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Design and Construction of Greenhouse in India

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Abstract
Greenhouse is popular throughout the country for growing high value crops, which is available in different designs suiting different agro climatic conditions but single design of greenhouse cannot be adopted throughout the country. The wind is the major force responsible for failure of the structure, therefore popular greenhouse designs Quonset, walk in tunnel, gothic and double arc single span and multi-span were selected for the study. In India, the basic wind speed varies from 33 to 55 m/s. All the forces acts on the structures due to individual and combination of loading were determined and behaviour of structural member analyzed and studied using ANSYS 15.0 (finite element model).Two wind angle of attack 0° and 90° were used in dynamic loading of the structures. Results were also validated in field for one of the selected design by installing its improved structure and it was found that total stress value reduced by 35- 46 per cent and deformation by 8-10 per cent. It means sufficient strength was added to the structure without dismantling and any additional cost.

Keywords: Greenhouse, designs, Quonset, structures, temperature, relative humidity, Control environment, polyhouse, GI pipes, bamboo, glazing material, Low Density Polyethylene (LDPE).

Introduction
Greenhouse refers to a structure which provide relatively better environment for plant growth. The goal is to create congenial temperature and relative humidity in desired range. The greenhouse covered with polythene sheet, also called as polyhouse, has polythene sheet (UV stabilized 200 micron LDPE sheet) as covering over a relatively rigid frame (made of GI pipes, angle iron, bamboo) which entraps the solar energy to increase the temperature and provide light for plant propagation. A normal greenhouse has four basic components: 1) frame made from rigid material like GI pipes, wood or bamboo; 2) glazing material, which is transparent to provide enough light for plant propagation; 3) climate control system, which may be natural ventilation or forced ventilation using fans with or without cooling pads, shading nets, pigment painting etc. and 4) plant growing medium (soil or artificial media like cocopeats) with needful arrangement for supplying inputs (water, fertilizers, pesticides, etc.). The design of greenhouse involves structural design of frame with enough climate control mechanism. It mainly depends on shape, size, material of frame, local climatic conditions, wind pressure, and desired height from crop production point of view.

Different shapes of greenhouse are being fabricated which depend mainly on local conditions and needs. In snow affected areas, the slope of the roof should enable easy sliding of snow, while high windy a should make roof to ease out wind pressure without causing me damage Gable shape, gothic arc shape, quonset shape are mostly prevalent for single span greenhouses while, multi-span gutter connected saw tooth type polyhouse are being constructed to cover larger areas. Cooling/heating requirement of any greenhouse depends on local climatic conditions, temporal (weekly/fortnightly/monthly well as diurnal) variation in climatic parameters, eg. temprature, relative humidity, sunshine hours, incident radiations (quantity and angle) etc. Natural ventilation using chimney effect concept, forced air circulation evaporative cooling, shading etc are some of means to achieve cooling for moderately control conditions. Earth air heat exchangers are also being developed to reduce the overall cost of climate control. Such system is already being used in higher altitudes eg. Ladhakhi green houses etc.

The greenhouses are constructed to provide completely or partially controlled climate for plant growth and reproduction. Greenhouse is generally referred to a structure which provides relatively better environment for plant growth by creating congenial climatic conditions including soil and water regime. The best environment for most of the plant cultivation is 25-30°C, 70-80% relative humidity, light intensity of 60.000-80.000 lux for 8-10 hours, and higher concentration of carbon dioxide. Under greenhouses, efforts are made to bring the climatic conditions as close as possible to the values.

Earlier glass panels were used as glazing material for greenhouses, but now it has been replaced mostly with UV stabilized Low Density Polyethylene (LDPE) sheet, while other forms of plastics sheets (fiberglass reinforced plastics, acrylic panels, polycarbonate panels, and sheets) are also in use for different purposes. A normal polyhouse has following four components:

- Frame made of metallic (mostly Gl) pipes, wooden or bamboo.
- Gazing material which is transparent to provide enough light for plant propagation. It is mostly 200 micron UV stabilized LDPE sheet, suitably joined to have one sheet covering for whole of the structure.
- Climate control system to create congenial climate inside the structure and consists of different mechanism as per need.

Design of A Polyhouse

Design of a polyhouse involves determining its dimensions, ventilation requirement, and stability against adverse forces like winds, snow, heavy rains, hailstorm, etc. The BIS standards (IS 14462:1997) provides guidelines to determine the design load from different sources, eg dead load due to fixed service equipment (heating, ventilation, air circulation, electrical, lighting, watering, etc.), live load (temporary load including repair crews and hanging plants), snow load, and wind load. In order to design ventilation/climate control system, the need for peak heating or cooling requirement has to be worked out. It depends on actual climatic conditions of the particular location, season, desired conditions to grow the desired crop, size and shape of the structure, total volume of air in the structure, etc. Mostly energy balancing is done to determine needed cooling or heating requirement using mathematical equations which are developed using modeling approach. Some software uses direct numerical models to work out required head/ cooling load. After determining the energy load that is to be managed then particular climate control system is selected and designed accordingly. Some of the design aspect is also discussed in the following text for fabrication of a particular component.

Construction of Polyhouse

The ultimate goal of fabrication of a polyhouse is to provide the congenial climatic conditions (temperature and humidity), provision of enough sunlight, and enhancing the CO, concentration, to achieve maximum production and quality of the produce. For this, the major issues to be considered include appropriate site selection, orientation, structural strength and joints, covering with appropriate quality glazing material and fixing with the frame, installation and making operational the climate control system (including shading), preparing soil bed installation of microirrigation and fogging system, and finally soil treatment to disinfect the whole environment (soil as well as air inside).

Site selection is very crucial in ensuring enough light availability by avoiding shading, water drainage, and protection from high speed winds. The size of plot selected should be large enough to have provision for future expansion, service floor area, storage, approach pathways, etc. Topography of the land selected should level as far as possible, or suitably terraced with enough soil depth to have appropriate cultivation practices. The ideal greenhouse site would be slightly southern facing slope (less than 3%) for good winter light and protection from northern light. The BIS standard (15 14462 1997) enlists various essential points to be considered during site selection and layout of a greenhouse. The important decision before construction is about floor layout. Good planning for floor layout for polyhouse cultivation area service buildings (for storage of inputs/produce), water pump, working space, pathways, etc. certainly minimize time consumed in movements and service activities. Suitable locations for keeping water storage tanks fertigation tanks and other units are important for real time application of fertilizers and other pesticides. Provision of water for cultivation and other needs, and electricity to operate various appliances has to be made appropriately.

Types of Polyhouse

Broadly, they are classified based on shape, material used for frame construction, cost of construction, or its utility.

1. Shapes of Polyhouse: Polyhouse may be single span or multi-span depending upon size and length width ratio of the land and proposed house. Normally up to 8-10 m width, a single span polyhouse is preferred, but for higher width, the multi-span is preferred Single span polyhouses may be gable shape (even span slanted roofed, hut shape), Gothic arch shape (pointed arch which is relatively stronger than gable and hence may have wider polyhouse), quonset shape (nearly semi-circular tunnel), or saw-tooth type (for naturally ventilated polyhouse). While multi-span polyhouse may be saw tooth, ridge and furrow (may be gable or Quonset shape) each connected with well graded gutters to remove the rainwater, and provide enough stability. The roofs and sides may be supported by trusses and buttresses.

2. Materials used for Frame: Bamboo or wooden frame is constructed for low-cost polyhouse which is cheaper and easily affordable for the resource poor farmers. But, such frame has very less life (3-5 years) and has to re-build or carry out major repair (changing rotten components) along with change in polythene sheet. Permanent type of frame is constructed using metallic material such as GI/MS pipes, MS angle iron, GI/MS Channels, etc. But most common is GI pipes which are stronger as well as corrosion resistant and has life more than 25 years, if remains protected against any damage by external forces like wind or snow.

3. Cost of Construction: Considering the initial cost of construction and operation polyhouse may be high cost, medium cost and low cost. High cost polyhouse maintain climatic parameters (temperature and humidity) in a very narrow range and have stronger frame with cost of construction more than 3000/m² of floor area. Medium cost polyhouse maintain climate relatively wider range (partially controlled environment) and also has relatively stronger frame with cost of construction of 2500-1500/ m². Both types have mostly GI pipe frames. While bamboo/wooden frame polyhouse has less cost of construction (200-300/m^2), but has life only 3-5 years.

4. Utility: Polyhouse may be constructed for research purposes in which climate have to be controlled in relatively narrow range. Polyhouse constructed for growing high quality medicinal plants, export quality flowers/vegetables need to maintain congenial climate throughout the cultivation period including effective control of disease and pest attack, nutrient supply and irrigation.

Glazing Material: Historic evidences indicate that transparent stones were used as first glazing material for growing cucumbers in Rome during the 1" century. Later on oiled translucent paper and glass were used to grow and warm plants against severe cold (Jensen and Malter, 1994) after 1600 AD, glass was the major covering material. Polythene film was developed in the late 1930s. The polythene film was first used to cover greenhouse to replace expensive glass panels in 1948 by Prof. E.M. Emmert in University of Kentucky to reduce the cost of construction (Espi et al. 2006). After that it is adopted all over world and almost replaced the glass panels except for special purpose greenhouses. However, plastic rigid panels are also being used in place of glass panels with similar results.

Several types of plastic films are in use for relatively less expensive construction of greenhouses, e.g. polythene (UV stabilized LDPE, mostly 200 micron thick), PVC film, polyester sheet, Tefzel T2 film (ETFE, ethylene tetrafluoroethylene). Rigid plastic panels (fiber reinforced plastics panels, PVC panels, acrylic and polycarbonate panels, etc.) are also being used for research or specific purpose polyhouse, but they are seldom used for commercial type polyhouse construction. The main reason is their diminishing transparency over the time due to dust deposition and abrasion. Nowadays, multilayered cross-laminated sheet (as per IS 14611-1998) is also being used which has higher mechanical strength, but has less light transmission.

Wooden/Bamboo Frame Polyhouse: The locally available or forest waste wooden material is used for construction of low cost polyhouse by the small and marginal farmers especially in hills. Use of bamboo is also an ideal material as it has better strength and relatively longer life. The life of bamboo can be enhanced using water and chemical treatment to remove cellulose part which is the main constituent responsible for rotting or attack by termites and other insects/pathogens (Leise and Kumar, 2003). Such treatment can enhance the life of bamboo from 3 to 5 years to more than 50 years. They are used for building or structural construction for public use.

GI Pipe Frame Polyhouse: The Gl pipes are used in most of the playhouse where durability is to be ensured as these pipes are quite strong, corrosion resistant, and relatively cheaper. The GI pipe framed polyhouse may be semi permanent or permanent type depending upon factor of safety taken in designing the frame and method of construction. Naturally-ventilated polyhouse are normally constructed high (4.5-6.5 m or more) which require higher strength against wind, which is not possible to be created using bamboo frame economically.

Conclusion

All the structures were analyzed as per the estimated load for respective wind zone. The design wind load on the roof was determined as resultant effect of internal air pressure and external air pressure. It was found that in most of the design only two type of truss were used one is king post and w type truss. In theoretical calculation by method of joint and section, it was found that in case of arc type structure the tensile forces in rafters are maximum just above the ground level, as the height of structure increases these gets reduces. In case of purlins the tensile forces reduces as height of the structure increases. The top purlins carry maximum compressive forces i.e. the ridgeline, as compared to bottom purlins. Maximum stress occurs at the eaves i.e. the junction between the columns, rafters and purlins. Ratio of Length-width: 80: 20 or 75:25 then Side Height should be in the range of 3-5m and central height is 3- 9m. Gothic shape type design was found to be best in heavy snow load conditions. In semi-arid regions, it is recommended that side vent of 1m without shade net provides favorable microclimate inside polyhouse structure

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