

**INTEGRATED RESEARCH ON SAND SUPPLETION
AS A COASTAL DEFENCE SYSTEM
- APPLICATION TO THE FLEMISH EAST COAST -**

Marc Huygens¹, Ronny Verhoeven¹, Marc Willems², Frank Mostaert²

¹Hydraulics Laboratory, TW15V, Faculty of Applied Sciences, Ghent University,
Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium

Tel. +32 / 9 / 264 32 84 Fax. +32 / 9 / 264 35 95 E-mail : Marc.Huygens@rug.ac.be

²Flanders Hydraulics, Administration Waterways and Coast, Department Environment and
Infrastructure, Ministry Flemish Community, Berchemlei 115, B-2140 Borgerhout, Belgium

Tel. +32 / 3 / 236 18 50 Fax +32 / 3 / 236 95 23 E-mail MarcL.Willems@lin.vlaanderen.be

Abstract

An integrated technical research explores a complete synergy of physical scale modelling, numerical simulations and field records in order to validate the potential use of sand suppletion as a coastal defence for the Flemish East coast. Detailed analysis of the rich field data forms an optimum reflective mirror to put the respective design and calculation tools in both a comparative and evaluating framework. Combining all available instruments in an interactive modelling approach leads to an optimum design and a more economic application of beach nourishment techniques in this area.

Key words : sand suppletion, integrated modelling, coastal defence

INTRODUCTION

Along the Flemish East Coast persistent regression of the coastline forms an acute threat. Indeed, the recent seaward extension of the harbour of Zeebrugge intersects the easterly longshore tidal flow and locally disturbs the morphological equilibrium. As a result, a local tidal trench called "Appelzak" shifts ground and re-establishes itself just in front of the groynes before the coast of Knokke. The natural shore profile is gradually weakening and intervention is needed to ensure a sufficient safety level of shore protection. A rehabilitation of the natural sea-land environment, new technical potentialities and political accents have made that since the seventies preference is given to "soft", eco-friendly measures, i.e. beach nourishment, taking into account the natural dynamics of the shore profile [CUR Rijkswaterstaat and Delft Hydraulics].



Figure 1. Storm erosion at Knokke-Zoute beach

FIELD DATA

A first beach replenishment ($7\,000\,000\text{ m}^3$ sand over a 8 km reach) was executed in 1977 but a second nourishment ($730\,000\text{ m}^3$ sand over a reach of 2.9 km) was already necessary in 1986. [Roovers et al.] Again, intense local erosion at the beach of Knokke-Zoute transported the total sand volume out of the region in a period of only 5 years. Therefore, in order to identify the drastic instability and the morphological impact on the area, an extended research program is set up to explore a basic understanding of the local beach morphology. As an initial link in the integrated «coastal zone management»-chain, an integrated hydromorphological study is explored. By using physical model tests together with computer simulations and in-situ registration, a complete synergy between all components leads to a fully integrated description. As a starting point for the research, a detailed analysis of all existing information is compiled. The high importance (touristical – ecological – economical – social) of the beach region under consideration explains the wealth of available data [Kerckaert et al.]. A profound analysis gives a long-term development picture of the coastal area. The recent extensions of the harbour of Zeebrugge not only cause an intensive beach erosion before Knokke, but also a dramatic silting up of the tidal entrance to the Zwin-reserve. It is clearly identified that, due to the complex interaction of wave-induced on- and offshore transport, longshore tidal drift and the impact of the breakwater obstruction by the harbour extension of Zeebrugge, a traditional beach nourishment will not provide a complete and durable solution for the coastal defence of the Flemish East coast.

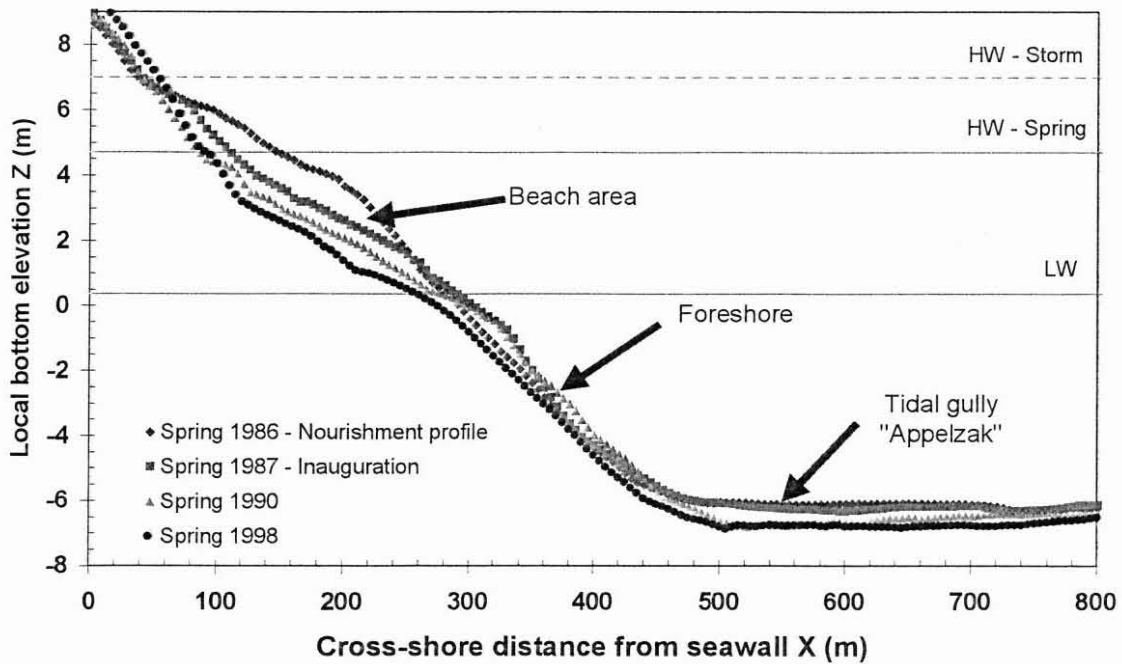


Figure 2. Field records of the cross-shore profile

RESEARCH PROJECT

To ensure a proper coastal defence design, a fundamental knowlegde of the local beach morphology is explored. As indicated before, the research project is developed as a complete synergy between field registrations, physical scale model studies and numerical simulations.

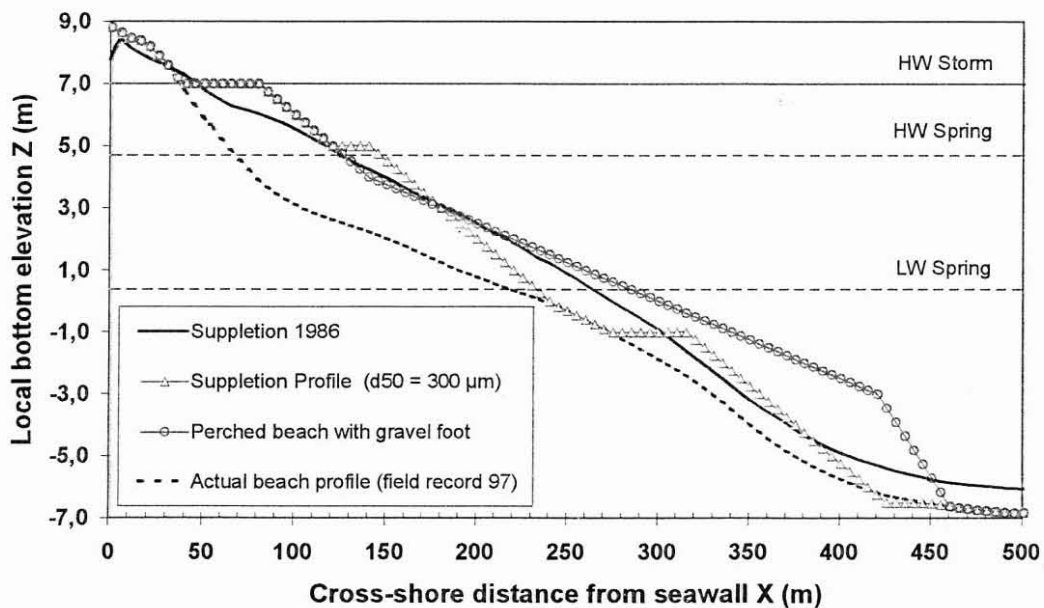


Figure 3. Beach suppletion profiles

In order to generate an appropriate model-climate the determining local hydraulic and morphological in-situ characteristics near Knokke-Zoute are collected and analyzed. During a field measuring campaign in the tidal gully “Appelzak” detailed flow registrations reveal the transport mechanisms; while detailed sediment investigations identify the mobility of the local sea bottom. The initial physical scale model tests in a 1D-wave flume (scale 1/25) generate an overall qualification of the beach nourishment stability as a cross shore unit. Simultaneous numerical simulations with SBEACH and LITPACK reveal some interesting agreements and operational (sensitive) features of both software tools [Larson et al.]. As an intermediate result, a specific beach suppletion profile (with horizontal terraces) is indicated as the most stable cross-shore form, together with a perched suppletion beach. A "stable" beach suppletion profile is at this stage of the research described as a cross-shore unit that keeps the sand as high as possible, close to the landward sea wall, in the profile. The basic idea behind this approach was to prevent the cross-shore wave-induced transport to remove the suppletion sand offshore from the beach to the foreshore; because there the local longshore tidal flow will interactively rupture the formation of a breaker berm. The numerical simulation with SBEACH is artificially adapted to that continuous interaction of the normal wave-induced cross-shore transport with the longshore ebb/flood current; showing a good agreement with the field records.

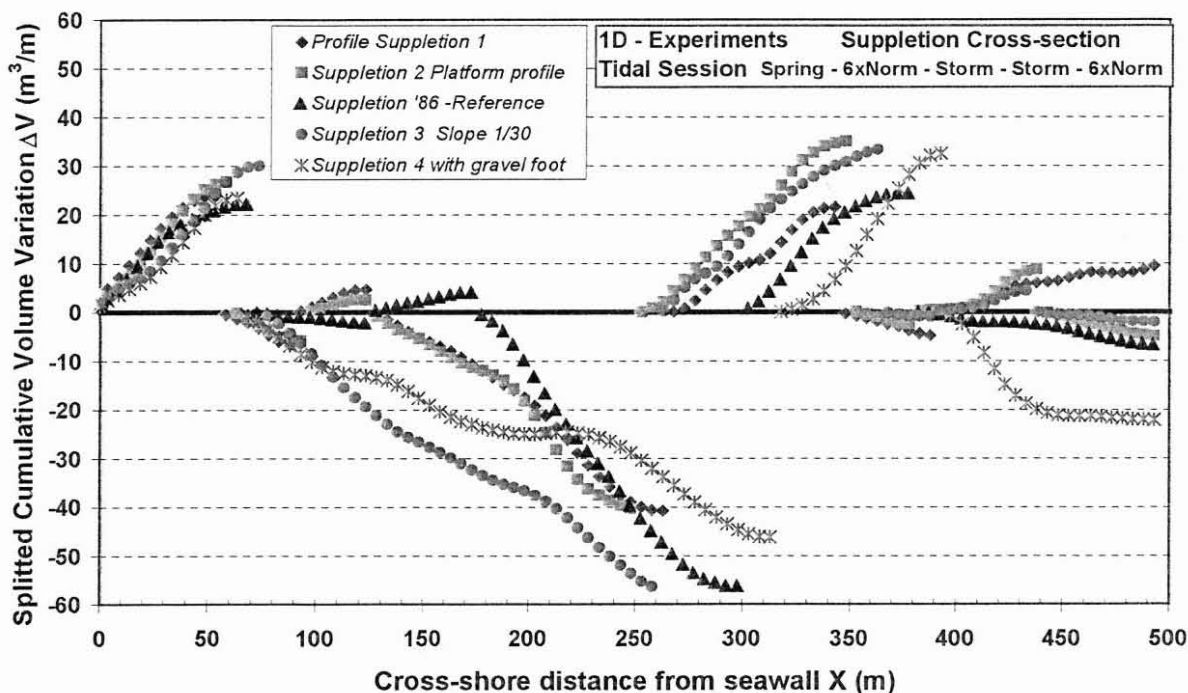


Figure 4. 1D-physical scale model Resulting Volume Balance Development

Comparisons with detailed field registrations of the local bathymetry for the reference 1986-suppletion show the complex wave-longshore tidal current interaction not to be represented in the 1D-physical scale modelling. Therefore, an extended physical model (scale 1/60) is explored in a computer-controlled 2D wave tank installation [Hughes]. The local complex hydrodynamics, as a combination of perpendicular random waves, longshore ebb-flood currents and vertical tidal variation, generate a realistic sediment transport development. Breaking (storm) waves transport the beach material offshore to the seaward limit of the foreshore, into the tidal gully "Appelzak" from where it is carried away by the predominantly northeasterly-flowing tidal current. A good agreement between physical test results and the in situ data confirms these morphological processes in the area as the main cause of the local structural erosion problem. It is clearly identified that the preliminar "stable" profile suppletion (with the horizontal terraces) no longer stays stable under the combined wave-flow impact. The longshore flow partly removes the underwater plateau ($Z = -1.00$ m) where the breaker berm was kept in the 1D-model. As a result, sand is no longer hold high on the beach profile; but is even rapidly removed offshore under wave impact. Therefore, the structural erosion in the coastal area of the Flemish East Coast will not be simply resolved by a traditional beach nourishment scheme with adapted cross-shore profile.

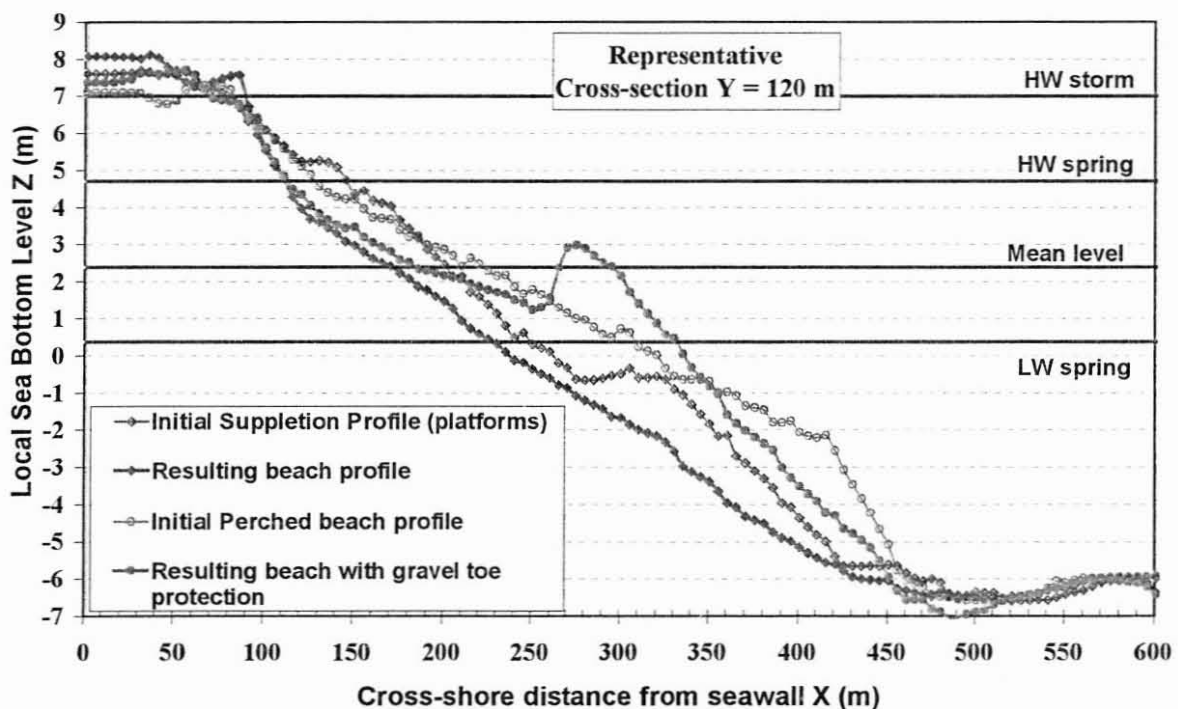


Figure 5. Profile development under fully 2D-hydrodynamic impact

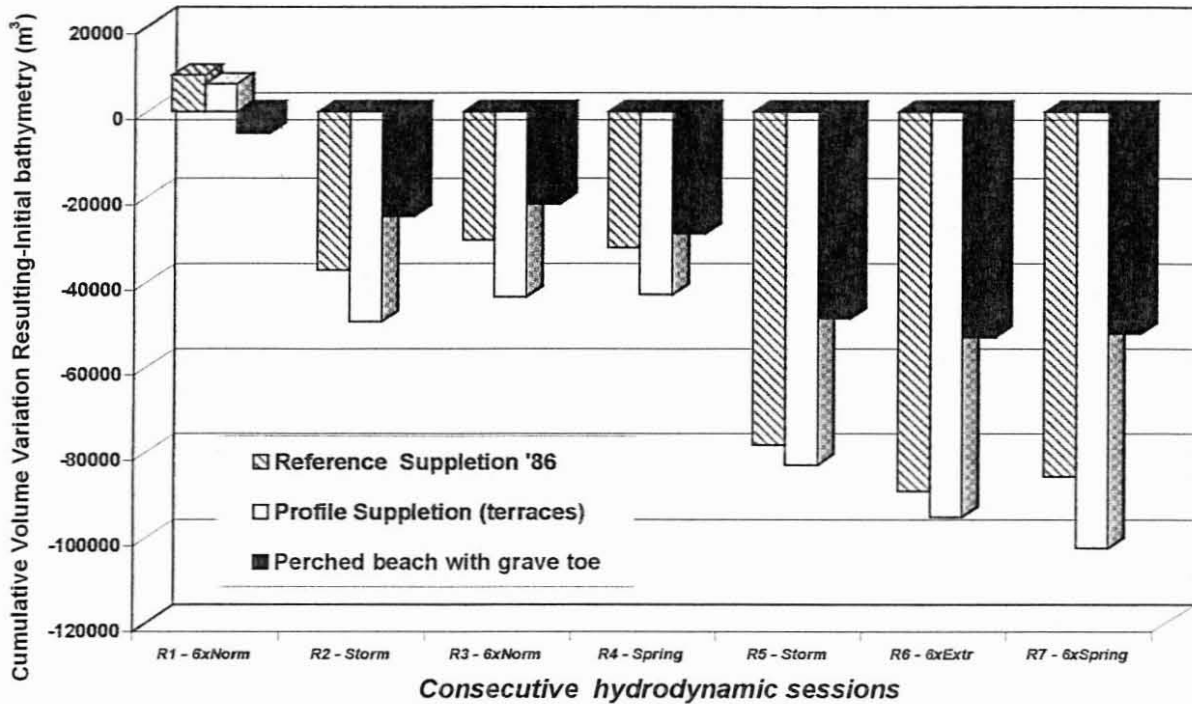


Figure 6. Cumulative Sand Balances in 2D-scale model.

An alternative solution, a perched beach protected by a seaward gravel foot, is identified as a more suitable coastal protection system for the area. The gravel toe not only supports the beachward sand massive; but also catches the offshore transported sand in an effective coarse gravel frame to build a protective breaker berm on the seaward end of the gravel massive on one side and acts on the other side as a dike protection against longshore tidal flow for the landward beach suppletion. By that, this perched beach with gravel foot protection can be seen as an intermediate stage (both from technical as ecological point of view) to the fully (underwater) breakwater-option. The resulting, cumulative volume variation (over a cross-shore distance of 600 m from the sea wall) clearly shows a less erosive sand balance for this alternative: the gravel toe protection of the more concave suppletion sand massive works well under the combined wave-tidal flow impact. While the resulting sand volumes for both "traditional" sand suppletions (the 1986-reference and the new design with horizontal terraces) have a quite similar magnitude, the beach nourishment scheme with a gravel toe at the foreshore reduces the erosive sand volume with 40% ! The general bathymetric differential map for the suppletion profile with gravel massive in figure 7 confirms the above mentioned morphological trends.

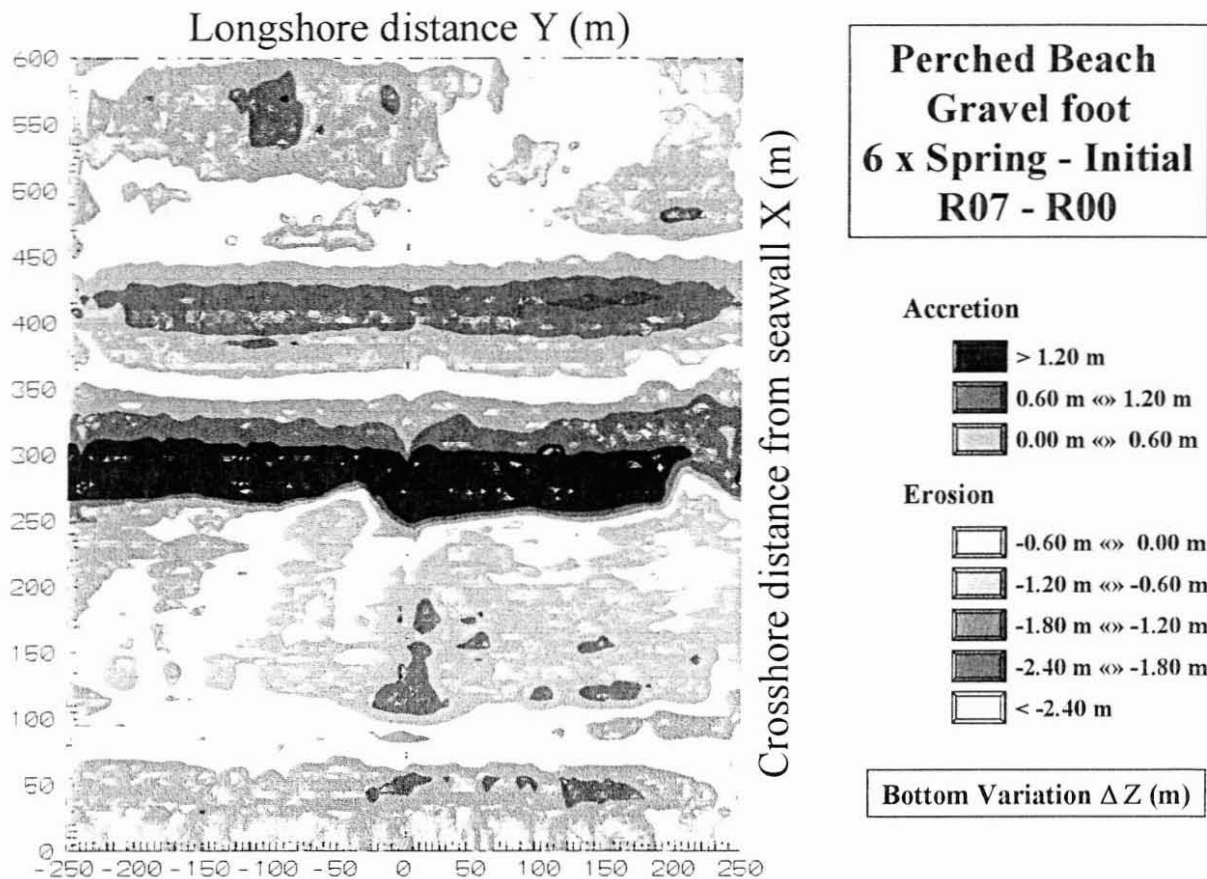


Figure 7. Differential bottom map for the perched beach with gravel foot.

CONCLUSIONS

As a result, by deploying a complete synergy of field data, computer results and physical scale modelling, a better insight into the morphological and hydrodynamic behaviour of artificial beach nourishment for the Flemish coast forms a major step to a more reliable and scientifically based design of local coastal defence systems for sandy beaches. An optimum beach protection for the studied coastal area should surpass the traditional sand suppletion if one is looking for a long-term stable beach policy. A perched beach with gravel foot protection at the foreshore can be an alternative solution to the actual, regular maintenance suppletion in this case.

REFERENCES

CUR Rijkswaterstaat and Delft Hydraulics (1987), Report 130 Manual on Artificial Beach Nourishment, CUR Gouda ISBN 90 212 6078 6.

Fredsoe J. and Deigaard R. (1992), Mechanics of coastal sediment transport, Advanced Series on

Ocean Engineering Volume 3, World Scientific Publishing Co. Singapore.

Hughes S.A. (1993), Physical Models and Laboratory Techniques in Coastal Engineering, Advanced Series on Ocean Engineering Volume 7, World Scientific Publishing Co. Singapore.

Kerckaert P., Maes E., Fransaer D. and Van Rensbergen J. (1990), Monitoring shore and dune morphology using bathymetric soundings and remote sensing techniques, Proceedings SII 27th Int. PIANC Congress, Osaka.

Larson M. and Kraus N.C. (1989), SBEACH: numerical tool for simulating storm-induced beach change, Technical Report CERC 89-9, US Army Engineering Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg MS.

Roovers P.P.L., Kerckaert P., Burgers A., Noordam A. and De Candt P. (1981), Beach Protection as part of the harbour extension at Zeebrugge, Proceedings 25th Int. PIANC Congress, Edingburgh.