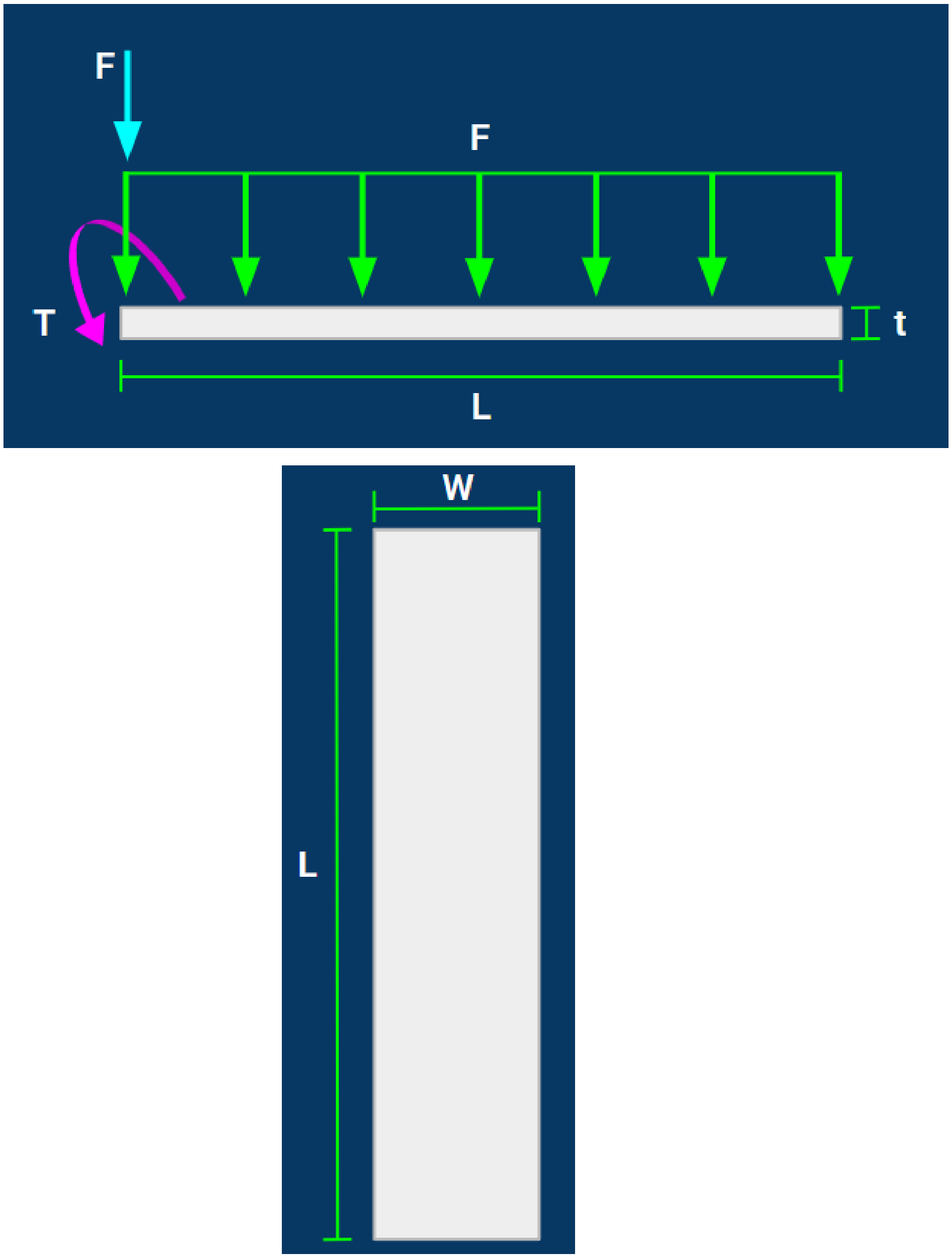

Figure 3: Snowboard board core as simplified geometry

OBJECTIVES	CONSTRAINTS	SIMPLIFIED GEOMETRY	DESIGN (FIXED) VARIABLES	FREE (UNCONSTRAINED) DIMENSION
Minimize mass Minimize dollar cost ($) Minimize sustainability cost (CO2, EE, or H2O) Maximize flexibility / deflection	No fracture No permanent deformation Vibration damping	Rectangular Slab	Vertical Force, F Bending Force, B Length, L Width, W Torsion, T	Slab thickness, t

Table 2: Design criteria table

My reasoning in selecting this simplified geometry and these corresponding design constraints is first due to the fact that a snowboard is very closely resembling a rectangle. Though in reality it includes rounded corners and edges, a rectangular shape is going to be the simplest geometry that most accurately depicts the board's original shape. As for the constraints themselves, I selected these based on my own knowledge of snowboards, trying to capture the best characteristics of a snowboard that would not complicate the overall analysis. Snowboards need to be able to flex without experiencing any permanent geometry changes and also "absorb" the effects of the terrain it rides on. This supports the vibration damping constraint, as well as no fracture and no permanent deformation.

Board Base

Figure 4: Snowboarder with load on tip of board
https://neversummer.com/cdn/shop/articles/2024_Valhalla_MattWilliams_HugeHeelside.jpg?v=1692034909

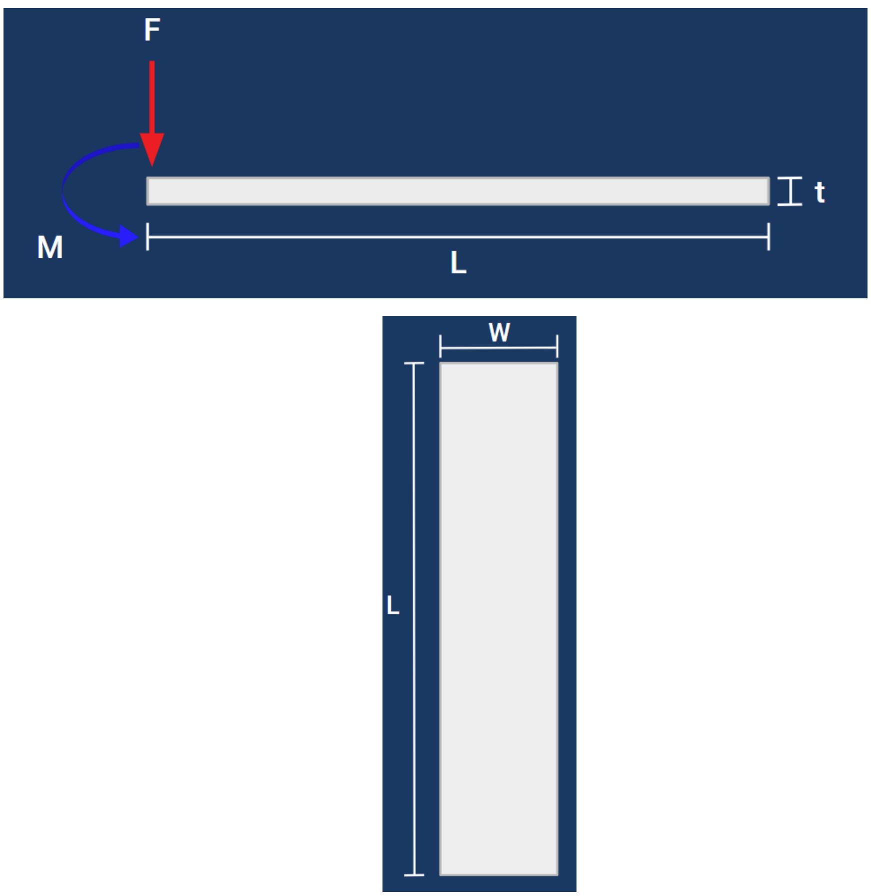

Figure 5: Snowboard base board as simplified geometry

OBJECTIVES	CONSTRAINTS	SIMPLIFIED GEOMETRY	DESIGN (FIXED) VARIABLES	FREE (UNCONSTRAINED) DIMENSION
Minimize mass Minimize dollar cost ($) Minimize sustainability cost (CO2) Variety of colors available	No permanent deflection No fracturing Limit stress below yield strength	Rectangular Slab	Vertical Force, F Bending Force, M Length, L Width, W	Slab thickness, t

Table 3: Design criteria table

We want the snowboard to be as light as possible, while still being functional under extreme conditions. To do this, we want to minimize the mass while ensuring it doesn't fracture or deflect beyond elasticity. I will be analyzing the base board under a loading scenario where the force is focused on the tip of the board. As it is simplified to a rectangular slap, this creates a moment on the board from the point force if the other side of the board is assumed to be constrained/fixed. In addition to minimizing the mass, we want to ensure it will be affordable and sustainable to the environment. Finally, as snowboarders want to be able to express themselves on the mountain an additional hump of material selection is ensuring the material comes in a variety of colors.

Foot Binding Straps

Figure 5: Picture of foot binding straps

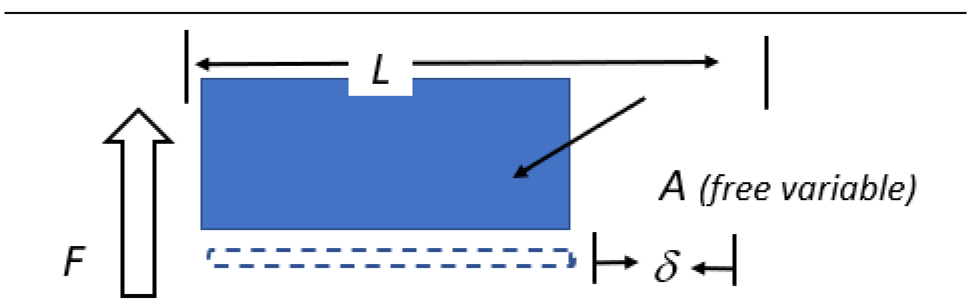

Figure 6: Simplified foot binding straps geometry

COMPONENT	OBJECTIVES	CONSTRAINTS	SIMPLIFIED GEOMETRY	DESIGN (FIXED) VARIABLES	FREE (UNCONSTRAINED) DIMENSION
Binding Straps	1. **Minimize Sustainability cost (C02 or EE or H2O)** 2. **Minimize dollar cost ($)** 3. **Minimize mass** 4. Improve adjustability	• Vertical and lateral forces • Rider's weight • Elastic or plastic deformation • Maintain secure boot grip	Hollow Triangular/prismatic frame with rectangular strap slabs	• Length (L) • Strap width(w)	Wall Thickness(tw), Slab Thickness(ts)

Table 4: Design Criteria

The goal is to minimize the mass of the snowboard and to minimize the cost while still ensuring the functionality of the food binding straps and quality of the entire product. In order to accomplish this, I will be analyzing the foot binding straps under vertical and lateral forces, rider's weight and deformation. When the rider puts their foot into the binding straps derived from figure 5, they are applying a vertical load onto the binding and when the rider moves to shred the slope, they are applying a lateral force to the board. The rider's weight is also applying a force onto the foot bindings every time they move or attempt to pick up their foot. As the simplified geometry of the food binders are a rectangular slap, we can consider the length and width of the binding to be our variables and the thickness of the slab to change depending on conditions. The foot bindings are important to the snowboard as a whole because it allows the rider to manipulate the board in the direction of the slope and allows the rider to ride the slope.

Top Sheet

Figure 7: Snowboarder on rail
https://ar.inspiredpencil.com/pictures-2023/snowboarding-rail-wallpaper

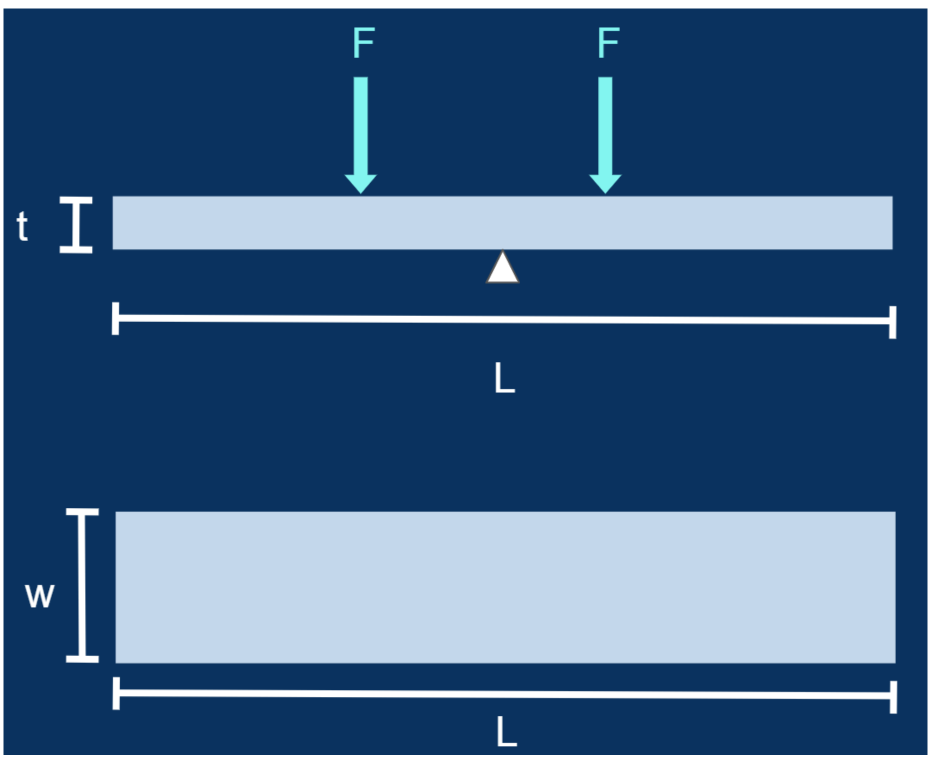

Figure 8: Simplified geometry and loading of snowboard top sheet

Table 5: Design criteria table for the top sheet

OBJECTIVES	CONSTRAINTS	SIMPLIFIED GEOMETRY	DESIGN (FIXED) VARIABLES	FREE (UNCONSTRAINED) DIMENSION
Minimize mass Minimize dollar cost ($) Minimize sustainability cost (EE) Industrial design considerations (variety of aesthetic options)	Does not fracture Elastically deforms under loading Must withstand temperatures down to -30 °C	Rectangular Slab, Loading analyzed as a beam	Length, L Width, w Vertical Force, F	Thickness, t

The loading scenario I am analyzing for the top sheet is the rider on a rail. The basic geometry of a snowboard can be simplified as a rectangular slab. For the purposes of my analysis, the geometry of the top sheet is simplified further to be analyzed as a beam. The beam is supported in the center with two forces on either side acting as the rider's feet.

The constraints were selected from basic functions of a snowboard. The materials of the board must not fracture or permanently deform under expected loading conditions. The snowboard must also be able to function in cold weather. -30C is roughly equivalent to -20F. Below these temperatures, people have a greater risk of frostbite, especially with windchill. Resorts often shut down below this temperature to protect riders and the functionality of the lifts.

Active Constraint Analysis & Ranking

Development of Performance Eq.'s & Material Indices

Objective	Constraints	Preformance Eq's	Material Indices
$m = WLt\rho$	$\delta_m + \delta_w = \frac{10FL^3}{EWt^3}$	$\longrightarrow m_1 = 10^{\frac{1}{3}} * (\frac{F^{\frac{1}{3}} * L^2 * W^{\frac{2}{3}}}{\delta^{\frac{1}{3}}}) * (\frac{\rho}{E^{\frac{1}{3}}})$	$\longrightarrow M_{1,max} = \frac{E^{\frac{1}{3}}}{\rho}$
	$\sigma = \frac{F}{A}$	$\longrightarrow m_2 = (F)(L)(W)\left(\frac{\rho}{\sigma_y}\right)$	$\longrightarrow M_{2,max} = \frac{\sigma_y}{\rho}$
cost= $WLt\rho C_m$	$\delta_m + \delta_w = \frac{10FL^3}{EWt^3}$	$\longrightarrow cost_1 = 10^{\frac{1}{3}} * (\frac{F^{\frac{1}{3}} * L^2 * W^{\frac{2}{3}}}{\delta^{\frac{1}{3}}}) * (\frac{\rho C_m}{E^{\frac{1}{3}}})$	$\longrightarrow M_{3,max} = \frac{E^{\frac{1}{3}}}{\rho C_m}$
	$\sigma = \frac{F}{A}$	$\longrightarrow cost_2 = (F)(L)(W)\left(\frac{\rho C_m}{\sigma_y}\right)$	$\longrightarrow M_{4,max} = \frac{\sigma_y}{\rho C_m}$
CO2= $WLt\rho CO2_{kg}$	$\delta_m + \delta_w = \frac{10FL^3}{EWt^3}$	$\longrightarrow CO2_1 = 10^{\frac{1}{3}} * (\frac{F^{\frac{1}{3}} * L^2 * W^{\frac{2}{3}}}{\delta^{\frac{1}{3}}}) * (\frac{\rho CO2_{kg}}{E^{\frac{1}{3}}})$	$\longrightarrow M_{5,max} = \frac{E^{\frac{1}{3}}}{\rho CO2_{kg}}$
	$\sigma = \frac{F}{A}$	$\longrightarrow CO2_2 = (F)(L)(W)\left(\frac{\rho CO2_{kg}}{\sigma_y}\right)$	$\longrightarrow M_{6,max} = \frac{\sigma_y}{\rho CO2_{kg}}$

Figure 9:Equation derivation for mass minimization objective combined with deflection and strength constraints. m = mass, A = cross-sectional area , L = length, F = axial force, d = deflection, dmax = deflection limit r = density, E = elastic modulus, s = stress, sy = yield strength, CO2kg = carbon dioxide emissions, Cm = cost

Corresponding Granta Plots & Material Candidates

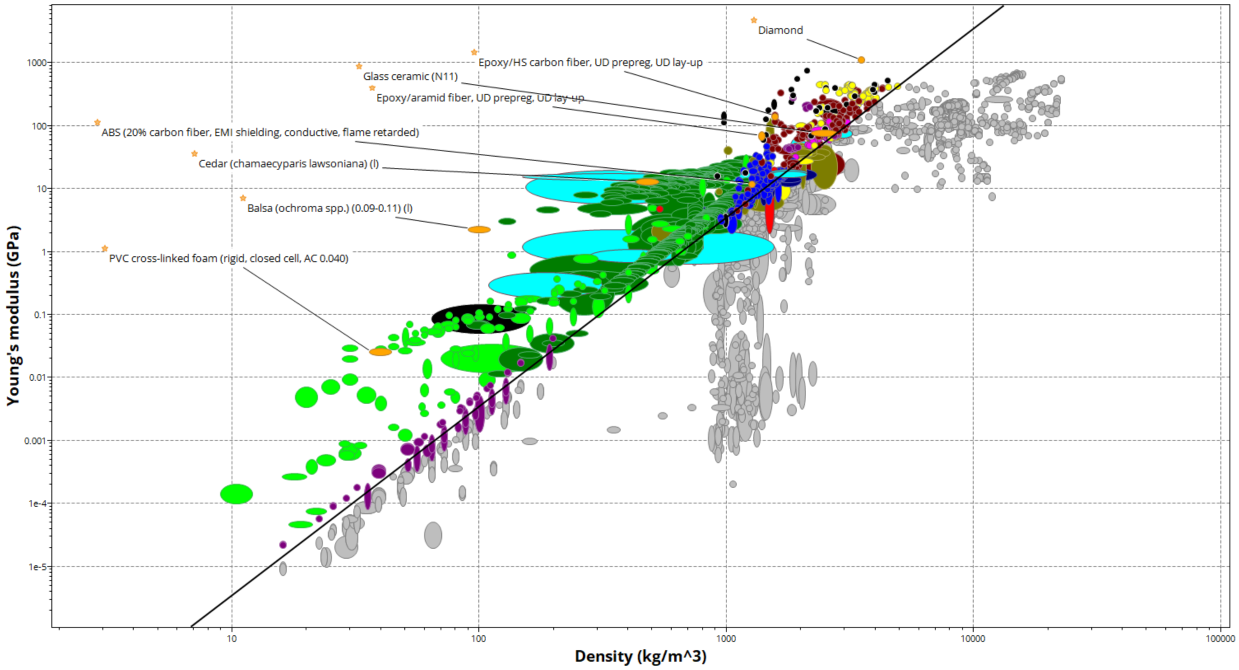

Figure 10: Corresponding Granta plot for M_1

MATERIAL	
1	Balsa, ULD
2	Diamond
3	CFRP, epoxy
4	AFRP, epoxy
5	Cedar
6	ABS(20% CF)
7	Glass ceramic
8	PVC cross-linked foam

Table 6: Corresponding materials for M_1

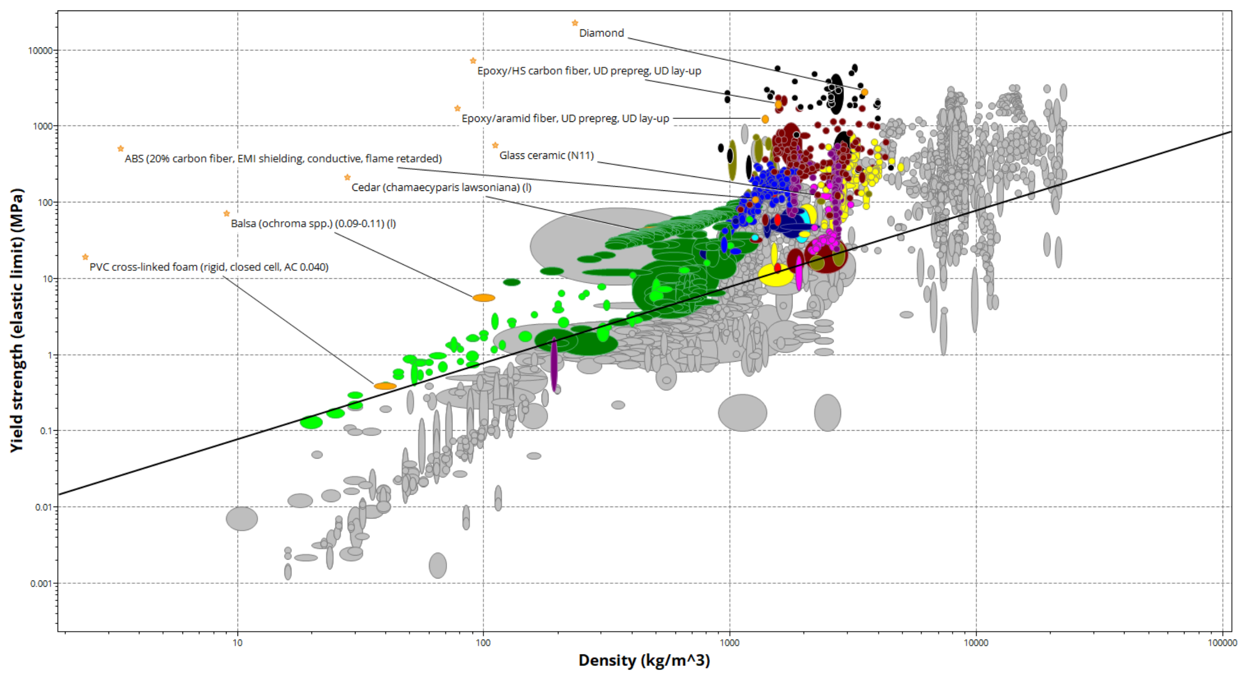

Figure 11: Corresponding Granta plot for M_2

MATERIAL	
1	Balsa, ULD
2	Diamond
3	CFRP, epoxy
4	AFRP, epoxy
5	Cedar
6	ABS(20% CF)
7	Glass ceramic
8	PVC cross-linked foam

Table 7: Corresponding materials for M_2

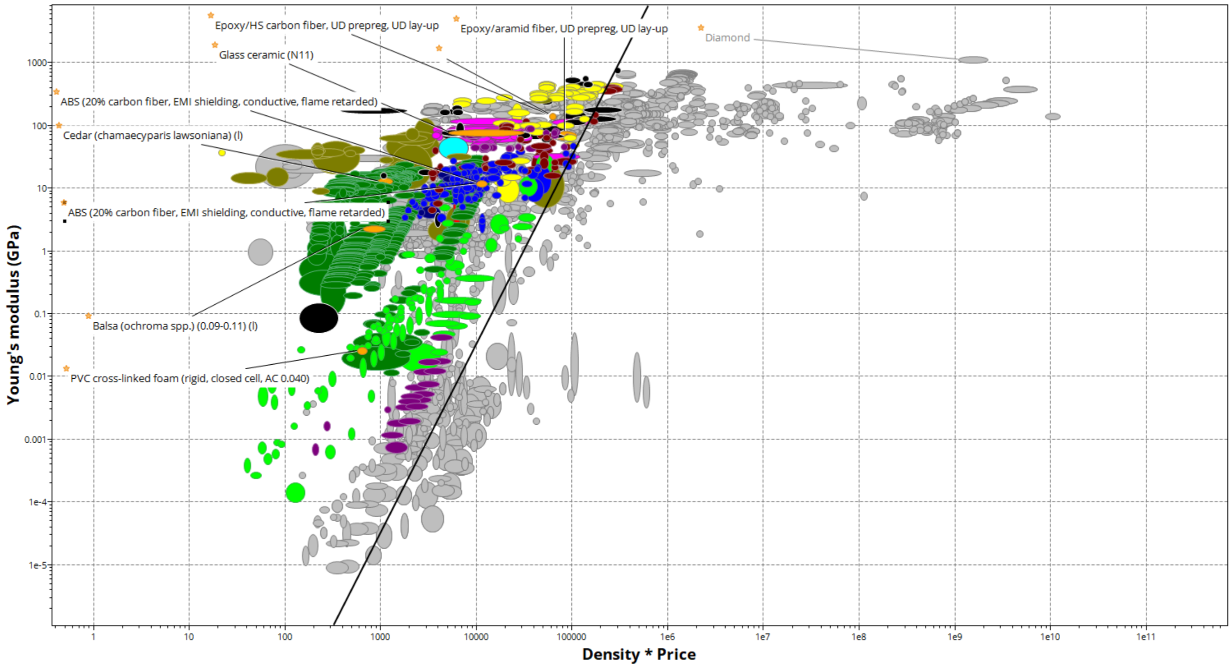

Figure 12: Corresponding Granta Plot for M_3

MATERIAL	
1	Balsa, ULD
2	~~Diamond~~
3	CFRP, epoxy
4	AFRP, epoxy
5	Cedar
6	ABS(20% CF)
7	Glass ceramic
8	PVC cross-linked foam

Table 8: Corresponding materials for M_3

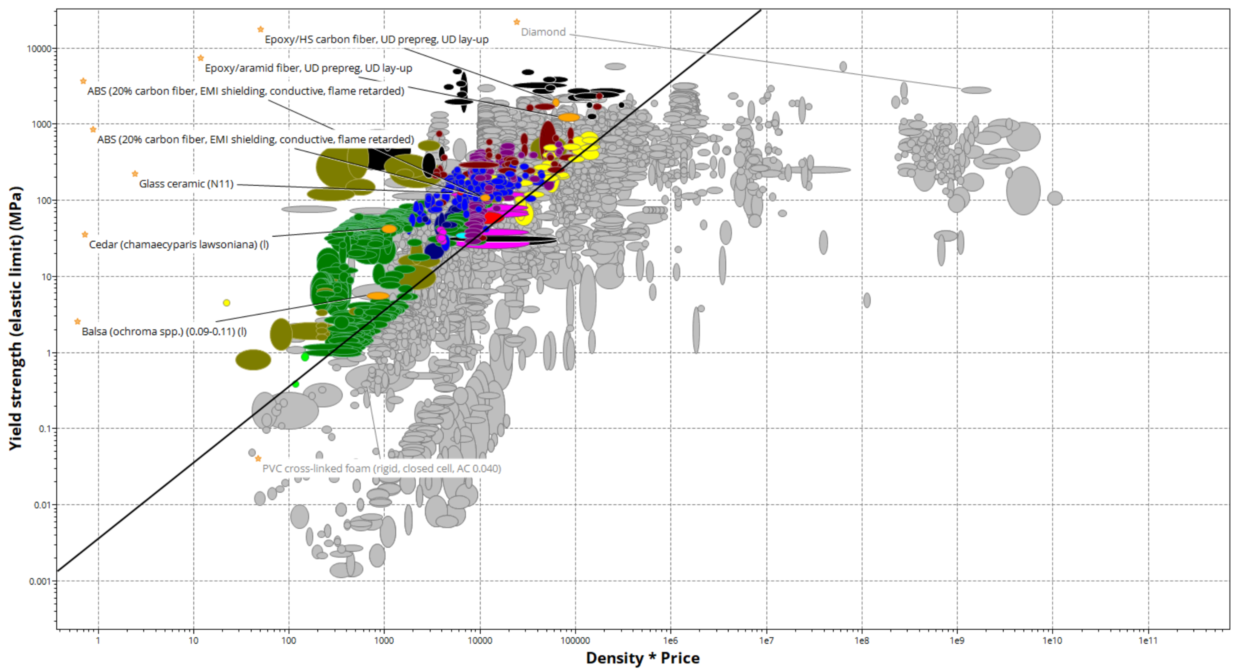

Figure 13: Corresponding Granta Plot for M_4

MATERIAL	
1	Balsa, ULD
2	~~Diamond~~
3	CFRP, epoxy
4	AFRP, epoxy
5	Cedar
6	ABS(20% CF)
7	Glass ceramic
8	~~PVC cross linked foam~~

Table 9: Corresponding materials for M_4 (Essentially same as M_3)

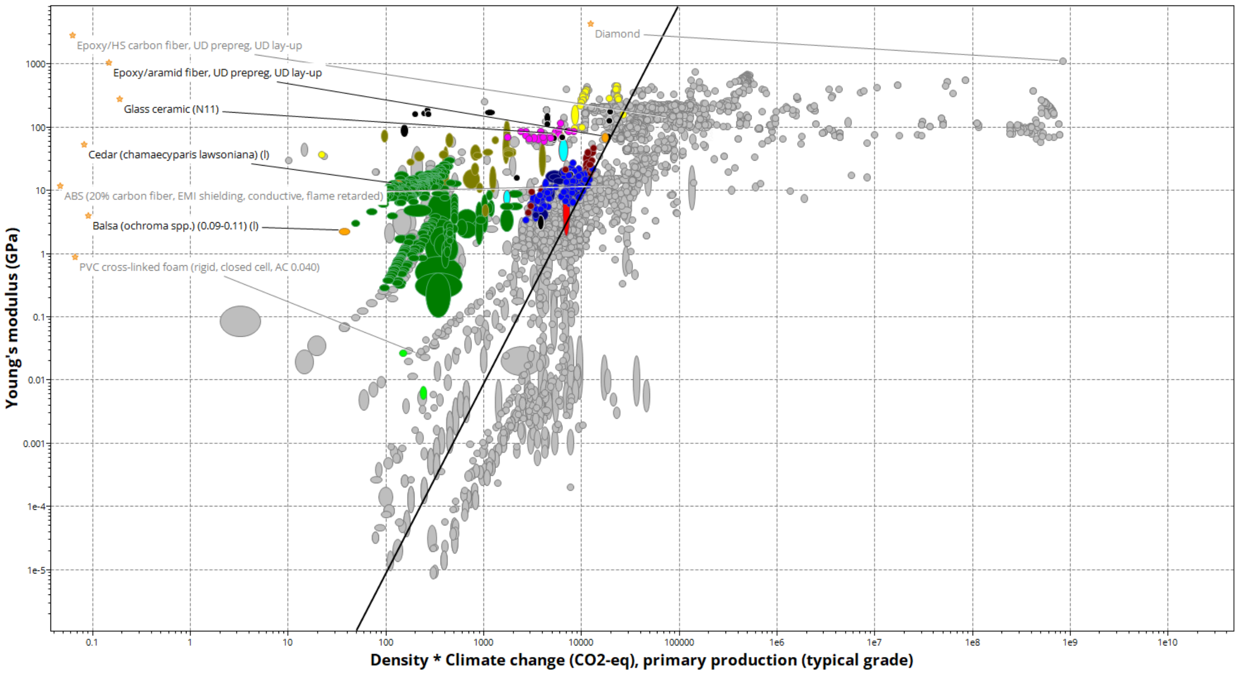

Figure 14: Corresponding Granta Plot for M_5

MATERIAL	
1	Balsa, ULD
2	~~Diamond~~
3	~~CFRP, epoxy~~
~~4~~	AFRP, epoxy
5	Cedar
6	~~ABS(20% CF)~~
7	Glass ceramic
8	~~PVC cross-linked foam~~

Table 10: Corresponding materials for M_5

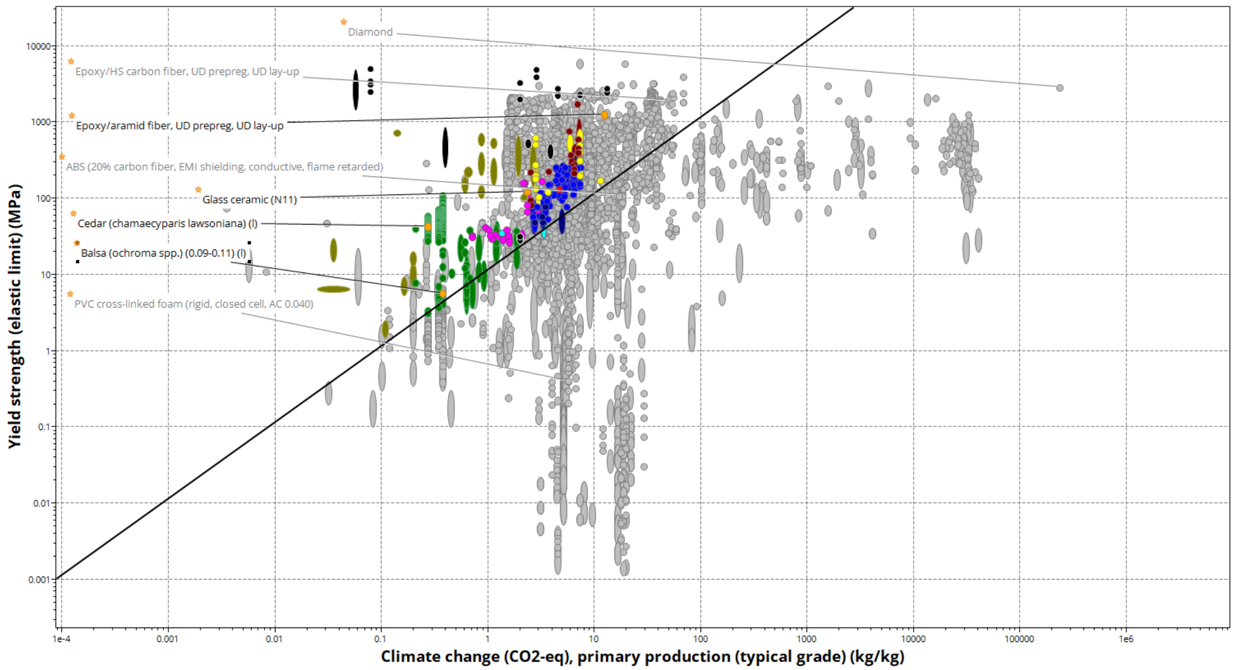

Figure 15: Corresponding Granta Plot for M_6

MATERIAL	
1	Balsa, ULD
2	~~Diamond~~
3	~~CFRP, epoxy~~
4	AFRP, epoxy
5	Cedar
6	~~ABS(20% CF)~~
7	Glass ceramic
8	~~PVC cross-linked foam~~

Table 11: Corresponding materials for M_6

Constraint Analysis Sheets

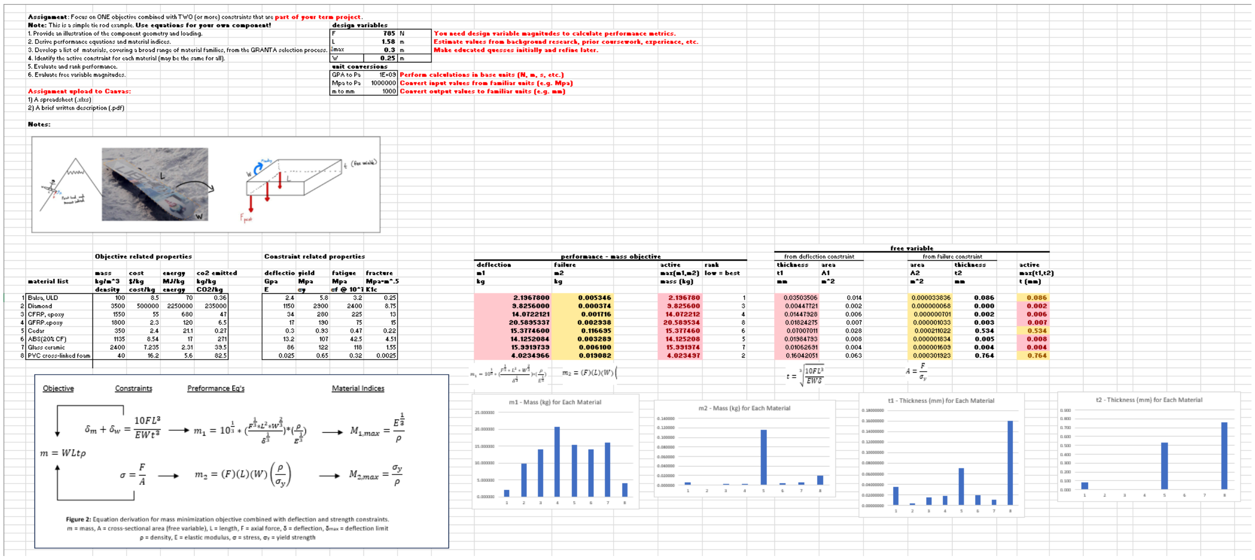

Figure 16: Constraint Analysis Sheet #1 (Mass)

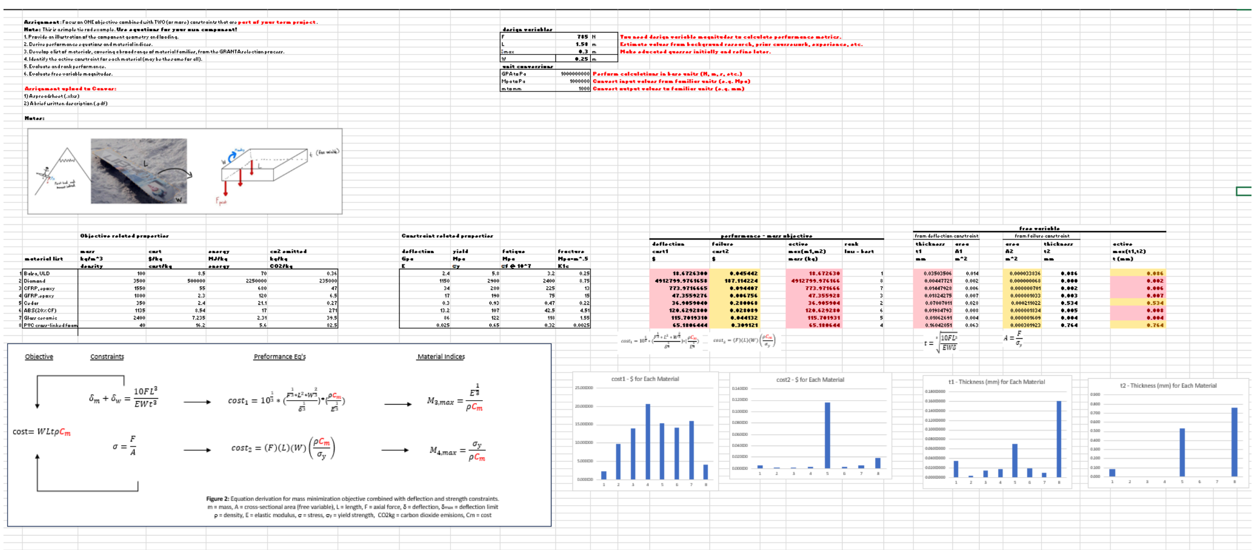

Figure 17: Constraint Analysis Sheet #2 (Cost)

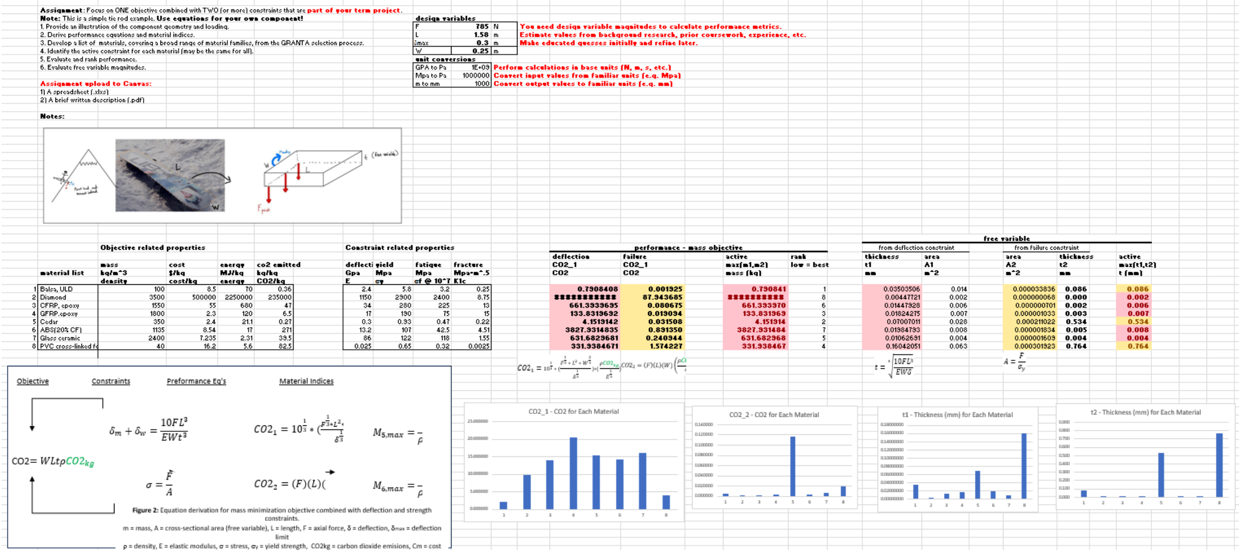

Figure 18: Constraint Analysis Sheet #3 (Sustainability)

Performance & Free Variable Rankings

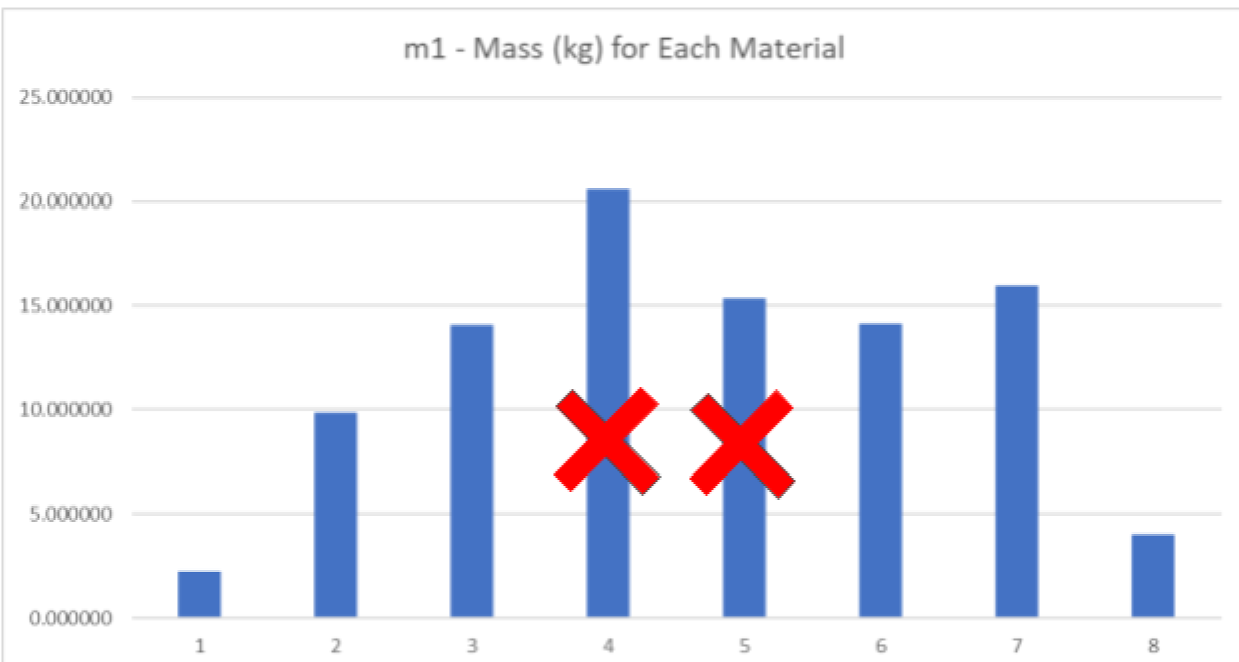

Figure 19: Ranking immediate eliminations for materials for Sheet #1

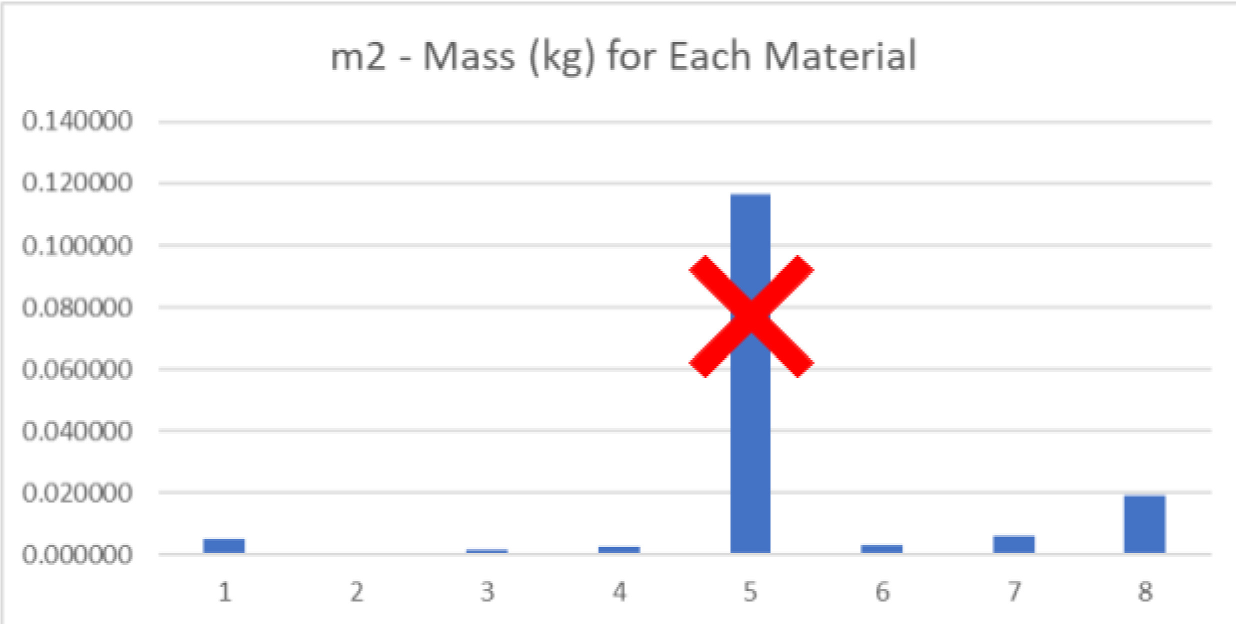

Figure 20: Ranking immediate eliminations for materials for Sheet #1

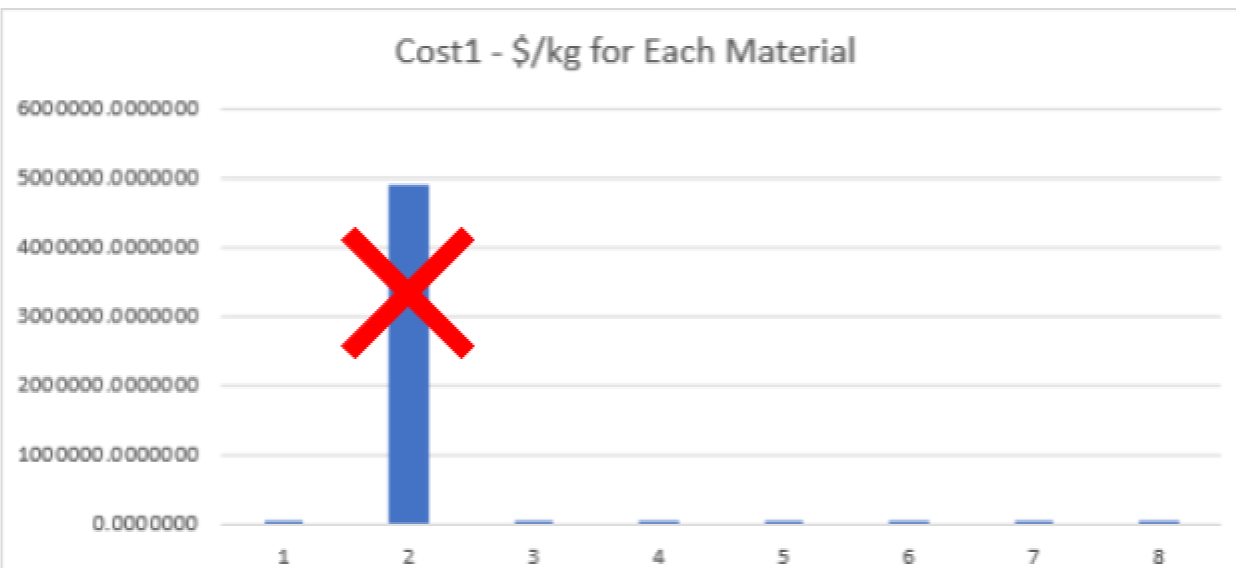

Figure 21: Ranking immediate eliminations for materials for Sheet #2

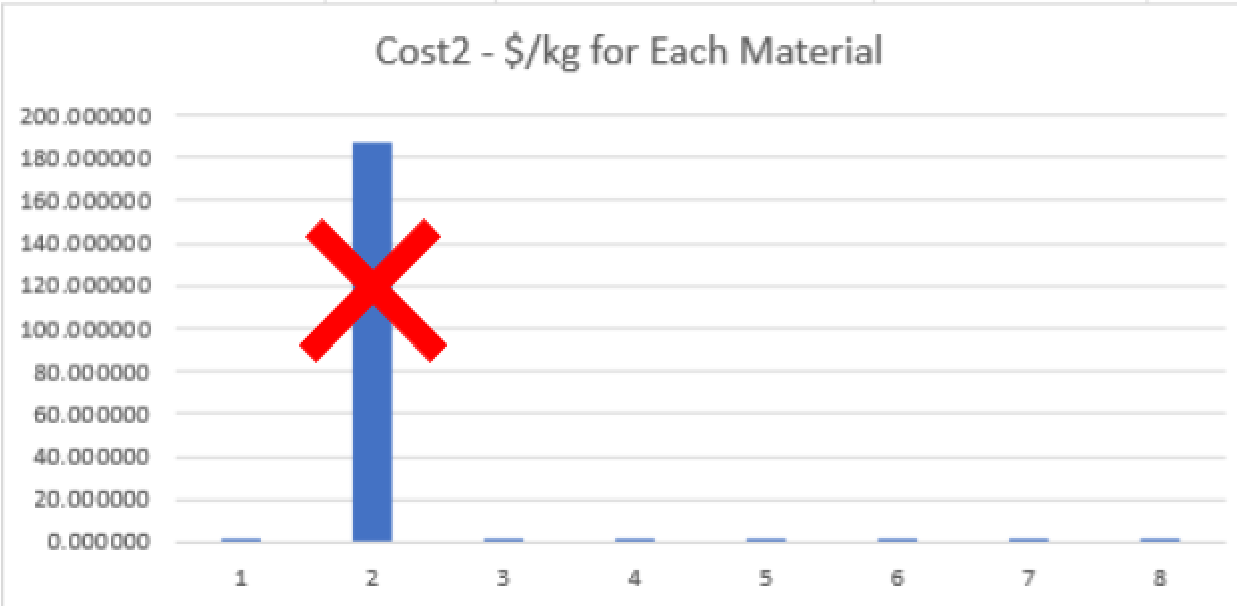

Figure 22: Ranking immediate eliminations for materials for Sheet #2

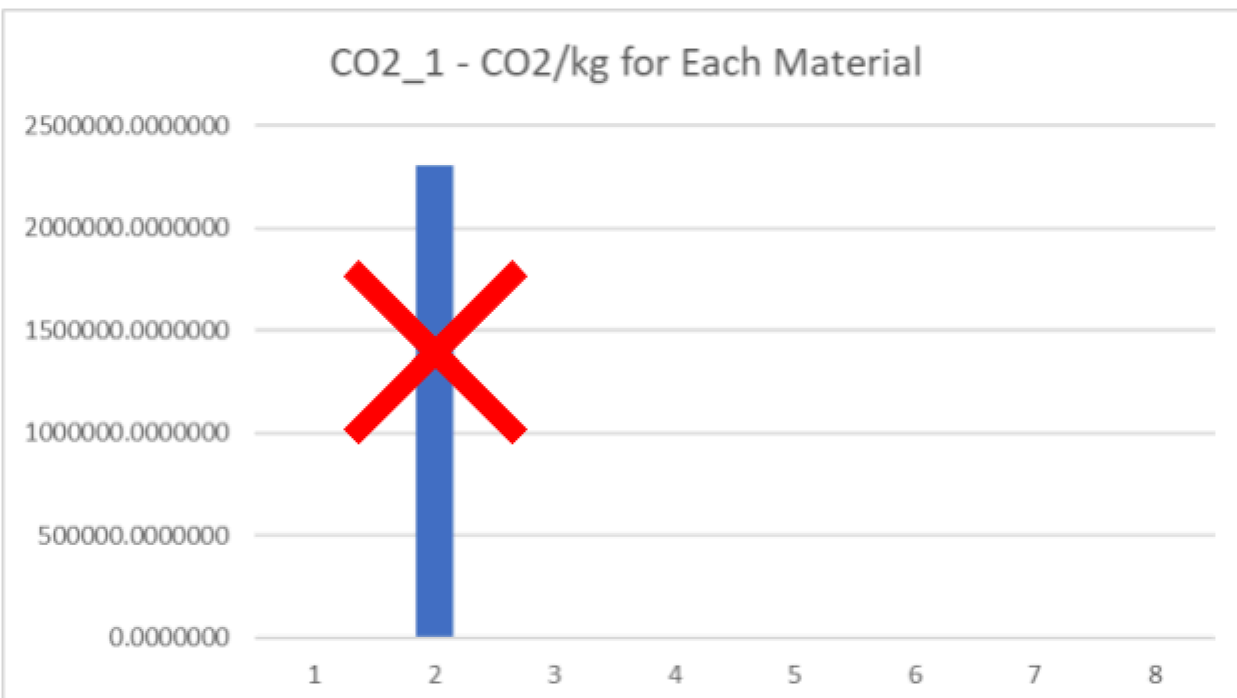

Figure 23: Ranking immediate eliminations for materials for Sheet #3

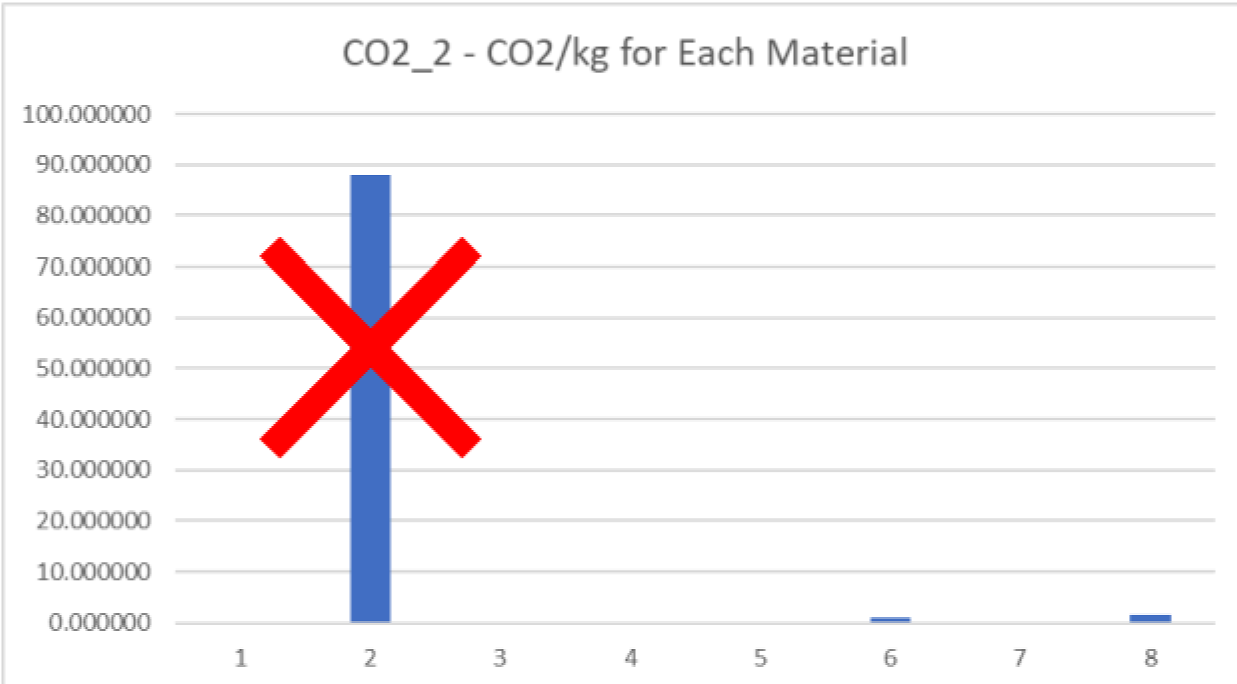

Figure 24: Ranking immediate eliminations for materials for Sheet #3

Free variable rankings available in sheet overview.

List of Materials Remaining

Between each of the three sheets, only 3 materials were immediately removed. They are as follows:

MATERIAL	
1	Balsa, ULD
2	~~Diamond~~
3	CFRP, epoxy
4	~~AFRP, epoxy~~
5	~~Cedar~~
6	ABS(20% CF)
7	Glass ceramic
8	PVC cross-linked foam

Table 12: Remaining materials after selection

Discussion

Some of these materials seem reasonable for a snowboard base board, at least on paper. One of the more obvious choices is carbon fiber, but I was honestly surprised by how heavy the aramid reinforced carbon fiber turned out to be. Because of how the constraint equations work in this project, the material is forced to carry the entire load by itself. In reality, the topsheet and the core would share that load, so several materials I expected to perform well ended up getting eliminated once I started plotting and analyzing the values. Still, a few materials held up better than I expected. Balsa wood, for example, surprised me. It has an ultra low density but still came out strong enough for this application.

PVC foam, on the other hand, feels a little unreasonable. It might be difficult to manufacture in this form and it's not great environmentally, but its properties do land somewhat close to what the application needs. It's one of those materials that looks good numerically but brings practical challenges that make you hesitate.

Another thing that stood out is that all of the materials ended up heavier than I anticipated. If the base board had to serve as the full core and topsheet, meaning it carried the entire load, the final board would be pretty heavy. But because this is just one component of the whole system, we can expect the final assembly to be much thinner and lighter once it's combined with the rest of the structure. That makes the results more reasonable and highlights why real snowboard construction spreads the load across several layers.

Conflicting Primary Objectives

Trade Space Plots

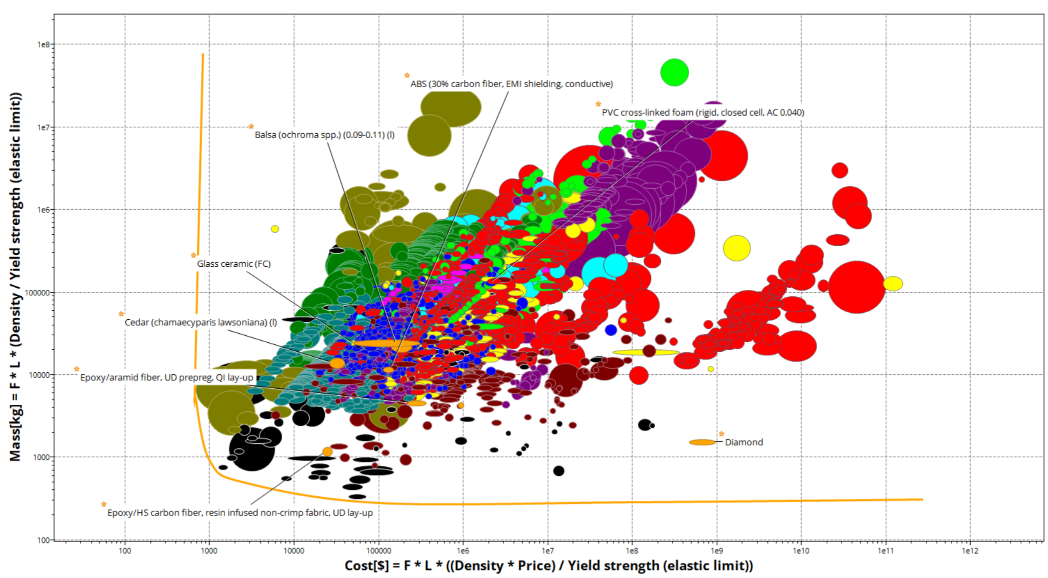

Figure 25: Mass (kg) vs. Cost ($) trade space plot (F = 785N, L = 1.58m)

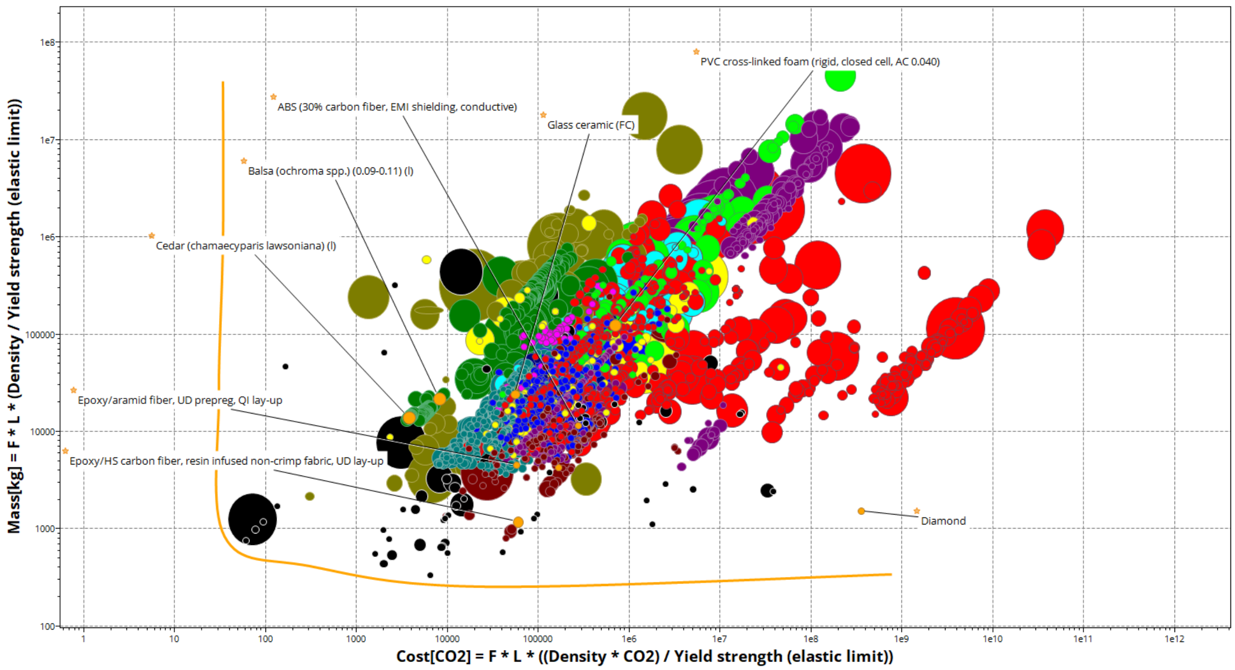

Figure 26: Mass (kg) vs. Cost (CO2) trade space plot (F = 785N, L = 1.58m)

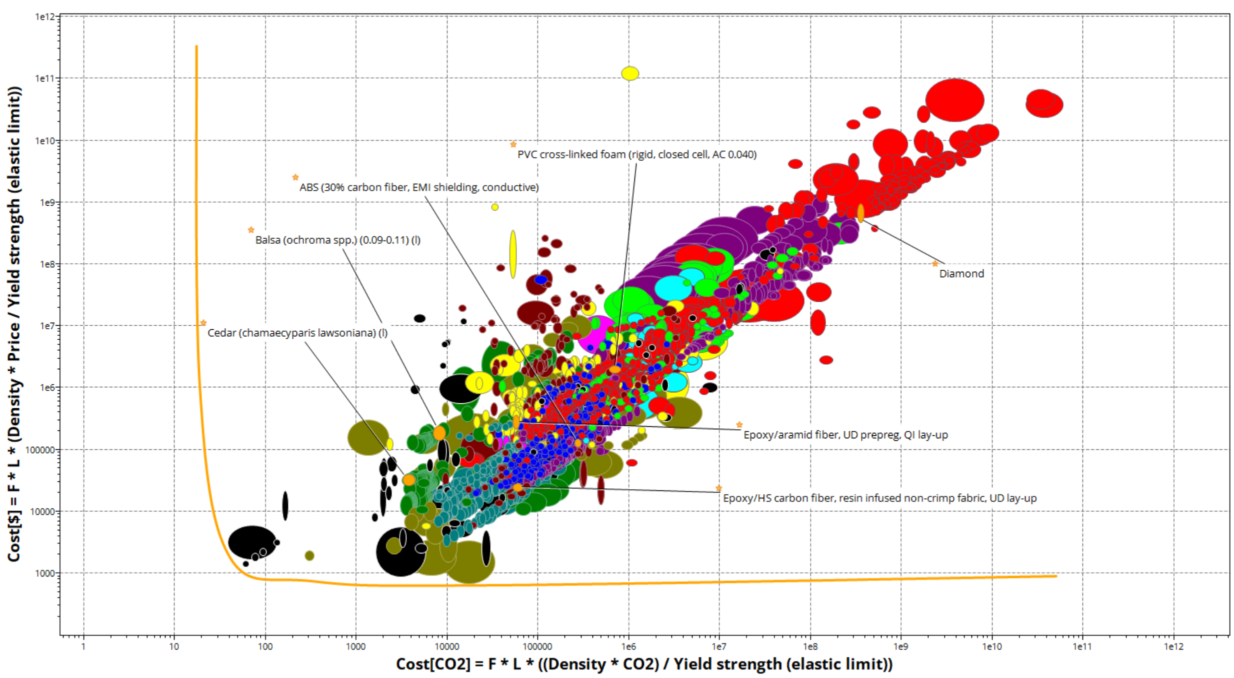

Figure 27: Cost ($) vs. Cost (CO2) trade space plot (F = 785N, L = 1.58m)

Discussion

Looking at the trade space line and comparing it to my selections, the closest matches were the carbon fibers and aramid fibers since they are both light and strong. The natural materials, balsa and cedar, also looked good across the plots. One consistent outlier was diamond. I originally selected it thinking that even though it's dense, its properties would make it stand out. That turned out to be a bad assumption for this application. It ended up being too heavy and far too unsustainable. ABS sat right in the middle of the pack in most of the plots, which makes sense since it's strong but not exceptionally cheap or environmentally friendly. I wasn't surprised by how the composites performed either. They're already common in snowboard construction, and this whole process of analyzing the plots just gave me a deeper understanding of why they work so well compared to the other materials.

Final Materials Selection

When it comes to any sport, standing out from the crowd is something a lot of people care about. In snowboarding, how do you do that? Sure, people switch up their goggles, jackets, and pants, but a big part of their identity is their snowboard itself. It's what you see when someone is flying through the air or getting photographed with the base exposed, so the board becomes a way to define yourself on the mountain. Because of that, one of the final material selection objectives is that the material should be available in multiple colors. Unfortunately, Granta doesn't offer a built-in way to filter materials by color availability, so there weren't any plots to help guide this part of the decision. Instead, I will do my own research and tabulate the data below.

MATERIAL	Available in Color Options?
Balsa, ULD	No; only natural wood tones (raw material not sold in colors)
Diamond	No; industrial diamond plates are clear only
CFRP, epoxy	Yes; colored resins and dyed carbon weaves commercially available
AFRP, epoxy	Yes; aramid fabrics sold in multiple dyed colors
Cedar	No; natural wood tones only (raw lumber not color-variable)
ABS(20% CF)	Yes; ABS is widely colorable, even when fiber-filled
Glass ceramic	Yes; commercial glass-ceramics offered in multiple colors
PVC cross-linked foam	Yes; available in several colors depending on manufacturer

Table 13: Project specific objective analysis

Discussion - project specific objective

Most of the materials are available but because Balsa is not available in color variants it does affect its overall final material selection. Alternatively you could pick any material and put some sort of wrap on it with any graphic but that isn't something we explore in the scope of this course so I will do my selections assuming it has to come from the factory with the colors.

Final Material Tabulation

RANKING	MATERIAL	ANALYSIS
1	ABS (20% CF)	Performed best all around, well on the trade-space plots, light enough, and available in colors. Could have a better sustainability.
2	Balsa, ULD	Thought this was going to be ranked first as it is affordable, sustainable and not too heavy. However, it is limited to wood grain patterns and stains.
3	AFRP, epoxy	Performed the best on the trade-space plots and available in colors. Could have a better sustainability and is too heavy.
4	CFRP, epoxy	Very similar to ABS, it performs well but it is not as sustainable as higher rankings.
5	PVC cross-linked foam	It is rigid, available in colors, but it is too close to yielding to be higher on this list.
6	Cedar	It looked like a top contender as it is cheap, rigid and sustainable. But it was too heavy to withstand this load scenario.
7	Glass Ceramic	Heavy, on the lower end of sustainability.
8	Diamond	Heavy, expensive and not sustainable. Very rigid.

Table 14: Final material selection and analysis

Conclusion

After going through this entire process, starting with breaking the board into components, simplifying the geometry, and deriving material indices for an extreme load scenario, I think I ended up with two solid options for the base board. The first step would be to ask the customer whether they care more about color variety or cost and weight. If they want something expressive, ABS is the better fit. If they want something sustainable and affordable, balsa is the lighter, cheaper option. Personally, I would pick balsa because I don't care much about color choices, but I know a lot of people do, so ABS still feels like the stronger overall choice.

Earlier in the report I went into this a bit, but if we think of the snowboard as a full system, the base board isn't actually supporting the entire load by itself. The top sheet and the core help resist deflection too. That means some of the materials I ranked lower could actually perform better once those supporting components reduce how much the base needs to carry. It makes the decision less straightforward than it seemed at the start.

I also didn't realize how contradictory this process would feel. There's a lot of back and forth when you try to figure out what the core priorities really are for the base board. There wasn't one perfect material. Instead, every option seemed to excel in one area and fall short in another. Diamond is a great example. It has the highest modulus, so if you're chasing the strongest possible board, it looks unbeatable at first. But as soon as you factor in cost, weight and emissions, it becomes one of the worst choices. So material selection ends up turning into this game of deciding which hoops you're willing to hit and which ones you absolutely need to clear.

Overall, I learned a lot about how well natural materials actually perform and how almost "magic" composite materials can feel. Woods have been used forever in countless applications, and now I understand why after looking at their properties. On the other hand, seeing composites that are both lighter and stiffer than wood makes you wonder why they're not used everywhere. Then you run into questions about manufacturability, cost, and sustainability, and it becomes clear why the trade-offs matter. This whole process showed me how much really goes into material selection, and using Granta made it a lot easier to analyze everything in a structured way.