Blending Solar Panels with Roof Profiles

Simulation guides the design of innovative solar panel frames, reducing molding time, material and cost.

By Matthew Stein, President, Stein Design, California, U.S.A.

Open Energy SolarSave® panels are designed to integrate and interweave with standard roofing tiles so as to blend in with the roof profile and color.

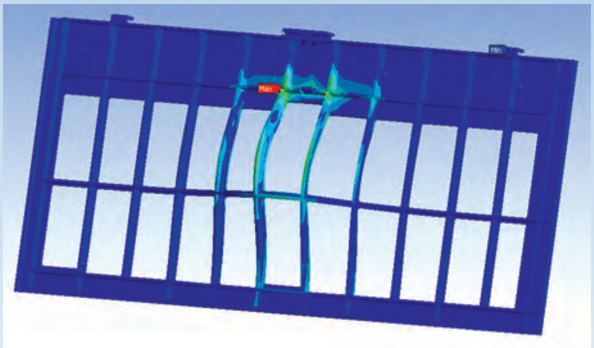
One of the most efficient sources of renewable energy is rooftop photovoltaic (PV) solar cells, which convert sunlight into electricity for homes and business. Use is hampered, however, by high upfront costs as well as aesthetics, with most solar panels mounted on unattractive brackets that do not blend well with house and building designs.

Open Energy solar panels being installed

Open Energy Corp. of Solona Beach, California, has overcome these drawbacks with SolarSave® panels — a solar roof solution unlike anything previously available in the industry. Panels are designed to integrate and interweave with standard roofing tiles so as to blend in with the roof, an important consideration in subdivisions with strict homeowner bylaws pertaining to roof profiles and solar panel installations. These integrated panels are also cost-effective, as they are installed as tiling over part of the roof rather than as an add-on above traditional coverings. The lightweight panels are warranted for 25 years, are easily handled, and can be walked on, simplifying installation for roofing contractors and solar integrators.

In their continuing efforts to improve the cost-effectiveness and performance of these solar panels, Open Energy commissioned Stein Design to complete a redesign of the panel with the goal of reducing unit cost while improving strength and reliability. The new design was to be a four-foot-long PV panel to replace existing three-foot models, cutting square-foot costs by reducing the number of electrical connections, related junction boxes and other hardware. Analysis work was done exclusively using ANSYS DesignSpace software.

Stein Design started the redesign by first evaluating the existing three-foot panel product. Three-dimensional solid CAD model assemblies were generated in SolidWorks® and then imported into the ANSYS DesignSpace tool to perform the stress analysis. Two load cases were considered: (1) a 300-pound per-square-foot pressure, satisfying at least 99 percent of structural building code requirements across the United States and Canada for snow loads; and (2) a 400-pound load concentrated in a three-inch-diameter area, representing a concentrated heel-load of an installer on the

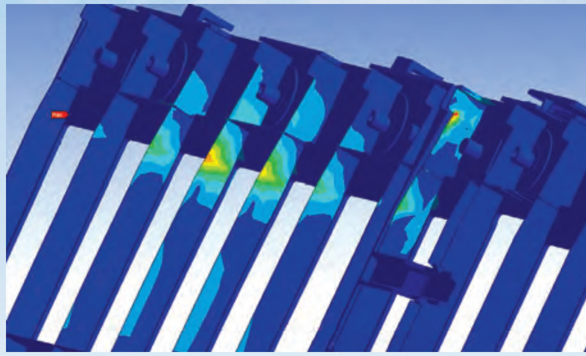


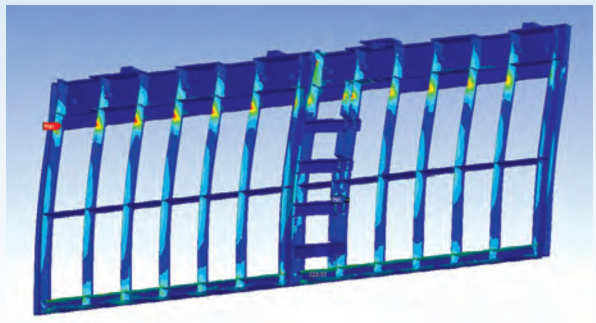
Stress distribution and deformation for walk-on load on the three-foot panel frame

panel. Experimentally, this walk-on requirement is typically checked using an industry-standard 200-pound load transferred to the glass panel via a three-inch diameter steel puck. Given the weight of some contractors and the heavy equipment they carry, 400 pounds was considered a better target, providing more of a safety margin than the code requirement of 200 pounds.

Analysis showed that the original three-foot plastic frame was strong enough to support both the walk-on and snow loads. However, further investigation was necessary for the new four-foot panel, since analysis indicated that a 400-pound walk-on load (twice the industry standard) created stress that was 40 percent greater than the allowable tensile stress of the solar panel glass (6,000 pounds per square inch or psi). Moreover, there was concern that in some cases the bond between the glass panel and its plastic mounting frame might be compromised over time due to temperature expansion differences in the materials, since the coefficient of thermal expansion for the solar glass is about one-tenth that of the frame's polycarbonate plastic. This results in a one-quarter-inch linear expansion difference across the frame when subjected to a 200 degree Fahrenheit temperature change — from extreme heat in direct summer sun to sub-zero nighttime temperatures in extreme winter climates. To account for these effects, the four-foot plastic molded frame was split into two parts, and an interlocking expansion joint, as well as 10 percent glass-fill to the polycarbonate frame material, was added. These changes reduced the thermal expansion difference between the solar glass and the four-foot plastic frame to one-third that of the original three-foot frame.

The next step in the redesign was to reduce thicknesses and reconfigure the frame walls and ribs to use less material and shorten molding cycle time, thus lowering production cost. The original three-foot panel design had nominal wall thicknesses of 0.210 inches and nominal rib thicknesses of 0.150 inches, but some walls were as thick as 0.260 inches, resulting in a slow molding cycle time. ANSYS DesignSpace technology was used to verify the design as it progressed through multiple iterations in which nominal wall thickness was trimmed by 0.085 inches and rib thickness by 0.065 inches. Even though nominal wall thickness was reduced by 40 percent and nominal rib thickness by 43 percent, the maximum frame stresses rose by only 33 percent overall, through improved rib design and placement. The maximum stress in the four-foot molded frame increased to approximately 2,550 psi — from a level of approximately 1,700 psi in the three-foot frame — well within the design target of a 3-to-1 safety margin for the 9,000 psi tensile strength polycarbonate material. The resulting four-foot panel frame uses less material than the original frame and can be injection-molded in two-thirds the time, yielding a finished four-foot assembly that costs the same to manufacture as the original three-foot panels.





In this reconfigured design that reduced production costs, frame stress increased somewhat for both the walk-on load (top) and snow load (bottom), but remained well within targeted safety margins.

The use of ANSYS DesignSpace capabilities was critical throughout this entire redesign process and is part of the reason Stein Design can provide clients fast turnaround with designs that meet stringent requirements. Its ease of use enables engineers to get up to speed quickly, even if several months may pass between analysis projects. Furthermore, the software interfaces seamlessly with SolidWorks mechanical design software, so part geometry can be readily changed and analysis solutions regenerated quickly to investigate "what-if" scenarios throughout the development process. In this way, the technology guides the design to an optimum configuration that satisfies multiple engineering requirements and enables projects to be completed much faster than would otherwise be possible. ■