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Ship induced geotextile tensile stresses during installation under water: Theoretical assessment and verification

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ABSTRACT: During installation under water a geotextile can be subjected to high tensile stresses caused by the flow pressure of natural or ship induced currents. Theoretical deliberations have been verified by the results of field measurements carried out in 1987.

1 INTRODUCTION

In connection with the enlargement of the existing German waterways geotextiles are used as a filter in bank and bottom revetments. In this use geotextiles are to be installed even under water whereat shipping must not be interrupted.

Placing a geotextile under water in the planned position is only possible with technical assistance, since the usual geotextiles do not sink to the subgrade due to their gravity.

During the installation stage a geotextile can be subjected to tensile stresses caused by the flow pressure of ship induced currents when placing it from a pontoon. Damage may occur if it is not designed in the necessary manner. Prerequisite for design is the knowledge of the possible site loads in the special application case.

In 1986 the tensile loads due to flow pressure acting on a geotextile during the critical installation phase had been assessed on the base of a theoretical model developed with respect to suitable requirements for a geotextile concerning tensile strengths at failure in dependence on flow velocity. The ship induced flow velocities in canals were known by a lot of earlier field measurements or could be determined e.g. according to BOUMEESTER (1977). But no knowledges were available how to consider the influence of site equipment and geotextile installation method on flow velocities.

These deliberations have been verified by ABROMEIT (1987) when measuring the forces rising in a geotextile unit from current loads during installation with the objective to confirm the rightness of the existing requirements for geotextiles on tensile strength, stated in the German Technical Supply Conditions for Geotextile Filters (TLG 1987).

2 LOCAL SITUATION

The measurements were executed during the installation of the geotextile units used for a bottom revetment in a standard cross section of a ship canal. The canal data were:

area of the canal cross section:	A	=	184 m²
water depth (construction stage):	d_w	=	5 m
water level width:	w	=	53 m
permitted max. beam	b	=	9 m
permitted max. draught	d_S	=	2.5 m.

The width of the geotextile units to be installed has been 18 m. Installation was executed by using a floating pontoon (fig. 1).

The permissible maximum ship speed in the site area is generally $v_S = 6$ km/h.

3 MEASURING-METHODS

3.1 *Force measurements*

One geotextile unit of 18 m width has been prepared for the measuring programme by sewing seven

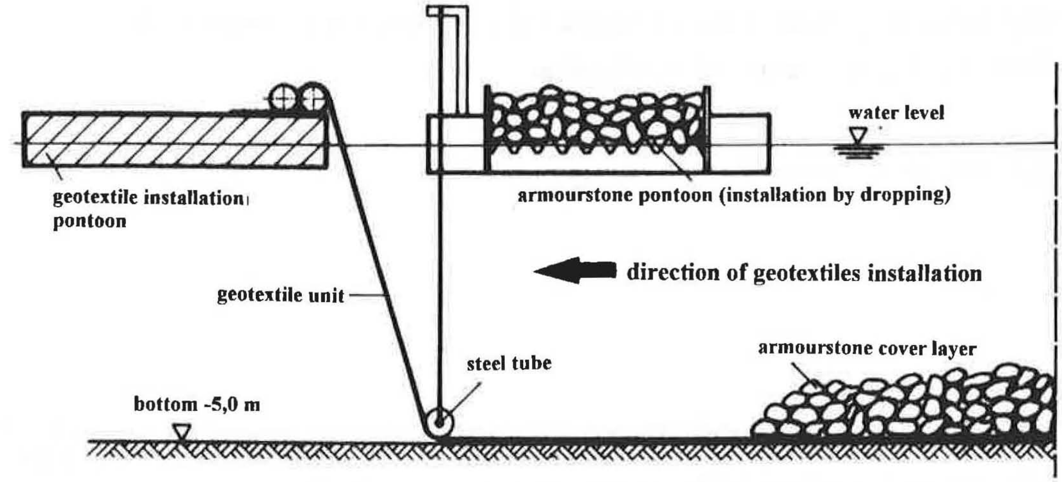

fig. 1: Principle of placing a geotextile unit under water

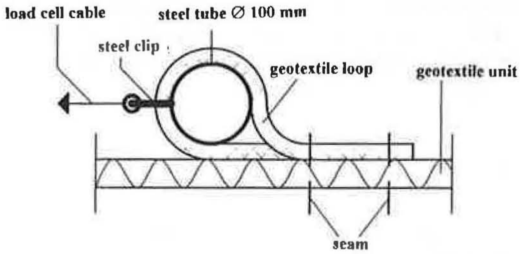

fig. 2: Principle of attaching the measuring system to the geotextile unit

geotextile loops on it, each with an opening appropriate to introduce a steel tube of 100 mm diameter (fig. 2). The length of the loops and of the tubes was 3 m each except the two verge loops the length of which was only 1.50 m each.

Each tube has been linked with a load cell by cable, effective range 50 kN. The load cells were moored on the back of the geotextiles installation pontoon.

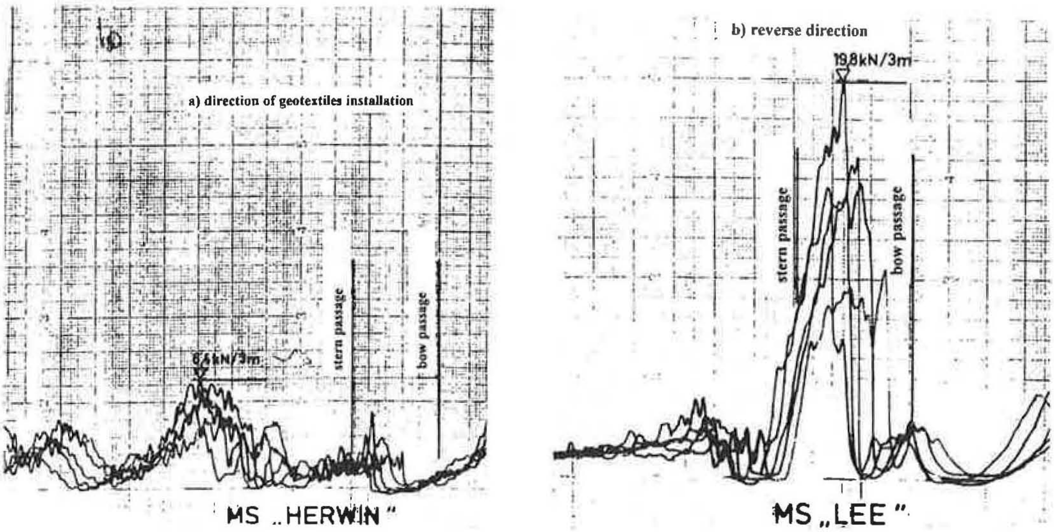

fig. 3: Example of the temporal force process measured at the 7 load cells

3.2 *Flow-velocity measurements*

The flow velocities of ship induced currents were measured with two flow-velocity gauges, in a distance of 1 m on both sides of the pontoon, about 2 m beneath the water level.

3.3 *Ship-speed measurements*

The speed of the ships passing the installation pontoon was determined by measuring the time needed for a fixed distance between two reference lines.

3.4 *Ship data*

The technical data as beam and draught of each freighter passing the installation pontoon were noted.

4 RESULTS

4.1 *Tensile-stress measurements*

13 freighters running in the direction of placing the geotextile units and 20 freighters running in the reverse direction were included in the measurements.

The forces measured at each loading cell were continuously recorded. The temporal force process of the 7 load cells is shown by an example in fig. 3 for both directions of ship traffic an the case of very similar ship data.

The maximum values occurred succesively whereat the highest values were measured always at the middle three load cells. The maximum local single force measured has been 7.5 kN/m, the maximum total force acting on the geotextile unit during a ship passage was determined with a size of 4.5 kN/m. The cumulative total forces higher than 50% of the maximum cumulative total force measured persisted about 15 s or less.

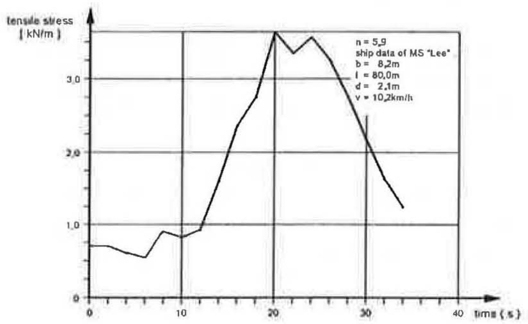

fig. 4: Typical process of the cumulative total tensile stress of a geotextile unit during a ship passage

The typical process of the cumulative total tensile stress during a ship passage is shown in fig. 4.

The forces generated by the freighters running in the direction reverse to geotextiles installation were significantly higher than in the direction of geotextiles installation, due to the different possibilities to move (fig. 1).

4.2 *Flow-velocity measurements*

The maximum flow-velocity has been measured at v_f = 1.4 m/s, generated by freighter velocity of 11.2 km/h and n = 5.8.

The following dependency of ship speed and maximum flow-velocity could be found out:

$$v_{f\,max} = 0.75 \cdot v_S / n \qquad (4.2)$$

with

$v_{f\,max}$ = maximum flow-velocity [m]

v_S = ship speed [km/h]

n = ratio of canal cross section (less immersed area of the geotextile unit) and immersed ship cross section

Considering the permissible ship speed (see 2) and the largest permitted ship dimensions the possible minimum value of the n-ratio (here n = 5.2) the utmost ship induced flow velocity is v_f = 0.9 m/s according to equation (4.2).

5 CALCULATION

5.1 *Dependency of the measured maximum total tensile stress on ship speed*

The dependency of the measured maximum total tensile stress of a geotextile unit during a ship passage can be presented on ship speed or on ship induced flow-velocity.

With respect to the practice it is more advantageous to use the dependency on ship speed (fig.5).

From fig. 5 an equation for the maximum total tensile stress of a geotextile unit per meter can be derived by a straight line covering the maximum values of all ship passages in the direction reverse to geotextiles installation on the safe side as follows:

a) depending on ship speed

$$F_{max} = 2.5 \cdot v_S / n \text{ [kN/m]} \qquad (5.1)$$

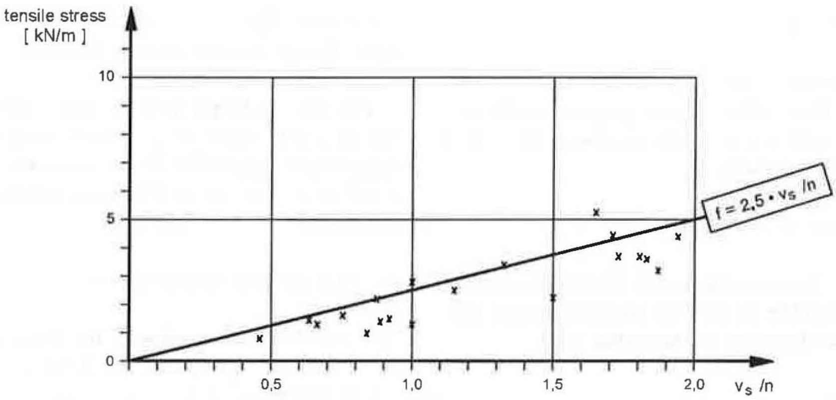

fig. 5: Maximum total tensile stress of a geotextile unit dependent on ship speed and on n-ratio

b) depending on ship induced flow velocity

$F_{max} = 3.3 \cdot v_{f\,max}$ [kN/m] (5.2)

5.2 *Theoretical dependency of the maximum total tensile stress on flow pressure*

The flow pressure on a geotextile area poured up by water can be calculated by the well known equation

$$p = \frac{\rho_w \cdot v_f^2}{2} = 0.5 \cdot v_f^2 \quad [\text{kN/m}^2] \qquad (5.3)$$

Using this equation the resulting total force acting on the area of a geotextile unit per meter width is

$F = p \cdot A = 0.5 \cdot v_f^2 \cdot A_g$ [kN/m] (5.4)

with

ρ_w = water density [t/m³]

v_f = flow velocity [m]

A_g = geotextile area poured up by water flow per meter width [m²/m]

5.3 *Comparison of the theoretical and the measured tensile stress of a geotextile unit*

The equations (5.2) and (5.4) for calculating the tensile stress of a geotextile unit due to flow pressure of a passing ship shall be compared following. The tensile stress which results for an arbitrary chosen example of a ship-induced current of v_f = 1.0 m/s will be:

a) using equation (5.2)

F_{max} = 3.3 kN/m

b) using equation (5.4) (A_g = 5 m²/m, see 2)

F_{max} = 2.5 kN/m

The differences between measured and theoretical result may be explained by the unsufficient measurement of the real flow velocity distribution, but the dimension of the results is nearly the same.

6 CONCLUSIONS

The field measurements have shown that the existing German limit value on tensile strength at failure of 12 kN/m stated in the Technical Supply Conditions for Geotextile Filters (TLG 1987) ist sufficient with regard to tensile loads generated by passing freighters during the installation of geotextiles under water. The maximum total strength was determined at 5 kN/m but being active only for a few seconds. When keeping the maximum ship speed of v_S = 6 km/h permitted in the site area the maximum tensile stress of a geotextile unit will be 3 kN/m in the worst case, i.e. the existing requirements on tensile strength at failure are sufficient.

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