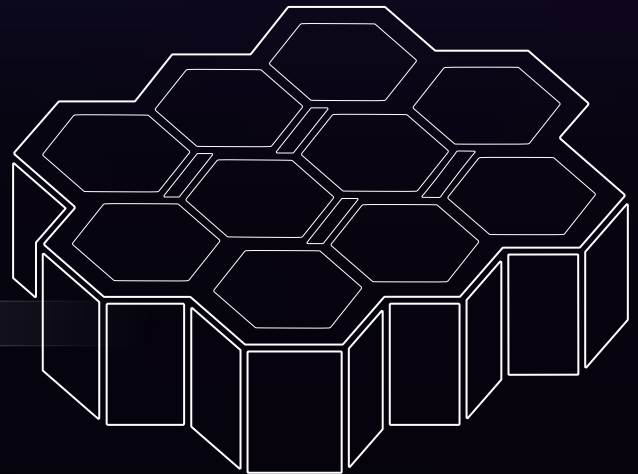


Selecting the right structural materials

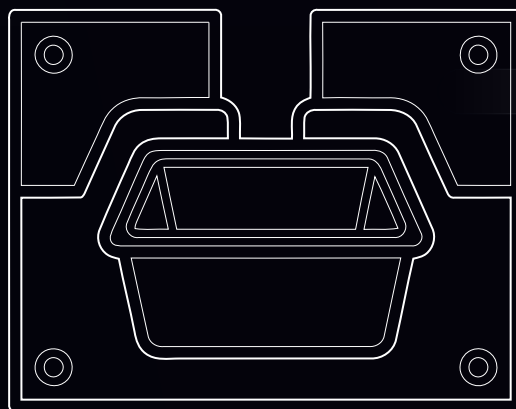
Metals



Composites



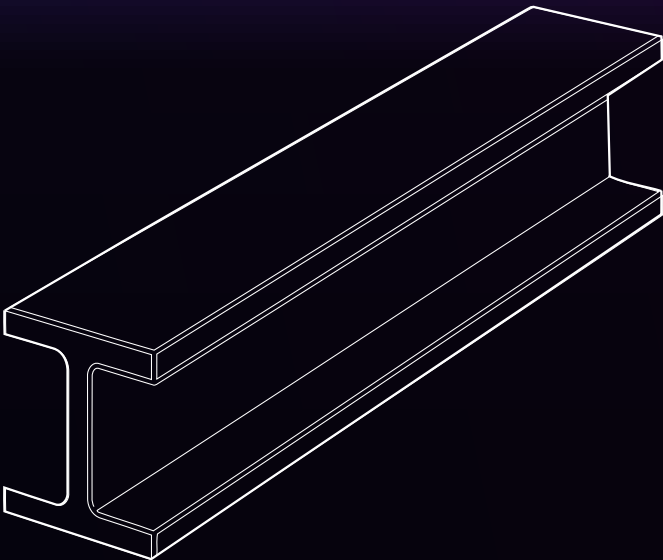
Polymers



Selecting the right structural materials

Metals

Metals are the most established structural material class in engineering. Their strength and durability under sustained and dynamic loading make them reliable across a wide range of applications, with well-documented material behavior. When metals do fail, they typically yield before fracturing, giving a detectable warning before catastrophic failure occurs.



The main tradeoff is specific strength. Metals can carry significant loads, but they are generally denser than polymers and composites. In applications where mass has a direct impact on performance, that weight can work against the design.

BEST WHEN

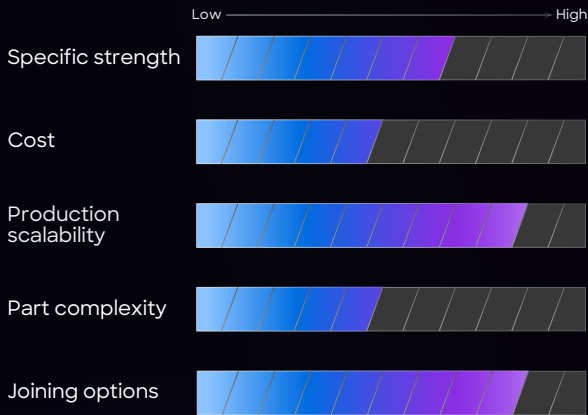
- ✓ Strength is essential but weight is not overriding constraint
- ✓ Part geometry is straightforward
- ✓ Versatile joining options are possible

Design freedom depends on the manufacturing process. While CNC machining can produce complex metal parts, stamping, casting, and die casting impose constraints around wall thickness, draft angles, and bend radii—with intricate geometries often requiring additional machining or finishing steps. For straightforward geometries, these constraints are usually manageable.

THE TRADEOFF

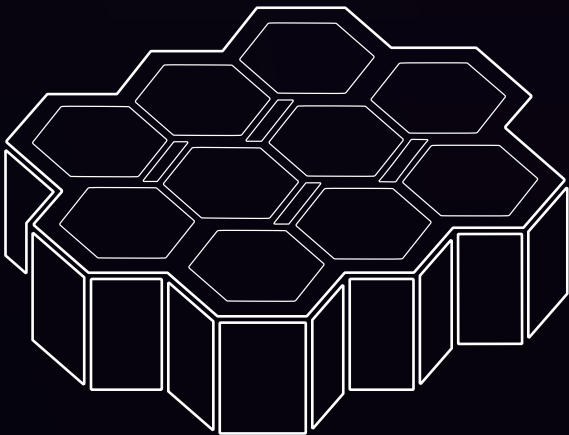
Metals trade weight and some design freedom for strength, scalable production, and flexible joining options.

Metals offer the broadest range of joining options, including welding, riveting, bolting, and adhesive bonding. They are also well suited to high-volume production; stamping and die casting are among the fastest, most scalable processes available, keeping per-part cost low once tooling is in place. Raw material cost varies by alloy, but the right process can keep metals cost-effective in many structural applications.



Selecting the right structural materials

Composites



Composite materials combine two or more constituents to produce properties neither could achieve alone. This section focuses on fiber-reinforced polymers used in mechanical components. Carbon fiber and fiberglass are the primary forms, woven into mats and impregnated with an epoxy resin matrix to produce a material that is lighter and stronger than metals on a mass-for-mass basis.

This specific strength makes composites a strong choice where reducing mass has benefits, such as aerospace components and racing vehicles. However, composites are expensive at both the material and process level, so the weight savings need to justify the added cost and complexity.

Composite failure is also characteristically abrupt. Unlike metals, composites do not yield visibly before fracturing, which makes damage harder to detect before it becomes critical.

Design freedom is mixed. Composites can follow complex curves well, but fiber orientation and mold complexity place practical limits during manufacturing.

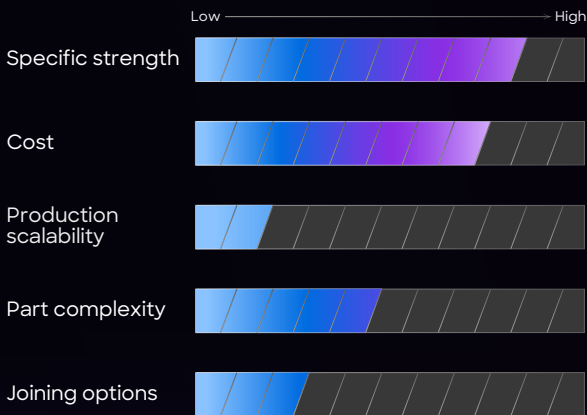
Composites are poorly suited to high-volume production. They involve slow, labor-intensive processes that do not scale like stamping, die casting, or injection molding. Joining adds another constraint; thermoset composites cannot be welded, so parts must be bonded, mechanically fastened, or both.

BEST WHEN

- ✓ Parts must be both lightweight and high-strength
- ✓ Performance demands justify higher material and manufacturing cost at low-to-moderate production volume
- ✓ Complex curved geometry must be achieved without adding mass

THE TRADEOFF

For composites, the tradeoff is cost and production complexity in exchange for exceptional specific strength and controlled, lightweight form.

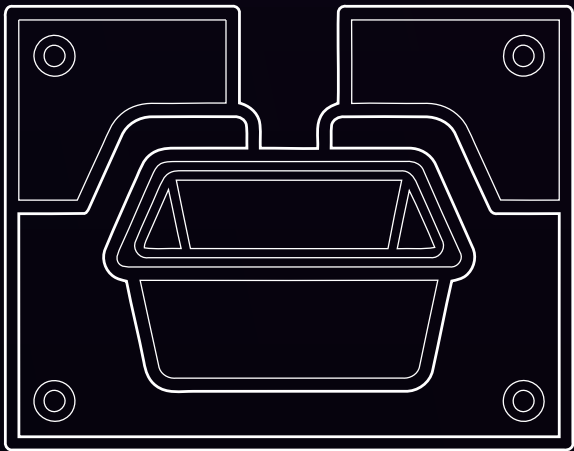


Polymers

Polymers cover a broad range of materials, falling into two main categories: thermosets, which cure into a permanent rigid structure, and thermoplastics, which can be reheated and reshaped. Across both, stiffness and strength are lower than metals or composites, which makes polymers a poor fit for load-critical parts. Polymers are also susceptible to creep under sustained load and can lose structural stability as temperatures change, in ways that metals and composites do not. For many applications, though, maximum strength is not the deciding factor.

The main advantages of polymers are cost, weight, and design freedom. Injection molding allows features such as ribs and undercuts to be built into the part, reducing the need for secondary operations. It is also purpose-built for high-volume production; once tooling is amortized, fast cycle times and inexpensive raw material can make polymers the lowest-cost option.

Joining options are more limited than metals but more flexible than composites. Thermoplastics can be heat-welded and snap-fit, reducing the need for fasteners in some assemblies. Mechanical fastening is also possible, though less structurally reliable than metal equivalents.

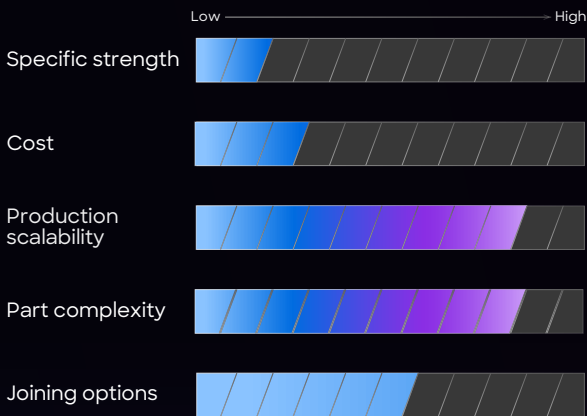


BEST WHEN

- ✓ High production volume makes tooling investment worthwhile
- ✓ Part geometry is complex
- ✓ Cost and weight matter more than maximum structural performance

THE TRADEOFF

Polymers trade load-bearing performance for low cost, high production volumes and greater flexibility in part geometry.



Structural material selection and tradeoffs for real-world applications

Golf club shafts

Steel was long the standard material for golf club shafts, on account of its durability and cost-effectiveness to manufacture at scale. Carbon fiber composite entered the picture thanks to its influence on the physics of the swing.

A composite shaft delivers comparable or greater stiffness at significantly lower weight, enabling faster swing speeds and more precise energy transfer at impact. The layup process can also be tuned to achieve specific flex profiles and torque characteristics that are difficult to replicate in steel. However, composite shafts require more expensive materials and do not scale well to high-volume production.

THE TRADEOFF Steel remains a legitimate choice where cost and durability are the primary criteria. When performance matters and the application can absorb the cost premium, carbon fiber composite is the stronger alternative.



Smartphone housing

Early smartphones commonly used polycarbonate housings. As the market matured, many flagship devices moved to aluminum unibody construction because it offered greater durability and a rigid metallic feel that polycarbonate lacked. Nevertheless, polymer housings are still being used in other devices.

Engineering-grade polymers can provide enough strength for a phone housing while keeping the part lighter and less expensive to produce at volume. Injection molding also allows tighter integration of antenna windows or internal mounting features within a single part. With aluminum, those same requirements translate to additional machining or assembly steps.

THE TRADEOFF Aluminum still has the advantage when heat dissipation and impact durability are priorities. Where those demands are moderate, polymers can meet the functional need with simpler production and more flexibility in part geometry.

