A SUPERIOR SHADEHOUSE DESIGN FOR THE AGRICULTURAL AND NURSERY INDUSTRY: THE SUPERSPAN MEMBRANE STRUCTURE

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INTRODUCTION

In areas of the world with high incidence of sunshine, the need for protection of agricultural areas from the climate is well recognised. Shadehouses are used to provide a suitable growing environment for a variety of potted plants, vegetables, cut-flowers and herbs. The development of knitted shade cloth, which has superior strength and flexibility, has made a new design feasible.

The membrane shadehouse structure, a new and radically different design, has been introduced to the agricultural and nursery industry over the past nine years. It is similar in concept to a circus tent in that the entire roof and wall sections are made in one continuous piece. There are now many membrane shadehouses currently being used in Australia, the USA and South America. These range from 0.1 to 4.4 hectares.

This paper discusses the engineering history and features of the Superspan shadehouse design now manufactured and marketed under licence agreement.

SUPERSPAN MEMBRANE STRUCTURE

The roofing material consists of a lightweight knitted fabric supported by a system of columns and cable guy anchors.

The perimeter of the structure is supported by columns only, while the interior usually has columns spaced at 14.33 metres.

The roof is fabricated as a series of square panels (usually 14.3 x 14.3m) with seat belt webbing sewn continuously in a curve. Internally, four panels meet at a column. Actual connection to these points is via the webbing, with no connection of the actual fabric to supporting members. The perimeter columns are held secure by guy cables anchored to the concrete footings. Side wall panels extend from the edge of the roof to be anchored at various points on the ground.

The original concept of the shadehouse was in response to a number of agricultural and engineering requirements.

AGRICULTURAL REQUIREMENTS

Shade : The main purpose of a shadehouse is to reduce the amount of sunlight incident upon a particular area. The amount of shade provided is dependent upon the "weave" of the fabric, for example a popular cloth employed in Australia has a 70 % shade rating. The shade level can also be increased by having more than one layer of shadecloth.

Protection From Climatic Extremes : The existence of a shadehouse over a particular area reduces the impact of heat, wind, hail and frost upon the crops. The soundness of a shadehouse directly affects the risk of damage to the underlying crops, with obvious implications in the insurance area. The crops beneath the structure are usually of much higher value than the shadehouse itself, and hence two different levels of failure, with vastly different implications can be envisaged. The less dramatic failure mode involves failure of a small number of structural connections, resulting in localised damage to the structure. The more dramatic failure involves widespread collapse of the structure with a high level of damage to the underlying crops, from both the impact of the structure's collapse and an increased exposure to the sun.

Environmental Control : A certain degree of temperature and humidity control within the shadehouse is possible. Current investigations are underway to quantify these more accurately using new forms of fabric.

ENGINEERING REQUIREMENTS

Cost : One of the major aims in the original shadehouse design was to devise a structure which used standard components, and hence reduce the fabrication costs. Thus only two sizes of cloth panels and two column heights are used, with the number of panels dictating the area covered. Non standard layouts of panels are possible as well as "freeform" structures.

Flexibility : The areas to be covered by shadehouses can vary greatly in size and shape and the use of square panels allows a certain degree of flexibility, while retaining standard components. Thus a major design feature of the shadehouse system is that the component forces are largely independent of the panel arrangement. Theoretically an infinite area could be covered using the same components as for a single panel. The ability to expand the area covered at a later date is also inherent.

Structural Integrity : The major challenge to the structural soundness of a shadehouse comes from wind loadings, due to the large areas of unsupported cloth.

Durability : The durability of the shade cloth usually determines the life of the structure as a whole. The cloth must be able to resist fatigue type loading from wind gusts, as well as sustained stressing induced by pretensioning.

Clearance and Access : A major design objective is to provide as few internal columns as possible over a particular area, to reduce the impedance to machinery use. Various service vehicles require access to the area under the shadehouse and sufficient clearance must exist for these vehicles and to ensure that the cloth does not come into contact with any obstructions.

Access also requires the existence of a gate structure that can be opened and locked as required without affecting the integrity of the structure as a whole.

STRUCTURAL BEHAVIOUR

The main reason for the structure's resistance to high wind loads lies in its ability to move and hence alleviate stresses. Traditional shadehouse structures have employed rigid frames which developed excessive stresses at connection points under high wind loads.

The lightness of the shadecloth means that considerable movement occurs under even the lightest of winds. Experience has shown that the fabric moves in a wave-like motion. with the wavelength decreasing as the wind speed increases. Wavelengths of about 3-4 metres are typical for high wind conditions.

With this wave-like movement of the fabric existing, the important design criteria for the fabric itself is to ensure that during such movements the fabric always remains in tension. If this does not occur then excessive fatigue-like stresses could cause tearing of the fabric as it suddenly changes from a slack condition to a stretched state. The use of curved seat belt webbing induces a near biaxial stress state. This eliminates any chance of slackening of the fabric under wind loads.

Wind and hail loads acting upon the roofing fabric are transmitted to the columns via the curved seat belt webbing. The use of continuously sewn webbing overcomes the problems of high local stresses inherent in the earlier structures where the fabric was connected at a small number of points.

The internal columns are able to transmit tension to the ground as well as compression. Experience has shown that the uplift forces occurring during high speed wind gusts can be sufficient to lift the columns off the ground if not securely anchored down.

COMPUTER AIDED DESIGN AND DRAFTING

One of the major advantages of this structure is its use of standard size panels and members. This allows the development of a relatively simple computer program that can plot any layout of panels required. These plan and elevation drawings can be accompanied by standard detail drawings of the supporting members. The net result is an appreciable saving in design costs, as well as fabrication costs.

CREDITS

1. W. J. Brazenor and Dr. P. W. Kneen, "Design and Construction Aspects of an Agricultural Shade Net Structure System", Proceedings of Second Ausualian Seminar on Practical Membrane Structures, June 1982.

2. Reference material for this presentation was obtained from a serial publication 630 US ISSN 0271-9916 by Dr Michael R. Williamson. Dr Williamson is an assistant specialist with the Department of Agricultural Engineering, College of Tropical Agriculture and Human Resources, University of Hawaii at Maroa, USA.

3. Special thanks goes to Dr Peter Kneen, Senior Lecturer at the University of New South Wales, Sydney, Ausualia who acts as the specialist consulting structural engineer for Superspan. Dr Kneen is an eminent member of the Membrane Structures Association of Australiasia and performs design, analysis, and ancilliary consulting services on an international basis.

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