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Confirming the Strength of Residential Roof Structures for Solar Installations

A National Laboratory report presents ground-breaking data on wood residential rooftop strength, shedding new light on the question of solar PV loads

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Suggested introduction or sidebar text #1:

Researchers at the U.S. Department of Energy's Sandia National Laboratories conducted a first-of-its-kind study to help dispel misperceptions that many existing rooftops cannot carry the actual load created by rooftop solar photovoltaic (PV) installations. Test data on rooftop structure load capacity wasn't previously available to the industry, and research to collect such data was made costly by the need to test each scaled structure to the point of failure. The Energy Department funded this study to provide scientific data to the industry that can decrease uncertainty, help eliminate misperceptions, and ultimately alleviate extraneous solar PV permitting costs.

The rooftop solar PV permitting process involves a number of steps. Jurisdictions follow state or national codes but may interpret these codes and insert additional requirements without a proven safety benefit. In some locations, a rooftop structural analysis conducted by a professional engineer is required before a rooftop solar permit is issued. This extra step is not universally applied across states or municipalities, which can make it difficult for solar installers who work in multiple regions. Where this step does apply, it can add extra expense and delays to the permitting and installation of rooftop solar PV.

"Throughout a project I oversaw to create a regional solar permit checklist for residential systems, I noticed that some plan reviewers automatically require plans stamped by a structural engineer, regardless of the structure's condition. The unnecessary application of this requirement slows down the permitting process and adds considerable cost," said Laura Machala, Solar Energy Coordinator at Mid-America Regional Council

The U.S. Department of Energy's Solar Energy Technologies Program took a keen interest in regional reports of high solar permitting costs. (See sidebar 2.) Permitting costs are a significant contributor to the installed solar system price, and cost reductions are crucial to meet the Energy Department's SunShot goal to reduce the installed cost of solar energy systems to $.06 per kilowatt-hour by 2020.

In support of the SunShot goal, Sandia National Laboratories examined the methodology behind the structural engineering analysis required for some solar permits and conducted the first study of its kind to produce actual rooftop assembly load capacity data for wood residential structures.

SIDEBAR 2

Why are solar permit costs important?

Barriers to residential solar PV deployment often include factors unrelated to PV efficiency or system cost. Two detailed 2012 reports from the Energy Department's National Renewable Energy Laboratory found that non-hardware costs — often referred to as "soft costs" — now comprise up to 64 percent of the total price of residential solar energy systems, reflecting that such costs are becoming an increasingly larger portion of the cost of installing solar. [1]

Soft costs may include permitting, inspection, and installer costs, among others. An industry study found that local permitting and regulatory processes can contribute up to $2,513 in additional costs to a solar system. [2]

[1]"Benchmarking Non-Hardware Balance-of-System (Soft) Costs for U.S. Photovoltaic Systems, Using a Bottom-Up Approach and Installer Survey – Second Edition," Friedman et al., October, 2013. http://www.nrel.gov/docs/fy14osti/60412.pdf

[2]"The Impact of Local Permitting on the Cost of Solar Power," SunRun Report, 2011.

A thorough look at the methodology behind a typical structural engineering analysis helps clarify the difference between the actual load a rooftop structure can support and the load calculated during such an analysis. When engineers analyze rooftop strength, it is customary to calculate stresses on the basis of an individual beam, rafter, or truss. This reflects an assumption that each piece of the structure acts alone, an oversimplification that doesn't evaluate the rooftop system as a whole or consider the load-sharing and load redistribution effects of a roof system.

The solar PV and racking system load isn't supported solely by the rafter below it. The load is deflected and distributed to the next rafter, and the next. The load-sharing effect is significant, yet it is ignored in the standard engineering analysis.

The engineering analysis also fails to consider the added strength resulting from the interaction between the joists, sheathing materials, and glue or nail fasteners. Sandia's research reveals that the composite action effects of nailing the sheathing to the joist increase the joist's strength as much as 35 percent, and the effects of gluing the sheathing to the underlying rafter increase the beam strength by as much as 74 percent.

[Insert revised illustration here; image will be recreated to improve print quality]

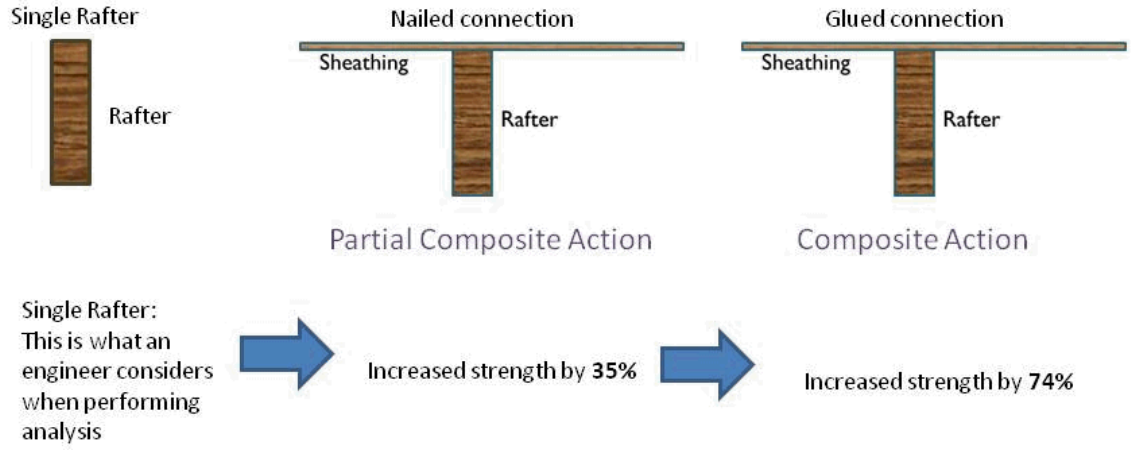

Figure 1. The system effects of the rafter, sheathing, and nailed or glued connection add strength to the structure which is typically not factored into structural engineering analysis.

Image courtesy of Stephen Dwyer, Sandia National Laboratories

For those who would argue that a conservative approach to the structural engineering analysis is appropriate or reasonable in an industry where safety is a top priority, consider that the conservative analysis is layered on top of an already stringent building code that uses highly conservative stress values for wood. That means the calculations to estimate wood rooftop load capacity include multiple layers of conservatism, resulting in an excessively cautious estimate. One that is not representative of real conditions.

Actual Load Test Results

Sandia National Laboratories conducted a series of tests to evaluate the structural behavior of common residential roof structures. This involved a wide range of destructive tests on scaled wood structures, stressing the structures to the point of failure while producing and capturing data on the actual rooftop load capacity. Testing was conducted at the University of New Mexico's Centennial Engineering Structures Laboratory, and results were collected on two separate instruments, providing added confidence to the data accuracy.

[Insert figure 2]

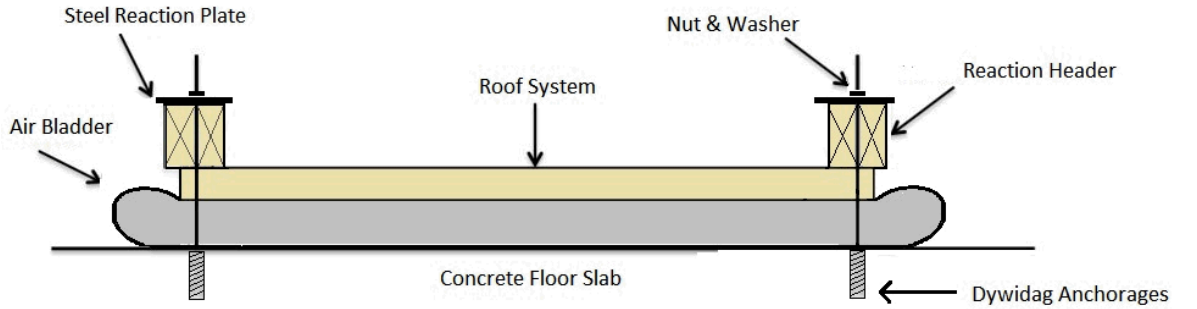

Figure 2. Diagram of the test setup, conducted on top of a custom air bladder.
Image courtesy of Sandia National Laboratories

[Insert Figure 3]

Figure 3 Testing of a rafter system.
Image courtesy of Stephen Dwyer, Sandia National Laboratories

***The Sandia study demonstrates that rafter-supported roofs are 330% stronger than required under the National Design Standard*.**

Sandia's comparison of the actual rooftop capacity data collected in the study vs. the load capacity calculated during the engineering analysis revealed a large discrepancy. On average, rafter-based tests demonstrated that rooftops could support load capacities 330 percent greater than indicated by the National Design Standard.

Andrew Truitt, a solar installer who works for Dividend Solar shares his perspective, “This is exciting news for residential PV installers in jurisdictions where PE stamps are required by default. A roofing system is exactly that: a system; and it should be treated as such when considering its capacity to bear attached loads. This study shows that a typical residential roofing system's capacity to bear the additional load of a PV array is much higher than expected, and installers, engineers, and other stakeholders should make sure that any AHJs that still require PE stamps for residential systems are aware of the study's findings."

Why are these results important?

Safety is and should remain a top priority of the building industry. But there is a cost to homeowners, the solar industry, and solar installers when solar PV permits are unnecessarily rejected and PV installations are cancelled. The results from Sandia’s study shed new light on the additional benefits of composite action and load-sharing effects. In turn, the results create questions about the use of the commonly accepted engineering analysis to deny solar PV permit applications. The excess load capacity data collected by Sandia suggest that a well-built home that meets local building standards and has not been adversely modified or damaged has adequate load-bearing capacity to support a roof-mounted PV system.

Download the study and accompanying content on the topic on Sandia National Laboratories’ website:

Empirically Derived Strength of Residential Roof Structures for Solar Installations

Full URL http://energy.sandia.gov/wp/wp-content/gallery/uploads/dlm_uploads/SAND2014-20600_EmpiricalData_2-11-15.pdf

Short URL http://go.usa.gov/33brW

Structural Code Considerations of Solar Rooftop Installations

Full URL http://energy.sandia.gov/wp/wp-content/gallery/uploads/dlm_uploads/SAND2014-20601_Code_2-11-15.pdf

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