Artificial Beach Nourishment: Lessons learned from Field Experiments
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International Conference
Development of Artificial Lands on Shores, Near-Shore and Off-Shore Zones
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Aerial View from Baltrum West to Norderney East
The topic of the Conference “Artificial lands on Shores, Near-Shore and Off-Shore Zones” is directed towards coastal engineering on a large scale.

In contrary, this presentation relates to quite small projects and its focus is rather on technical aspects than on the use of artificial beach and foreshore nourishment as a tool to cope with conflicting demands for an “Integrated Coastal Protection Management”.

Remark
Norderney

Integration of Beach Nourishment (BN) into the historically developed seawall-groyne-system.

Sand Losses from restored beach areas

Field Experiments

Calculation

- Control Volume
- Equilibrium Profile
- Closure Depth
- Half Period
- Cost-Benefit Optimum

Valuation, Perception
Western spit of Norderney Island with its tidal-inlet and ebb-delta shoals (reef-bow)

Left: Depth-contour lines, resulting currents, littoral drift, test site (D1-E1)

Right: Aerial view displaying the reef-bow during low water conditions

Kunz (1993)
Norderney: Sea wall from 1857/58 (S-profile, lime-stone) with added food protection (basalt) in a status of severe beach erosion: Artificial Beach Nourishment needs to be added
Coastal Protection System Norderney
Groynes, Sea Walls and Beach Nourishment (1951/52 - 2000)
German–Russian Field-Experiment „Norderney 94“ - Location test site (groyne field D1-E1) and Devices

Location of the investigated cross-section and measurement points (groyne-field D1-E1)

Cross-section with the installed measurement devices (groyne-field D1-E1)

Kunz (1997)
Test Site Norderney (D1-E1), middle cross-section (m) with equipment for the German-Russian Field Experiment Norderney 94
Examples for Artificial Sand Nourishments on German Barrier Islands

(1) Combined groyne-seawall-beach nourishment-protection

(2) Highly raised recreational beach

(3) Combined beach restoration and cliff/dune-sand depot

(4) Combined beach nourishment and landwards located sand depot

Kunz (2001)
Examples for Artificial Sand Nourishments on German Barrier Islands

1. Combined groyne-seawall-beach nourishment-protection

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Temporary Sand Groynes as part of the Combined Beach and Shoreface Nourishment, Norderney 1992

Design of the Temporary Sand Groynes

Development of the sand groyne shape (D1-E1) during the first month after BN

Date of Survey
22.5.92
27.5.92
18.6.92

Kunz (1995)
Calculation of Sand Losses out of a defined Control Volume and Example for Volumes (V) and related Half Period ($t_h$) over time

**Cross-section BN**

- **Reference Profile**: Beach Profile which approximates the site specific “Equilibrium Profile”
- **Initial Profile**: Profile of the nourished beach after the natural transformation into a shape which is adapted to the site specific conditions (related Initial Losses)
- **H**: Height/Depth of the Beach

**Volume of sand above the reference profile** (adapted to the “equilibrium profile”) and to the depth boundary (Control Volume)

**Reference Profile**

- Beach Profile which approximates the site specific “Equilibrium Profile”

**Initial Profile**

- Profile of the nourished beach after the natural transformation into a shape which is adapted to the site specific conditions (related Initial Losses)

**H**: Height/Depth of the Beach

**BN**: Artificial Beach Nourishment

**$t_h$**: Half Period: The Sand Losses out of the Control Volume reach 50% of the Initial Volume

**Kunz (1993)**
Sand losses over time out of nourished beaches with related approximations – Norderney (Section C-A), Nourishments 1952/52; 1976; 1984; 1989

$\Delta V_{\text{III}}$

$\Delta V$ Sand within the defined Control Volume fixed by the Reference Profile and the Depth Boundary (e.g. „Closure Depth“ – see Kunz 2003).

$\Delta V_{\text{I}}, \Delta V_{\text{II}}$: Approximation by e-Function

$\Delta V_{\text{III}}$: Non-exponential approximation

$t_h(\Delta V_{\text{III}})$: Half Period related to the Beach Nourishment (BN): Elapsed Time after BN when the losses are 50%
Specific Costs of different beach nourishments (BN) - techniques (A, B, C) and associated BN - sand losses from the side specifically fixed Control Volume (L) in relation to the specific BN-volume (m³/m).

Specific Costs per m (e.g. €/m) for the nourished beach until the next BN-project is necessary (beach profile reaches the tolerable depth limit).

Kunz (1995)
The calculation and interpretation of sand losses requires the side specific definition of boundaries

- reference profile ← equilibrium profile
- depth limit ← closure depth

Generally it is not necessary to put emphasis on beach profiling to approach natural slopes, as this will be quickly done by waves and current.

“Visible” losses create “invisible” benefit in deeper parts of the profile and should not be in total misinterpreted as final losses.
Langeoog

Adaptation of artificial sand nourishment on temporary changes of natural boundary conditions.

Artificial nourishment in reliance of sand supply by the littoral drift

Examples for projects

Artificial sand nourishment as flexible responses to shore- and beach-erosion
Migration (Littoral Drift) of Sand Bars (1937 to 1970) and development of ebb delta shoals which sporadically supply Langeoog West with Sand

Group „D“ of Bars 1937/1970

Source: Homeier & Luck 1970

Kunz (1995)
Ebb Delta Shoals of the Wichter Ee-Inlet
Aerial View 1996 during Low Water

Norderney East  Wichter Ee  Baltrum

Kunz (1987)
Migration (Littoral Drift) of Sand Bars (1937 to 1970) and development of ebb delta shoals which sporadically supply Langeoog West with Sand

Group “D” of Bars 1937/1970

Source: Homeier & Luck 1970
Beach Nourishment and Dune reinforcement on Langeoog Island (1972 to 1994)

borrow side for the dune reinforcement

LANGEOOG

(1972): sand filled textile tubes

XXX (1997, 1999): dune reinforcement

0 1 km

H.K. 07/09 Kunz & Stephan (2001)
Beach Nourishment stabilised by sand filled textile tubes

Langeoog (1971/72)

DUNE FOOT

CROSS SECTIONS

HIGHER AREA

-50m 10.0m 8.00m

LOWER AREA

1:50 to 1:80

Filter Matting with Sand Filled Pockets

Ø 1.00m

8.00m

Sand Filled Tube Works

Sand Filled Tube Works

Kunz (1987)
Sand Filled Tube Works on Langeoog

After Erosion (Situation 2005)
Beach Nourishment and Dune reinforcement on Langeoog Island (1972 to 1994)

borrow side for the dune reinforcement

(1972): sand filled textile tubes

XXX (1997, 1999): dune reinforcement
Artificial Beach Nourishment on Langeoog during periods without sufficient natural sand supply by merging sand bars

Kunz & Stephan (2001)
Beach Nourishment and Dune reinforcement on Langeoog Island (1972 to 1994)

borrow side for the dune reinforcement

(1972): sand filled textile tubes

XXX (1997, 1999): dune reinforcement
Beach Erosion

Dune Erosion

Vulnerable against Breakthrough

Beach Erosion
Juist

Erosion on the western part (island and foreshore) created by structural hydro-morphological processes

Artificial Sand Nourishment ("soft") contra Solid Constructions ("hard") to cope with the problem of land losses and breakthrough
Impact of Osterems Inlet and of Sand Bars on Juist/Memmert
Juist West - Course of Sediment Transport within Sand Bars
Aerial View 2001

Source: Ladage & Kunz (2002)
Beach and Fore Shore Juist West: Development 1933 - 1990

PROFILE 15: EROSION

shore line retreat

Time-Distance Lines

- MSL -1.0 m
- MSL ±0.0 m
- MSL +1.0 m
- MSL +2.0 m

Source: Ladage & Kunz (2002)
Artificial Nourishment - Juist West

- dune re-inforcement,
- "security stock",
- limited retreat of the shore line is tolerated

deepening and steepening of the fore shore
The political valuation of the tool “artificial nourishment” is influenced by a balance between public demands, economical benefits and effects on the environment. This asks for a comprehensive knowledge about the natural processes and the interaction with impacts of technical works.

Accept limitations given by nature, restrict yourself to reasonable targets and agree to minimise harmful impacts of a project on the coastal environment. This calls for an integrated management concept (e.g. ICZM).

An acceleration of the regional sea level rise as well as higher storm surges are a realistic perspective. This enhances the public demands for solid coastal defence works, possibly combined with artificial sand fills.