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Structural analysis of greenhouses: A case study in Turkey

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Abstract

This study was carried out to determine the structural and functional characteristics of the greenhouses in greenhouse enterprises of Turkey. Greenhouse enterprises are widely common along the Marmara, Aegean and Mediterranean cost lines. Marmara region was selected as the study area since it is the pioneering region and has large areas allocated to greenhouses, and has various greenhouse types. Information about greenhouse types, material properties, placement, and arrangement of greenhouses in the study area was gathered by a questionnaire; then greenhouses in enterprises were divided into groups based on cover material, load bearing materials and directional placement. A total of four types of greenhouse with the most economic cross-section, one from each group, were selected and load acting on structural members of greenhouses were calculated. Loads acting on beams of each greenhouse were analysed by Force Method and Moment Distribution Method. The results obtained were compared statistically to determine the best methodology for structural analysis of greenhouses. As a result, no statistical difference was found between moments and shear forces obtained from both methods. However, a difference occurred based on greenhouse types and it was determined that the values obtained for trussed block greenhouse were higher than the other ones.

Keywords: Greenhouse; Force method; Moment distribution method; Turkey

1. Introduction

Greenhouses provide a suitable environment for the intensive production of various crops. They are designed to provide control of solar radiation, temperature, humidity and carbon dioxide levels in the aerial environment. In hydroponics greenhouses, nutrient levels and root temperatures can also be controlled.

Turkey is located between the latitudes with sufficient light and temperature for greenhouse production. That's why it has advantages over Northern European countries. In 1975, there were approximately 3500 ha of glass and plastic greenhouses in Turkey and it increased to 9100 ha in 1985; and to 14,200 ha in 1995. Total greenhouse coverage reached 29,954 ha in 2003. Approximately 22% of the total greenhouses are glasshouses, and the remaining 78% are plastic houses [1,2]. Greenhouse culture in Turkey has been widely accepted by the growers in the Mediterranean, Aegean and Marmara regions. Initially, production in greenhouses has started out as family enterprises in the country. During the last decade, large agricultural enterprises with modern production techniques have been formed and they are common in Mediterranean region, and corresponding to about 20% of the greenhouses [3]. Marmara region has a greenhouse history of about 50 years and it is the pioneering region in cut-flower production. Being closer to large markets such as Istanbul has provided an advantage to the region over the other regions. With the experiences of the years, it is possible to see small family enterprises and larger commercial enterprises together with various greenhouse styles in the region. That is why, Marmara region was selected as the research area to represent the development of greenhouses in Turkey.

Greenhouses are constructed with a principle that they have a rigid load-bearing frame, which is placed at

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certain spans and not deformed under the loads acting on them, and a transparent cover material placed on them. Most of projects are designed through strength of material analysis. Structural design of greenhouse should bear safely to the wind, snow and plant loads and also allows a maximum light to the plants [4].

Based on frame material, there are four types of greenhouses in Marmara region; steel framed greenhouses, wooden framed greenhouses, steel and wood together framed greenhouses, and plastic tunnel type greenhouses. While steel framed glass covered greenhouses are common in commercial enterprises, wooden framed plastic covered greenhouses are common in small family enterprises. Various structural sections with different shape and cross-sections are used as frame material for steel framed greenhouses. Since smaller cross-section steel members are used in small family enterprises to reduce the cost of construction, the strength and economical life span of the greenhouses are small. Width of the steel framed greenhouses varies between 1.4–3.0 m and they have a length of about 33 m. Structural members are all made of wood the in wooden framed greenhouses and plastic is used as cover material. Since the strength of wooden frame is low against various loads, most of the greenhouses are destroyed by severe storms and high-speed winds. Width of the wooden framed greenhouses varies between 5 and 27.5 m, length of them varies between 25 and 50 m and height of them varies between 1.75 and 2.35 m. Steel and wood as construction materials are used in steel and wood together framed greenhouses and they have a lower cost and higher strength. Generally, plastic is used as cover material in these greenhouses and their width varies between 4 and 40 m, length of them varies between 22 and 40 m and height of them varies between 2 and 3 m [5]. In Yalova, farmers of the region in a short time adapted high tunnels constructed by using steel pipe section as frame material and they became common type of the region. These types are called ''tunnel type greenhouses'' and they are very common in small family enterprises. They are constructed with arc shaped one and half diameter pipe sections and these arc shaped sections are spaced 3 m from each other until the desired length. Width of these single unit greenhouses varies between 8 and 8.5 m and length of them varies between 30 and 40 m. Based on the angle of arc, their height varies between 2.5 and 3.5 m [6,7].

In this study, greenhouse types in greenhouse enterprises of Marmara region, which is the pioneering region in development of greenhouse facilities in the country, were evaluated and selected greenhouses were structurally analysed by using force method and moment distribution method. Final results were compared to determine the best method to be used in greenhouse analysis.

2. Materials and methods

2.1. Study area

Marmara region is located on the northwest of Turkey. The total surface area of the region is approximately $66,000\,km^2$, or about 8.5% of the total surface area of Turkey. It is surrounded by Black sea, Marmara and Aegean Sea (Fig. 1).

Marmara region exhibits a transition climate with average annual temperature of 14.4 °C and the lowest temperature of −25.7 °C in February. In Yalova Province, which has a climate similar to Mediterranean climate, summers are hot and dry and winters are warm and rainy. Average annual temperature is 14.3 °C and the average lowest temperature is −9.7 °C in February. The average number of cloudy days, which is an important factor for greenhouse temperature and photosynthesis, varies between 86.6 and 99.5. Another important factor in greenhouse design, the average annual wind speed is between 1.8 and 2.7 m/s and direction is 35.2 SSE. Annual shiny period varies between 6.42 and 7.42 h/min [8].

In Marmara region, greenhouse facilities are common in especially Yalova, Kocaeli, Balikesir, Sakarya, Canakkale, and Bursa provinces (Table 1). Greenhouses in the region are used for cut-flower and pot flower production. Ecological and positive market conditions and existence of skill, experience and knowledge about landscape plants have led the production toward the landscape plant production. The most important income source of Yalova province is from cut-flower production, and clove has 80%, cut rose has 10% and other flowers have 10% share in cut-flower production. There are 762 facilities in the province dealing with extensive cut-flower production. Also there is a few number of vegetable and hybrid seed producer in the region.

2.2. Structural analysis

Information about type, directional placement, and construction materials of greenhouses in the region was gathered by a questionnaire. Information obtained from questionnaire was evaluated and greenhouses in enterprises were grouped based on cover material, frame material, and directional placement. A total of four greenhouse type with the most economic cross-section, one from each group, were selected and detailed drawings were prepared for these greenhouses (Table 2). Then the structural analysis was performed for the selected greenhouse types by using force method and moment distribution method and the results were compared [9,10]. Before the application of both methods, loads acting on each beam of greenhouses due to own weights of the structural members (G),