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Finite Element Analysis of Composite Truss Structures Containing Pre-tensioned Cables

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Introduction

Composite materials have been used extensively to build truss structures owing to their remarkable properties. Composite truss structures have attracted tremendous research interests due to their superior strength and performances, and have been utilized in the construction of civil structures. Considerable efforts have been placed on the development and analysis of truss bridges, which usually consist of concrete and steel. Research works have been focused on material characteristics, truss joint design, and processing and construction of structural components. In the nineteenth century, composite trusses for aerospace applications were investigated [1-3], which are distinctly different from civil structures regarding materials, strength, stiffness, and weight. The effects of prestressed cables in composite structural system were studied [4]. In recent years, experimental study and numerical analysis have been carried out on composite space trusses with prestressed cables made of steel and compression members made of concrete [5,6]. The performances and characteristics of overall composite truss structures have been studied [7, 8].

Although publication works on composite trusses have been found in the literature, further investigation on systematic design and analysis of composite trusses containing pre-tensioned cables is needed. Unlike the previous research concentrated on civil structures, this paper is devoted to the study of light weight high strength composite truss structures, which can be employed in aerospace structures.

Finite Element Analysis

Various 2D and 3D composite truss structures will be first proposed, and two typical configurations are shown in Figures 1 and 2. The procedure of finite element simulation is similar to conventional approach. Based on the characteristics of structural members, they can be simulated as beams (compression-tension-bending element), bars (compression-tension element), and cables (tension-only element). It is known that the element type of ANSYS LINK10 is capable of dealing with tension-only property of cable structures. Equivalent material properties of structural members are applied. For example, the honeycomb sandwich panel will be approximated as orthotropic materials. Joints are assumed to be perfectly connected to truss members. Since this kind of finite element models involves tension-only elements, nonlinear solver of ANSYS will be applied. Convergent solution will be obtained under specified sub step settings. Once displacements are solved, the undeformed and deformed configurations of the truss can be generated (Figure 3).

In this study, tentative research tasks are proposed in the following:

1. Static analysis is carried out on 2D and 3D composite trusses with different configurations respectively.
2. The performances of composite trusses with pre-tensioned cable systems are studied in contrast with those without cables. The initial strain of tension-only cables can be specified.
3. Different positioning and configurations of pre-tensioned cables are studied. The deformations of the trusses with respect to variations of pre-tensioned forces are compared. The replacement of beam/bar structural members with pre-tensioned cables is discussed.
4. The effect of variation of stiffness and geometry of structural members on the strength of composite trusses is discussed.

Discussion and Design Considerations

By comparison of deformations and load distributions of truss members, the advantages and disadvantages of a variety of configuration designs can be attained. It is shown in this work that pre-tensioned forces of cables are of extreme importance to behavior of composite truss structures. Based on the numerical results obtained from finite element simulation, the key issues in configuration design are summarized.

It should be noted that the finite element simulation provided in this work only consider the strength under specified loading conditions. The aim of this study is to provide some general guideline for composite truss design. Optimal design of composite trusses can be achieved by comprehensive and systematic consideration of weight, strength, cost, and loading conditions, and this topic is beyond the scope of the current work.

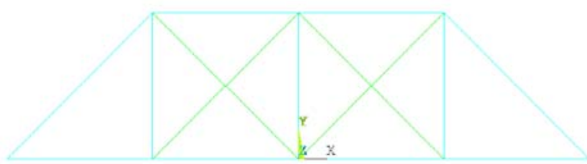

Figure 1. Schematic of a 2D truss

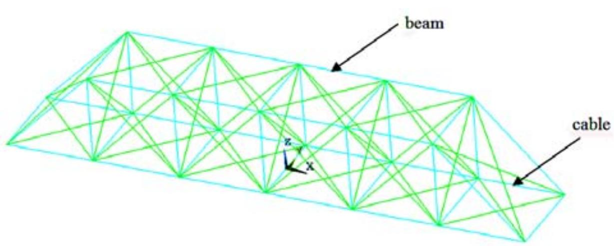

Figure 2. Schematic of a 3D composite truss

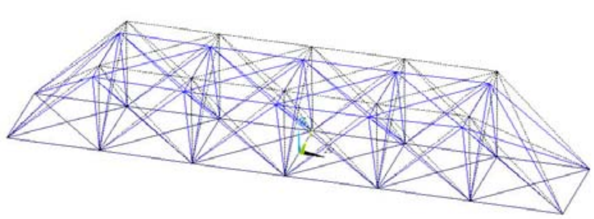

Figure 3. Undeformed and deformed configurations

Summary and Conclusions

In this paper, various configurations of composite trusses containing pre-tensioned cables are proposed and analyzed. The commercial finite element package ANSYS is used to study the static behavior of composite truss structures, and the deformations, strains, and stresses are obtained. The effect of pre-tension cables on structural stiffness and strength of composite trusses is studied. The key issues concerning configuration design of trusses are discussed.

The results indicate that appropriate and optimal positioning and pre-tensioned loading of cables has significant influence on the performance of composite trusses. This investigation can be used as a reference in configuration design of composite trusses containing pre-tensioned cables. This research work provides insight into the research and development of advanced composite structures suitable for aerospace application.

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