ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

NEW APPROACH FOR PREDICTING SHAPE OF GEOTEXTILE TUBES BASED ON DEGREE OF FILLING FA

YASSINE AMALLAS [1], YOUSSEF AJDOR [2]

[1]Laboratory of Civil Engineering, Mohammedia School of Engineers, Av Ibn Sina B.P 765, Agdal -Rabat. Morocco

[1]Laboratory of Civil Engineering, Mohammedia School of Engineers, Av Ibn Sina B.P 765, Agdal -Rabat. Morocco

E-mail: [1] yassine.362@gmail.com ; [2] ajdor@emi.ac.ma

ABSTRACT

Geotextile tubes are severally more and more used in maritime field as systems to protect beaches against coastal erosion or as core of dykes. They are envelope of geotextile in the form of tubes, filled by pumping sand or other dredging material and installed in the site to protect the beach against erosion. The predicting of dimensions of these tubes is very important. In literature, because these dimensions give the structure its stability against several conditions of wave and current of the site installation. There are many studies to calculate dimensions of these structures (Silvester 1986 [6], Leshchinsky et al. 1996 [2] [3] [4], Kazimirowicz 1994 [5], Plaut and Suherman 1998, Malík 2009, Cantré and Saathoff 2010 [6], Chu et al. 2011, Guo et al. 2011, 2013), but they require the running of a computer program and this limit their access to general public. The most popular is the approach presented by Leshchinsky et al. (1996)[2] in the program GeoCoPS 2.0 [3] [4].

In this paper, a new numerical approach was established to calculate dimensions of geotextile tubes regarding the filling rate FA (%).The results were presented in an computer program. The approach developed is based on same relationship used by Leshchinsky and other authors and iterations of all parameters. At the conclusion of this paper formulas, depending only on FA (%), to calculate dimensions of filled geotextile tube are proposed.

Keywords: *Geotextile Tubes, Coastal Erosion, Filling Rate, Predicting Of Dimensions, Computer Program.*

1. INTRODUCTION

When a geotextile tube is empty and lying flat on the ground surface, its width is equal to half its circumference. When it is fully filled (degree of filling 100%), it has a circular shape with a radius $R_{100\%}$ = circumference/2.π). In practice, a degree of filling of between 60% and 85% can only be obtained [1].

The shape of geotextile tube is obtained where the underside of the cross-section is flat, the sides approximate quadrants of a circle and the upper side approximates a (half) ellipse [1].

With a certain degree of filling FA (%), theses conventions and notations are considered:

B: width Contact with subsoil (m);
W: Total width of geotextile tube (m);
H: Height of geotextile tube (m);
r: Radius of quadrant circle (m);
a: Major axis of the half ellipse (m);
b: Minor axis of the half ellipse (m);
c: Focal length of the half ellipse (m);
L: Circumference of geotextile tube (m);
A: Area of geotextile tube (m²);
P_0: Initial pressure (pumping pressure) (Kpa);
F_A: Degree of filling regarding to the area (%);
F_H: Degree of filling regarding to the height (%);

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

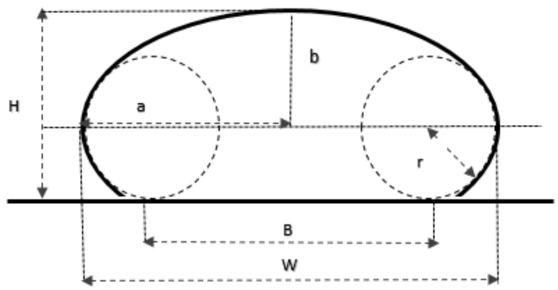

Figure 1. Cross section view of geotextile tube: convention and notation

In literature, the degree of filling FA (%) is expressed as a percentage of the theoretical cross-sectional area of a 100% filled geotextile tube:

$$F_A = \frac{A}{A_{100\%}}.$$

However, in practice, the degree of filling is usually related to the theoretical height of the tube at 100% filling FH. Because it is more easy to measure the height than the area of the cross-sectional witch is impossible to measure during filling phase:

$$F_H = \frac{H}{H_{100\%}} = \frac{H}{2.R_{100\%}}$$

2. ASSUMPTIONS

Manuscripts must be in English (all figures and text) and prepared on Letter size paper (8.5 X 11 inches) in two column-format with 1.3 margins from top and .6 from bottom, and 1.25cm from left and right, leaving a gutter width of 0.2 between columns.

The following assumptions are considered in the establishment of the program:

The problem is tow-dimensional (i.e plane strain) in nature. The geotextile tube is long and all cross-sections are perpendicular to the long axis are identical in terms of geometry and materials. Hence, the pressure loss due to drainage through the geotextile tube during filling and possible material segregation is ignored.

- The geotextile shell in thin, flexible and has negligible weight per unit length;
- No shear stresses develop between the material filling and geotextile.

The geotextile tensile force T along the circumference of geotextile tube must be constant, since there is no shear stress between filling material and geotextile, and it is equal to that develop in the quadrants of circle:

$$T = P.r$$

With P is the pressure in geotextile at the contact between the quadrant circle and the subsoil:

$$P = P_0 + \gamma H$$

The pressure along the base B in geotextile is constant and equal to P, the equilibrium of forces in the base B gives the following formula:

$$P \times B = \gamma \times A.$$

3. METHODOLOGY AND PROGRAM ESTABLISHED

A computer program was established for the determination of the shape of geotextile tube. It is basing in the principle of iteration.

This program is based on degree of filling and the circumference as inputs and gives F_H ; a ; b ; r as intermediary results, and H ; B ; W ; T as final results.

For the half ellipse, we have:

$$c = \sqrt{a^2 - b^2} = \sqrt{(a - b)(a + b)} = \frac{B}{2}$$

So, $$(a - b)(a + b) = \frac{B^2}{4} \quad (1)$$

And $$b = H - r = H - (a - c) = \frac{B}{2} + H - a$$

So, $$a + b = H + \frac{B}{2} \quad (2)$$

We change $(a + b)$ in formula (1) and we obtain theses equations:

$$a - b = \frac{B^2}{4H + 2B} \quad (3)$$

The summation of $(2) + (3)$ gives

$$2a = H + \frac{B}{2} + \frac{B^2}{4H + 2B}$$

So, $$a = \frac{2H + B}{4} + \frac{B^2}{8H + 4B} \quad (4)$$

(2) – (3) gives $2b = H + \frac{B}{2} - \frac{B^2}{4H + 2B}$

So, $$b = \frac{2H + B}{4} - \frac{B^2}{8H + 4B} \quad \textbf{(5)}$$

We have $r = a - c = \frac{2H + B}{4} + \frac{B^2}{8H + 4B} - \frac{B}{2}$

So, $$r = \frac{2H - B}{4} + \frac{B^2}{8H + 4B} \quad \textbf{(6)}$$

As the shape of geotextile tube is assimilated to a half-ellipse, two quarter of circle and a rectangle, the circumference and the area of geotextile tube are given by the formulas (7) and (8).

$$L = B + \pi r + \frac{\pi}{2}\sqrt{2(a^2 + b^2)} \quad \textbf{(7)}$$

$$A = \frac{\pi}{2}ab + Br + \frac{\pi}{2}r^2 \quad \textbf{(8)}$$

The total with W of geotextile tube is given by formula:

$$W = B + 2.r \quad \textbf{(9)}$$

In order to determine different dimensions of the filled geotextile tube at a certain degree of filling F_A (%), we follows these steps.

3.1. Step 1: initial parameters

a) Take the first approximation for F_{H0} as $F_{H0} = \frac{F_A}{1.2}$ and $B_0 = R_{100\%}$

b) Calculate : $H_0 = 2.R_{100\%}.F_{H0}$

c) Calculate r_0 ; a_0 ; b_0 ; A_0 and W_0 by equations above

3.2. Step 2 : intermediate iterations

a) For each i in the serie , we calculate L_i , r_i , a_i , b_i , H_i , A_i , B_i, $L_{irecalculated}$, F_{Ai}, $F_{Ai\,recalculated}$ and F_{Hi} as follow:

$$L_i = L$$

$$F_{Ai} = F_A$$

$$F_{Ai\,recalculated} = \frac{A_i}{A_{100\%}}$$

$$F_{Hi} = F_{Hi-1} + \frac{F_{Ai} - F_{Ai-1\,recalculated}}{100}$$

$$H_i = 2.R_{100\%}.F_{Hi}$$

$$B_i = B_{i-1}\left(1 + \frac{L_{i-1} - L_{i-1\,recalculated}}{L}\right)$$

$$L_{i\,recalculated} = B_i + \pi r_i + \frac{\pi}{2}\sqrt{2(a_i^2 + b_i^2)}$$

$$r_i = \frac{H_{i-1}^2}{2H_{i-1} + B_i} ;$$

$$a_i = \frac{2H_{i-1} + B_i}{4} + \frac{B_i^2}{8H_{i-1} + 4B_i} ;$$

$$b_i = \frac{2H_{i-1} + B_i}{4} - \frac{B_i^2}{8H_{i-1} + 4B_i} ;$$

$$A_i = \frac{\pi a_i b_i}{2} + B_i r_i + \pi\frac{r_i^2}{2} ;$$

b) We compare for each i :

- $F_{Ai\,recalculated}$ and F_{Ai} and F_{Ai-1}
- $L_{i\,recalculated}$ and L_i and L_{i-1}
- F_{Hi} and F_{Hi-1}
- B_i and B_{i-1}
- r_i and r_{i-1}
- a_i and a_{i-1}
- b_i and b_{i-1}
- A_i and A_{i-1}
- W_i and W_{i-1}

3.3. Step 3 : final results

We repeat the step 2 until we obtain theses equalities, with an error marge of 10^{-6}):

- $F_{Ai\,recalculated} = F_{Ai} = F_{Ai-1} = F_A$
- $L_{i\,recalculated} = L_i = L_{i-1} = L$

Journal of Theoretical and Applied Information Technology
15th December 2018. Vol.96. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

- $F_{Hi} = F_{Hi-1}$
- $H_i = H_{i-1}$
- $B_i = B_{i-1}$
- $r_i = r_{i-1}$
- $a_i = a_{i-1}$
- $b_i = b_{i-1}$
- $A_i = A_{i-1}$
- $W_i = W_{i-1}$

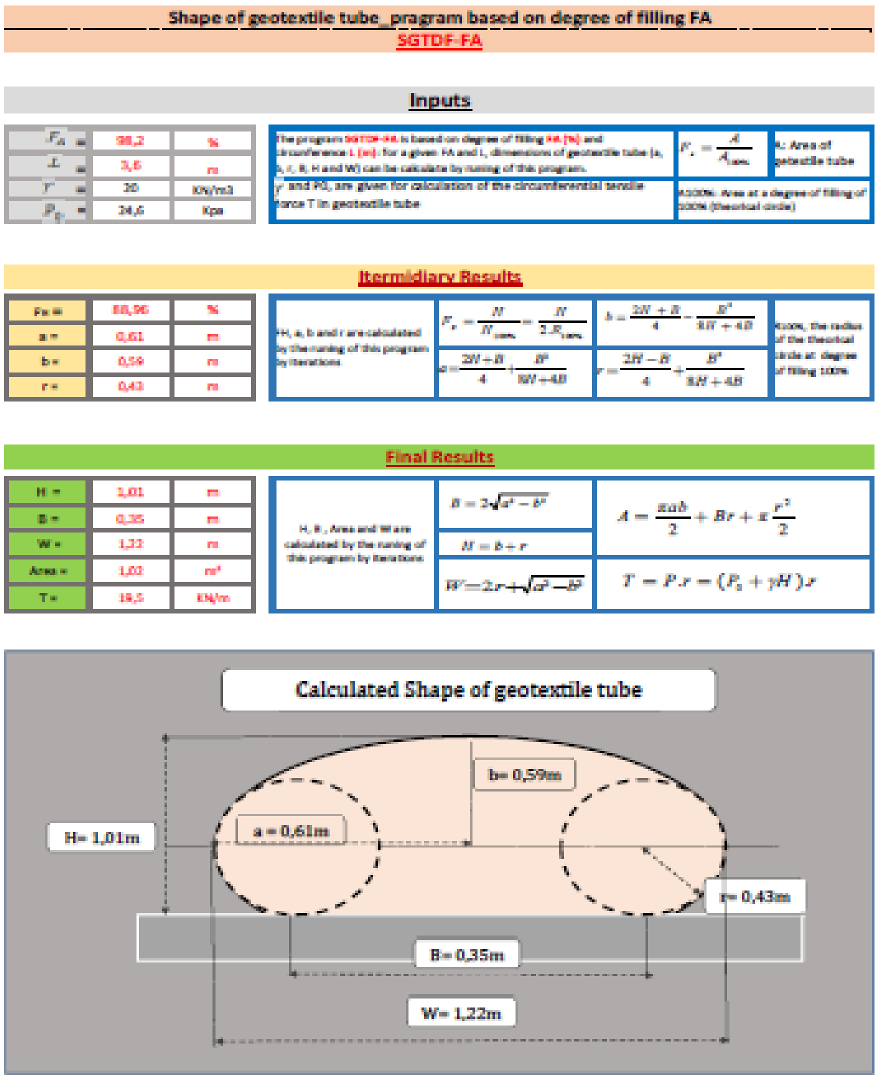

Figure 2: Computer program for determination of the shape of a filled geotextile tube based on F_A

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4. RESULTS : DETERMINATION OF CHARACTERISTIC DIMENSIONS OF GEOTEXTILE TUBE AS A FUNCTION OF DEGREE OF FILLING

4.1. Degree of filling FH as a function of degree of filling FA

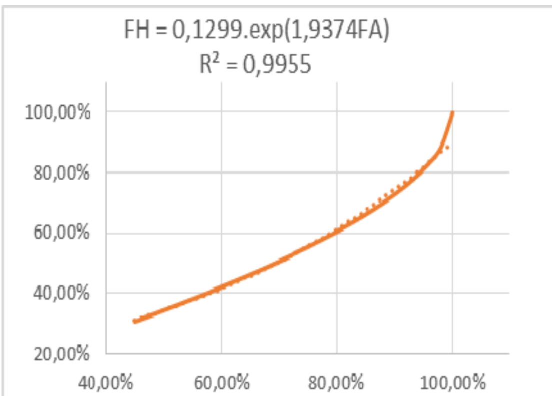

Figure3: Degree of filling F_H as a function of degree of filling F_A

$$F_H = 0.1299.\exp(1.9374 \times F_A)$$

This equation is obtained from results of the established program for degree of filing FA between 45% and 98% and a very small error marge between -2% and 2%.

4.2. Height of tube as a function of degree of filling FA

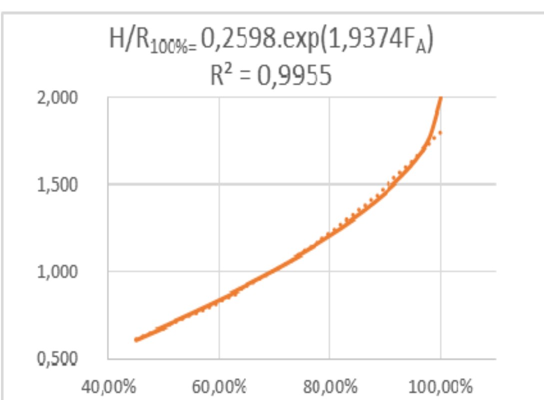

Figure 4: Height of geotextile tube as a function of degree of filling F_A

$$H = 0.2598 \times R_{100\%}.\exp(1.9374 \times F_A)$$

This equation is obtained from results of the established program for degree of filling FA between 45% and 98% and with a very small error marge between -2% and 2%.

4.3. Width of tube B as a function of degree of filling FA

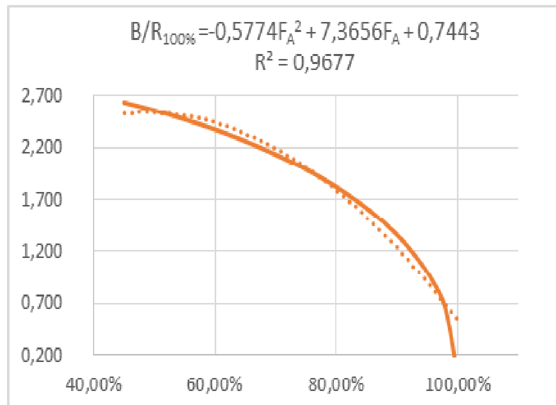

Figure 5: Width of geotextile tube as a function of degree of filling F_A

$$B = R_{100\%} \times (-7.5774F_A^2 + 7.3656F_A + 0.7443)$$

This equation is obtained from results of the established computer program for degree of filing FA between 45% and 98% and with a very small error marge between -3% and 4%.

4.4. Total Width of tube W as a function of degree of filling FA

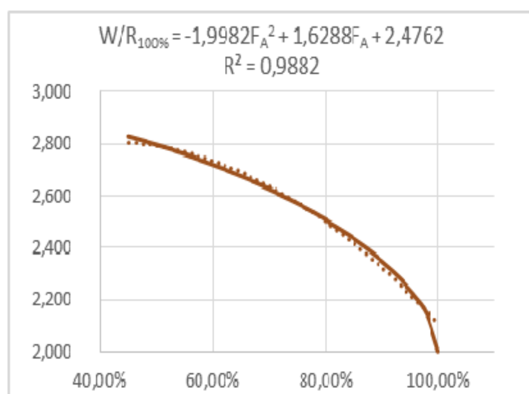

Figure 6: Total width of geotextile tube as a function of degree of filling F_A

$$W = R_{100\%} \times (-1.9982F_A^2 + 1.6288F_A + 2.4762)$$

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

This equation is obtained from results of the established program for degree of filing FA between 45% and 100% and with a very small error marge between -1% and 1%.

4.5. Radius of the quadrant circle of tube r as a function of degree of filling FA

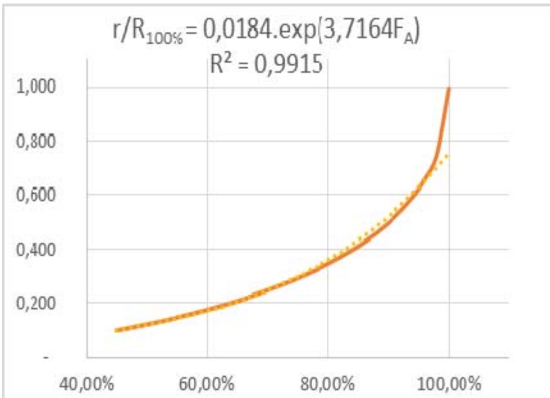

Figure 7: Radius of the quadrant circle of geotextile tube as a function of degree of filling FA

$$r = 0.0184 \times R_{100\%}.\exp(3.7164 \times F_A)$$

This equation is obtained from results of the established program for degree of filing FA between 45% and 98% and with a very small error marge between -2% and 5%.

5. COMPARISON WITH EXISTING METHODS

Different results obtained from the established program SGTDF-FA were compared with three most existing popular methods in literature. Leshchinsky et al. 1996 (computer program GeoCoPS) [2] [3] [4] Silvester (1986) [6] and A.Bezuijen and E.W.Vastenburg (2013) [1].

As exposed in tables and figures below, the comparison highlights that there is a very good agreement between SGTDF-FA and the three methods.

5.1. Comparison with A.Bezuijen and E.W.Vastenburg (2013)

It is demonstrated from the established computer program that with a certain degree of filling FA (%) of the geotextile tube, the degree of filling FH (%), relative radius of curvature r/R100%, relative width B/R100%, relative total width W/R100% and relative height H/R100% have the same values regardless of the circumference L. Tables 1 to 3 show the comparison between the values of W, H and r for the established computer program and recommendations of A.Bezuijen and E.W.Vastenburg. There is a very good agreement between the two methods.

Table 1: Comparison of total width W of the established program and A.Bezuijen and E.W.Vastenburg [1]

F_A (%)	$W/R_{100\%}$ (-)		
	Bezuijen & Vastenburg	Amallas	Difference (%)
100%	2.00	2.00	**0%**
95%	2.28	2.24	**2%**
90%	2.40	2.35	**2%**
85%	2.49	2.44	**2%**
80%	2.56	2.51	**2%**
75%	2.63	2.57	**2%**
70%	2.69	2.63	**2%**
65%	2.74	2.68	**2%**
60%	2.79	2.72	**3%**

The table 1 shows that there is a very good numerical agreement for the total width of geotextile tube W between the values calculated from the established program and those prescribed by A.Bezuijen and E.W.Vastenburg.

Table 2: Comparison of Height H of The Established Program and A.Bezuijen and E.W.Vastenburg [1]

F_A (%)	$H/R_{100\%}$ (-)		
	Bezuijen & Vastenburg	Amallas	Difference (%)
100%	2,00	2,00	**0%**
95%	1,59	1,62	**-2%**
90%	1,42	1,45	**-2%**
85%	1,29	1,32	**-2%**
80%	1,17	1,21	**-3%**
75%	1,07	1,11	**-3%**
70%	0,98	1,01	**-3%**
65%	0,89	0,92	**-4%**
60%	0,81	0,84	**-4%**

The table 2 shows that there is a very good numerical agreement for the height of geotextile tube H between the values calculated from the established program and those prescribed by A.Bezuijen and E.W.Vastenburg.

Table 3: Comparison of radius of curvature of the established program and A.Bezuijen and E.W.Vastenburg [1]

FA (%)	r/R100% (-)		
	Bezuijen & Vastenburg	Amallas	Difference (%)
100%	1,00	1,00	**0%**
95%	0,70	0,62	**11%**
90%	0,58	0,50	**15%**
85%	0,50	0,41	**18%**
80%	0,43	0,34	**20%**
75%	0,37	0,29	**21%**
70%	0,32	0,25	**23%**
65%	0,28	0,21	**26%**
60%	0,24	0,17	**27%**

The table 3 shows that there is generally a numerical agreement for the radius of curvature of geotextile tube r between the values calculated from the established program and those prescribed by A.Bezuijen and E.W.Vastenburg.

5.2. Comparison with Leshchinsky et al. 1996 (computer program GeoCoPS)

Table 4: Comparison of results obtained from the established program and GeoCoPS : (For γ = 20 KN/m3 And L=3.6m) [3]

	Inputs			Results					
N	P^* (Kpa)		F_A** (%)	Source	H (m)	B (m)	W (m)	Area (m²)	T (KN/m)
1	P	44.6		GeoCoPS	1.00	0.46	1.27	1.04***	17.4
	P_0	24.6							
			98	Amallas	1.01	0.36	1.23	1.02	19.5
2	P	30.2		GeoCoPS	0.91	0.64	1.32	1.00	9.7
	P_0	12							
			93	Amallas	0.89	0.65	1.31	0.96	9.8
3	P	22.2		GeoCoPS	0.82	0.83	1.38	0.94	5.8
	P_0	5.8							
			88	Amallas	0.80	0.84	1.37	0.91	5.7
4	P	18.1		GeoCoPS	0.75	0.95	1.42	0.90	4.2
	P_0	3.1							
			83	Amallas	0.74	0.97	1.41	0.86	4.0
5	P	13.7		GeoCoPS	0.63	1.15	1.52	0.81	2.4
	P_0	1.1							
			75	Amallas	0.63	1.15	1.48	0.77	2.2
6	P	11.6		GeoCoPS	0.55	1.25	1.56	0.74	1.7
	P_0	0.6							
			68	Amallas	0.55	1.26	1.52	0.70	1.5

(*):Pumping pressure P0 is given by formula: P0=P- γ.H

(**): FA is calculated using the formula :

$$F_A = 0.5138\ ln\left(\frac{H}{2.R_{100\%}}\right)+1.052$$ which is obtained from equation in figure 3.

(***): The value of the area of 1.04 m2 is impossible to achieve because the area of the geotextile tube at a degree of filling of 100% is only 1.031m². The present established computer program gives for a degree of filling of 100% an area of 1.031m² equal exactly to A100%.

The table 4 shows that there is a very good agreement for results obtained from the established program and those calculated by the program GeoCoPS.

A comparison of results found by Leshchinsky with the experimental tests of Liu (1981) in laboratory was exposed in [4]. Liu conducted experiment tests on PVC tubes, each about 2.5m long , filled either with water or mortar. The mortar-filled tubes were submerged in water. A transparent Plexiglas "foundation" supported the tubes so that the width B could be measured accurately. After different experimental tests, Liu traced the geometry of the filled geotextile tube. Results are in perfect harmony with those of Leshchinsky witch are in a very perfect harmony with the results calculated from the present computer program.

Journal of Theoretical and Applied Information Technology
15th December 2018. Vol.96. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5.3. Comparison with Silvester (1986)

Table 5: Comparison of results obtained from the established program and Silvester : (For γ = 20 KN/m3 And L=3.6m) [3] [6]

	Inputs			Results					
N	P* (Kpa)		FA** (%)	Source	H (m)	B (m)	W (m)	Area (m²)	T (KN/m)
1	P	44.6		Silvester	1.00	0.48	1.27	1.05***	17.5
	P0	24.6							
			98.2	Amallas	1.01	0.36	1.23	1.02	19.5
2	P	30.2		Silvester	0.90	0.65	1.32	0.99	10.1
	P0	12.2							
			93.4	Amallas	0.89	0.67	1.31	0.96	9.6
3	P	22.2		Silvester	0.80	0.82	1.38	0.95	5.8
	P0	6.2							
			88.0	Amallas	0.79	0.88	1.38	0.90	5.5
4	P	18.1		Silvester	0.70	0.94	1.43	0.89	4.2
	P0	4.1							
			83.4	Amallas	0.69	1.04	1.44	0.83	3.5
5	P	13.7		Silvester	0.60	1.05	1.50	0.81	2.8
	P0	1.7							
			74.5	Amallas	0.60	1.19	1.49	0.74	2.1
6	P	11.6		Silvester	0.51	1.21	1.55	0.74	2.0
	P0	1.4							
			67.5	Amallas	0.52	1.31	1.54	0.67	1.4

(*):Pumping pressure P0 is given by formula: P0=P- γ.H

(**): FA is calculated using the formula : $F_A = 0.5138\, ln\left(\frac{H}{2.R_{100\%}}\right) + 1.052$, which is obtained from equation in figure 3.

(***): The notice in precedent chapter is also available for this case

The table 5 shows that there is a very good agreement for results obtained from the established program and those calculated given by Silverster (1986).

6. CONCLUSION

The studying of stability against wave and current of geotextile tubes filled by sand elements or other dredging materials requires the knowledge of structure's dimensions, in particular the height H (m) and the width along the contact with subsoil B (m). In this paper, a computer program was established for calculation of dimensions of the tube for a given degree of filling FA (%). From this computer program, very simple formulas were obtained for calculation of the height of tube H (m) and the width along the contact with subsoil B (m). These formulas are expressed, for degree of filling between 45% and 100%, as below:

$$H = 0.2598 \times R_{100\%}.\exp(1.9374 \times F_A)$$

$$B = R_{100\%} \times (-7.5774 F_A^2 + 7.3656 F_A + 0.7443)$$

The other dimensions of the tube are given as follow:

$$r = 0.0184 \times R_{100\%}.\exp(3.7164 \times F_A)$$

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$$W = R_{100\%}{}' \ (-\ 1.9982F_A^{\ 2} + 1.6288F_A + 2.4762)$$

Another parameter, which is very important and should be controlled during the filling process, is the tensile force T along the circumference of geotextile tube. It is expressed by:

$$T = (F_0 + \gamma H).r$$

REFERENCES:

[1] A.Bezuijen and E.W.Vastenburd (2013). Geosystems: design rules and applications.*1st edition CRC Press/Belkama.*

[2] Leshchinsky, D., et al., 1996. Geosynthetic tubes for confining pressurized slurry: some design aspects. *Journal of Geotechnical Engineering, 682–690.*

[3] D. Leshchinsky and O. Leshchensky. GeoCoPS (2.0): Supplemental note. *ADAMA Engineering, Inc. 33 The Horseshoe. Newark, Delaware 19716, USA.*

[4] Adama Eng., 1996. GeoCoPS—Geotextile Tubes Contained Pressurized Slurry. *Computer Program. ADAMA Engineering, Newark, Delaware.*

[5] Kazimirowicz, K., 1994. Simple analysis of deformation of sand-sausages. *Fifth International Conference on Geotextiles, Geomembranes and Related Products, Vol. 2, Hydraulic Applications and Related Research, Singapore, 1994, pp. 775–778.*

[6] Silvester, R. 1986. Use of grout-filled sausages in coastal structures. *Journal of Waterway port Costal and Ocean Engineering, ASCE. 112(1). 95-114*.

[7] Liu, G. S. 1984. Design criteria of sand sausages for beach defences. *The 19th Congress of International Association for Hydraulic Research, New Delhi, India. Subject B(b), paper No. 6. 123-131*.

[8] P. van Steeg, E. Vastenburg, A. Bezuijen, E. Zengerink and J. de Gijt. Large-scale physical model tests on sand-filledgeotextile tubes and containers under wave attack. CSt2011p0021.

[9] Ir. P. van Steeg, Ing. E.W. Vastenburg : Deltares, 2010. Large scale physical model tests on the stability of geotextile tubes, Deltares report 1200162-000, February 2010, Delft.

[10] Bezuijen A., K.W. Pilarczyk (2012). Gesynthetics in hydraulic and coastal engineering filters, revetments and sand filled structures . Proc. EuroGeo 5, Valencia, pp 65-80

[11] Pilarczyk (2000): Geosynthetics and geosystems in hydraulic and coastal engineering. A.A. Balkema, Rotterdam, the Netherlands