

CHAPTER 12

GREENHOUSE STRUCTURES

INTRODUCTION

***Protected agriculture:** the modification of the natural environment to achieve controlled or improved plant growth.

***Protected agriculture** can include

- Mulches of organic or synthetic materials placed on the soil around the plants to make conditions more favorable for plant growth.
- Shade cloth over the plants to protect them against high light intensity.
- Plastic row covers to protect young plants against the cold early in the season
- Open-sided, plastic roofed structures to protect against rain
- The “ultimate” in protected agriculture: Totally enclosed structures: greenhouses & growth chambers (CEA)

***Controlled environment agriculture (CEA):** The growing of plants, usually in a greenhouse or growth chamber, with control of the aerial environment including temperature, humidity, gas composition, light and air circulation. Can also include hydroponics with control of the root zone (water, growing medium and plant nutrition).

GREENHOUSES

***Greenhouse:**

- A framed (or rarely inflated) structure used for cultivating plants.
- It is covered with a transparent material (glazing) that allows for optimum light transmission of the appropriate wavelengths (i.e., photosynthetically active radiation or PAR = 400-700nm; Ch 2 & 3).
- It protects against adverse climatic conditions.
- Control of the aerial environment to achieve goals (e.g., opt. yield, etc.)

***One of the first recorded greenhouses** was built during the first century A.D. It was covered with “transparent stone”, probably sheets of mica, to grow cucumbers out of season for the Roman Emperor, Tiberius.

***A greenhouse must provide protection** from adverse “abiotic” conditions such as

heat	cold	rain	wind	sleet
hail	snow	salt	blowing sand	dirt/dust
high light	low relative humidity			

***Greenhouse structures are rated for certain “design loads”** (the load or weight supported by the structure).

Dead Load = the greenhouse framing and everything hanging from it including the glazing (covering), pipes, heaters, fans, pads, shade cloth, motors, support cables AND any hanging crops (e.g., tomatoes, peppers, cucumbers) or baskets in place more than one month.

Live Load = transient greenhouse assembly or repair equipment, people who must climb onto the structure to perform various repairs, cleaning, servicing, etc. AND any hanging crops or baskets in place less than one month.

Wind Load = the load, in pounds per square foot, placed on the exterior of the greenhouse by wind. This will depend on

- The angle at which the wind strikes the greenhouse.
- The shape of the greenhouse (height, width, number of bays, etc.).
- Whether or not vents, doors, etc. are open or closed.
- NOTE: If a sufficient wind strikes the side of a greenhouse it could rip the roof off! (Local windbreaks – trees – can help.)

Depending on location, a typical design “wind load” = 80 mph or 16 lb/ft².
The greenhouse frame needs to be secured to the ground against wind.

With permanent structures, anchor the supports in concrete.

With temporary structures a cork screw device is used to anchor the greenhouse to the ground.

Snow Load = the load, in pounds per square foot, placed on the exterior of the greenhouse by snow accumulation. The type of snow makes a difference:

- 12 inches of dry snow equals 5 pounds per square foot of load.
- 3 inches of wet snow also equals 5 pounds per square foot of load.
- and 9 inches of wet snow can collapse a greenhouse!

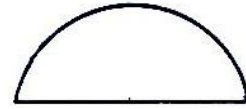
When it starts to snow hard – increase the heat in the greenhouse to melt it.
Early snow will melt easily. Succeeding snows will slide off.

***Building Codes:**

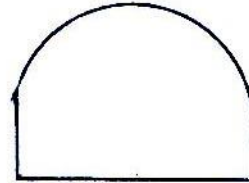
- Each city, county, state and country will have its own set of codes.
- Always make sure the builder and/or contractor is licensed, bonded and insured.
Get references. Set up a pay schedule tied to completion of various stages of the work – Never pay everything “up front”.
- Sometimes agricultural buildings will be exempt from the standard building codes or will be treated as “special structures”.
- For The University of Arizona’s CEAC teaching greenhouse just the opposite occurred:
The greenhouse had to be built to the codes of a classroom building since it is used as such, rather than a greenhouse.
It also had to be built to hold up against 80 mph wind loads.
All of these regulations required that there are more structural members than normal and therefore more shading than in a commercial style greenhouse.

TYPES OF GREENHOUSE STRUCTURES – Typical structures include:

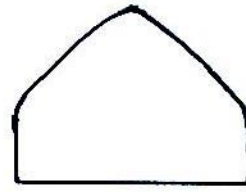
***Hoop House or Quonset:** A semi-circle design usually covered with a single layer of polyethylene film or with a double layer of film separated by an air layer maintained by a small fan for insulation. Used for low crops, potted plants, lettuce, etc. Inexpensive; with heating/cooling or not.



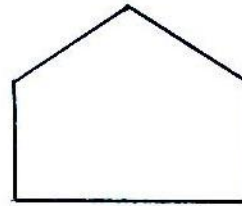
***The Arch:** A semi-circle design elevated by side walls. Can grow higher crops: taller potted plants, vining tomatoes, cucumbers, peppers, etc. UA example: CEAC Poly Tex greenhouses



***Gothic Arch:** A variation of the Arch with more rounded side walls. These can be for commercial greenhouses or for small hobby types (a little more “stylish”).



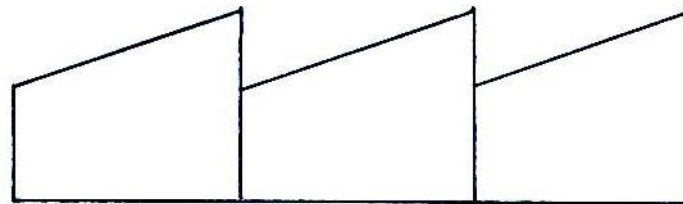
***The Gable:** A structure with side walls and a peaked roof. Depending on the height, good for plants on benches or for tall crops (i.e., vining tomatoes, cucumbers, peppers, etc.). UA example: smaller greenhouses (gutter-connected)



***Ridge and Furrow or Gutter-Connected:** Several gable (or other style) greenhouses connected together usually with no internal separations between the bays. Used for tall crops such as vining tomatoes, peppers and cucumbers. Note: UA greenhouse do have separations.



Venlo: A variation of the above with many ridges & furrows over each bay. Each ridge has vents. Ex: EuroFresh, Wholesum Family Farms.



***Sawtooth Design:** A variation with tall vents on the vertical sections of the roof to allow for natural ventilation. Usually gutter-connected and used for tall crops such as vining tomatoes, peppers and cucumbers. UA example: CEAC teaching greenhouse (2 bays)

NOTE: Any of these structures can be covered with insect screening or bird netting in areas where climate conditions are favorable but protection from insects, etc. is needed.

GREENHOUSE FRAMING MATERIALS

***Introduction:** Structural members, used for the greenhouse “skeleton”, must be strong enough to prevent structural failure during adverse weather conditions but be kept to a minimum size and number to reduce the amount of shading and to provide for maximum light transmission.

***Wood:** Due to increasing cost and availability of more suitable materials, wood is no longer generally used in large commercial greenhouse construction. If used for smaller greenhouses or in areas where other types of framing materials are not available, wood must be treated for protection against decay, especially the sections that come in contact with the soil. Treatments must be non-toxic to plants and animals (Ex: do not use creosote or pentachlorophenol). Chromated copper arsenate (CCA), ammonical copper arsenate (ACA) or other preservatives containing combinations of copper, chromium and/or arsenic are safe to use around plants. Also treat woods with “natural decay properties” such as redwood or cypress, especially in desert or tropical regions.

***Reinforced concrete:** Usually used for the greenhouse foundation and low walls.

***Reinforced concrete and bamboo:** In the People’s Republic of China, the concrete has been used as a support for a frame of bamboo. With passive Chinese Solar Greenhouses, the north side is composed of rammed earth or other solid material to which the bamboo, or also PVC pipe, is attached.

***PVC (polyvinyl chloride):** Hollow tubes of this plastic material (typical inside diameter of ½ inch) can be used for small scale hoop or arch style greenhouses. These may not necessarily be considered “permanent” structures.

Electrical conduit: This can also be used, like PVC pipe, for small scale hoop or arch style greenhouses. These may not necessarily be considered “permanent” structures.

***Air or air tubes:** The structures of some greenhouses of the hoop or arch style (covered with flexible polyethylene film) can be maintained solely by air pressure either by inflating the entire greenhouse or by inflating air tubes that act as structural members. This requires air handling equipment, and if the power fails the greenhouse will collapse.

***Steel (galvanized):** Almost all steel used in greenhouses today is single or double dip galvanized to protect against corrosion. It may be used in conjunction with aluminum. It is usually protected from direct contact with the ground (and subsequent corrosion) by being encased in concrete.

***Aluminum:** It may be used alone or in conjunction with galvanized steel. It is much lighter than steel but is only about one half the strength of an equally sized steel member. It is usually protected from direct contact with the ground (and subsequent corrosion) by being encased in concrete.

GREENHOUSE GLAZING (OR COVERING) MATERIALS

Introduction: The materials used to cover greenhouse structures must allow for maximum light transmission. They can be rigid or flexible, double-walled or single-walled, smooth or corrugated. Most “glazing” materials made today incorporate compounds that inhibit rapid degradation by ultraviolet (UV) radiation. However, all glazing material will age and they are therefore rated by the number of years they will maintain a certain level of light transmission capability.

As mentioned earlier, mica sheets were used in the 1st century A.D. as a glazing on Roman greenhouses. However, this material is no longer used, except perhaps as a demonstration of “ancient technology”.

***Glass:** This has been in use for over a century in Northern Europe (Holland, England, etc.). Early glasshouses required significant wood and later metal structures to hold small but relatively heavy panes of glass. This reduced incoming light. Modern glasshouses have large panes of glass with reduced framing of stronger materials to increase light levels. Light transmission (PAR) is between 71 and 92 % depending on the type of glass and the estimated lifetime is 25 years or more. However, glass is inflexible, heavy, easily broken (unless tempered) and expensive. Many growers are opting for plastic materials.

***Polyethylene:** First developed in England in 1938, this flexible, lightweight material is used extensively on hoop or arch style greenhouses because it is flexible, easy to work with and inexpensive. A single layer can be used or two layers can be applied with an air layer (maintained by a small fan) in between. This air layer adds insulation from heat and cold and adds structural strength with the double layer polyethylene houses being more stable in areas of high winds or typhoons. Light transmission (PAR) is around 85-87 %. Unfortunately, the estimated lifetime is only 2-4 years, depending on location and quality of the polyethylene. New innovations include “Solexx”, a double-walled, insulated, shatterproof but flexible polyethylene blend with UV protection and an 8 year warranty. The light transmission is only 70-77% but it diffuses the light.

***Polyvinyl chloride (PVC):** Another flexible film that has light transmission qualities similar to glass. This material has been used extensively in Japan. While polyethylene sheets can be wide, PVC is narrow which is a disadvantage in covering greenhouses.

***Corrugated Fiberglass (also known as fiber reinforced polyester):** It is inexpensive, rigid, strong and easy to work with. Light transmission (PAR) is between 60 % for double wall and 88 % for single wall. However, it is susceptible to UV light, dust and pollution (hose down or wash periodically), yellows with age and is extremely flammable. The estimated life is 7-15 years, depending on type of fiberglass.

***Acrylic:** This glazing material is rigid, lightweight, easy to work with and resistant to UV radiation and weather. Light transmission (PAR) is 83 % for double wall and 93 % for single wall. The estimated lifetime is 20 years or more. However, it is easily scratched, has a high expansion and contraction rate, becomes brittle with age, is expensive, and is flammable.

***Polycarbonate:** This glazing material is rigid (*), lightweight, easy to work with and is resistant to high impacts and fire. Typical light transmission (PAR) is 79 % for double wall and 87 % for single wall. The estimated lifetime is now over 10 years or more, depending on the type. There is some yellowing of the material with age.

(*) Single wall polycarbonate can be bent in half and straightened, without creasing!

- Previously, polycarbonate was known to scratch easily and have poor weatherability and UV resistance. However, recent advances in material properties have alleviated some of these earlier problems by coating the outer layer with acrylic.

- Also, recent advances have produced polycarbonates with light transmission properties equal to or even exceeding glass. “DynaGlas” (reg. TM of Palram Americas) is a single walled, corrugated polycarbonate which is used on the UA/CEAC teaching greenhouse.

It has a light transmission of 90% and blocks nearly 100% of the UV light (this was a concern early on since the bumble bees used for pollination (Chapter 7) “see” in the UV range – and although it may take the bees a few days to get oriented, they get use to the “dark” conditions in the greenhouse and are effective pollinators).

- Other DynaGlas products include polycarbonates with 85% transmission and 100% diffusion of light to reduce shadows on the plants.

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- 4. Web Sites:**
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