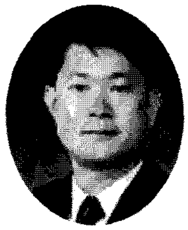
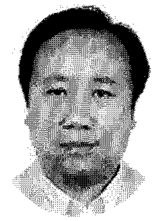
Uniaxial Tensile Test of ETFE Film

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1. Introduction

ETFE is the abbreviation of Ethylene Tetra Fluoro Ethylene, a sort of colorless and transparent granules. By extruding the base layer, ETFE film with 50μm to 300μm thickness is manufactured. With no base cloth, ETFE film has superior ability of daylight transmission and elongation while the strength of this material is lower than that of the fabric membrane[1].

The tensile strength of ETFE film changes from 40Mpa to 60Mpa and the tensile strain at break can get to about 400%. ETFE film is a sort of excellent transparent building material, which can transmit over 90% visible light. Comparing with the other transparent materials, ETFE film is superior to PVC film in the aging resistance, self-cleaning property, elongation and using temperature, and superior to glass in the resistance of destroy and lightweight[2].

ETFE film has been used as roof material since 1980s, such as the Eden Project in UK with the surface area of 30,000 m^2, Alliaze Arena in Munich (double layer air cushion) and AWD football station in Hanoverian (single layer). Now, the biggest ETFE project in the world is the National Swimming Centre for Peking 2008 Olympic Games, ETFE film covers 120,000 m^2 roof and wall surfaces.

The tensile properties of ETFE film are quite different from those of the fabric membrane materials. From the beginning of the tensile test to the end of break, the stress-strain curve passes two key points at which the slope of the curve changes greatly. The yield point of the material and the Young's modulus which are important in design, are usually determined by means of these two points. In this paper, the uniaxial tensile test of ETFE film is carried out and the tensile proprieties, such as the tensile strength, the strain at break, the yield stress, Young's modulus and Possion's ratio, are examined.

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2. Uniaxial tensile test

2.1 ETFE film specimen

Generally, the unfold direction of coiled ETFE film is called Machine Direction (MD for short) and the orthogonal direction Transverse Direction (TD for short). The dumbbell-shaped specimen shown in Fig 2 is used in the uniaxial tensile test and the specimens are taken from both Machine Direction and Transverse Direction[3].

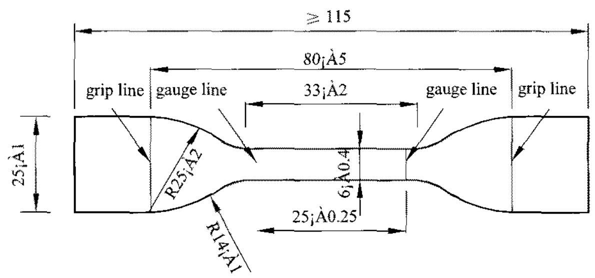

Fig 1. Dumbbell shaped specimen

2.2 Tensile speed

Tensile speed used in test has influence on the yield point, the tensile strength, the tensile strain at break, the Young's modulus, and etc. In this paper, tensile speed 50mm/min is taken in test, in this case, the tensile strain speed of the specimen between the gauge lines as shown in Fig 1 is about 100%/min.

2.3 Stress strain curves

The thickness the specimen in the test is 200μm and three specimens are cut from both MD and TD. In order to calculate the stress of specimen from the tensile load, the thickness of every specimen has been measured accurately. Fig 2 is the photo of the tensile test of ETFE film.

In calculating the stress of the specimen, the crossing area is obtained from the thickness and the width (at the part between the gauge lines) before the test starts, which means the change of the crossing area in test is ignored. The strain is calculated from the elongation of the two gauge lines. Fig 3 shows the stress-strain curves of ETFE specimens from test.

From Fig 3, it can be found that there are two key point A and B in the curse of stress and strain at which the slope of the curve changes greatly. When the stress is low (smaller than that of point A), the relationship between the stress and the strain can be taken as linear which means the film is in the elastic state. Usually, ETFE film should be designed in this elastic state. The stress of point A is about 17MPa while the strain 4%. When the stress becomes larger, the curse of stress and strain remains approximately straight, but the slope decreases immediately, until the next key point B appears. The film is considered as yield when the stress lies between point A and point B. When the stress passes the second key point B, the strain increases fast while the stress keeps growing slowly until the film breaks. The

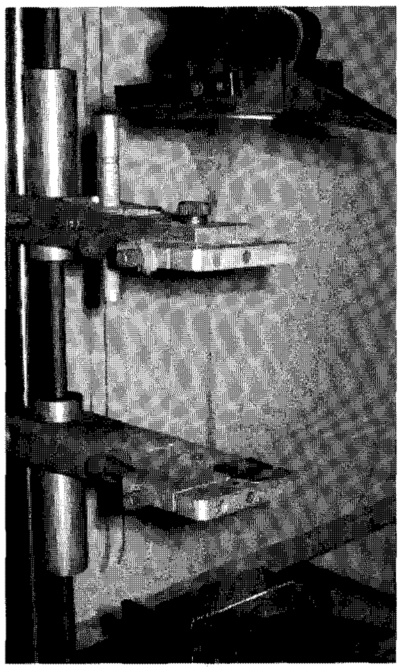

Fig 2. Tensile test of ETFE film

stress at break is about 50~60MPa while strain 350~400%.

Its is also found that there is no obvious difference between the tensile curves of the machine direction and the transverse direction, which means the ETFE film can be taken as an isotropic material.

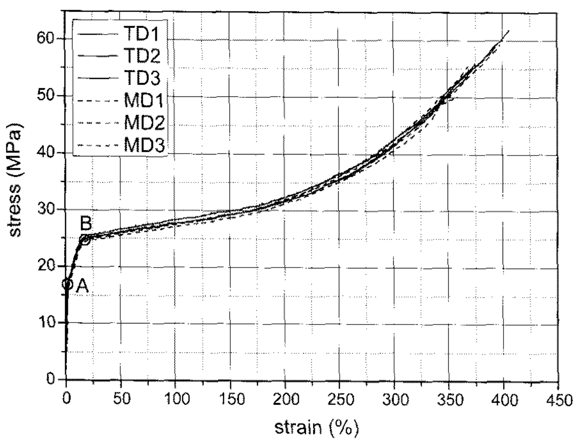

Fig 3. Stress strain curves of ETFE film

3 Mechnaical properities

3.1 Tensile strength and strain at break

According to the results of tensile test, the tensile strength and the strain at break of ETFE film are shown in Table 1.

Table 1 Tensile strength and strain at break

Direction	MD				TD			
Specimen	MD1	MD2	MD3	Average	TD1	TD2	TD3	Average
Tensile strength (MPa)	55.54	59.29	50.04	54.96	55.96	59.33	61.83	59.04
Strain at break(%)	369.0	398.1	359.9	375.7	375.1	394.9	406.3	392.1

3.2 Yield stress

As shown in Fig 3, the stress-strain curve of ETFE film experiences two rigidity turning point A and B. The slope of the curve between point A and B is far lower than that of the curve below point A, thus point A can be recognized as the beginning of yield. In order to get the yield stress, the method which takes the value of the crossing point of line a (see Fig 4, pass two key point A and B) and line b (the initial straight line) as the yield stress is convenient. Fig 4 shows the method of determining yield stress and the close-up of three typical stress-strain curves.

From Fig 4, the yield stress of ETFE film is 16.9MPa. This value is obtained when the tensile strain speed is 100%.

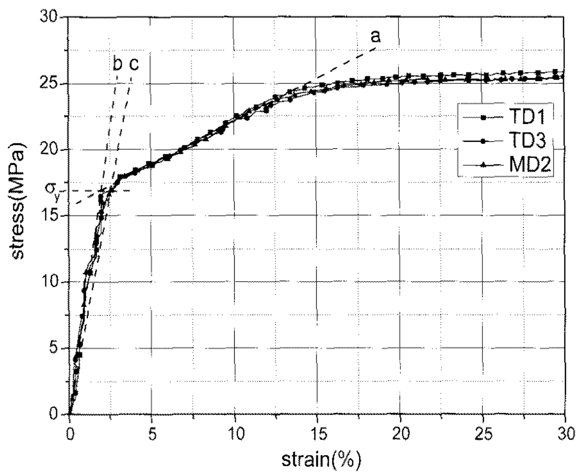

Fig 4. Determine yield stress and Young's modulus

3.3 Young's modulus and Poisson ratio

As shown in Fig 4, by using the point of the stress-strain curve at which the stress equals to the yield stress, we get line c. Line c can be considered as the secant line of the stress-strain curve while line a the tangent line. The Young's modulus of ETFE film when the stress is smaller than the yield stress can be estimated by means of the slope of line b or line c. The value from the slope of line b or line c is called the tangent Young's modulus or the secant Young's modulus, respectively.

The tangent Young's modulus of ETFE film from the test is 867MPa and the secant Young's modulus is 663MPa.

By the way, the slope of line a is 65.0MPa, which is only about 1/10 of the Young's modulus.

The Poisson ratio of ETFE film along the MD or TD is also obtained by using high resolution digital photos. The Poisson ratio is about 0.46 for both directions.

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References

1. S. Robinson-Gayle, M. Kolokotroni, A. Cripps and S. Tanno. ETFE foil cushions in roofs and atria. Construction and Building Materials 2001; 15:323-327.
2. The Membrane Structures Association of Japan. Recommendations for design and construction of ETFE film panels (draft). Research Report on Membrane Structures 2005; 19:II1-II51.
3. Chinese Standard GB 13022-91. Plastics-Determination of tensile properties of films.