Abstract

Reviewing the history of cable structures, it can be found that the development of cable materials can significantly promote the development of structures. Carbon Fibre Reinforced Polymer (CFRP) is an advanced composite material with advantages of high strength, lightweight, no corrosion and high fatigue resistance, which makes it suitable to be made into cables and replace steel cables in a broad range of applications.

The application of CFRP cables is now driving the progress of cable structures. The ideal structures for such cables are orthogonally loaded cable structures, which can be defined as cable structures with a majority of cables orthogonally loaded or approximately orthogonally loaded by external loads. In orthogonally loaded cable structures, such as many cable roofs and cable facades, the structural stiffness is mainly comprised of the geometric stiffness which is controlled by the pre-tension force of cables, instead of the elastic stiffness controlled by the Young's modulus of cables. This means, for such cable structures, increasing the tensile strength of cables, which can bring about the increase of pre-tension force, is a more efficient way to either raise the structural stiffness if the amount of cable used remains unchanged or reduce the amount of cable used if the structural stiffness is maintained, compared to increasing the Young's modulus of cables. This phenomenon also implies that using CFRP cables, whose tensile strength is considerably greater than that of steel cables, in the orthogonally loaded cable structures will improve the economic efficiency of structures, although the Young's modulus of CFRP cables is usually smaller than that of steel cables and their unit price is also much higher.

To illustrate the above argument, after introducing the history of cable structures and their structural behaviours, the forms of elastic stiffness and geometric stiffness of cables were strictly derived in this book, and then cable structures were classified into orthogonally loaded cables structures and other cable structures according to the proportions of elastic stiffness and geometric stiffness in total structural stiffness, which are determined by the control angle, i.e. the angle between the cable axis and external load.

Afterwards, two typical orthogonally loaded cable structures, i.e. the cable net facade and the spoked wheel cable roof, were selected and investigated in two case studies

successively. The mechanical properties and economic efficiency of these two structures with CFRP cables of different Young's moduli and different tensile strengths were compared with those of the corresponding steel cable structures. Because these two orthogonally loaded cable structures have different control angles, the influence of this angle on the advantages of using CFRP cables in orthogonally loaded cable structures was subsequently studied through comparing these two CFRP cable structures with each other.

In addition to the advantages, the feasibility of using CFRP cables in orthogonally loaded cable structures is also investigated in this book. In order to solve the challenge of anchoring CFRP cables in such cable structures, new design principles for CFRP cable anchorages were proposed based on analysing the existing anchorages of CFRP cables. According to these principles, two novel CFRP cable anchorages, i.e. the winding-clamp anchorage and the thimble-clamp anchorage, were designed and proposed herein. FEM simulations and experiment verifications of these anchorages were also presented.

Then, a prototype CFRP spoked wheel cable roof, which was designed and built by the author and colleagues in Technical University of Berlin, was introduced to show the feasibility of the construction of CFRP orthogonally loaded cable structures based on the present technology. Furthermore, a novel form of using CFRP cables, i.e. the continuous band winding system, which is suitable for CFRP orthogonally loaded cable structures, was also proposed in this book. The CFRP continuous band winding systems do not need any anchorage and thus offering a complete solution for the problem of anchoring CFRP cables.

The research results show that CFRP cables can effectively improve the mechanical and economical performances of orthogonally loaded cable structures and this improvement for orthogonally loaded cable structures with the control angle closer to 90° is greater than that in such structures with this angle farther from 90°; the proposed two new designs of anchorages are able to anchor corresponding CFRP cables with 100% anchoring efficiency. The successful construction of the prototype structure shows that design and building of CFRP orthogonally loaded cable structures are feasible based on the present technology and moreover the continuous band winding system is a possible form of using CFRPs in orthogonally loaded cable structures very efficiently.