Floating Greenhouses: an Expert System for Integral Design

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Keywords: greenhouses, construction, expert system

Abstract

The main advantages of floating greenhouses compared to greenhouses on solid ground are the possibilities for multiple use of space and for energy saving. As in the coming years large area's in the Netherlands will be necessary to create water storage, the capability to give these areas an additional function by facilitating crop production on the water will prove valuable. By using the capacity of the water under the floatation system for heat storage in addition to an aquifer, a cost effective way to save energy can be provided.

For the integral design of floating greenhouses, several key questions have to be answered. An expert system has been set up to support the design engineers with dedicated guidelines for the integral design of floating greenhouses.

The system is a software tool that contains relevant information on greenhouse construction, energy systems, material properties, floating elements etc. and guides the engineer by a set of relevant questions in a structured way.

INTRODUCTION

The increasing claim on space in the densely populated area's in the Netherlands for functions like housing, recreation, agricultural production and transport asks for innovative solutions for multiple use of space. The Netherlands has a long history of expanding the area of land by transforming water into land. However, today's policy is to give space to water (VROM, 2001) and generate possibilities for the multifunctional use of the scarce land and (sweet) water. A major reason for the new policy is that the lower parts of the Netherlands (e.g. the Westland area) have been frequently inundated after heavy local rainfall or threatened by high water levels in the canals and rivers after excessive rainfall upstream in Germany, Switzerland and Austria over the last decade. To solve this inundation problem, large areas of land will have to be transformed into retention basins to store the excessive water flows. Several plans have been presented over the last years to build floating houses, cities, roads and the first actual (recreation) houses have been realised, either permanently floating or amphibious (only at excessive water heights), (Dura Vermeer, 2004).

Greenhouses form an interesting possibility to be used on floats as they are generally light constructions and require large areas of land. The total greenhouse area in the Netherlands reaches about 11.000 ha most of this being concentrated in urban areas like the Westland. The total area is still increasing by several hundreds of hectares each year but the greenhouse area is under a constant pressure of the expansion of nearby cities. Land prices for horticultural use in these areas reach levels up to 50-75 Euro m^{-2}. Building floating greenhouses could be a promising solution to realize the different goals aimed at: create more space for housing and water storage without reduction of the economic very profitable greenhouse industry.

To combine greenhouse production with water storage on the same area, in principle two solutions can be worked out: water storage below the greenhouse, recently being introduced by Water block© (Fig. 1), or floating greenhouses (artist impression: Fig. 2).

Dura Vermeer, a top ten building company in the Netherlands, carried out a preliminary project on floating greenhouses, (Stellinga, 2001) followed by an additional intensive feasibility study by Spliet (2002) and de Knies et al. (2001). The major arguments for developing floating greenhouses are (Spliet 2001):

- Multiple use of space on a regional level and adding economic value to open water
- Multiple use of space on the greenhouse level by using the float for other functions
- Environmental friendly / sustainability (energy saving can be achieved by using the surface water for temporarily storage of heat/cold water
- Risk reduction (no inundations of greenhouses and related crop damage)
- Improvement of the image of the horticultural sector

Based on the conclusions of both studies two possible floats were selected as the most promising solutions: a rectangular concrete bucket where several functions (e.g. for environmental control systems, water storage or logistics) could be integrated within the float, and an EPS core with a concrete top layer. Both systems also are considered to be promising solutions for other floating functions like housing, industry, infrastructure etc. each of which has his own set of requirements.

As a first step in creating a general tool for "floating constructions" a first version of an expert system is set up to support the design engineers with dedicated guidelines for the integral design. Aspects like construction of the floats, location, type of water, type of crop, preferred greenhouse construction, energy system, logistic solutions but also the non-technical aspects like local and international regulations and estimated costs are included. The goal is to help the design engineer with providing guidelines for the final design process and during the interaction with the end-user. The system does not aim to generate a complete detailed design for a floating greenhouse but should support the design engineer by providing the consequences of each decision or added requirement. The architecture of the expert system enables easy expansion to other functions and adding new information e.g. from the first prototype of a floating greenhouse to be built in the autumn of 2004.

MATERIALS AND METHODS

Specific Greenhouse Designs Developed to be Used in the System

For the development of the expert system two different main lines were followed to generate the information to be used in the system. The first approach considered the current on-land situation as reference from the idea that to enhance the actual construction of floating greenhouses these must (economically) compete with traditional on-land greenhouses. The traditional greenhouse construction (Venlo-type or wide span: von Zabeltitz, 1999) was considered a given situation and the experts and engineers for the float were forced to design systems to be able to meet the requirements (according to NEN 3859, 1996) for normal greenhouses in terms of deformation etc. The second major boundary condition was a float price less than 90 Euro m^{-2} except for the additional costs for the logistic solutions. In this case the EPS core with a concrete top layer turned out to be the best solution form point of view of durability (>30 years), deformation and price.

In the second approach the opposite route was followed and the greenhouse engineers were asked to design greenhouses with innovative (flexible) constructions and environmental control systems integrated with the optimal float (designed with much less restrictions and based on current production methods). The designers concluded that the optimum float, based on the promising bucketsystem as concluded by Spliet (2002) with respect to material use, durability, (on site) production methods, floating capacity and the first results with floating houses (Dura Vermeer, 2004) etc. is a rectangular concrete bucket of 5 x 9.60 x 1.50 (Fig. 3). To make maximal use of the bucket system, a new air conditioning system for "closed greenhouses" was developed based on the principle of cold water fogging as heat exchanger (Campen en de Zwart, 2004). In Figure 4 the principle of the system is schematically presented. Each float unit has two (vertical) airducts to transport the greenhouse air to a ventilator. The air is distributed under the floor and cooled/dehumified by a coldwater air fog. The air is transported to the greenhouse through a "pressure camber" and four inlet ducts on the 5 x 9.60 area.

The inlet ducts were also used as part of the construction of the greenhouse. Since no final connection system for the concrete bucket floats has been developed at this point, new flexible greenhouse constructions were designed based on this specific dimensions. For the designs several new ideas for construction from earlier and recent studies were used (e.g. von Elsner et al., 1999; Waaijenberg and Hofmann, 2001). A recent design of a new greenhouse construction as presented by Waaijenberg et. al. (2004) formed the basis for further specific designs based on the 5 x 9.60 x 1.50 concrete float as shown in figure 4. Both for wide span or saw-tooth constructions several concepts were developed (Fig. 5 and 6).

In this way a wide range of possible solutions and combinations was investigated of which information was implemented in the system.

Design of the Expert System

The expert system is build as a Microsoft excel application. It is a case based expert system that consists (in the first version) of different modules each focusing on different aspects related to building on floats and more specific on greenhouses. In each module the user answers a range of questions related to the requirements with either the possibility to select from a range of pre set (default) values or free selected values.

The development of the system was done in the so called backwards approach:

1. Results the design engineers wanted to be generated by the expert system were formulated
2. The necessary information was identified and described
3. Calculation routines to transform the input to the final answer were set-up
4. Description of cross links between information needed for various answers
5. Formulation of the questions in the system
6. Search for and final description of additional background information needed as help for the user.
7. Implementation of the complete set of information in Microsoft Excel and user interface.

During the final implementation of the expert system each question formulated in stage 5 was linked with additional information in small pop-up windows and furthermore a range of links to the additional background information gathered during the project. This background information consists of e.g. construction calculation methods, material properties, standards for building and construction (e.g. NEN 3859 for greenhouses, British Columbia Float Home Standard, NEN 5996 for concrete), relevant summarized publications and new ideas for greenhouse construction, environmental control, ventilation etc., web-sites of relevant companies (greenhouse construction, installation, logistics and transport) legal and civil organizations, and various contact persons in the field of construction.

RESULTS AND DISCUSSION

In the system the state of the art knowledge of a wide range of disciplines (construction, materials, greenhouse cultivation, energy supply etc.) applied for Dutch conditions is brought together. The system has several main modules (see Fig. 7) that can be used randomly by the user:

- General information: focus on type of function, location within the Netherlands, planning etc.
- Regional conditions: focus on total available area for project development and maximum area floating buildings, guidelines planning and cost estimation for regional development
- Water system: focus on type of water (existing, new, open water, retention storage, chemicals/ pollution)

- Main function: Greenhouse type (natural ventilated or closed system), type of crop (vegetables, pot plants or cut flowers), type and insulating value of covering material
- Floatation: type of float selection, construction principles, technical and economical life time and degeneration effects
- Energy and climate control system: overall system design, required components and capacities.
- (International) regulation and standards: all relevant rules and standards to take into account and made available through linked web sites. Information on practical experience with floating buildings is made available.

The final result is a very easy usable case-based system which informs the user about synergetic and/or conflicting situations or difficulties that may occur during the final design and development stage of the floating greenhouses using the given requirements. E.g. the covering material can be selected between glass, plastic sheets or film, either in a single or double layer for many reasons. To achieve a high light transmission and consequently high production with fruit vegetables one might prefer glass as covering material. The consequence of this requirement is that a much more fixed construction with relative little deformation tolerance compared to a film covered greenhouse is needed to prevent glass damage. Using a traditional Dutch greenhouse construction (Venlo type) this means a very stable float with minimal deformation. If for other reasons (e.g. for reasons of producing the floats) the required float is a more small and flexible type, the conflicting requirements are indicated and it is suggested to reconsider the selections made in one of the modules. In this way the system generates interactive feedback to the user. The final output consists of an overall view of the final choices made and the resulting advice for type of float, type of greenhouse, energy conversion systems and required capacities (Fig. 8) and environmental control systems, suggestions for the way of construction, logistic systems to connect the floating greenhouse to the land and other relevant points to consider before entering the final design and engineering stage.

The scope and depth of this first version can and will be improved. The strategy used during development enables expansion of the system for either more in depth design of greenhouses or broadening the system for other floating functions.

The multidisciplinary approach with expertise from civil engineering, material experts and greenhouse specialists resulted in an unique software tool and integration of relevant and up-to date information for an innovative greenhouse design. Although the current application is demonstrative, the way of approach and the set up of the system enables rapid further development in the field of floating constructions.

ACKNOWLEDGEMENTS

The results described in this paper are performed within the framework of the project “Drijvende Kassen” (no TSGE 2005) funded by SENTER (Dutch Ministry of Economic Affairs). Besides the mentioned authors a wide range of experts in the field of construction, greenhouses, energy systems were included in the project team:
R. Haverkort (Intron), N.J. van de Braak, D. Waaijenberg, H.F. de Zwart, J. Campen (Agrotechnology and Food Innovations), P. Snel (Advin), L. Smal, T. Timmermans (Dura Vermeer) and the students M. Bunnik, L. Pieterse and G. Punt.

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Figures

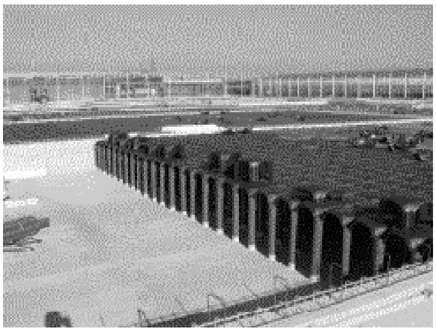

Fig. 1. Water storage under the greenhouse.

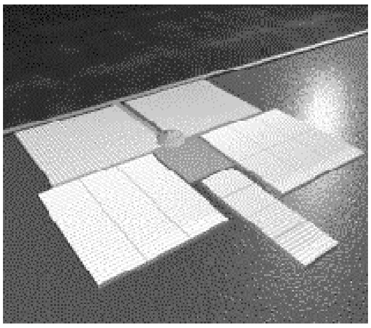

Fig. 2. Artist impression of floating greenhouses.

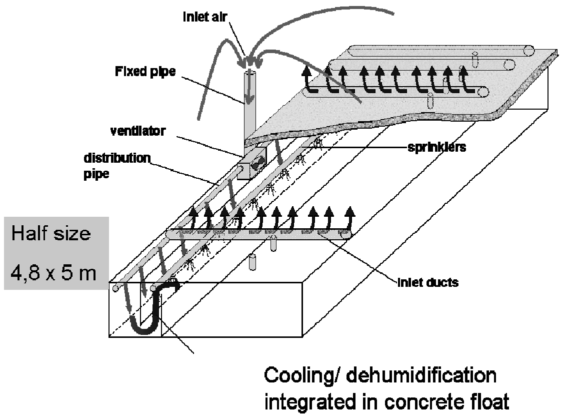

Fig. 3. Dimensions of a hollow concrete float (so called “bucket” system) with two vertical air ducts.

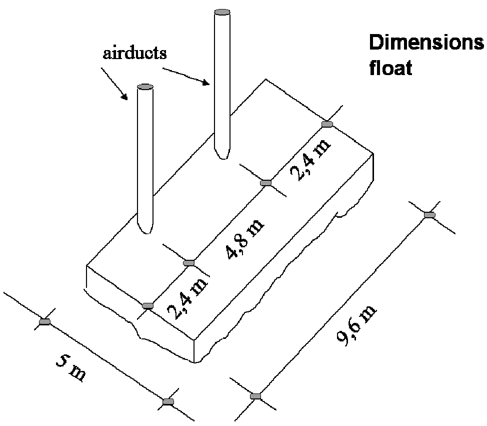

Fig. 4. Schematic overview of cooling/dehumidification system integrated in the float (this figure represents half of the system in one float). For description: see text.

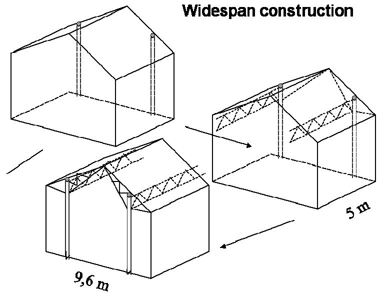

Fig. 5. Wide span construction based on the hollow concrete float with vertical air ducts as shown in Figure 3.

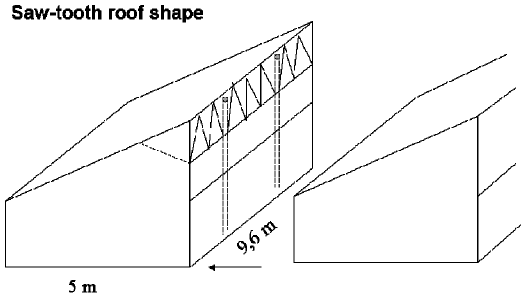

Fig. 6. Saw-tooth construction for the hollow concrete float with vertical air ducts as show in Figure 3.

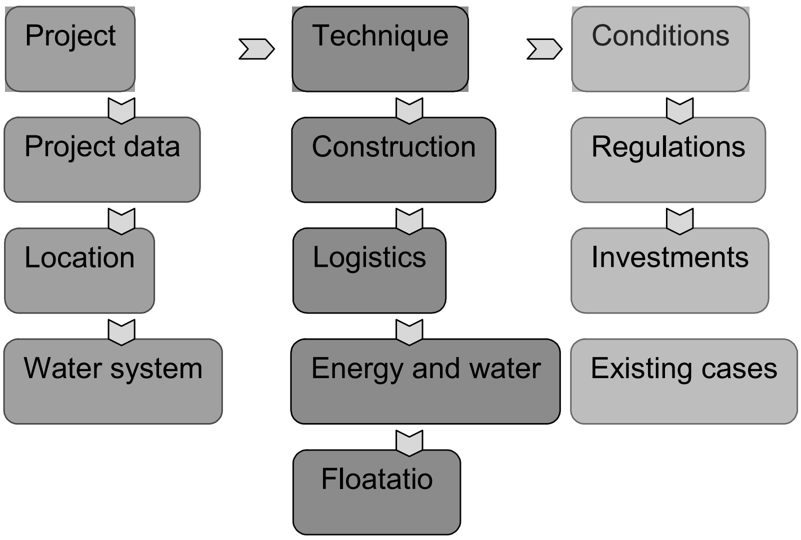

Fig. 7. Overview of all relevant modules of the expert system.

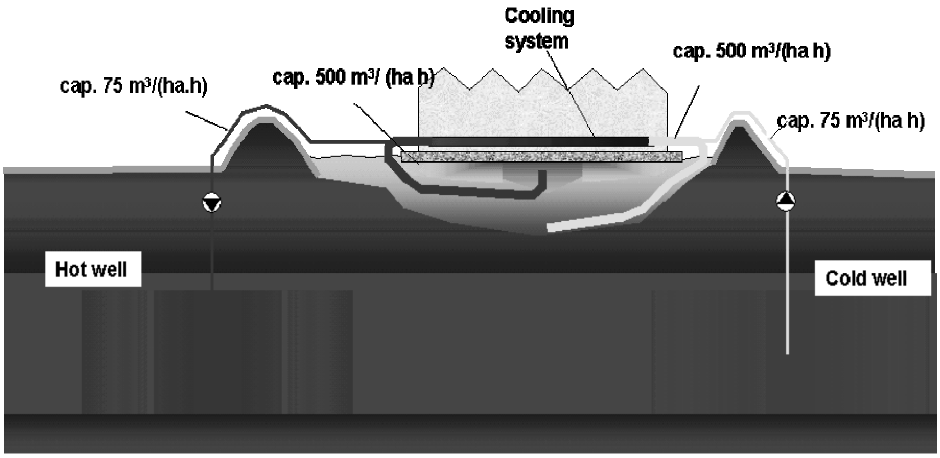

Fig. 8. Part of the final output of the expert system: system design and capacities for control of a floating closed greenhouse system based. The input by the user consists of (among others): type of greenhouse: closed, type of crop: tomato, type of water: water basin.