# Lightweight Thermoformed Structural Components and Optics

## Precise shapes can be replicated.

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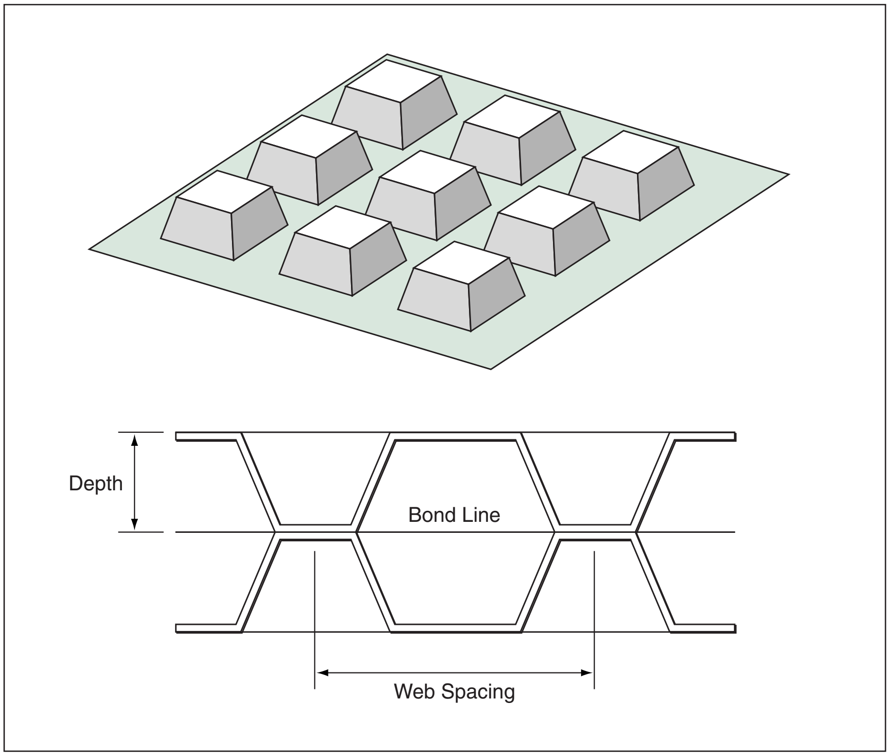
A technique that involves the use of thermoformed plastics has been developed to enable the design and fabrication of ultra-lightweight structural components and mirrors for use in outer space. The technique could also be used to produce items for special terrestrial uses in which minimization of weight is a primary design consideration.

Although the inherent strengths of thermoplastics are clearly inferior to those of metals and composite materials, thermoplastics offer a distinct advantage in that they can be shaped, at elevated temperatures, to replicate surfaces (e.g., prescribed mirror surfaces) precisely. Furthermore, multiple elements can be bonded into structures of homogeneous design that display minimal thermal deformation aside from simple expansion.

The design aspect of the present technique is based on the principle that the deflection of a plate that has internal structure depends far more on the overall thickness than on the internal details; thus, a very stiff, light structure can be made from thin plastic that is heat-formed to produce a sufficiently high moment of inertia. General examples of such structures include I beams and eggcrates.

For a more specific example, consider an eggcrate-like structure made from a polyimide film with a thickness of 5 mils (0.13 mm) [corresponding to an areal density of 0.175 kg/m$^2$]. The initially flat film can be locally elongated by >200 percent at a temperature of 300 °C, to produce a structure with a depth ≈70 percent of the two-dimensional web spacing (see figure). Such structures have been successfully fabricated by use of a pressurized machined mold. A particularly attractive configuration results when a mold is cross milled to produce truncated pyramidal posts as shown in the figure. The tip faces of the posts of two molded sheets are then bonded to produce a strong, lightweight panel. A 10-cm-diameter disk panel made in this configuration and optimally supported at three points would undergo a root-mean-square deflection of less than 10 nm under its own weight under normal Earth gravitation. At $10^{-4}$ × normal Earth gravitation, a disk panel of 1-m diameter but otherwise the same design would be deflected by the same amount.




**Thin Sheets of Plastic Are Thermoformed** into eggcrate-like components, which are then bonded together to produce a stiff, lightweight structure.

It has been shown that a precise mirror (which can be curved or flat) can be formed by replication, with minimal "printthrough," in a mirror face sheet of thermoplastic. An initially flat sheet of thermoplastic destined to become the mirror face sheet is placed on a mold surface shaped in the exact opposite ("mirror image") of the desired optical figure. Then a supporting structure of a lightweight design like the one described above is bonded to the rear surface of the mirror face sheet under pressure at elevated temperature. Either the face sheet can have been premetallized for high reflectivity, or else a reflective layer can be vacuum-deposited on the face sheet after fabrication. The web spacing of the support structure in this case would be matched to the thickness of the face sheet to yield an acceptably low level of deformation: Typically, in the case of 5-mil (0.13-mm)-thick face sheet, the web spacing for submicron deflection under normal Earth gravitation would be ≈1 cm, while the web spacing for submicron deflection at $10^{-4}$ × normal Earth gravitation would be ≈10 cm. Such a mirror composed of three 5-mil sheets would have an areal density of 0.525 kg/m$^2$ but the density could conceivably be reduced to as little as 0.125 kg/m$^2$ by use of 1-mil (0.025-mm) sheets instead.

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