Storm Surge Barrier Ramspol

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Summary

To protect West Overijssel against flooding due to high water at the IJsselmeer and Ketelmeer an inflatable rubber dam has been designed and is at this moment under construction. This dam will then be the largest barrier of its kind ever built. Since the size of this project is unique, 3D physical model studies have been carried out to study the dynamic behaviour of the rubber dam during inflation, operation and deflation.

1. Introduction

To protect West Overijssel, a province in The Netherlands, against flooding due to high water at the IJsselmeer and Ketelmeer an inflatable rubber dam has been designed and is at this moment under construction. For the total closure three identical dams will be installed with dimensions of 75 m long, 13 m wide and a design height of 8.35 m. With these dimensions it will be the largest barrier of its kind ever built.

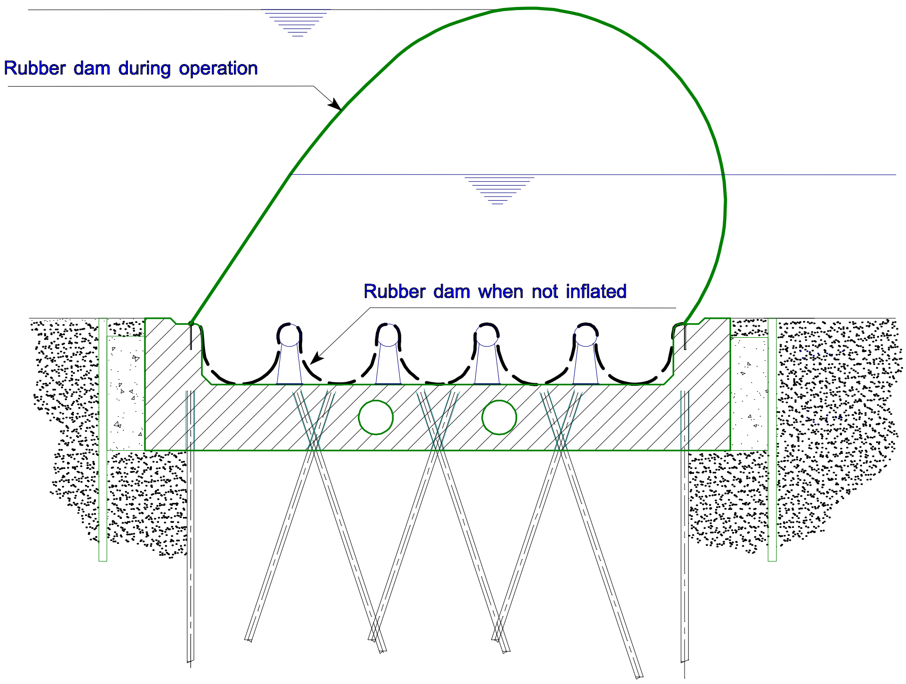

Figure 1 *Cross-section of rubber dam during inflated and deflated condition*

Traditionally, most inflatable dams are filled completely with air or completely with water. For the Ramspol Barrier a combination of air and water as an inflation medium is applied. This has been used to minimise the dimensions of the rubber body and the concrete sill and at the same time to optimise the inflation and deflation system of the dam.

The above aspects all had an economical advantage. More important for this choice, however, was the dynamical behaviour of the dam under wave conditions. Unfortunately there was only very limited data available about this subject. Therefore a desk study was undertaken, where the dynamic behaviour of the different type of dams (i.e. different fill medium) were compared. As a general conclusion it was found that the water/air fill medium combined all positive aspects of the two traditional solutions.

On the other hand, a complicated factor was introduced: due to the free water surface, sloshing of the water inside the dam could occur. Although it was possible to calculate the magnitude of the sloshing amplitude, the effect on the membrane forces was only partly known. Due to these uncertainties, a 'new' inflation medium and off course the unique size of this project, it was inevitable that physical model studies were required.

2. Physical model study

2.1 Inflation of the barrier

As mentioned in the introduction the inflation of the barrier was optimised by the combined air/water fill medium. For the inflation only relatively small air compressors are required, the water flows in automatically, without the help of pumps. This can be explained if the inflation procedure is looked at more closely:

When the water level has reached a certain level (NAP+0.5 m) the water pipes, which connect the inner side of the barrier with the upstream water level, are opened. At the same time the air valves on both sides of the barrier are opened and air is blown in by the compressors. As a result the air pressure inside the dam increases to 0.1~0.2 bar. The increase in pressure causes the parts above the abutments to rise above the water level like pillows.

At the same time the water flows in freely due the water head difference and increased volume. Due to the inflow of the water the sheet comes slowly out of the recess and moves to the downstream side where it rests on the bottom and forms a broad crested weir. This in combination with the pillows causes a contraction of the flow behind the dam. The water that flows over the dam follows the rising flank of the dam, but finally separates from the crest of the dam.

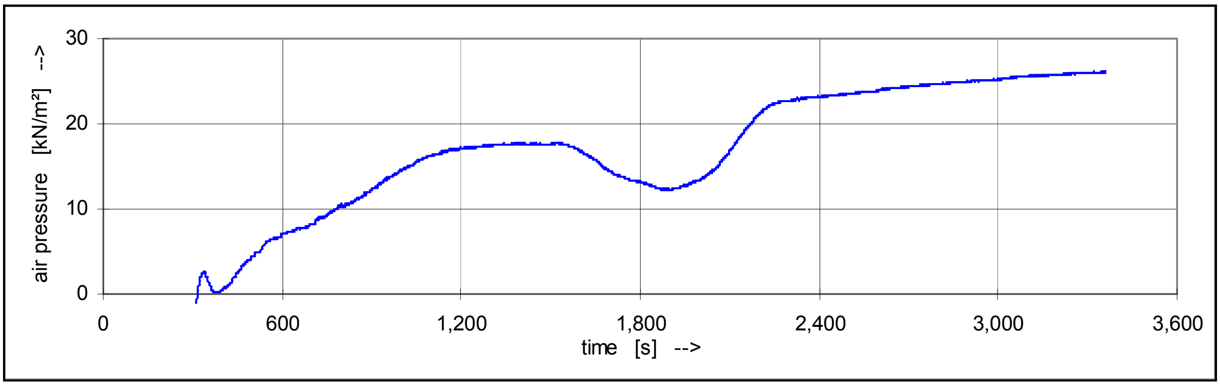

Figure 2 *Air pressure as function of time during the inflation of the barrier*

Meanwhile the dam is further filled with air and water and a so-called V-notch is formed in the middle. Eventually the dam rises above the water level, which causes the volume of the dam to increase. As a result the air pressure decreases for a short while (see Figure 2 at t = 1,800 s). At that moment the barrier has closed off the stream and the hinterland is protected from the storm surge. From that moment the blown in of air continues for a while until the air pressure has reached the required level (0.2~0.3 bar).

Due to the air/water filling a combined horizontal and vertical closure occurred. If only air was applied, the barrier was closed from both abutments towards the middle, which can be considered as a typical horizontal closure. This opposite to a water filled dam which arises horizontally over the full length slowly from the bottom through the waterline.

To what extend the Ramspol Barrier behaves as a fully air or water filled dam depends on the ratio of air and water discharge. If for example the diameter of the water pipes is increased, the barrier behaves more like a water filled dam. The stiffness of the dam, during inflation, becomes lower. In that case low frequent coupled vibrations are observed when the water flows over the dam. On the other hand if the diameter of the water pipes is smaller, the sheet is pulled out the concrete recess instead of lifted slowly by the water. If the barrier is inflated together with high current this occurs rather suddenly and uncontrolled, which is of course less desirable.

The chosen configuration of water pipes and air compressors resulted in an optimal solution. The inflation process goes smoothly and controlled, and no significant vibrations were observed.

2.2 Dynamic behaviour of the barrier during operation

2.3 Deflation of the barrier

When after a storm the water level is reduced, the barrier can be opened again, by means of deflation. To ensure complete deflation and safe storage when not in use, a corrugated floor configuration with rotating bars has been designed. In the hydraulic model the process of putting away the sheet in the bottom recess has been studied.

At the beginning of the deflation process the air valves are opened immediately after the start of the water pumps. The pillows on the abutments shrink slowly and in the centre of the dam a notch is formed, where water starts overflowing. The barrier settles further and the mid section sinks below the water surface until it lays on the bottom at the downstream side (phase 1 of Figure 3). From this moment the sheet has to be redistributed over the five troughs.

In first instance the sheet is for the greater part sucked into the first trough seen from the downstream side (phase 2). Subsequently redistribution of the sheet across the recess takes place, but in the final situation only the first two troughs are fully filled, while the sheet in the last three has no contact with the floor (phase 3 of Figure 3). Sometimes a large fold remains in the first trough, but in all cases the fold stayed well below the top of the concrete sill.

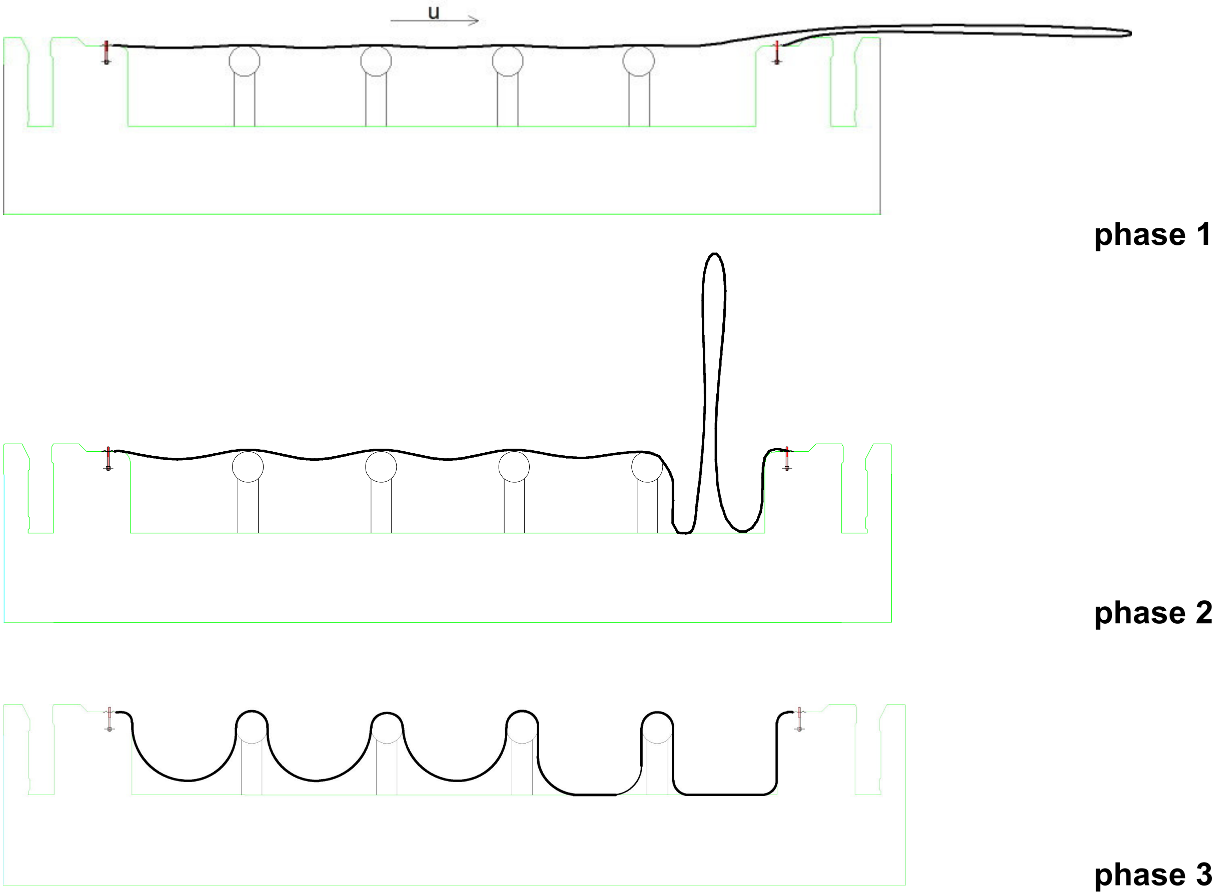

Figure 3 *Typical cross-sections of the barrier during the different phases of deflation*

Besides the hydraulic model tests a calculation method was developed for the phases as given in Figure 3. The distribution of the rubber sheet over the five troughs could be calculated very well with the help of three equilibrium equations and the geometrical boundary conditions (dimensions, height and distance of the rollers). From this calculation model it was found that the bearing friction of the rollers determined how the sheet is redistributed and the friction between the sheet and the bottom if the sheet can be redistributed.

During May/June 1997 a 3D physical model study with a scale of 1:25 was carried out at Delft Hydraulics. The purpose of this study was to examine the dynamic behaviour of the rubber dam during inflation, operation and deflation. In the same model also the adjoining bottom protection was tested. This paper only presents the results of inflated conditions under different operation conditions.

An important parameter for the behaviour of the dam is the overpressure ΔP in the dam. For the static situation the overpressure can be scaled with the same factor as the length scale. However, for the dynamic behaviour the absolute pressure is of importance. To model this correctly, the atmospheric pressure had to be scaled down. Since this was not a realistic option an alternative was found by increasing the volume of air by a factor of 18 times the volume present in the dam itself. This was achieved by connecting two expansion boxes to the dam via the abutments.

With this model the behaviour of the dam was tested for a number of different water levels, overpressures and wave conditions. During the tests sloshing inside the dam was observed and measured. No real oscillation of the sloshing and movements of the dam was observed.

Another conclusion was that the measured membrane forces were almost exactly the same as predicted. Since the applied mathematical model did not take into account a number of aspects, this should be considered as a remarkable coincidence. But on the other hand it proved that it was possible to predict the behaviour and the membrane forces of such a complex system with a relatively simple mathematical model.

Due to the increased forces in the rubber body the design could not revert to proven materials applied for existing dams. A rubber body reinforced with aramid fibres has been developed for this purpose.

3. Conclusions

The problems with scaling down a volume of air in a physical model could be solved in an adequate manner for the Ramspol Barrier. The results obtained with this model were all satisfactory. It was also found that with relatively simple calculation methods, the behaviour and the membrane forces of such a complex system, could be predicted very well.