WARSAW UNIVERSITY OF TECHNOLOGY Index 351733
FACULTY OF CIVIL ENGINEERING
COMMITTEE FOR CIVIL AND WATER ENGINEERING
POLISH ACADEMY OF SCIENCES ISSN 1230-2945

DOI: 10.24425/ace.2020.131799

ARCHIVES OF CIVIL ENGINEERING

Vol. LXVI ISSUE 2 2020

CHARACTERIZATION STUDY ON MECHANICAL PROPERTIES OF POLYESTER COATED FABRIC

A. AMBROZIAK [1]

The scope of the paper is to determine the mechanical properties of the Precontraint 1302 polyester coated fabric under uniaxial and biaxial tensile tests. The results are compared for Precontraint 1302 fabric and other types of coated fabrics. The author applied an orthotropic model and a dense net model to reflect the polyester coated fabric performance under uniaxial and biaxial tensile tests. Material parameters are specified for both constitutive models. In order to observe the variation of immediate mechanical properties, the biaxial cyclic tests are performed for different load ratios. During uniaxial and 1:1 biaxial tensile tests it is barely observable to recognize warp or weft directions on the stress-strain curves. Load history acts strongly on the mechanical properties of the Precontraint 1302 polyester fabrics. The cyclic loads cause variation of immediate longitudinal stiffness with a comparison of values determined for unloaded coated fabrics. The paper can provide scientists, engineers, and designers an experimental and theoretical basis in the field of polyester coated fabrics.

Keywords: polyester coated fabric; mechanical properties; uniaxial tensile test, biaxial tensile test, cyclic tests

[1] DSc., PhD., Eng., Prof. GUT, Gdansk University of Technology, Faculty of Civil and Environmental Engineering, St. Gabriela Narutowicza 11/12, 80-233 Gdansk, Poland, e-mail: ambrozan@pg.edu.pl, ORCID: 0000-0002-7735-7863

1. INTRODUCTION

Polyester coated woven fabrics are applied for temporary and permanent types of tensile structures. The coated woven fabric is also named technical woven fabric or architectural fabric. Coated woven fabrics are frequently used in civil engineering membrane or pneumatic tensile structures (see Fig. 1). The base fabric is a net of two thread families, named warp and weft (or fill), made of polyester, fibreglass or aramid fibre. The base fabric is both-side coated with the material like PVC (polyvinyl chloride), PTFE (polytetrafluoroethylene). In order to describe the coated woven fabric, a large number of constitutive models have been proposed and developed. A proper assessment of the mechanical properties acts strongly on the precision increase and economical design.

2. MATERIALS

The proposed research deals with experiments performed to specify the behaviour of the Precontraint 1302 S2 polyester coated fabrics back PVDF (polyvinylidene fluoride) under different tests with various load ratios. Additionally, a comparison is included of uniaxial and biaxial tensile test results with chosen polyester coated fabrics. This research is a supplement and development of the laboratory test described by Ambroziak [2], where biaxial tensile tests were investigated without the description of fabric behaviour under different load ratios. The basic properties of the Precontraint 1302 fabric, given by the manufacturer (see [14]), are total thickness 1.02 (mm), total weight 1350 (g/m2), yarn 1100/2200 Dtex (fiber decitex – the fineness of yarn – defined as the weight in g of 10000 m of the fabric material, see e.g. [15]) PES HT (high tenacity polyester yarns), tensile strength weft/warp 140/160 (kN/m), 300 microns thickness at the top of the yarns.

Fig. 1. Membrane hanging roof in Pruszcz Gdanski

In technical data typically published by manufacturers, no information is included on selected material parameters. These parameters, especially longitudinal stiffness, Poissons's ratio, are usually required while analysing a structure made of fabric. In order to specify longitudinal stiffness and Poissons's ratio, additional experimental tests should be carried out. The constitutive models used in numerical engineering calculations are usually simple and easy to identify by means of material parameters. The European Committee for Standardization (CEN) gives guidelines (see EN 17117-1 standard [12]) for biaxial stress state tests and methods for the determination of tensile sttifnesses and Poisson's ratios from biaxial load-strain test data.

In the proposed study, two different models known as orthotropic and dense net models are applied to characterize the Precontraint 1302 polyester coated fabric. Firstly, the dense net model is applied. The dense net model (see e.g. [3], [6]) belongs to the group of continuum models and can be used for preliminary design. This is possible since the coated woven fabric can be considered a continuum without an explicit reference to its discrete microstructure. The elasticity matrix $\mathbf{D}$ for the dense net model are:

$$\mathbf{D}_x = \begin{bmatrix} F_1(\varepsilon_1) + F_2(\varepsilon_2)\cos^4\alpha & F_2(\varepsilon_2)\sin^2\alpha\cos^2\alpha & F_2(\varepsilon_2)\sin\alpha\cos^3\alpha \\ F_2(\varepsilon_2)\sin^2\alpha\cos^2\alpha & F_2(\varepsilon_2)\sin^4\alpha & F_2(\varepsilon_2)\sin^3\alpha\cos\alpha \\ F_2(\varepsilon_2)\sin\alpha\cos^3\alpha & F_2(\varepsilon_2)\sin^3\alpha\cos\alpha & F_2(\varepsilon_2)\sin^2\alpha\cos^2\alpha \end{bmatrix}, \tag{1}$$

where $F_1(\varepsilon_1)$ and $F_2(\varepsilon_2)$ are stiffness functions of the threads. They can be called the longitudinal stiffness functions [kN/m], α is the actual angle between the thread families during the deformation process.

The determination of longitudinal stiffnesses is performed by means of piece-wise linear approximation for uniaxial and biaxial test results. Additionally, the range of load ratios for the proposed model is specified. It should be noted that the dense net model applied to coated woven fabrics was also successfully used by Lubowiecka [10, 11], to describe the surgical implant behaviour in hernia treatment.

Secondly, the mechanical behaviour of polyester coated fabric is described using an orthotropic model. In this model the elasticity matrix $\mathbf{D}$ can be written in the form [3]:

$$\mathbf{D} = \begin{bmatrix} \dfrac{F_1}{1-\nu_{12}\nu_{21}} & \dfrac{F_1\nu_{21}}{1-\nu_{12}\nu_{21}} & 0 \\ \dfrac{F_2\nu_{12}}{1-\nu_{12}\nu_{21}} & \dfrac{F_2}{1-\nu_{12}\nu_{21}} & 0 \\ 0 & 0 & G \end{bmatrix}, \tag{2}$$

where F_1 and F_2 are the values of longitudinal stiffness [kN/m]; ν_{12}, ν_{21} are the Poisson's ratios [-], G is the shear modulus [kN/m].

The symmetry of the elasticity matrix yields an additional condition to be fulfilled by the material parameters of the fabric $F_2\,\nu_{12} = F_1\,\nu_{21}$. The stresses may be calculated in directions representing warp (σ_1 [kN/m]) and weft (σ_2 [kN/m]). This is performed according to Eq. (2) as follows:

$$\sigma_1 = \frac{F_1}{1-\nu_{12}\nu_{21}}\left(\varepsilon_1 + \nu_{21}\cdot\varepsilon_2\right) \qquad \sigma_2 = \frac{F_2}{1-\nu_{12}\nu_{21}}\left(\varepsilon_2 + \nu_{12}\cdot\varepsilon_1\right). \tag{3}$$

a) b)

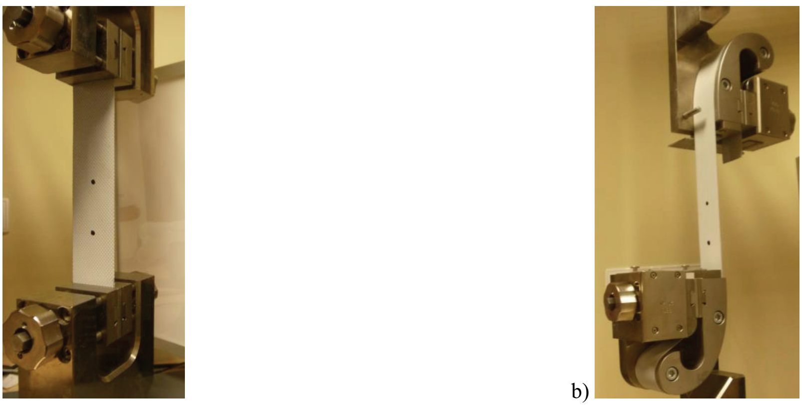

Fig. 2. Types of grips used in uniaxial tensile tests: a) flat, b) curved

3. LABORATORY TESTS

3.1. UNIAXIAL TENSILE TESTS

The initial laboratory tests applied for the analysed polyester coated fabric are the uniaxial tensile experiments. It should be noted, that the strip method (base method in ISO 1421 standard [8] while the alternative method in ASTM D751 standard [4]) and grab test methods are generally used to determine the tensile strength of coated fabrics. Both methods require a tensile machine with a constant rate of extension. Both standards show no recommendation for a video extensometer application in tensile tests (based on the digital image correlation method or feature extraction method). It should be mentioned that flat grips (see Fig. 2a) or curved grips (see Fig. 2b) can be applied during experiments. Nevertheless, to avoid close to grips breaks of specimens, that may be observed when the flat grips are used, the curve grips should be recommended. The curved grips cause more unique stress distribution near the fixing points; therefore, higher tensile strength values may be specified during laboratory tests.

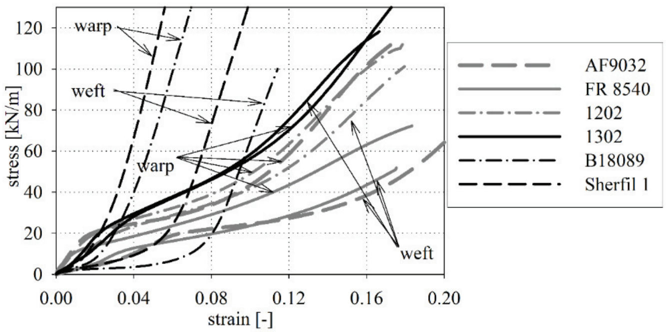

Fig. 3. Comparison of uniaxial tensile test results

The uniaxial tensile tests are carried out according to ISO 1421 standard [8]. According to standard requirements the grip separation of 200 mm, specimen width 50 mm and displacement rate of a flat grip of 100mm/min are accepted. Additionally, the constant base of an optical extensometer about 50mm is applied. All tests have been performed at room temperature (about 20°C) and carried out up to specimen failure. The seven specimens are tested in the warp and weft directions.

The stress-strain curves for Precontraint 1302 fabric are collected in Fig. 3 (solid lines) for uniaxial experiments and compares with other chosen polyester fabrics and PTFE coated fabrics. It can be observed that the stress-strain curves for weft and warp thread directions for Precontraint 1302 fabric are similar. The collection of chosen coated fabrics basic data are matched in Table 1.

Table 1. Basic data of chosen coated fabrics

	1302	1202	AF9032	FR8540	B18089	Sherfil I
weight [g/m^2]	1350	1050	1085	890	1150	1543
thickness [mm]	1.02	0.78	1.00	0.75	0.70	1.00
base material	PES HT	PES HT	PES	PES	fiberglass	fiberglass
type of coating	PVDF	PVDF	PVC	PVC	PTFE	PTFE
additional information	see [14]	see [13]	see [1]	see [7]	see [5]	see [17]

The tensile strength for the Precontraint 1302 polyester coated fabrics are collected in Table 2. The results of tensile strength are presented as a sum of mean values and standard deviations. It should be noted, that the differences between stress-strain curves (see Fig. 3) for thread directions are observed for AF9032 and FR8540 polyester coated fabrics. The shape and characteristics of stress-strain curves are typical for polyester coated fabrics: the stiffness in the warp direction is higher than in the weft direction, the strain under load for weft direction is greater than for warp direction. On the other hand, it can be seen that for and Precontraint 1302 fabric the differences between weft and warp directions are small. It can be concluded that the Precontraint 1302 fabric is manufactured under bi-directional tension during the manufacturing process. Additionally, the results for uniaxial tensile tests for Precontraint 1302 polyester fabric are compared with glass yarns coated with PTFE fabrics (Sheerfill-I and B18089), see Fig. 3. The PTFE coated fabrics show a low longitudinal stiffness in the first strain region and the next straightening is observed to failure of specimens. On the other hand, the polyester type fabrics show a specific shape of the stress-strain curves. Generally, for polyester coated fabrics 2-3 points of curvature change for the stress-strain curves can be distinguished, while for the PTFE coated fabrics a single point of curvature change is shown only.

Table 2. The value of stress at failure

	warp [kN/m]	weft [kN/m]
uniaxial	165.5±0.5	122±2
1:8	13.7±0.2	109±1
1:4	28.7±0.2	115±1
1:2	55±1	110±2
1:1	106±4	106±4
2:1	133±1	66±1
4:1	133.6±0.8	33.4±0.2
8:1	135.4±0.2	16.9±0.1

Table 3. Material parameters for the dense net model.

	F_1 [kN/m]	ε_1 [-]	F_2 [kN/m]	ε_2 [-]
uniaxial	600±25	0 ÷ 0.015±0.001	600±40	0 ÷ 0.01±0.002
	800±5	0.015±0.001 ÷ 0.038 ±0.001	1100±10	0.01±0.002 ÷ 0.025±0.001
	440±5	0.038 ±0.001 ÷ 0.118 ±0.001	420±5	0.025±0.001 ÷ 0.10±0.005
	1225±20	>0.118±0.001	1000±15	>0.10±0.005
biaxial 1:1	1600±10	0 ÷ 0.015±0.002	1950±20	0 ÷ 0.011±0.001
	440±20	0.015 ±0.002 ÷ 0.103 ±0.005	440±10	0.011±0.001 ÷ 0.092±0.002
	1020±50	>0.103±0.005	1000±50	>0.092±0.002

As mentioned above, for the stress-strain curves (see Fig. 3) the characteristic points of curvature change can be distinguished for the Precontraint 1302 polyester fabric under uniaxial tensile tests. According to this assumption, the inclination coefficients of straight lines F for warp and weft were determined. These coefficients specify the appropriate longitudinal stiffness. The longitudinal stiffness values F for uniaxial tests with strain ranges in Table 3 are given. Four intervals of the longitudinal stiffness are distinguished. The first region for warp and weft directions detects equal F values. In the second region, the increase of longitudinal stiffness for warp and weft is observed, while in the third region the stiffness for both warp and weft directions decreases, showing similar values (440 kN/m for warp and 420 kN/m for weft). Finally, when the warp and weft threads are straightened over 10% of strain, strengthening of the longitudinal stiffness occurs. These strengthening conditions remain up to the rupture of specimens.

It should be noted, that other types of tensile tests are performed. One of them is the off-axial tensile tests where the specimens are cut under different angles to warp and weft directions (contain different bias angles). This type of uniaxial test is used to analyse the failure mechanisms and strength criteria of coated fabrics, where e.g. Hashin fabric failure criterion is used (see e.g. [9], [18]).

3.2. BIAXIAL TENSILE TESTS

The biaxial experimental tests apply the strength-testing computer-operated Zwick machine, see Fig. 4. In the laboratory tests, the cross-shaped specimens are applied. The following geometry of specimens is used: cross length 400 mm and width 100 mm. Additionally, the grip separation 300 mm with a gage length of optical extensometer approximately equal 50 mm is applied. Biaxial tests are carried out with various constant load ratios. It should be clarified that load ratio $\sigma_1 : \sigma_2$ means proportion in the warp to the weft directions. The experiments are performed up to the failure of cross-shaped specimens. For biaxial tensile tests, the two samples are tested for each load ratio. The biaxial laboratory tests were performed according to an individual program.

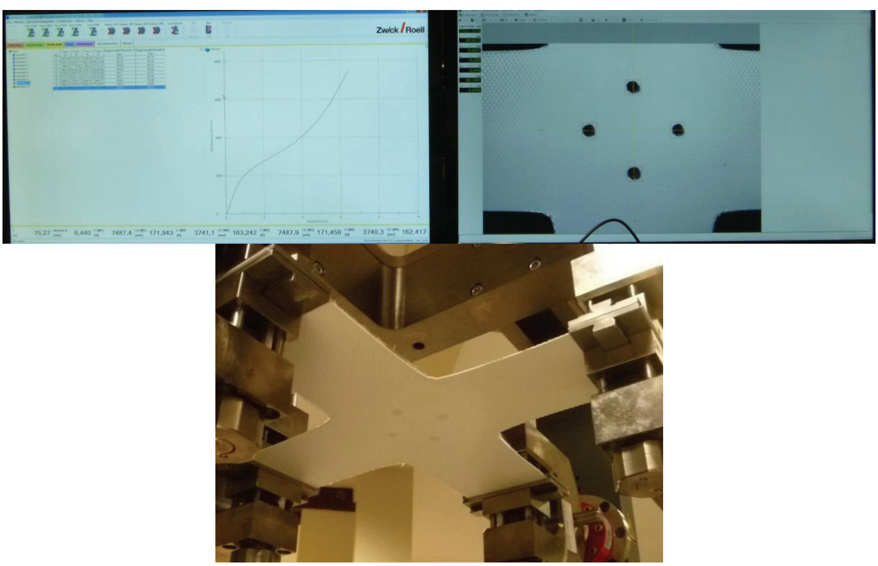

Fig. 4. Biaxial test stand

Firstly, the 1:1 biaxial tensile tests are carried out. The stress-strain curves for warp and weft directions under 1:1 biaxial tensile tests for the Precontraint 1302 and others chose polyester fabrics in Fig. 5 are compared. The shapes of the stress-strain curves for the Precontraint 1302 are similar like in uniaxial tensile tests for the warp and weft directions. Small shifts between the biaxial and uniaxial test results for the Precontraint 1302 are observed. The differences are observed for the first region of strains. Similarly to the uniaxial tensile test results, the longitudinal stiffness values are determined and collected in Table 3. The longitudinal stiffness values according to the second region for weft and warp directions are similar (about 440 kN/m) for 1:1 biaxial and uniaxial tensile tests. Additionally, it should be noted, that for AF9032 and FR8540 polyester coated fabrics differences between stress-strain curves for weft and warp directions are observed (like in the uniaxial tensile tests, see Fig. 3). On the other hand, it can be seen that for Precontraint fabric types (1302 and 1202) the differences between weft and warp directions are very small. It is hard to visually recognize the proper directions of warp and weft threads on the stress-strain diagram.

Following, the tensile tests for various load ratios are carried out. In Fig. 6 the stress-strain curves for biaxial tests are shown. The values of stresses corresponding to specimen failure are firstly determined and collected in Table 2. It can be assigned that the highest value of failure stress is received for the 8:1 load ratio. This value 135.4 kN/m reaches about 85% of uniaxial tensile strength given in Table 2. On the other hand, the lowest value is for 1:1 load ratio. It can be mentioned, that the lowest values of stress at failure for all investigated polyester fabrics are for 1:1 load ratio and the highest values are obtained while $\sigma_1 > \sigma_2$ (warp>weft).

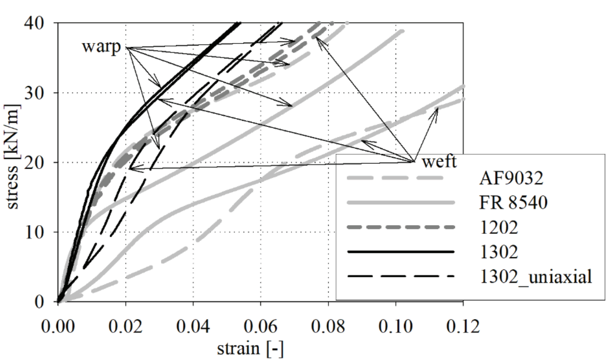

Fig. 5. Comparison of 1:1 biaxial tensile tests results

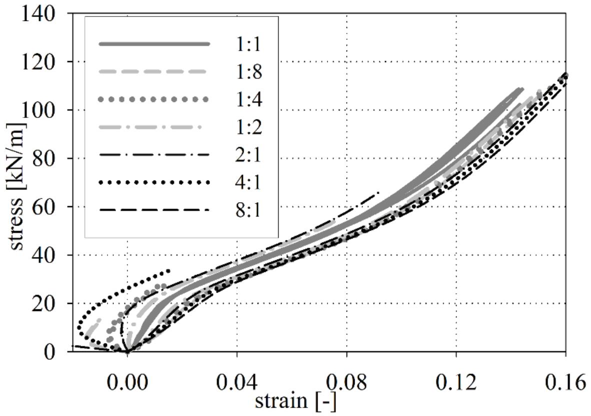

Fig. 6. Stress–strain curves with different load ratios

While one direction of threads net is more loaded than the other (e.g. warp direction in the 2:1, 4:1, 8:1 load ratios and weft direction in the 1:2, 1:4, 1:8 load ratios) the stress-strain curves are located close to 1:1 loading ratio case. On the other hand, in the direction of a lower load small negative strains occur. The large loaded thread of fabrics straightens while the others become folded. The Precontraint 1302 S2 fabric is suitable for the structures of comparable stresses in the warp and weft directions (about 1:1). Following these observations, it may be concluded, that in the preliminary design stage of engineering calculations the nonlinear parameters collected in Table 3 sufficiently characterize polyester coated fabric behaviour in the 2:1 ÷ 1:1 ÷ 1:2 stress ratio ranges.

Material parameters for an orthotropic model are determined in two cases: $\sigma_1 > \sigma_2$ and $\sigma_1 < \sigma_2$. It should be noted that the process of material parameter determination may be variable in their details. This process is sensitive to the initial values of the parameters. Thus, it is possible to obtain different values of the parameters for the same material. These different sets of parameters can exactly describe the behaviour of coated woven fabrics.

The case $\sigma_1 > \sigma_2$, when load proportions are: 2:1, 4:1, 8:1 the value of the Poisson's ratio ν_{12} is specified equal to 0.35 while the Poisson's ratio is calculated as $\nu_{21} = F_2 \cdot \nu_{12} / F_1$. The longitudinal stiffness values F_1 and F_2 are assumed according to Table 3, with an additional term F_2 equal to 420 kN/m (constant and determined for the third region). According to these assumptions, the value of ν_{21} ranges $0.120 \div 0.334$, constant in specific strain ranges.

The case $\sigma_1 < \sigma_2$, when load proportions are: 1:8, 1:4, 1:2 refers to a constant Poisson's ratio ν_{21} is also taken equal to 0.35 while the Poisson's ratio $\nu_{12} = F_1 \cdot \nu_{21} / F_2$. The longitudinal stiffnesses F_1 and F_2 are specified in Table 3. The additional conditions should be taken that F_1 equal to 440 kN/m (constant and determined for the third region). The values of the Poisson's ratio ν_{12} are $0.154 \div 0.367$. Numerical simulations (according to Eq. 3) and test results for 4:1 and 1:4 load ratios are compared in Fig. 7. The numerical simulation methodology is the same as in Ref. [2]. Compatibility is observed between numerical simulations and test results. The computed coefficient of determination R^2 (see e.g. [16]) fulfils the condition R^2>0.90. Good compatibility occurs between test results and numerical simulations.

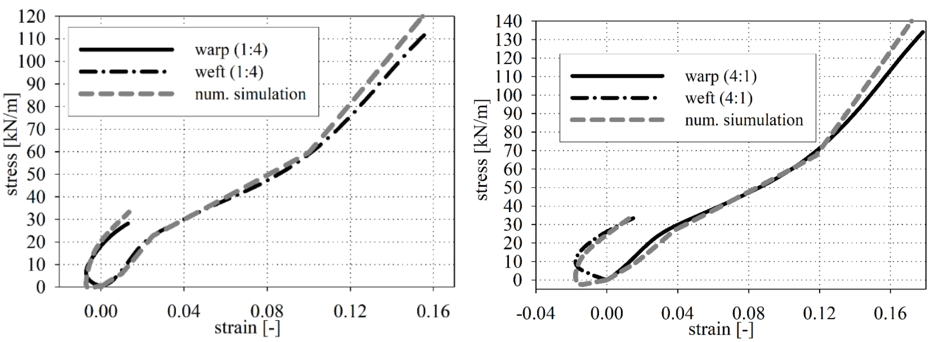

Fig. 7. Comparison of stress-strain curves with 1:4 and 4:1 load ratio

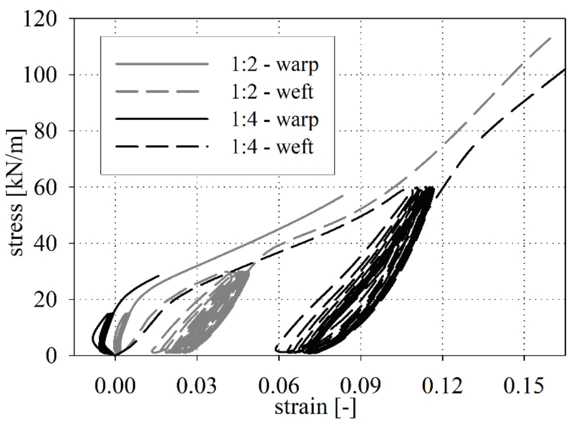

Fig. 8. Biaxial cyclic tensile stress-strain curves with 1:2 and 1:4 load ratio

3.3. BIAXIAL CYCLIC TENSILE TESTS

Biaxial cyclic tests are carried out to analyse variations of mechanical properties. The cyclic tests are performed for four various load ratios (1:2, 1:4, 2:1, 4:1), see Fig. 8. Each specimen is subjected to 20 cycles of loading and unloading. After cyclic loads, the specimens are tensioned up to rupture. In Figure 9 the stress-strain loading curves for N=0, N=1, and N=20 (where N is a number of the cycle) are drawn. Based on these loading curves, in Table 4 the residual strains $\varepsilon_I^{N=1}$, $\varepsilon_I^{N=20}$ and the $F^{N=1}$, $F^{N=20}$ are specified. It can be observed that the stress-strain loading curves tend to linear while the number of cycles grows. A similar conclusion occurred in the 1:1 cyclic tests investigated by Ambroziak [2]. The strains in the highly loaded thread directions are always positive while the strains in other directions are generally negative. The increment of residual strains and strengthening of longitudinal stiffnesses in each load cycle tends to zero. It can be concluded that while the number of cycles grows the specified mechanical parameters ($\varepsilon_I^{N\to\infty}$, F) stabilize.

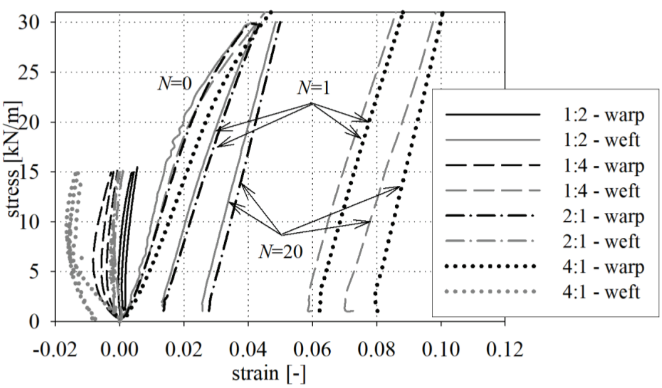

Fig. 9. Stress-strain loading curves

Table 4. Residual strains and longitudinal stiffnesses for specified cycles.

	warp				weft			
	$\varepsilon_I^{N=1}$ [–]	$\varepsilon_I^{N=20}$ [–]	$F^{N=1}$ [kN/m]	$F^{N=20}$ [kN/m]	$\varepsilon_I^{N=1}$ [–]	$\varepsilon_I^{N=20}$ [–]	$F^{N=1}$ [kN/m]	$F^{N=20}$ [kN/m]
1:2	0.00076[1)]	0.0018[1)]	2650[1)]	2815[1)]	0.0139	0.0257	968	1236
1:4	-0.0057[1)]	-0.0041[1)]	2425[1)]	2790[1)]	0.0598	0.0727	1093	1124
2:1	0.0136	0.0278	973	1284	0.00203[2)]	0.00198[1)]	2420[2)]	3232[1)]
4:1	0.0622	0.0803	1134	1489	-0.0152[1)]	-0.0135[1)]	2117[1)]	2667[1)]
1) over 5kN/m; 2) over 10kN/m								

4. DISCUSSION AND CONCLUSIONS

Mechanical behaviour is investigated of the Precontraint 1302 polyester coated fabric under uniaxial and biaxial tensile tests. In order to assess the Precontraint 1302 fabric characteristics, the results of uniaxial and biaxial tensile tests are compared with other fabric types (polyester and glass fiber fabrics). The Precontraint fabric shows a specific shape of stress-strain curve characteristics. During uniaxial and 1:1 biaxial tensile tests it is barely observable to recognize warp or weft directions on the stress-strain curves. In order to take advantage of the Precontraint fabrics in membrane structures, the stress ratios should be nearly the same. Load history acts strongly on the mechanical properties of the Precontraint 1302 polyester fabrics. The cyclic loads cause variation of immediate longitudinal stiffness (determined for unloaded coated fabrics). In this case, the non-linear characteristics of stress-strain curves under cyclic loads for weft and warp directions tend to linear.

The paper supplements and develops the former investigations carried out by the author and can provide scientists, engineers, and designers an experimental and theoretical basis in the field of polyester coated fabrics. The author used a similar methodology and laboratory devices in former investigations. The application of a similar procedure is necessary for the future comparison of mechanical properties of coated fabrics. The author intends to create a database of mechanical properties of coated fabrics.

The identification of material parameters for the dense net and orthotropic models is successfully performed based on tensile tests. The material parameters can be entered directly into finite element method analysis. The paper gives the designers directed into the structural design of fabric structure the necessary information on polyester coated fabric materials. Additionally, the paper is a possible base for new investigations. Given the mechanical properties of polyester fabrics undergoing uniaxial and biaxial tensile tests, it is possible to plan new detailed investigations of these materials. The obtained results encourage the author to continue the research, based on extended rheological experimental tests to assess parameters for time-variant constitutive models and on the bias biaxial tensile tests to the prediction of the bias tensile strength of coated fabrics with an application of different strength criteria.

REFERENCES

1. AF9032. Available online: https://www.architecturalfabrics.com/products/architectural-fabric-9032
2. A. Ambroziak, "Mechanical properties of PVDF-coated fabric under tensile tests" J. Polym. Eng. 35(4): 377-390, 2015.
3. A. Ambroziak, P. Kłosowski, "Review of constitutive models for technical woven fabrics in finite element analysis. AATCC Review 5-6: 58-67, 2011.
4. ASTM International, Standard Test Methods for Coated Fabrics, ASTM D751 (2011).
5. B18089 Available online: https://lightweightmanufacturing.com/wp-content/uploads/B18089-Type-III-Fabric.pdf
6. Cz. Branicki, Some Aspects of Cable nets static analysis, Ph. D. Dissertation, Gdansk University of Technology, Gdańsk 1969.
7. FR8540. Available online: https://www.mehler-texnologies.com/en/produkte-archive/8540-2/
8. ISO, Rubber or plastics-coated fabrics – Determination of tensile strength and elongation at brake, ISO 1421, 2016.
9. M. Klasztorny, D. Nycz, M. Cedrowski, "Modelling, simulation and validation of bending test of box segment formed as two composite shells glued together" Composites Theory and Practice 2: 88-94, 2015.
10. I. Lubowiecka, "Mathematical modelling of implant in an operated hernia for estimation of the repair persistence" Comput. Methods Biomech. Biomed. Engin. 18(4):438-45, 2015
11. I. Lubowiecka, C. Szymczak, A. Tomaszewska, M. Śmietański, "A FEM membrane model of human fascia – Synthetic implant systems in case of a stiff ventral hernia orifice." In Shell Structures: Theory and Applications; W. Pietraszkiewicz, I. Kreja, Eds., CRC Press: London, pp. 311-314, 2010
12. CEN, Rubber or plastics-coated fabrics – Mechanical test methods under biaxial stress states – Part 1: Tensile stiffness properties, EN 17117-1, 2018.
13. Precontraint 1202. Available online: https://www.sergeferrari.com/products/flexlight-range/flexlight-advanced-1202-s2
14. Precontraint 1302. Available online: https://www.sergeferrari.com/products/flexlight-range/flexlight-advanced-1302-s2
15. D. V. Rosato, M. G. Rosato, D. V. Rosato, "Concise Encyclopedia of Plastics". Kluwert Academic Publisher, 2000.
16. R.D. Retherford, M.K. Choe, "Statistical models for causal analysis". John Wiley & Sons, Inc., 1993.
17. Sherfill I. Available online: https://www.sheerfill.com/product-solutions/sheerfill
18. L. Zhang, "Off-axial tensile properties of Precontraint PVDF coated polyester fabrics under different tensile rates" Advances in Materials Science and Engineering Article ID 9856474: 1-12, 2016.

LIST OF FIGURES AND TABLES:

BADANIE WŁAŚCIWOŚCI MECHANICZNYCH POLIESTROWEJ TKANINY POWLEKANEJ

Keywords: poliestrowa tkanina techniczna, właściwości mechaniczne, testy jednoosiowe, testy dwuosiowe, testy cykliczne

STRESZCZENIE

Celem naukowym badań jest szczegółowe opisanie właściwości mechanicznych wybranej tkanin technicznych wykonanej z włókien poliestrowych typu Precontraint 1302. W pierwszym etapie badań poliestrowej tkaniny technicznej przeprowadzono badania jednoosiowe, prowadzące do zerwania próbki na kierunku wątku i osnowy oraz badania dwuosiowe do zerwania przy zastosowaniu stosunku sił rozciągających, odpowiadających odpowiednio następującym stosunkom naprężeń 1:8, 1:4, 1:2, 1:1, 2:1, 4:1, 8:1 ($\sigma_1 : \sigma_2$ gdzie σ_1 i σ_2 oznaczają naprężenia w kierunku osnowy i wątku). Wykorzystując model sieci gęstej, oraz model ortotropowy zidentyfikowano nieliniowo sprężyste parametry materiałowe, opisujące zachowanie się badanej poliestrowej tkaniny technicznej. W artykule przedstawiono wyniki dwuosiowych badań cyklicznych dla stosunków naprężęń 1:4, 1:2, 2:1, 4:1. W celu określenia zmiany doraźnych parametrów sztywności na kierunku wątku i osnowy, wyznaczono wartości modułu odkształcenia podłużnego (sztywność na rozciąganie) i odkształceń rezydualnych dla poszczególnych testów. Zaobserwowano wyraźną zmianę sztywności doraźnej w analizowanych zakresach naprężeń. Wraz ze wzrostem zakresu naprężeń, zaobserwowano asymptotyczny przebieg zmian końcowej sztywności tkaniny.

Artykuł uzupełnia i rozwija badania prowadzone przez Ambroziaka [2]. Poznanie i opisanie właściwości mechanicznych danego materiału badanego w różnorodnych warunkach stanowi podstawę do jego szerszego zastosowania i wykorzystania w różnych gałęziach przemysłowych. Wyznaczone parametry mechaniczne, opisujące tkaninę techniczną pozwalają na ukierunkowanie innych badań nad charakterystycznymi parametrami badanych tkanin. Inżynierom projektantom wyznaczone właściwości wskazują na potencjalne możliwości jak najlepszego ich wykorzystania w projektowanych konstrukcjach inżynierskich.

Received 10.08.2019, Revised 08.04.2020