Simulation-based approach to strength evaluation and material optimization in polytunnel structures for protected agriculture

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Protected Agriculture (PA) is one of the greatest technological contributions to traditional farming and a promising solution for improving crop productivity, ensuring food security and enhancing resource use efficiency. Polytunnels are one of the most popular PA systems due to their ability to adapt to climatic changes and prevent pests and diseases. However, polytunnel structures are still constructed based on informal methods without proper structural evaluation, which can result in structural failure, or the over-use of materials. This research study introduces a simulation-oriented design approach with a standardized procedure to optimize material usage by evaluating the structural strength of the polytunnel before construction. The mathematical calculation of wind loads acting on the structure is a key focus of this study. These forces are calculated in all possible directions and applied individually to each structural beam in a 3D model designed using SolidWorks based on the structural standard ASCE 7-16. The simulation data allows for detailed analysis to support final decisions. Structural strength and material safety can be evaluated using the stress scale (Factor of Safety), while functionality and serviceability can be assessed using the displacement scale (deflection ratio). In this research, a modified Quonset structure was selected among the existing polytunnel structural shapes, and several simulations were conducted by including and excluding structural members, as well as re-sizing the shape and structural components. The final simulation results were obtained with 5.893±0.001 safety factor which exceeds the minimum requirement of 1, and (6.603±0.001) mm maximum displacement which is within the allowable displacement limit of 8.889 mm. The proposed method is a replicable procedure ahead of construction that developers, especially beginners can adopt to validate the design based of environmental factors ensuring the stability, strength and material efficiency without compromising reliability.

Keywords: *Modified Quonset structure, Protected Agriculture, ASCE 7-16, Deflection ratio*