

Summary

The Stevelduct is a new type of transport for containers, invented by Aad van den Ende. It combines the technique of the aqueduct and that of "stevelen" (Dutch), hence the name Stevelduct. Stevelen is a phenomenon that occurs on flowing waters, objects drifting on the surface of the water can achieve higher speeds than the water speed, because of the component of the object's weight acting in the direction of the slope, due to the gradient of the water.

The Stevelduct will consist of a channel with a small gradient, causing the water to flow about 5 km/h. In the channel unmanned, non-motorized pontoons are used to transport containers (2 TEU's), a lift is used to place a loaded pontoon in the channel every 30 seconds. The pontoons are driven by the momentum of the flowing water and extra speed will be gained by the effect of stevelen, achieving a total speed of about 6 km/h. The pontoons are guided by rails, where a surplus in buoyancy pushes the pontoons against the rails.

The main goal of this research is to analyze the technical feasibility of the Stevelduct, to check the viability of the project. The research is focused on the basal functioning of the Stevelduct, In order to do this, the concept is further elaborated, the main dimensions and the energy usage are determined. Different aspects of the concept will be addressed, such as the required gradient, the effect of stevelen, the transport loss factor (TLF), logistics and others. With the results found an analysis of a possible Stevelduct connection between the Maasvlakte and Roosendaal is made, after which conclusions about the technical feasibility of the Stevelduct can be drawn.

The channel cross-section shape has been analyzed with the help of Chezy's formula for uniform flow in open channels. The required channel gradient depending on four different channel shapes (triangular, rectangular, trapezoidal and circular) has been minimized for a constant water flow speed and cross-sectional area. This resulted in that the channel gradient is minimum for a semicircular shape.

The pontoons require a surplus in buoyancy, which needs to be as small as possible to reduce the rolling resistance of the guidance, but large enough to maintain contact with the rails and wheels. The required buoyancy surplus has been determined by the imbalance of uneven loaded containers and the distance between the guide rails.

With the buoyancy surplus, the maximum weight of the containers and the estimated weight of the pontoon, the pontoons have been dimensioned for the different channel shapes. The shapes of the cross-section of the pontoons have been chosen the same as the channel shape. Under the condition that a minimal channel cross-sectional area is required to allow flow around the pontoon, the semicircular shape performed the best, as the distance from pontoon to the channel wall is the largest and thus the effect of the channel walls on the water flow is the smallest. The minimum area requirement for the semicircular channel has resulted in an upper bound for the channel gradient of 0.24 m/km, as the gradient and cross-sectional area are related.

The stevel speed of the pontoons depends on the weight component due to the gradient of the channel (the stevel force), the rolling resistance, water drag of the pontoon and air resistance. By balancing the forces, a relation between the gradient and stevel speed was found. Maximum loaded

pontoons start to stevel at gradient of 0.10 m/km and a stevel speed of 1 km/h (total speed 6 km/h) is reached at a gradient of 0.15 m/km, which is the lower bound of the channel gradient. The effect of wind has a great influence on the speed of the pontoons, a 5 Bft frontal wind reduces the speed with about 75%.

Pontoons with low loads compared to the maximum load sail at lower speeds, as stevel force becomes smaller, while the rolling resistance increases. Since the mass of the containers varies, so will the speed of the pontoons. This can be prevented by ballasting the loaded pontoons to an equal weight, with the result that all pontoons have the same speed, which increases the predictability of the system.

The energy usage of the Stevelduct depends on the mass flow rate of the water, pontoons and load and the height of the channel. For a constant flow speed the energy usage decreases as the gradient increases, due to the relation between the cross-sectional area and channel gradient. The energy usage for the boundaries of 0.15 and 0.24 m/km are respectively 45 and 33 kW/km for non-ballasted pontoons and 47 and 37 kW/km for ballasted pontoons. Some additional power, between 13.7 and 31.0 kW, is required to accelerate the water and pontoons to the flow speed of the water.

The TLF of the ballasted pontoons varies between about 0.0060 and 0.0076 depending on the channel gradient, for non-ballasted pontoons this is about 10% lower. This is in the region of the TLF of trains and ships, which have the lowest TLF, but with the advantage that green electricity can be used.

A Stevelduct connection between the Maasvlakte and Roosendaal, which was proposed in the concept, has been analyzed with the previous found results. The usage of tunneled section was mentioned, but in the case a pump or lift fails, large volumes of water, pontoons and containers are still inside the channel and keep flowing to the end of the channel. This would require sufficient drainage and buffers for the pontoons, containers and water, which could be problematic underground.

The results found in the analysis of the different aspects concerning the functioning of the Stevelduct and that of the Maasvlakte-Roosendaal connection are technically feasible, thus it can be concluded that the Stevelduct is technically feasible. However, wind and the varying mass of the containers can greatly influence the characteristics of the behavior of the pontoons, but the channel can be protected from wind and the mass can be equalized by ballasting the pontoons. Also problems could occur in case of equipment malfunction in tunneled sections of Stevelduct. Pump or lift failure could be problematic in tunneled sections as the drainage and storage of such large volumes of water, pontoons and containers is difficult underground.

All with all it can be concluded that the Stevelduct is technically feasible, but the pontoons should be protected from wind and the usage of tunneled sections could be technically infeasible.