Short term morphological wave impact on the Zandmotor; a conceptual model

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ABSTRACT

The Zandmotor is world's first project on mega nourishments at the Delfland coast, the Netherlands. This hook shape nourishment consists of 18,5 million m^3 of sand and has been implemented in July 2011 at one location. During the design most researches on the morphological behavior of the Zandmotor was focused on the long term development, based on model calculations with an average wave climate for the next 20 years. However, aerial photos up to January 2012 show significant morphological changes within months due to a more extreme wave climate.

The focus of this research is to understand the short term (i.e. monthly) morphological behavior of the Zandmotor due to the wave climate of July 2011 to January 2012. Hindcasts have been performed with the morphodynamic Delft3D model with updated bathymetries based on monthly measurements. Based on these hindcasts, bathymetric measurements and aerial photos, the hydrodynamic and morphodynamic processes around the Zandmotor have been analyzed. This analysis has resulted in a conceptual model, which presents the morphological change of the Zandmotor due to waves from different directions. With this model, the morphological development over the period July 2011 to January 2012 may be explained.

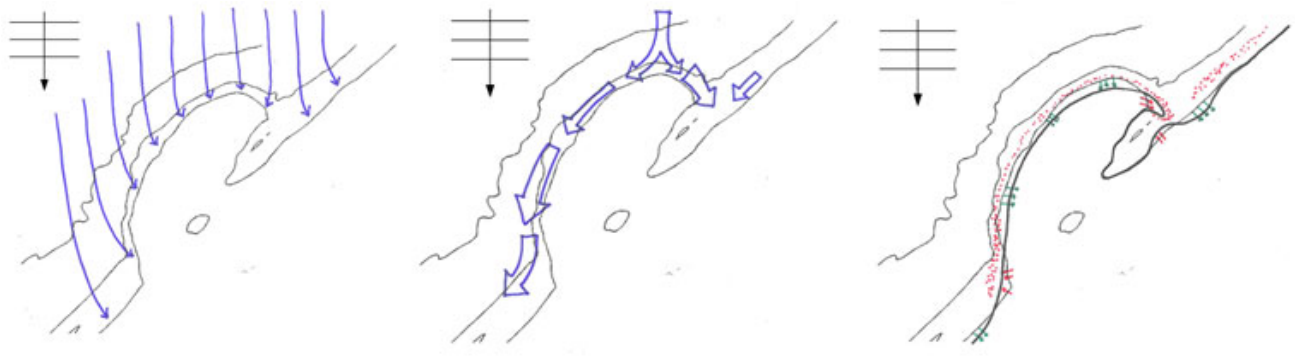
INTRODUCTION

The Zandmotor project has been initiated as to find an alternative to the periodic (e.g. 2 to 5 year) nourishment program for the Holland Coast. This mega nourishment located between Kijkduin and Ter Heijde is expected to nourish the Delfland coast in order to meet the flood safety standards for the next 20 years. The design study by Deltares (2009) has predicted the morphological development of the Zandmotor for the next 5, 10, 15 and 20 years with an average wave climate. However, in the period July 2011 and January 2012 the Zandmotor has experienced several storms, which caused significant morphological changes. In comparison to the research on the long term development, the morphological development within this period is stronger than expected.

This study has been set up to understand the behavior of this mega nourishment with individual extreme events. A conceptual model will be developed based on the hydrodynamic and morphodynamic processes around the Zandmotor.

CONCEPTUAL MODEL

Wave directions determine the locations of erosion and deposition along the Zandmotor. The quantity of sediment transport depends on significant wave height of the waves and tidal current velocities. Analysis of the hydrodynamic processes with the hindcasts results has shown that due to refraction of waves, only four dominant wave directions occur around the Zandmotor. Figure 1 presents the conceptual model for waves with North as wave direction, with the black lines representing the zero, -5 and -10 meter bed level lines.



A. B. C.

Figure 1. Conceptual model for July 2011 bathymetry: (a) Refraction of Northern waves, (b) Direction and magnitude of longshore wave driven currents by Northern waves, (c) Erosion (green arrows), deposition (red arrows and dots) and new shape (bold line) of the Zandmotor after event with Northern waves.

Oblique waves lead to wave driven currents along the Zandmotor, which divides in two directions at the split location (figure 1b). The refracting waves cause most of the erosion along the Zandmotor, which is transported into the directions of the wave driven currents. Erosion of the Zandmotor is most significant along the West side of the Zandmotor, which causes the cross shore width to decrease (green arrows in figure 1c). With the hook shape, 'shadow' zones come to exist in the North and South of the Zandmotor. These zones are sheltered from currents and waves, which lead to lower current velocities in these zones. Suspended sediments are likely to be deposited in these zones (red arrows in figure 1c).

The longshore drift in the Northern shadow zone causes a longshore spit development. The direction of the spit development is dependent on the wave directions: currents by Northern waves are in cross shore direction, currents by Southern waves are in longshore direction. Significant for events with Southern waves is that a channel into the South of the Zandmotor will be originated. Overall, the Zandmotor diffuses, which means that it decreases in cross shore width and increases in longshore direction.

MORPHOLOGICAL EVOLUTION

Hindcast analysis of the morphological impact on the Zandmotor with the past wave climate has shown clear hydrodynamic conditions, which have caused significant short term morphological changes. The past wave climate of July 2011 to January 2012 has been classified in these extreme events. In total, 20 different events have occurred varying in wave direction and significant wave height. Especially, the month December is characterized with the most severe conditions. For each event the morphological changes have been schematized with the conceptual model. This has led to the short term description of the Zandmotor morphology presented in figure 2.

It is clearly visible that the cross shore width of the Zandmotor has decreased. Eroded sediments from this side have been deposited at the North and South and caused the shape to 'flatten'. The spit development at the North of the Zandmotor is paired with the channel development along the shore. A comparison with the aerial photos taken on different dates, confirms the development described with the conceptual model. With observation on the photos taken at the start of the Zandmotor and in January 2012 (figure 3), it could be concluded that the Zandmotor shape has change significantly within months. The cross shore width of the Zandmotor has reduced and a spit has developed at the North side.

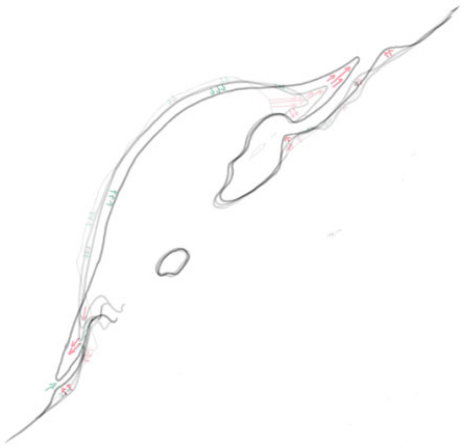


Figure 2. Morphological development for July 2011 to January 2012 (bold grey line) due to wave events. Developments between July 2011 and January 2012 are indicated with light grey lines; red arrows indicate deposition; green arrows indicate erosion.

CONCLUSIONS

This research has presented a conceptual model for schematization of the short term morphological impact of wave events on the Zandmotor bathymetry. This model is based on analysis of hindcasts performed with Delft3D models, bathymetric measurements and aerial photographs. The directions of waves define the location of erosion and deposition along the Zandmotor. The significant wave height is related to the quantity of sediment transport. From the evolution described with the model and observations of the aerial photos it is concluded that the short term morphological impact of waves is significant.

REFERENCES

Deltares, 2009. Achtergronddocument, Morfologische berekeningen, MER Zandmotor. *(in Dutch)*

Man, W.Y., 2012, Short term Zandmotor Morphology, MSc. Thesis, University of Twente

Figure 3. Aerial photos taken on 11th of July 2011 (left) and 10th of January 2012 (right) (source: Rijkswaterstaat, 2012).