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Non linear behaviour of an inflatable beam and limit states

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Abstract

In this work, we consider inflatable beams and define their limit states, in terms of displacements, wrinkling, and collapse of the beam. The definition and properties of the collapse load are highlighted. Concerning the displacements, the strength of material dedicated to inflatable tubes has been studied by different authors, and is considered as well-known now in the linear part of the behavior (before the wrinkle appears). The need concerns now the behavior of the beam in the non-linear part of its behavior. An analytical formulation that allows to get the displacement in this non-linear part, i.e. between the winkling load and the collapse load has recently been written. This approach is here extended to the use of a beam finite element with which the displacements can be obtained from light loads to the collapse load of more complex structures. The case of an inflatable arch is presented as an example.

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Keywords: Inflatable beam, inflatable arch, pneumatic collapse, limit states, finite elements

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1. Introduction

1.1. Inflatables in construction

Textile structures are increasingly present in architecture. The basic principle of using fabrics in buildings is to previously ensure a pretension in the membrane. This pretension is carried out by using the action of air.

In the field of architecture, the various parts of the fabrics are joined together. Fabrics and joints can withstand relatively high tensions and it is possible to impose strong pressure in the inflatable elements. This leads to an increase of the stiffness.

Using inflatable beams directly to support loads is possible. They can be used as masts to support features such as lighting or cameras. It is also possible to join pressurized tubes and get frames that can be covered (see Fig. 1).

a b

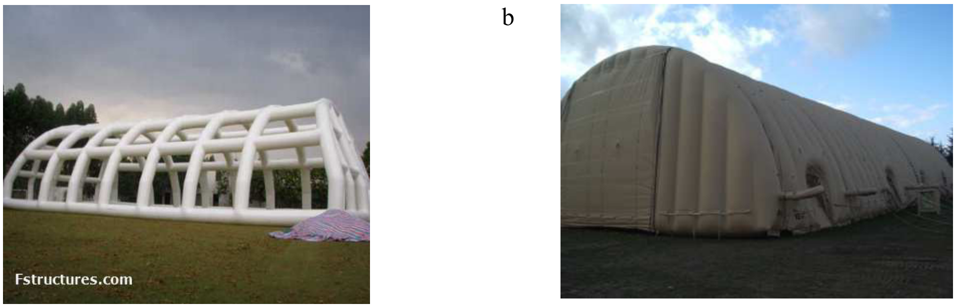

Fig. 1. Example of inflatable structures.

Assemblies of beams may also be used. The buildings of type of Figure 1. (b) may be considered as inflatable curved beams juxtapositions.

Although this is the simplest structural element, the mechanics of the inflatable beam allows to design more complex structures, if it is well known. The main features of its behavior may be generalized to all the air-inflated structures.

1.2. Normalization

The growing interest that the tensile textile structures cause makes it necessary to coordinate design rules in Europe. That is why the European community decided in 2010 to set up a working group in order to write a Eurocode dedicated to textile membrane structures.

In order to follow the Eurocode approach, it is necessary to clearly define the limit states and express them mathematically to perform a reliability analysis, since the calibration of partial safety factors can be done by using a semi-probabilistic method.

This work is focused on the behavior of an inflatable beam in general, in order to identify its limit states, and to present theoretical and numerical tools that can be used to design beam-type inflatable structures.

2. Behavior of an inflatable beam and definition of its limit state

2.1. Behavior of an inflatable beam

Let us consider a simply applied inflatable beam. The first step of use is the pressurization of the beam, which inducts to the structure its original geometry as well as its rigidity properties. The constituent material is supposed to be an orthotropic membrane that can represent a woven fabric coated. If one of the orthotropic directions of the