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TEXTILE MEMBRANES FOR CASE OF EMERGENCY FLOOD PROTECTION

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Summary: With this document you get an overview about textile membrane structures used for flood barriers in case of emergency. This project creates a connection between membrane construction and environmental technologies. It is a part of the German ZIM project of the government department. Insights of mobile flood protection using membrane structures are delivered. Two different kind of non rigid structures and their basically functions are described. A short overview about the selection procedure and requirements of the material is given. The simulation process is mentioned and serves insights about the form finding of water filled membrane structures and statically analyses. A short description of the system testing is given on the end.

1 INTRODUCTION

Nowadays more and more flooding appears which contain al low level of lead time and is not estimated on several locations. So it is an advantage to employ new recovery systems as mobile flood barriers. The needs of such a system are a short term implementation without heavy devices and a fast built up time. Such barriers are called none planned and in case of emergency barriers. This means a flood is more rising up then usual and the fixed barriers (for example dikes) are in the process of fail. The unplanned barriers assist for a short period the fixed system. With those Systems a maximum flooding level of 70 cm is allowed and there has to be no research of the consistence of the floor before.

Together with the University Leuphana of Lüneburg [1], the companies Optimal GmbH [2] and Daedler [3] and the University of Applied Science Munich [4] a research group was founded and were placed in a ZIM koop project of the German government [5]. The aim of the project is to realize an unplanned barrier out of membrane structures. The concept is to use a membrane container without any rigid structures. The stability is given by the connection of internal water pressure and the thin walled membrane structure.

The part of this project of the University of applied Science Munich/Karlsruhe Institute of Technologies is focused on the material behavior, the statically analysis and the structural properties under water pressure of such barriers.

2 SYSTEM DESCRIPTION

The system consists out of an envelope of membrane material, without any rigid structure. The barrier body is reached by filling this envelope with water. So you get a heavy structure and the end shape is given by an interaction of internal hydrostatic pressure and the cutting pattern. The principia of the system is the hydrostatic pressure, the water level of the barrier has to be higher than the flooding water level. The dam level shouldn’t increase more than 70 % high of the head of water inside the barrier [6]. Otherwise the difference between the resulting loads is getting to low and the barrier receives too much buoyancy. Thus the friction force will be undervalued to hold the system.

Two different systems were observed. These thin-walled membrane constructions filled with water differ especially in the primary shape of the cross-section. The one system has a trapeze cross-section and the shape is enhanced by membrane stiffener walls. The other one has a circular cross-section and is attached to a second smaller cylinder to avoid rolling. (Figure 1)

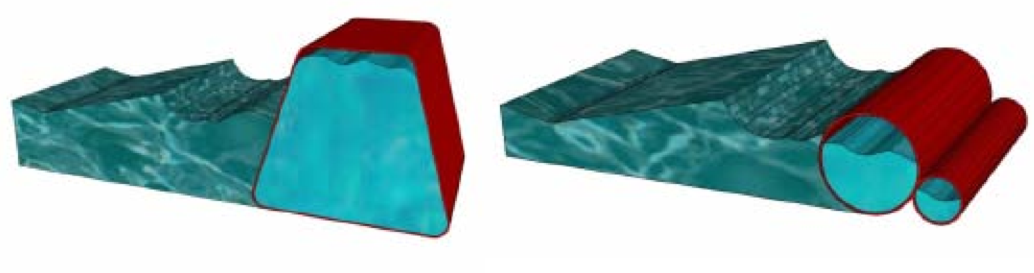

Figure 1: Sketch of the systems with a trapeze and circular cross-section

The shape of the trapeze cross-section is marginal changing by the influence of the inner hydrostatic pressure. The circular cross-section changes into the shape of a water drop and looses about 20 % of the high given by the diameter in fact of normal filling. This means with an overpressure of 7000 Pa. The trapeze system was never used by an overpressure.

3 MATERIAL SPECIFICATIONS

A range of membrane material was observed to use it as the envelope. For this a profile of requirements was prepared. Flooding water has to be assumed as “contaminated”. The membrane should be resistant against chemicals, UV radiation, oil and water. Since the barrier will be pulled over different surfaces during operation a certain abrasion resistance must be given. To ensure the utilizability of the system without being mounted to the ground, the friction coefficient with .respect to different surfaces, especially to wet surfaces, is important. The material should be easily in processing and cost efficient. The main criteria for the material are the structural requirements resulting out of different hydrostatic load cases.

Several testing procedures were applied to achieve the required results of the different materials. The resistances against environmental influences were dispute with the manufacturer. Also concerning to the proceeding and cost efficiency it results a PET fabric coated with PVC/PU.

Another decision criterion was the friction coefficient of the material on operation surfaces, for this the testing procedure DIN EN ISO 8295 [7] was used. Potential membranes where tested on:

- green dry/wet
- concrete dry/wet
- asphalt dry/wet

The table (Figure 2) shows the determined result of four different PET fabrics coated with PVC.

	friction coefficient			
	material 1 μ	material 2 μ	material 3 μ	material 4 μ
green	0,53	0,53	0,61	0,63
green wet	0,66	0,62	0,65	0,68
concrete	0,66	0,64	0,69	0,64
concrete wet	0,51	0,53	0,52	0,52
asphalt	0,77	0,75	0,79	0,81
asphalt wet	0,77	0,77	0,79	0,80

Figure 2: friction coefficients of PET fabrics PVC coated

The most significant criterion was the stiffness of the material. The membrane has to hold the stress out of the internal pressure and additionally the different load cases given by the BWK [6]. So the different materials were analyzed by uniaxial tensile testing under consideration of the DIN EN ISO 13934 [7]. Also different welding seams had been investigated, at this high frequency and hot air seams had been used. As a result of this test it derived that the seams don’t decrease the stability of the material. The tearing was tested on the same way.

For determining the material properties for the simulations the most valuable material was loaded in a biaxial tensile testing application.

Out of the operational demands and requirements it appears that a safety factor of 2.5 is an adequate value.

4 SIMULATION

A part of the simulation was the form finding. This means how the end shape appears under the internal hydrostatic pressure. The structure of the barrier has no rigid body and is an interaction between membrane and the hydrostatic pressure. This complex behavior demands a geometrical non linear calculation of the force equilibrium. An adequate tool is the program “Easy” by the Technet GmbH [8]. It is intended for textile roof form finding and stress analysis. The theory is based on a cable grid and calculates with force density.

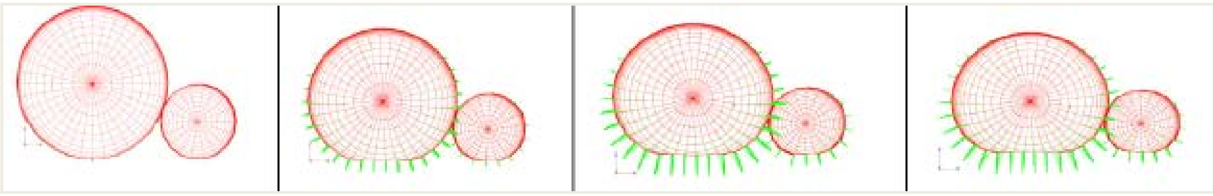

Figure 3: iteratively increase of the internal load

For the adoption on the water filled flood barriers that is a non common problem, some extra tools had to be integrated. A contact algorithm was implemented. One point was the “floor” contact, to transfer this physical behavior in the program the internal pressure was iteratively applied and step wise increased (Figure 3). During these steps the algorithm controlled the element nodes which move below the z-axis and force them back onto the floor plane (figure 4 Pic. 1). So the geometric is changing and the equilibrium has to be recalculated that is achieved by the geometrical non linearity of the program. With this effect it is also possible to simulate rolling of the water filled cylinder.

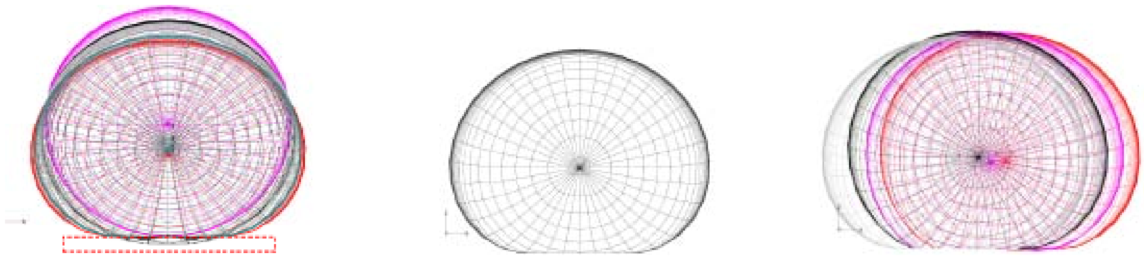

Figure 4: floor contact and rolling

Because this kind of simulation was a new operation field for the program verification experiments had to be done to improve the virtual conditions. For this purpose a water filled membrane cylinder was measured by the laser grid distance method. The original cylinder diameter was 0,5 m and was filled with an overpressure of 7000 Pa on the top. The blue triangle in figure 5 describes the head of water that was applied. The simulation (black line) was done with the same parameters and reflects accurate the measured shape (red line). Under consideration of error in measurement matches the simulation excellent.

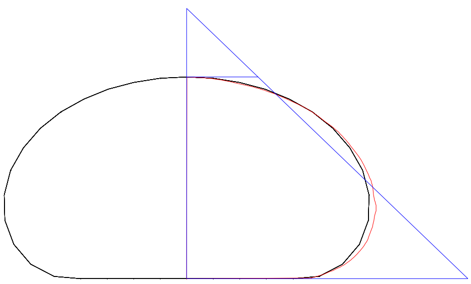

Figure 5: comparison of laser distance measurements and “Easy” simulation

After the form finding the algorithm was used to improve and optimize the stability and failure under different load cases and combinations. The required loads for the following analysis are given by the German BWK [6]. The considered loads for the analysis are:

- inside hydrostatic pressure (Figure 6 Pic. 1)
- internal over pressure
- external hydrostatic load (Figure 6 Pic. 2)
- external hydrodynamic load
- wave pressure (Figure 6 Pic. 3)
- impact (Figure 6 Pic. 4)

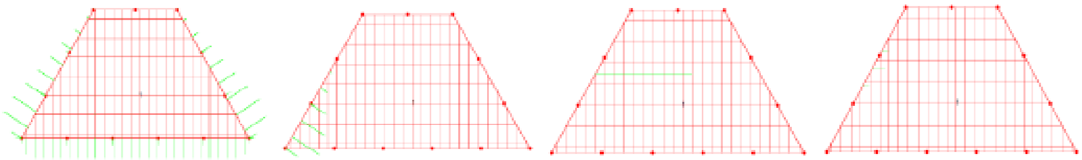

Figure 6: load cases of the statically analysis

The structural analysis with respect to the different load cases was done with volume consistency. The enclosed water was considered as incompressible. As a result of a load case the structure has different force equilibrium, so the cross-section shape is changing geometrically while the case (Figure 7). The results of the simulation also reflect the tensile stresses in the membrane.

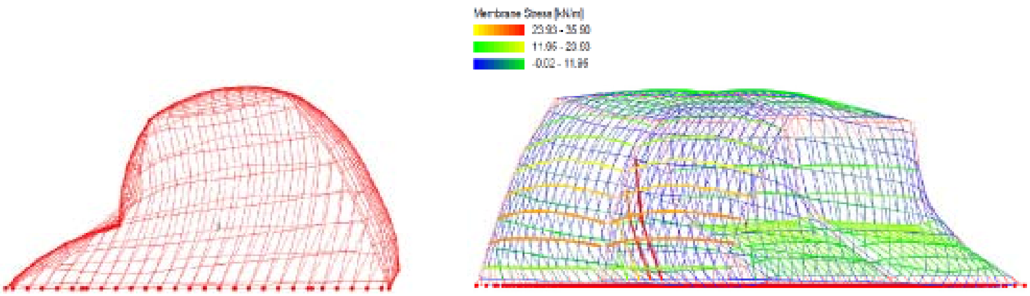

Figure 7: deformed shape and statically analysis results

Local stress peaks are decisive for the tensile stress calculation and were compared to the material tests regarding the safety factor. These peaks vary in their location and dimension regarding the different load cases. This is due to the fact, the geometry of system is totally changing, and therefore the load imitation into the membrane is completely different. So it is possible that smaller but similar load cases create other stress peaks. With this the iterative increase of a load case could be an advantage.

During the time of the project both systems were modified and emerge a large amount of versions. An initial selection had been chosen by simulating and much system testing time was saved by this.

Nevertheless there were still an amount of versions which had been tested. For this the Technicians in heavy-duty fabric needed several cutting pattern of the parts. This was partly made with the program “Easy” as well. At the circular cross-section system it is important for corner elements to avoid bigger angles than 22,5 °. Otherwise the cross-section of the corner increases to such an extent that the load distribution is so different by changing the geometry and the barrier high level decreases on that point.

5 SYSTEM TESTING

Several versions of Prototypes had been built and tested in field experiments. During the project the different versions had been tested in an area at the banks of the Elbe River near by Hamburg, where the river has a good defined tidal range. So the water tightness and the stability could be investigated on a basic level. This field experiments served a good wealth of experience by optimizing the construction and handling. More specific test on the aim of the different load cases and defined water tightness was made at a water channel of the University of Hamburg Harburg [9].

6 CONCLUSION

The construction of mobile flood protection with textile membranes affords new and advantageous options. The investigations show the structural behavior of water filled flood barriers and serve the possibility of optimization regarding cutting pattern, stability, stiffness and economical aspects. Geometric non linear calculation methods generate accurate results of water filled membrane structures without rigid structures. This was verified on a first way. The products already ready for the marked and the next step will be the certification. For further research the dynamic behavior has to be mentioned, like slushing. Rules for mobile flood protection in case of emergency have to be more prepared. At the point of statically the structural concept has to be more discussed on the base of safety factors.

REFERENCES

[1] http://www.leuphana.de/birgitt-brinkmann.html
[2] http://www.alles-optimal.de
[3] http://www.daedler.de/
[4] http://www.ar.hm.edu/
[5] http://www.bmwi.de/
[6] , *Mobile Hochwasserschutzsysteme*, BWK, Merkblatt 6/BWK, Dezember 2005.
[7] Beuth Verlag, http://www.beuth.de/
[8] http://www.technet-gmbh.de/
[9] http://www.tu-harburg.de/wb.html