Chapter 1 – Introduction

1.0 General

This National Greenhouse Manufacturers Association (NGMA) Structural Design Manual is intended to provide a consistent set of criteria and design approaches for member manufacturers to use for design of production and commercial greenhouse structures.

Designs meeting this manual will comply with the International Building Code's (IBC) structural design criteria and its referenced standards such as ASCE 7.

Cladding Design

Cladding design is considered non-structural and not included in this manual. Certain elements of greenhouse structures contain systems not specifically considered in building codes. An example would be some types of cladding materials, which do lend themselves to a rational analysis using code specified loads.

Further, greenhouse enclosure elements may be of materials not included in building code structural provisions or elements that are not installed as anticipated by the building code. Non-included materials are the acrylics, polycarbonate, and polyethylene enclosure materials. Glazing in buildings is designed in accordance with the building code to be supported on four sides while in greenhouse construction it is typically supported on two sides. Acrylic, polycarbonate, and polyethylene design is in accordance with the manufacturer provided information and test information, called manufacturer's information in this handbook. Glazing requires a different set of tables currently based on engineering judgement and soon to become an industry standard.

1.1 Greenhouses Defined

This manual covers two types of greenhouse structures. These are defined as:

- GREENHOUSE, PRODUCTION - A building not normally occupied. *(It is considered the same as an agricultural building in the IBC.)* A greenhouse that is occupied for growing plants on a production or research basis, without public access. *Incidental use such as tending or moving products and other incidental use is considered production activities and does not deem the building a commercial greenhouse.*

- GREENHOUSE, COMMERCIAL - Any other greenhouse structure used for the display and sale of horticultural products and supplies. For the purposes of this manual all greenhouse structures other than production are considered commercial greenhouses.

1.2 Intent

Greenhouse structures are built in many variations to meet grower needs and site specific conditions. This applies to all components of the basic structural system. Cladding is not included

in this manual. Because of the nature of the structures a number of design approaches have evolved. Some of these approaches are consistent with the building code, others may be ad hoc; and some based on the specific product manufacturer's tests and published data. In some cases there may be specific design safety issues. Some may not meet building codes. In order to establish a code complying baseline for greenhouse design, this Structural Design Manual has been developed.

The manual summarizes design provisions of the International Building Code 2000 Edition applicable to greenhouse structures. Building code provisions that are not applicable, such as provisions for multi-story structures, are omitted. Special provisions for agricultural structures, often contained in footnotes in building codes are included herein.

Each type of common greenhouse structural system is covered. The design of these different systems must be based on a rational analysis. Since most are of light metal construction the design is to AISI or other standards adopted by reference in the building code. The exact implementation of the standards may use differing analysis techniques based on the judgement of the engineer. In some cases physical testing may be required. Where engineering judgement is noted, available manufacturer's literature or other information is presented. Where there is an industry consensus of the approach, it is included. Where judgement is necessary available guidance is included.

1.3 Limitations

This manual is based on the International Building Code (IBC) and its adopted reference standards, including ASCE 7. ASCE 7 is updated on a three year cycle. The standard is being reformatted and equation and section numbers will change.

The National Fire Protection Association (NFPA) Building Code – NFPA 5000 is new. It references ASCE 7 for loads. The NFPA code provisions for structural may be different for some sections of ASCE 7.

Specific codes in a state or jurisdiction may vary and contain other limitations not included herein. Users should check locally for specific local code requirements.

This manual covers the structural design only. Not all cases or issues can be included since designs will vary. Further, other design requirements are not included, notably fire safety. Building codes may limit the size and percentage of plastic materials on roofs depending on the use. Designers must consider these requirements.

Other limitations not covered include fabrication and erection of the structure and cladding elements, specifications, energy conservation requirements and similar attributes.

1.4 How to use this manual

This manual guides the designer through the building code provisions for production and commercial greenhouse structures. Included are the provisions for roof live load, snow load, wind loads as well as seismic and collateral loads as contained in the building code or reference standards.

The manual then goes on to detail the structural design methods for various roof framing systems, the support columns and the lateral bracing systems. For each type of structure and element the design approach and assumptions are summarized. References are made to applicable building code and consensus standards and provisions, industry standards, manufacturer's literature and finally engineering judgement issues.

The table below shows some of the differences in IBC requirements for production and commercial greenhouses.

Table 1.1 - Greenhouse Design Comparison

	PRODUCTION GREENHOUSE	COMMERCIAL GREENHOUSE*
Structural material selection	ASCE 7 Category I (IBC Category IV)	ASCE 7 Category II (IBC Category I)
Cladding selection	No limitations	Overhead glass Overhead plastic Flame-resistant membranes
Loads	I_s = 0.80 I_w = 0.87 (Non-Hurricane Prone Regions) I_w = 0.77 (Hurricane Prone Regions) Collateral loads	I_s = 1.0 I_w = 1.00 Earthquake loads Collateral loads
Structural design	Larger deflections may be allowed (per IBC Table 1604.3)	More control of deflection
Cladding design	No limitations	Fire safety

* Note: Refer to the Code for structures that can be classified in other Categories due to the number of occupants or use.

1.5 Methodology

Production versus Commercial Greenhouses

The first question that must be addressed before starting a greenhouse design is whether it will be a production greenhouse or a commercial greenhouse (retail, etc.). The distinction between a production greenhouse and other commercial greenhouses may lead to differences in major design parameters such as building area. In addition, it leads to differences that may be significant in four areas:

- Selection of cladding materials (to determine the dead loads)
- Loads
- Structural design
- Structural members supporting cladding is are to be designed.

The IBC assigns importance factors (I) as a function of building use. Agricultural buildings, including production greenhouses, are assigned a lower importance factor than other buildings, and this leads directly to a reduction in snow loads ($I_s = 0.8$) and wind loads ($I_w = 0.87$ or 0.77 for hurricane regions) on both the structural system and the cladding.

The IBC exempts agricultural buildings, including production greenhouses, from seismic design requirements. In other greenhouses earthquake loads imposed on the structure by nonstructural components (mechanical equipment, irrigation equipment, etc.) may need to be considered and could be the critical load in some cases. In production greenhouses the code allows these loads to be ignored.

The IBC requires that structures be designed to support collateral loads, (i.e. growing racks, irrigation equipment, etc.).