"Innovation in the use of coastal rock protection"

MAFF research project, consultation workshop 13 June 2000

William Allsop

HR Wallingford and University of Sheffield

Matt Crossman

HR Wallingford

HR Wallingford

Objectives of workshop

13 June 2000

- Identify levels of knowledge and uncertainty / conflict in design and use of unconventional rock structures on the coastline.
- Identify whether cost savings and/or better performance are possible.
- Summarise design methods and/or data that need improvement to generate these gains.
- Scope research and data gathering / analysis to generate the required improvements.

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Innovation in use of rock

Workshop programme - morning

10:00 Introduction to the project - W. Allsop

10:15 Design methods - J. Simm & P. Starr

10:45 Construction aspects - R. Gardner & W. Shields

11:15 Owners view of innovative approaches - P. Barber & A. Bradbury

11:45 Contributors' case studies and discussion

12:30 Formation of work teams, Session 1 - "Present knowledge & experience of innovative and conventional structures "

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Innovation in use of rock

Workshop programme - afternoon

14:00 Team session 1b - "Present knowledge & experience of innovative and conventional structures"

14:30 Team report back on session 1

15:15 Team session 2 - "What needs to change? Summary of requirements for data collection, analysis & research"

16:30 Team report back on session 2

16:45 Summary of actions, closure

Project output

end July 2000

Report from the study team to MAFF:

• Summary of knowledge and experience in design / use of unconventional rock structures.

• Identify sources for cost savings and/or better performance.

• Summarise gaps in design methods and/or data that need improvement.

• Summarise areas for research and/or data gathering and analysis.

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Thank you for your input

With particular thanks to
Matt Crossman, Jonathan Simm,
Andrew Bradbury, Phil Barber, Paul Starr,
Ron Gardner, and Will Shields

HR Wallingford

Rock structures on unprepared foundations

Design

Jonathan Simm (HR Wallingford)
Dr Paul Starr (SWK)

HR Wallingford

Outline of presentations

Design of rock structures on unprepared foundations

Jonathan Simm

- **Waves**
- **Rock Armour**
- **Filters**

Paul Starr

- **Settlement and consolidation**
- **Slope stability**
- **Toe stability**
- **Scour**

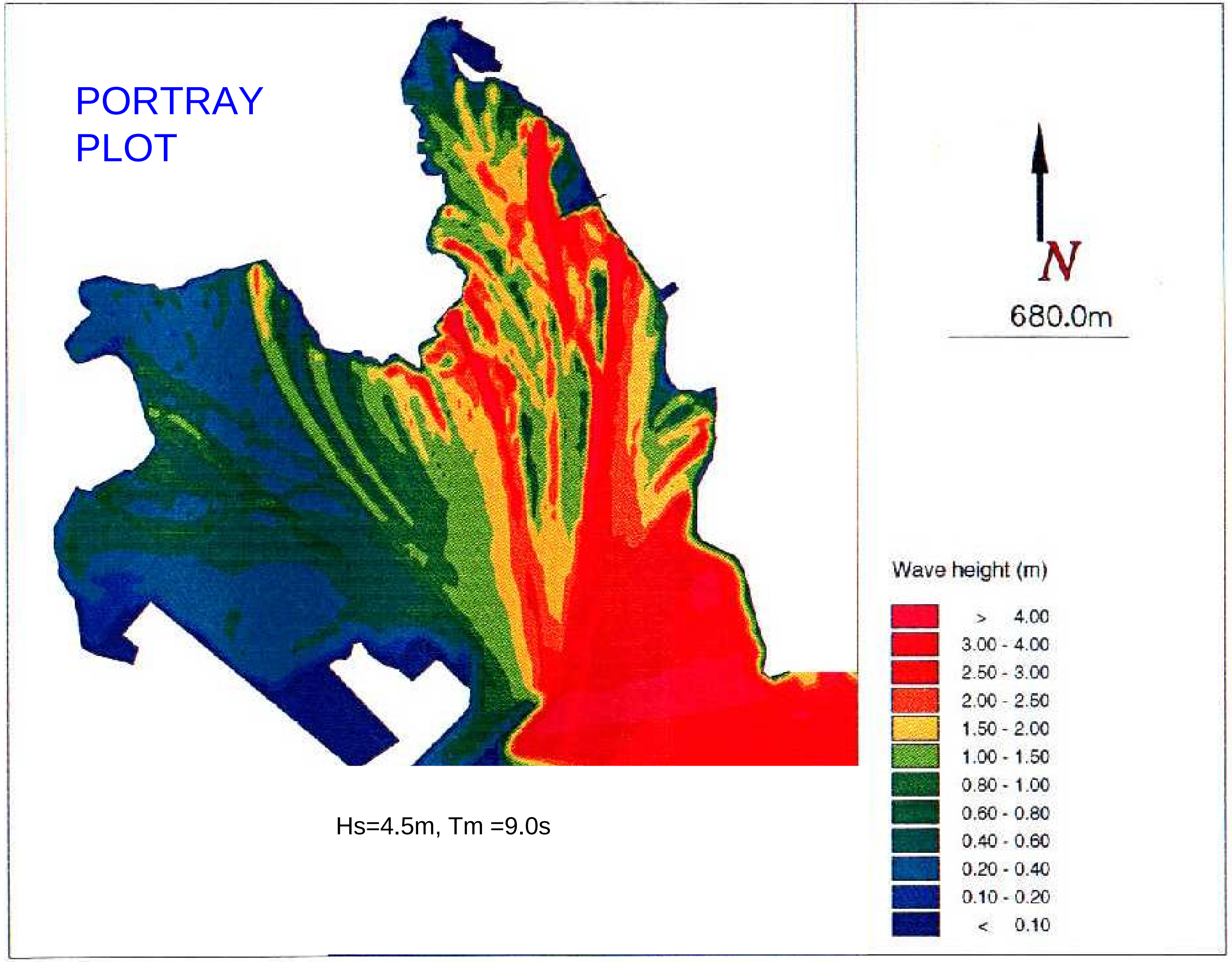
Design aspects - initial thoughts

Wave & sediment conditions

Design of rock structures on unprepared foundations

- Offshore conditions
  - Waves (height/period/direction), water levels and joint probability
- Conditions at site
  - Transformation of offshore conditions into site

Inshore wave heights



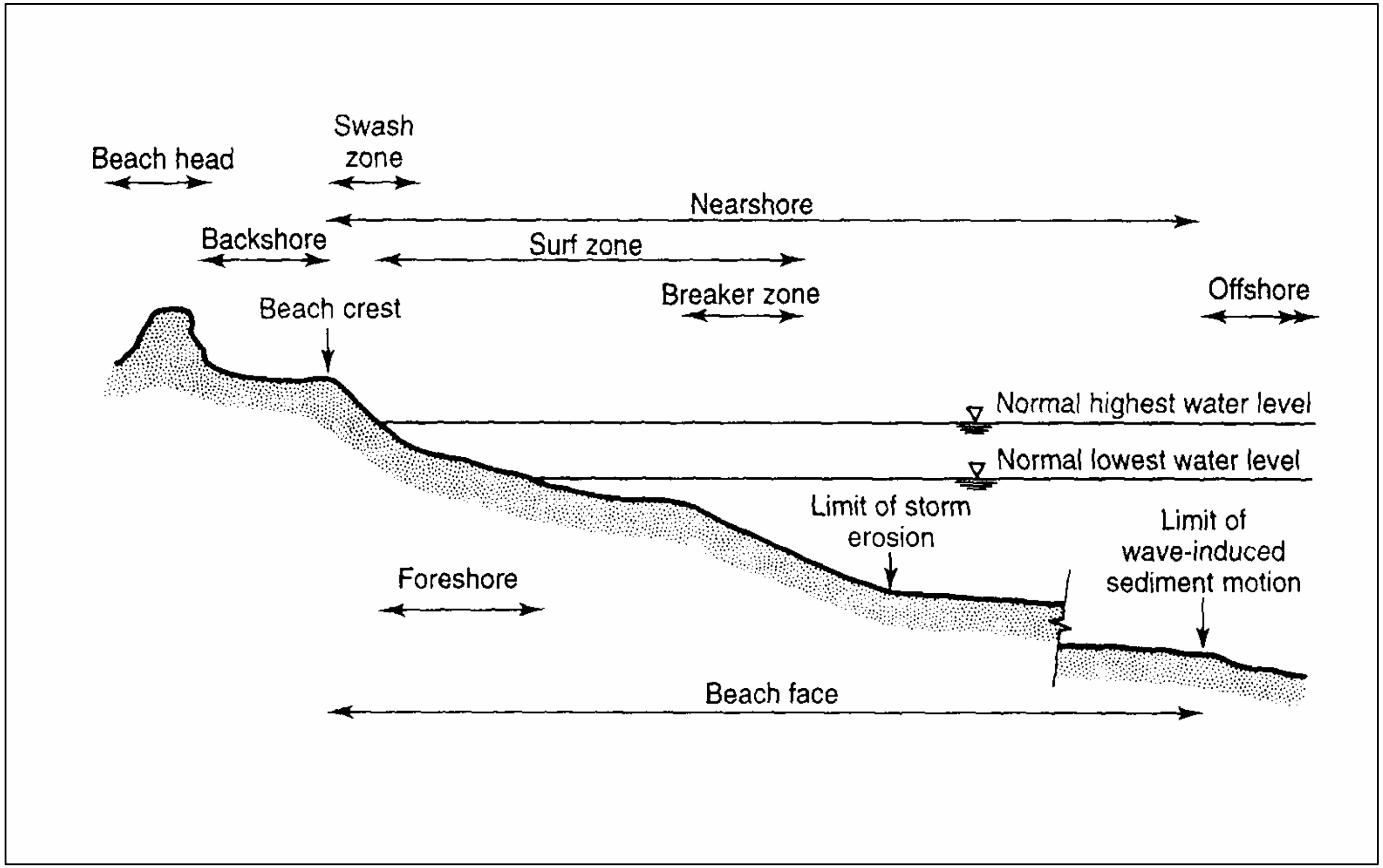
Wave & sediment conditions

Design of rock structures on unprepared foundations

- Offshore wave conditions
  - Waves (height/period/direction), water levels and joint probability
- Conditions at site
  - Transformation of offshore wave conditions into site
  - Inshore changes to waves due to depth limitation of waves (shoaling, wave breaking)
  - Global sediment transport patterns and associated erosion or accretion of beach/seabed

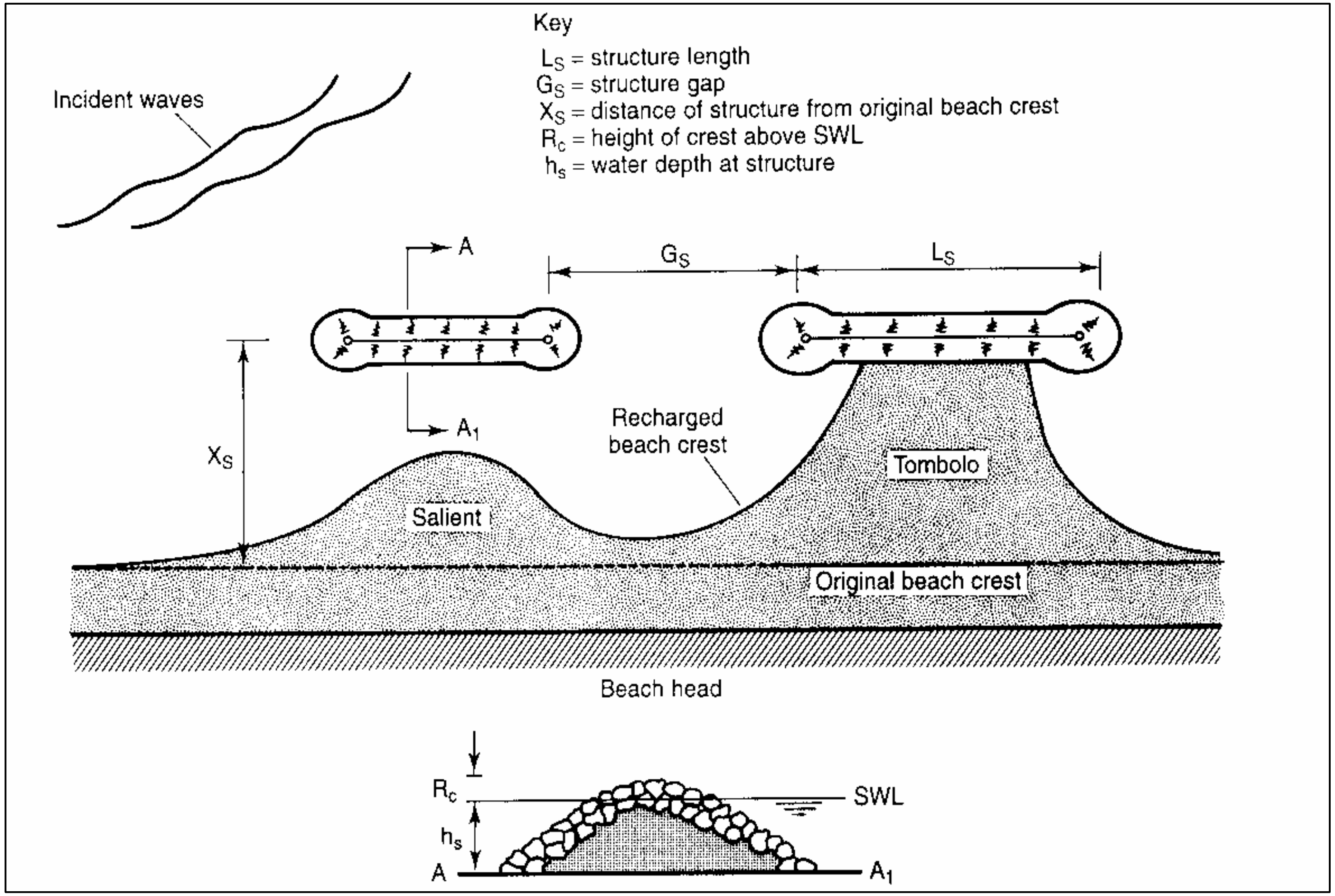
General beach profile

Design of rock structures on unprepared foundations



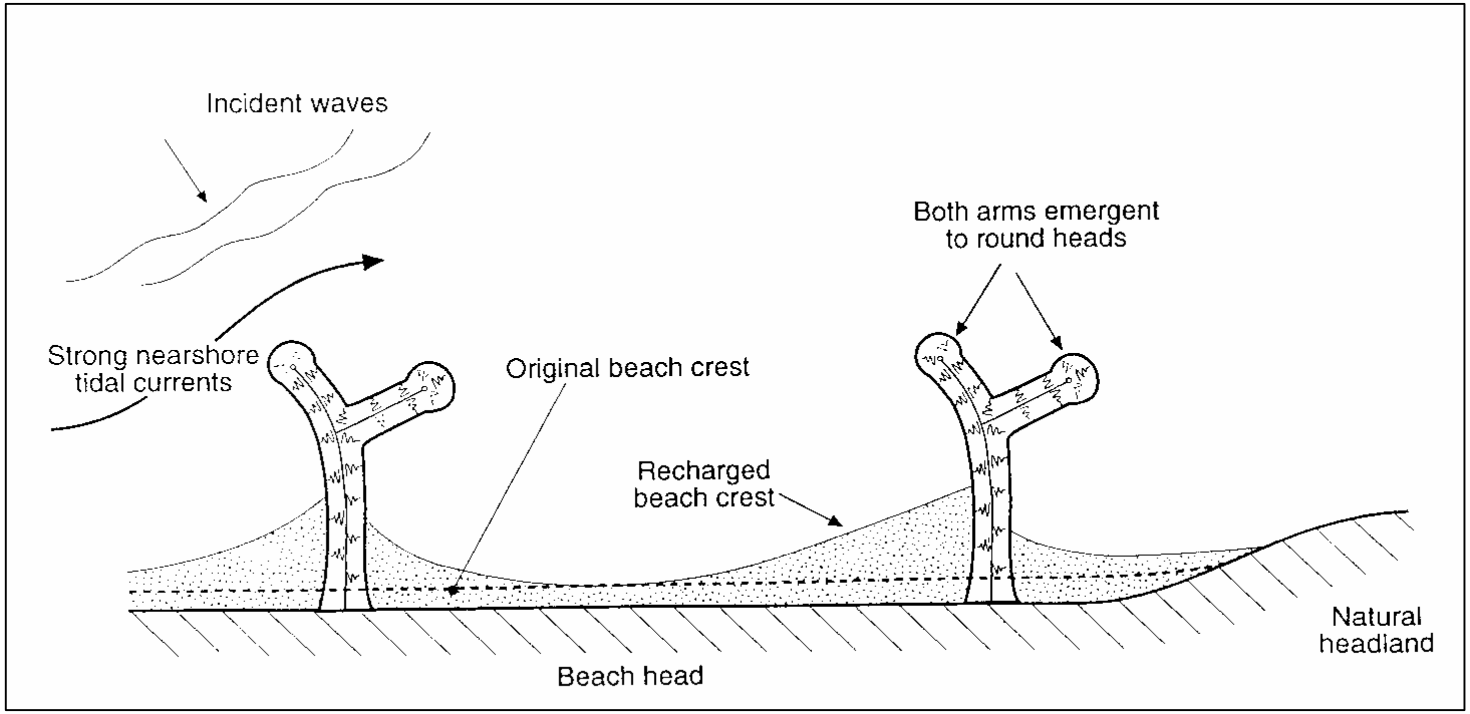
Detached breakwaters

Design of rock structures on unprepared foundations



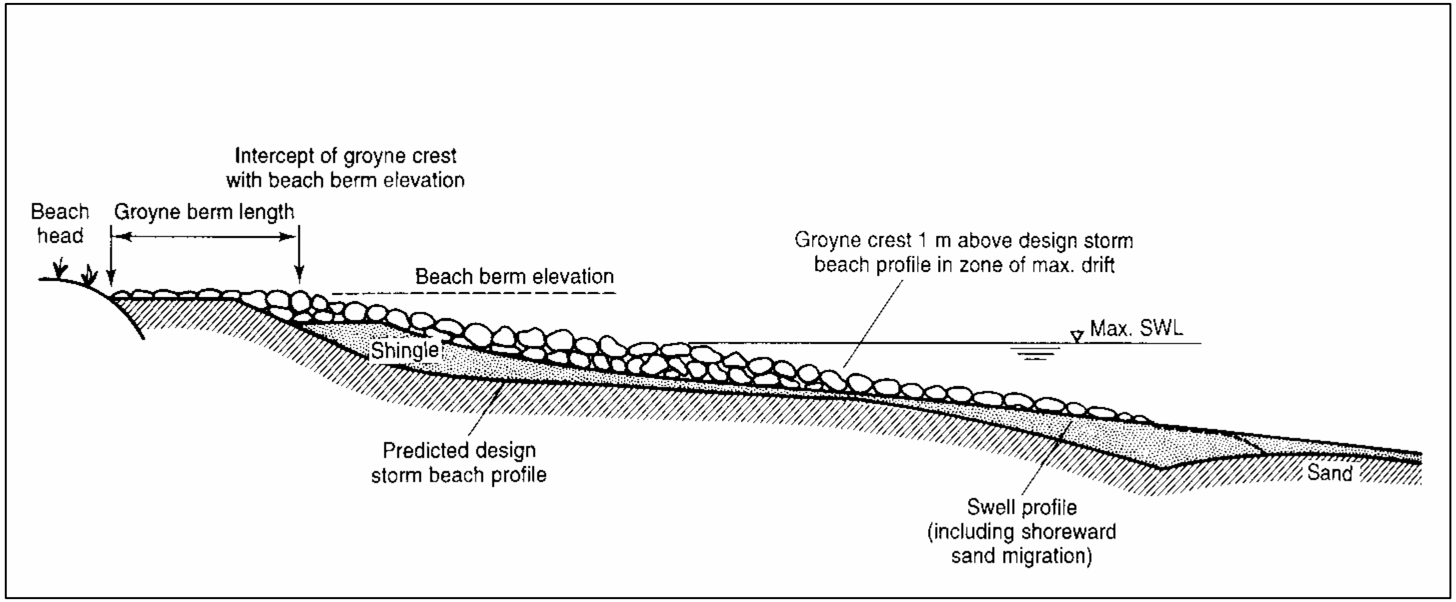
Shore-connected breakwater

Design of rock structures on unprepared foundations



Groyne (profile)

Design of rock structures on unprepared foundations



Revetment

Design of rock structures on unprepared foundations

Backshore protection

Design of rock structures on unprepared foundations

Rock armour and filters

Design of rock structures on unprepared foundations

- Design formulae “well known”, so is there a research issue here?

Rock armour & filters - issues

Design of rock structures on unprepared foundations

- Design formulae "well known", so is there a research issue here?
- Issue for armour and filters relates to meaning of phrase "rock structures on unprepared foundations." This implies:

1. Simplified construction
2. Smaller numbers of construction processes:
   - Reduced no. of armour gradings/layers
   - Reduced amount of excavation (Paul Starr)
   - Changed use of geotextiles (Paul Starr)

Simplifying construction (1)

Design of rock structures on unprepared foundations

To simplify structure:

1. Change the **TYPE OF ROCK**

   – use less numbers of rock gradings/sizes

   – use wider rock gradings (but should these be selected based on D50, D30, D15 or what?)

   – place more rock of a given grading (not in excavated toes/foundations, but in increased layer thicknesses.) May include sacrificial thicknesses (but more information needed on the performance of thick wide graded layers - berm breakwater research available but not necessarily in a form to permit it to be applied directly to nearshore situations?)

Simplifying construction (2)

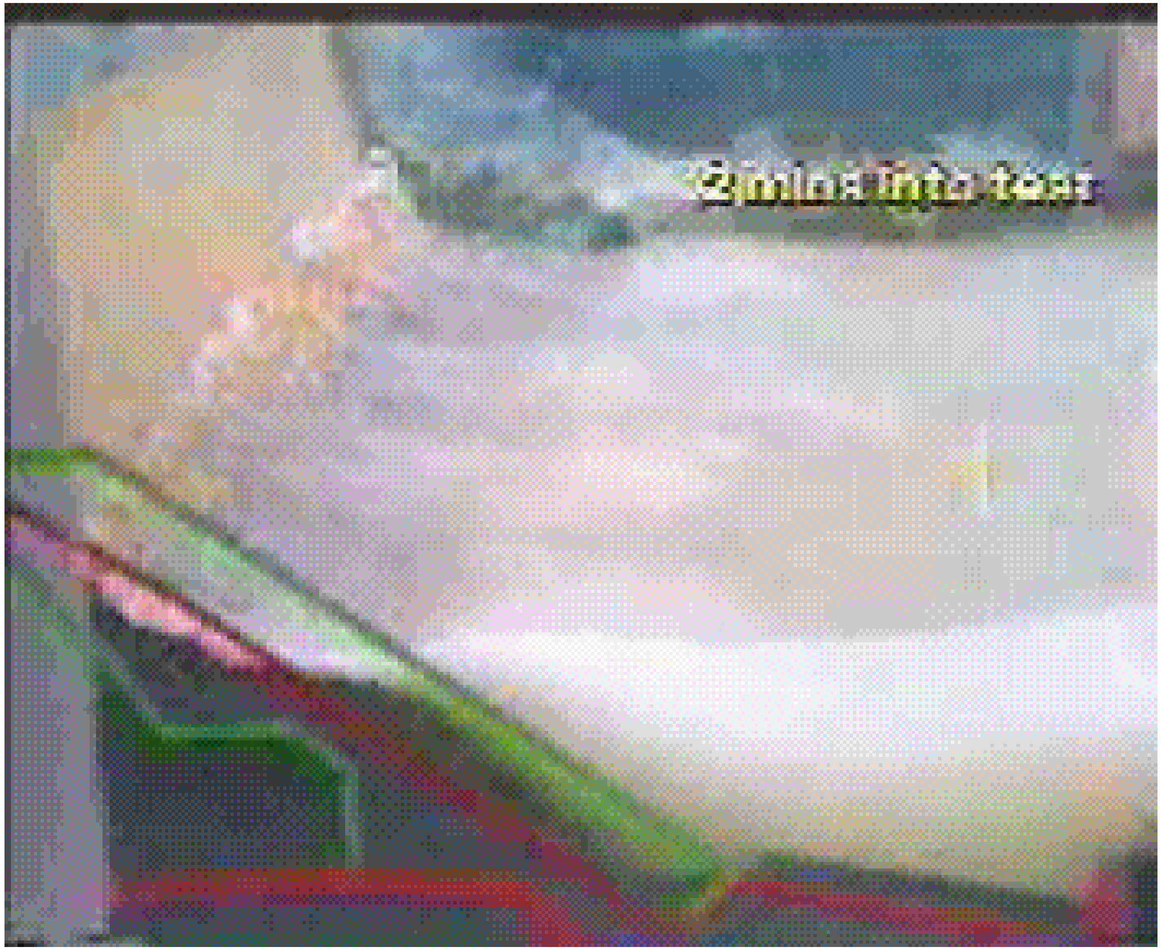
Design of rock structures on unprepared foundations

To simplify construction:

2. Improve the BUILDABILITY of the structure:
   - make better provision for temporary stability of underlayers

Temp stability of filters

Design of rock structures on unprepared foundations



Simplifying construction (2)

Design of rock structures on unprepared foundations

To simplify construction:

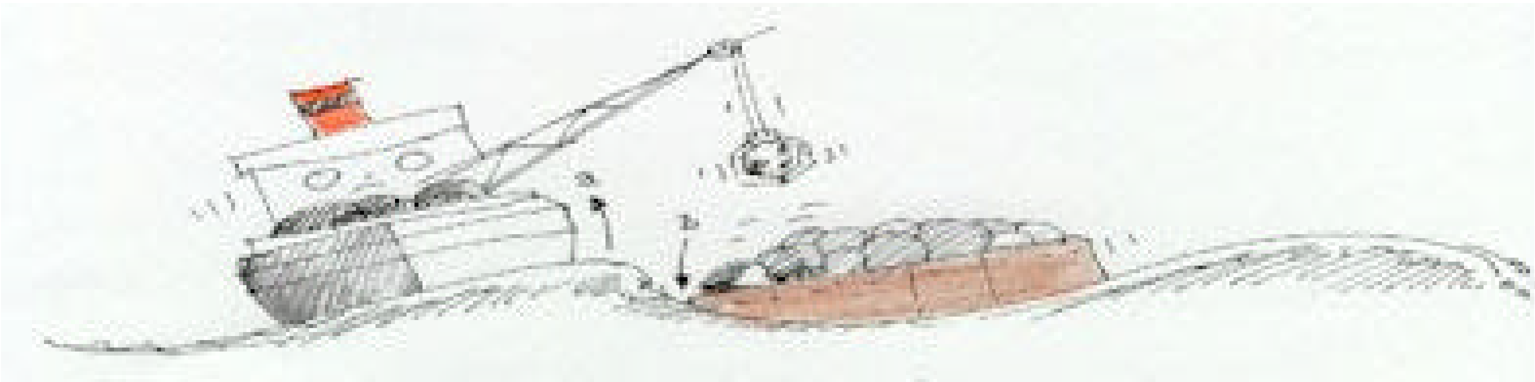
2. Improve the BUILDABILITY of the structure:

   – make better provision for temporary stability of underlayers

   – relax the way the rock is packed together (some research on rock packing and its dry/wet implications is underway at HR Wallingford)

Handling rock - marine plant

Design of rock structures on unprepared foundations

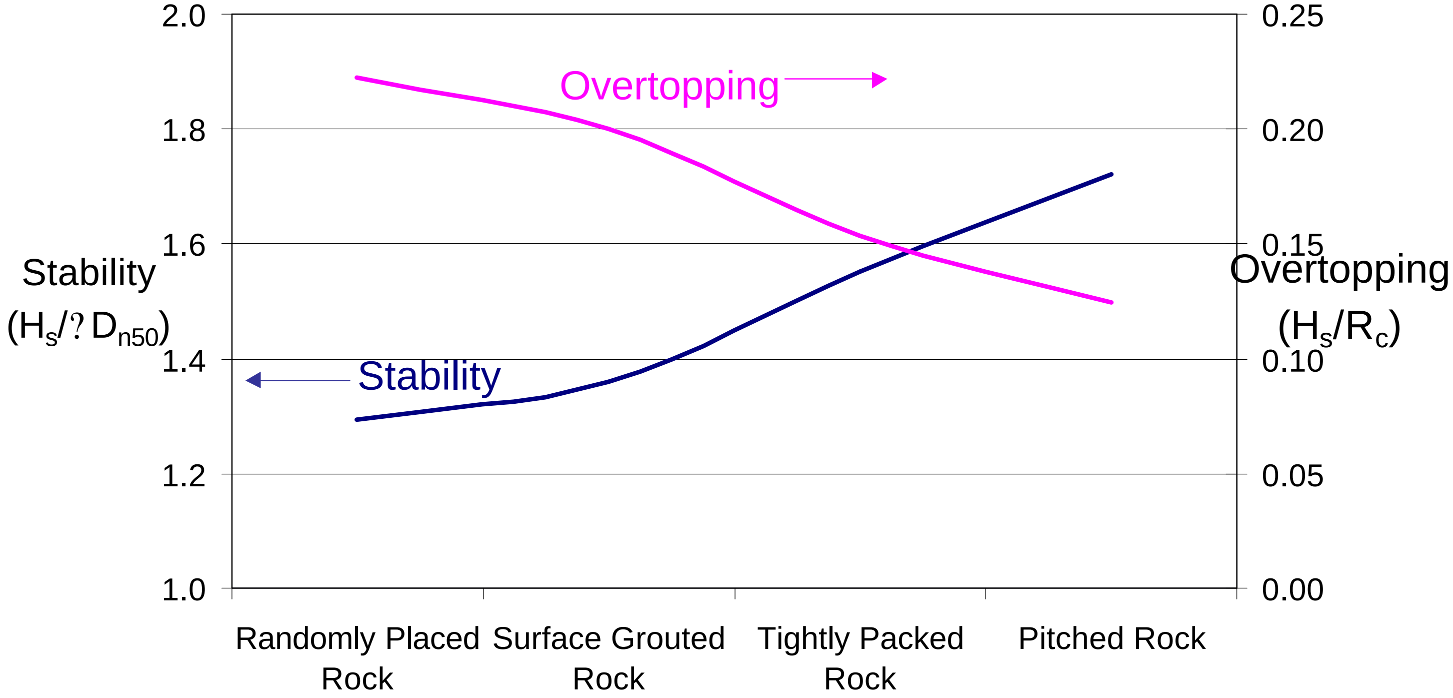


Handling rock - marine plant

Design of rock structures on unprepared foundations

Effects of rock packing

Design of rock structures on unprepared foundations



Simplifying construction (2)

Design of rock structures on unprepared foundations

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   – relax the way the rock is packed together (some research on rock packing and its dry/wet implications is underway at HR Wallingford)

   – avoid use of "Terzaghi rules" based filter layers where natural filters can develop over time (better information on hydraulic gradients within different types of structures needed to do this)

Armour/filter design in future

Design of rock structures on unprepared foundations

Designers: what would induce you to put your PI insurance "on the line" with such structures?

Armour/filter design in future

Design of rock structures on unprepared foundations

Designers: what would induce you to put your PI insurance "on the line" with such structures?

Suggestions:

1 No-blame approach to full scale trials of such schemes (not just at low-energy sites).

Armour/filter design in future

Design of rock structures on unprepared foundations

Designers: what would induce you to put your PI insurance "on the line" with such structures?

Suggestions:

1 No-blame approach to full scale trials of such schemes (not just at low-energy sites).

2 Better design guidance on points such as:

- selection criteria for wide gradings
- thickness recommendations for wide gradings
- methods for assessing hydraulic gradients and associated filter rules, where necessary

Design of Rock Structures

There are two main elements of rock structure design:

1. Rock armour size and filter layers

2. Foundation materials and toe details

What are the design issues?

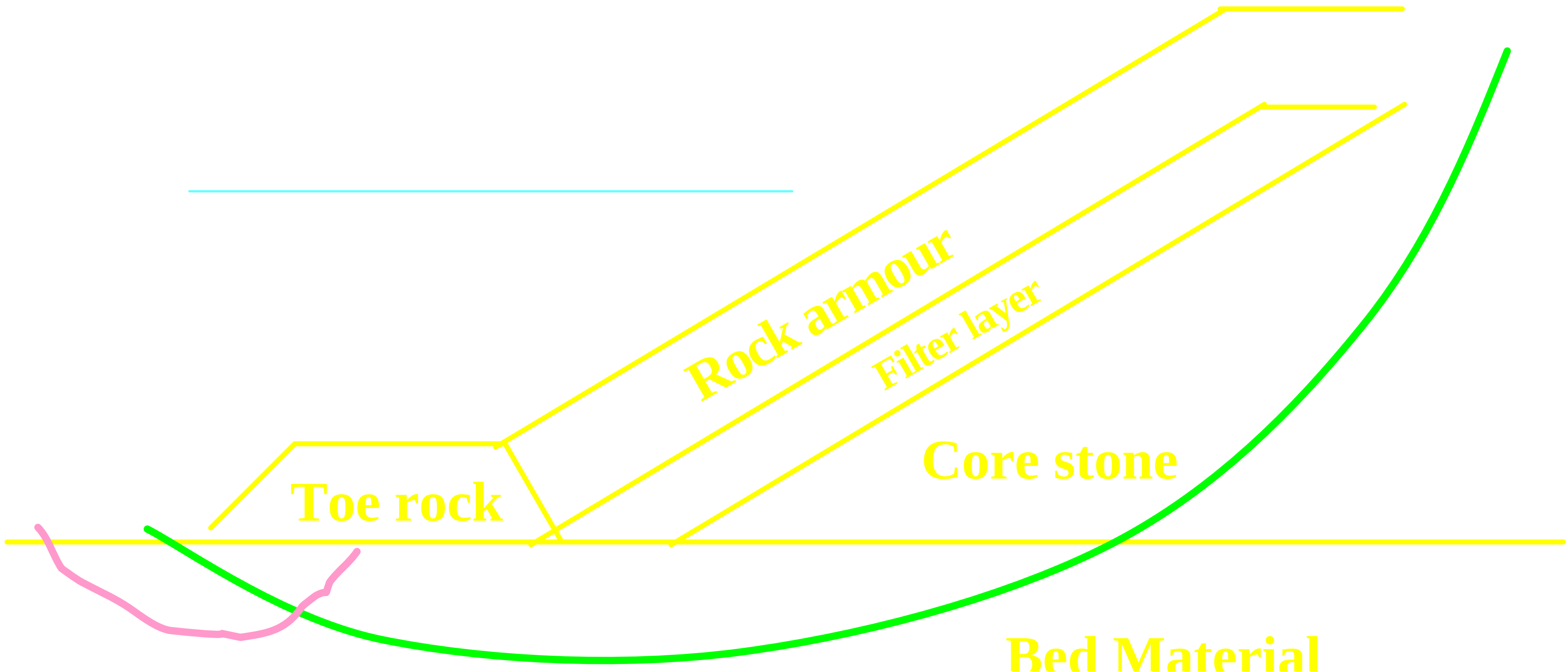
- Settlement and consolidation

✍ Slip circles

✍ Toe stability

✍ Scour

Failure Modes



Foundation Materials

This presentation will discuss the following common foundation materials:

Rock

Gravel or sand

Soft Clay or Silt

Typical toe detail on rock

Prepared rock bed

Advantages

- Toe very stable
- Minimal risk of slips
- Minimal risk of sliding
- Insignificant settlements
- Excellent bearing capacity
- No need for filter layers or geotextile on bed

Disadvantages

- Dredging or digging trench can be expensive

Toe detail on unprepared rock

Unprepared rock bed

Advantages

- Cost of trenching eliminated

Disadvantages

- Effective water depth at toe reduced (may result in larger wave forces on toe)
- Risk of sliding

Example of failed toe

Typical toe detail on sand/ gravel

Prepared sand/ gravel bed

Advantages

- Provision of trench reduces risk of scour at toe
- Slips unlikely
- Good bearing capacity
- Small settlements

Disadvantages

- Formation of trench expensive
- Filter layers required between bed and structure
- Placement of geotextile underwater expensive

Toe detail on unprepared sand

Unprepared sand/ gravel bed

Advantages

- Cost of trenching eliminated
- Minimal risk of slip circles

Disadvantages

- Scour blanket required to prevent undermining of structure
- Effective water depth at toe reduced, increasing risk of damage to toe

Toe detail on prepared soft clay

Prepared clay or silt bed

Advantages

- Poor materials replaced with more competent material such as sand
- Slips usually unlikely
- Good bearing capacity
- Steep armour slope reduces volume of materials
- Potential settlements reduced

Disadvantages

- Dredge and fill operations expensive
- Use of vertical drains expensive
- Scour mattress required to protect against scour

Toe detail on unprepared clay

Unprepared clay or silt bed

Advantages

- Insitu material can remain in place
- Imported fill material not required for foundation

Disadvantages

- Shallower slope probably needed to ensure slip stability
- Geotextile probably required between core material and clay
- Scour mattress required to protect against scour
- Risk of slip and sliding
- Large settlements

Conclusions

- Economy of design depends on the adequacy and applicability of the ground investigation.
- Investment in design can lead to significant savings in capital cost.
- Stability of the toe is essential to ensure global stability of a sloping structure.

COASTAL ROCK STRUCTURES ON UNPREPARED FOUNDATIONS

WILL SHIELDS

POTENTIAL DISADVANTAGES

- High wastage if dedicated armour quarry
- Plant unable to run on poor formation


CAT
DEAN DYBALL

POTENTIAL DISADVANTAGES

- High wastage if dedicated armour quarry
- Plant unable to run on poor formation
- No toe retention

POTENTIAL ADVANTAGES

- Reduced construction time

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- Reduced construction time
- Less risk of damage to partially built structures
- No disposal of excavation arisings
- Less variety of plant
- Less turbidity
- Greater degree of confidence in conformity of construction
- Single stone product
- Safety


DEAN & DYBALL
CAT

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- Single stone product
- Safety
- Relationships


CHARLIE
ROCK

Coastal Rock Structures on Unprepared Foundations

Construction Aspects of Marine Structures in the Low Water Region and Beyond

Coastal Rock Structures

- Plant and Equipment
- Foundation Preparation
- Influencing Factors

Coastal Rock Structures
Plant and Equipment

- **Crane Barges**
- Split Barges
- Side Stone Vessels
- Specialist Vessels

Coastal Rock Structures
Plant and Equipment

- Crane Barges
- **Split Barges**
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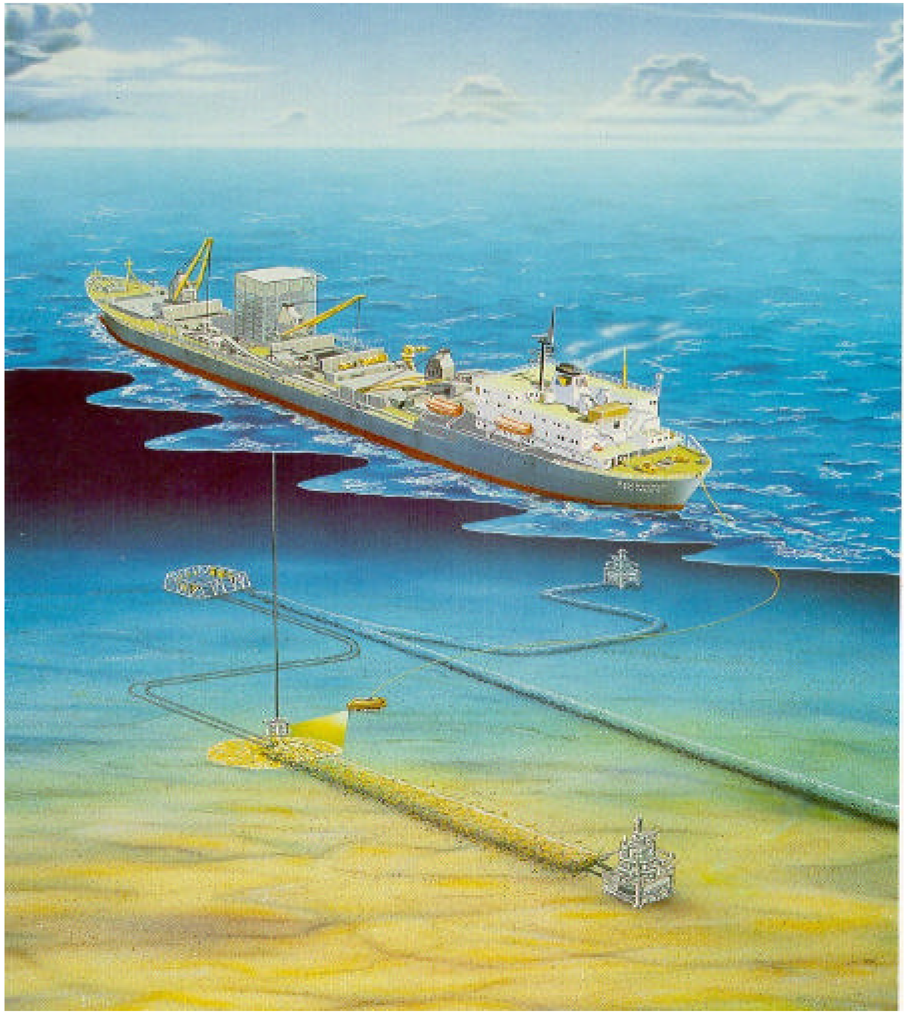
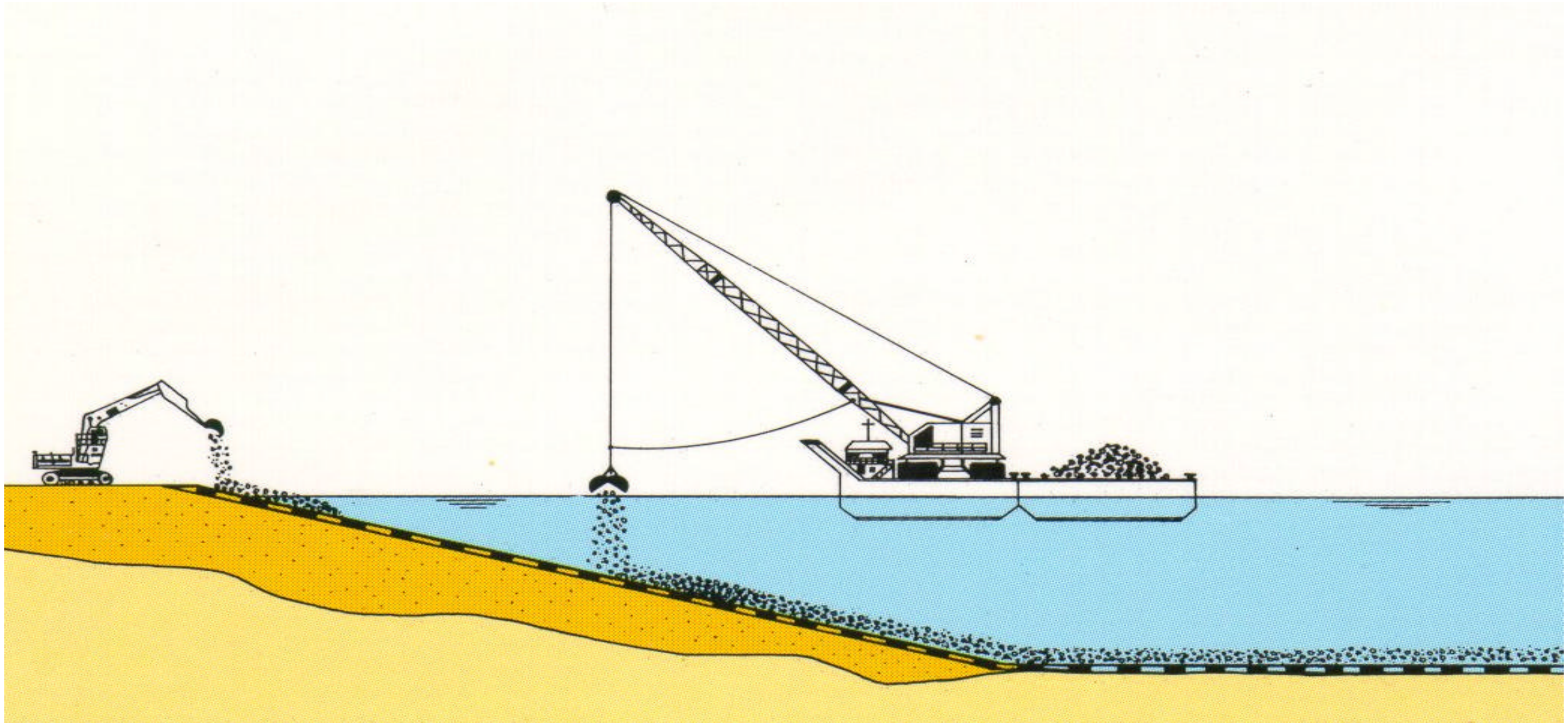


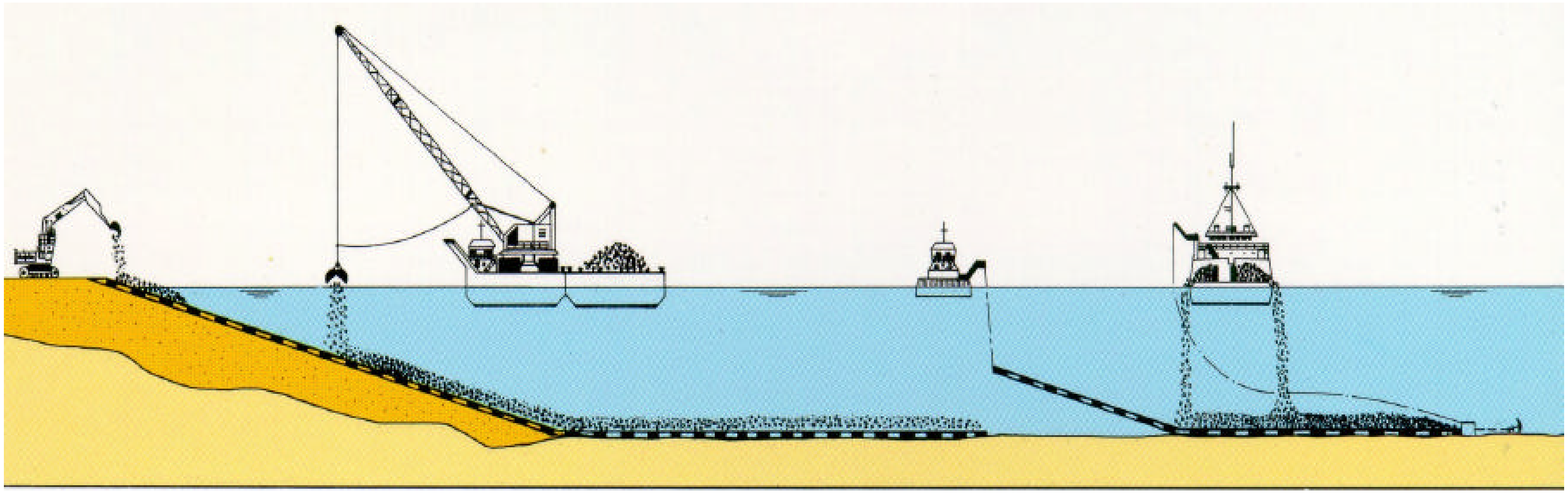
Coastal Rock Structures Foundation Preparation

- Silt removal by dredging
- Laying of geotextiles or facine mattresses
- Graded stone filters
- Final structure

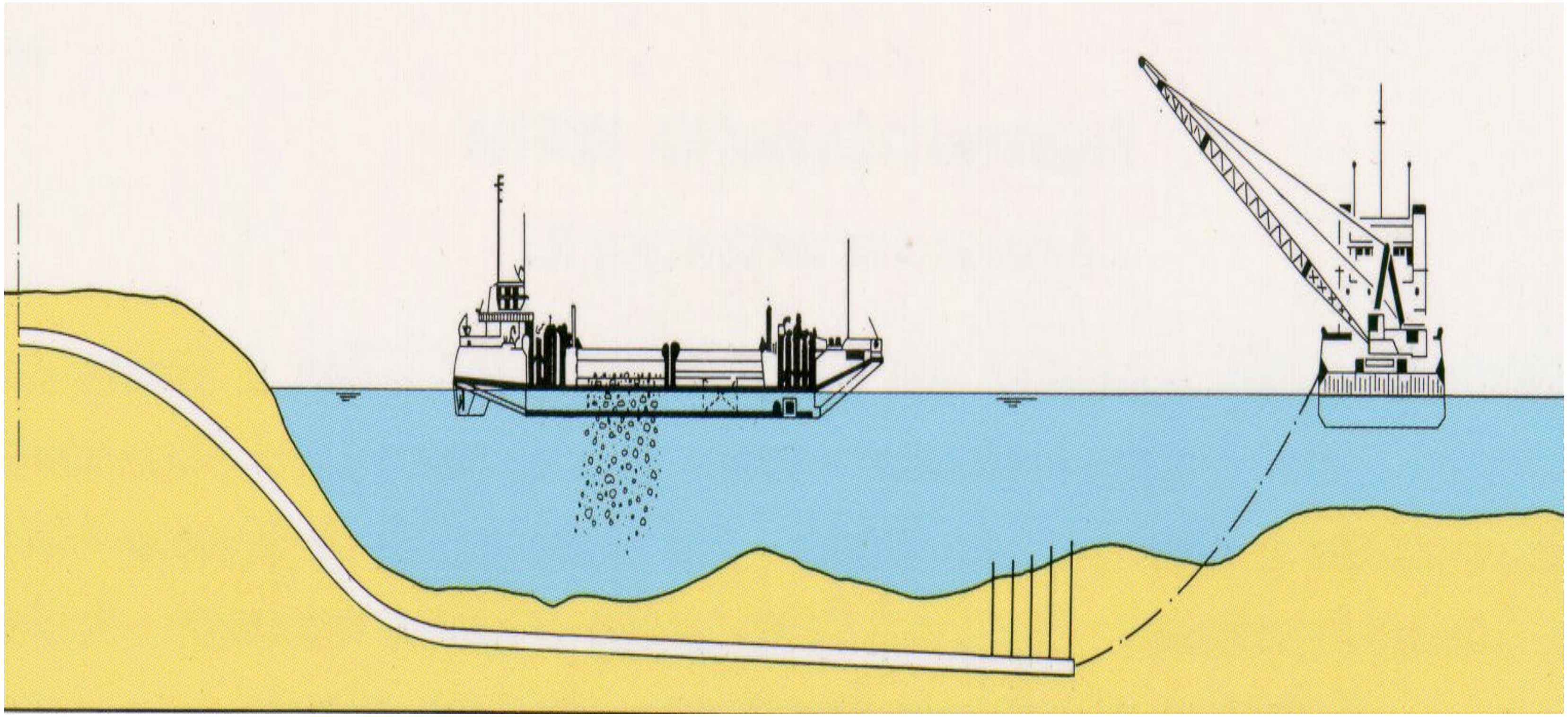
Coastal Rock Structures



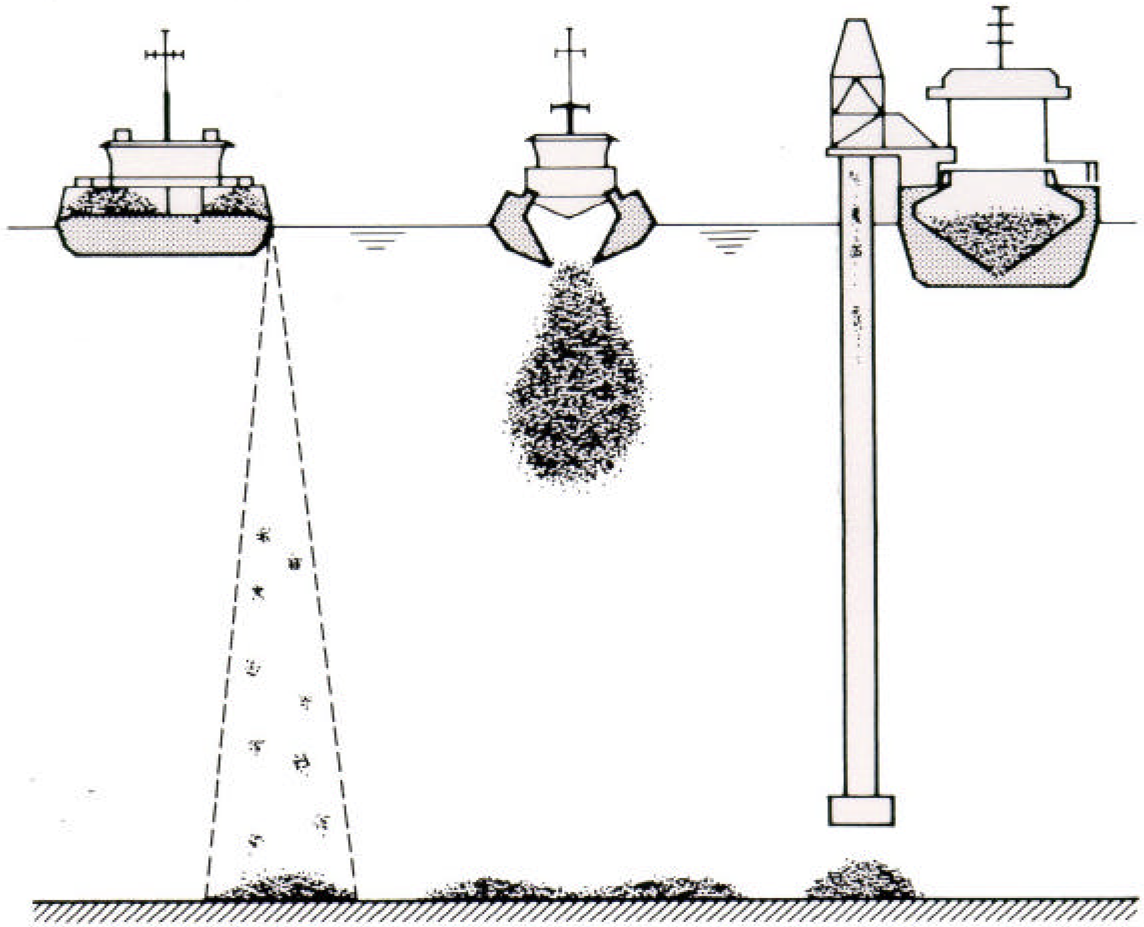
Coastal Rock Structures



Coastal Rock Structures



Coastal Rock Structures



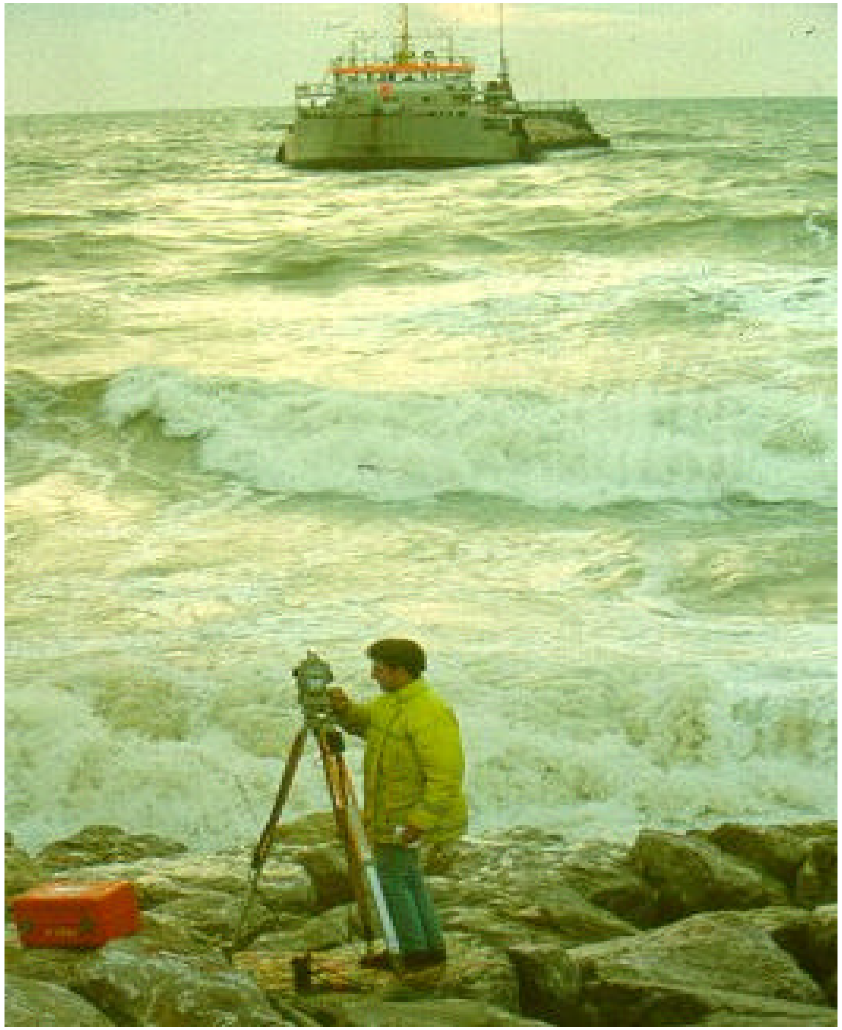
Coastal Rock Structures
Factors influencing Marine Construction

- Tides
- Weather
- Navigational Access
- Time Windows
- Risks and Safety

Coastal Rock Structures

Coastal Rock Structures

Coastal Rock Structures



Coastal Rock Structures

Coastal Rock Structures
Marine Construction
Summary

- Different Plant
- Foundation Characteristics
- Influencing Factors

- **Potential Advantages**

Innovative Use of Rock Armour
in
Coastal Structures

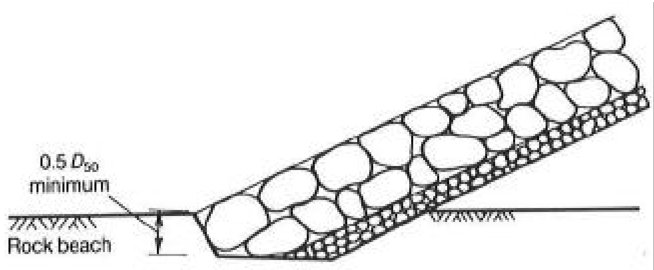
- some of the issues
- some of the experience
- potential opportunities

Some of the Issues

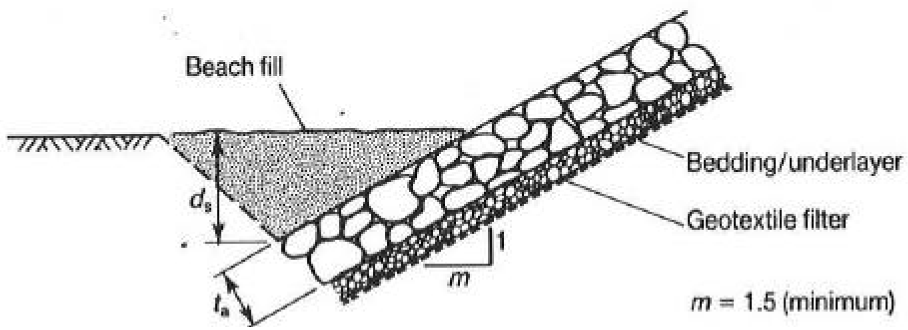
1. Rock armour only construction

- Beach or sea bed interface detailing (sacrificial material)
- Optimisation of quarry yield (broadening of grading)
- Bulk settlement (appropriate allowances)
- Simpler construction (single rock-type, no geotextiles)

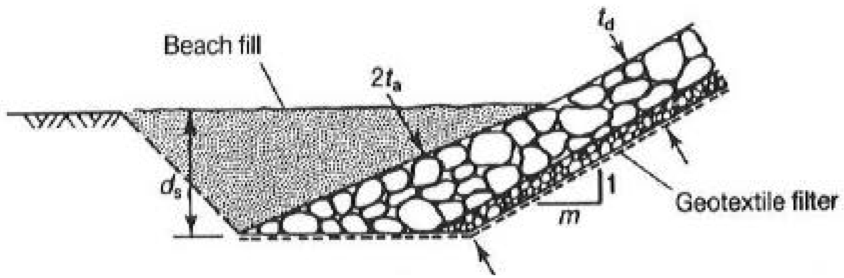
Toe details



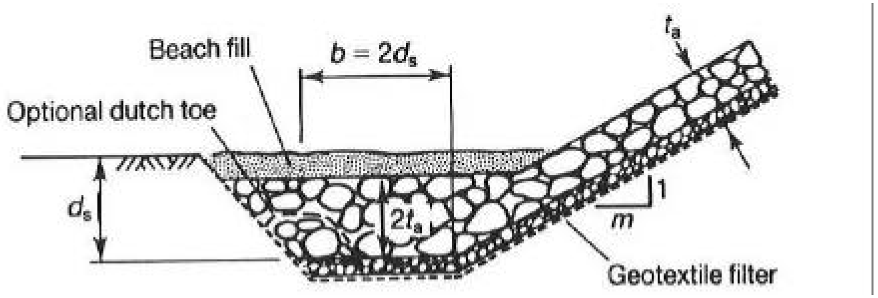
revetment on rock beach



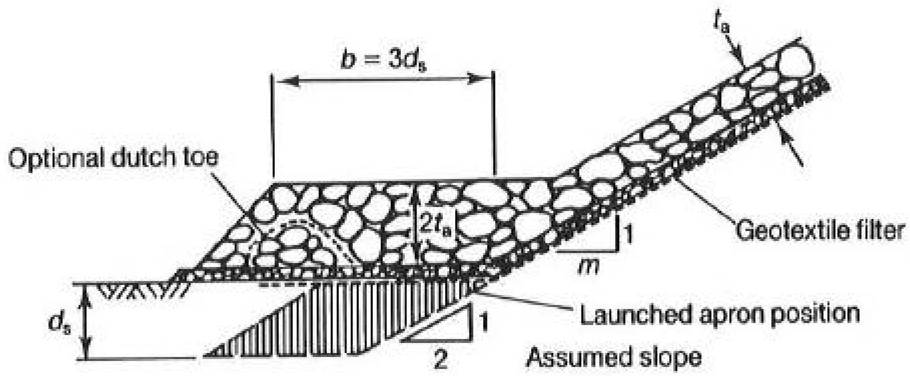
low scour potential, dry construction



low to moderate scour potential, dry construction

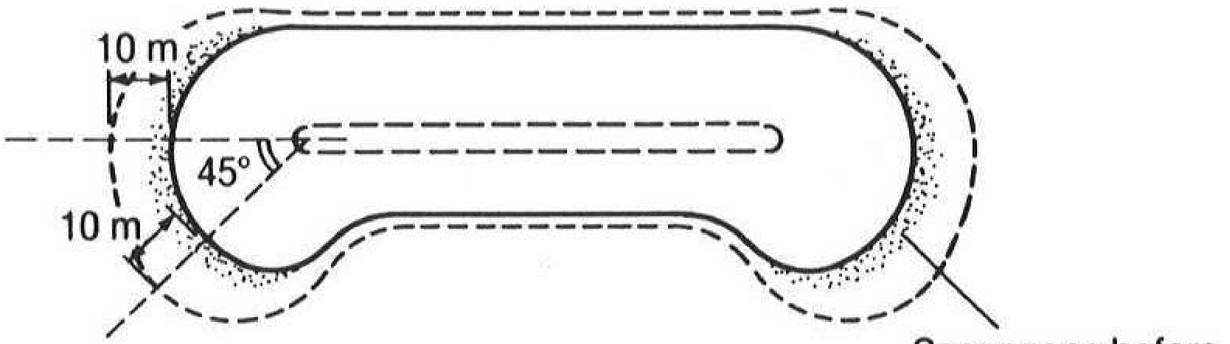


moderate to severe scour potential, wet construction possible

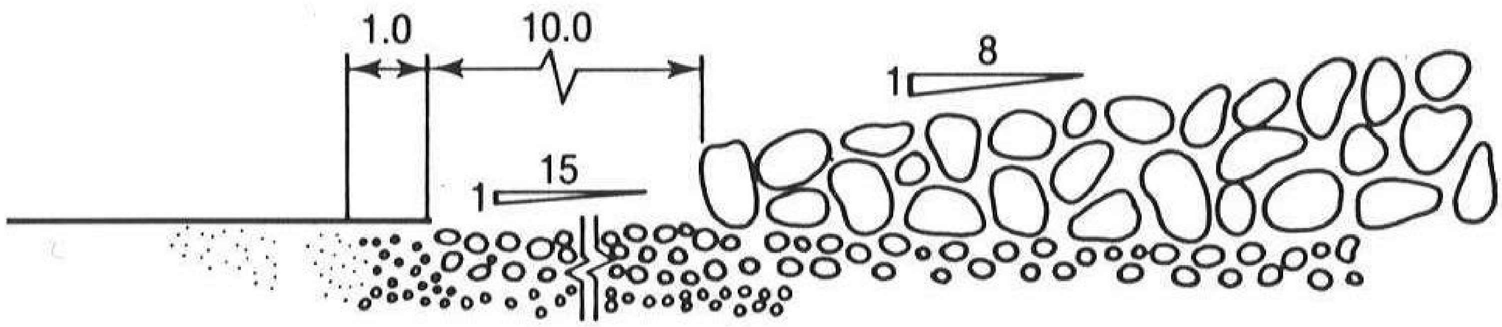


moderate to severe scour potential, construction underwater

Transition details Leasowe Bay offshore breakwater

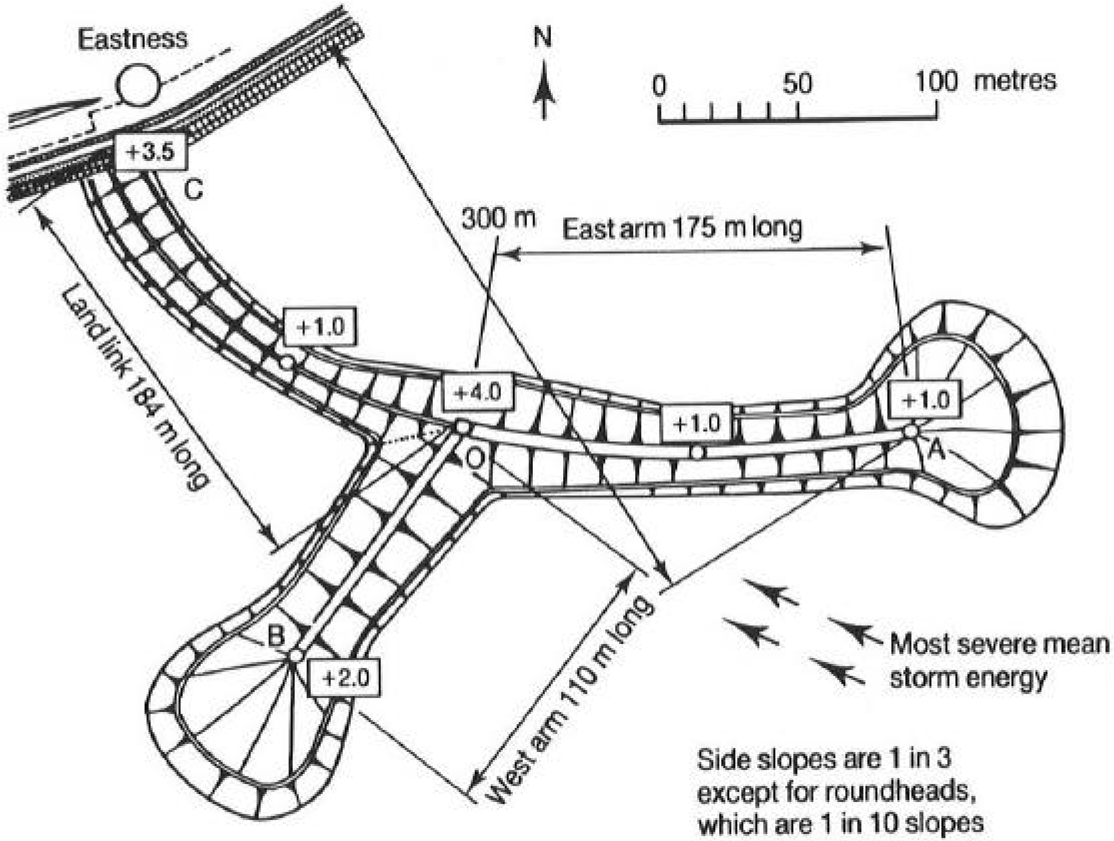


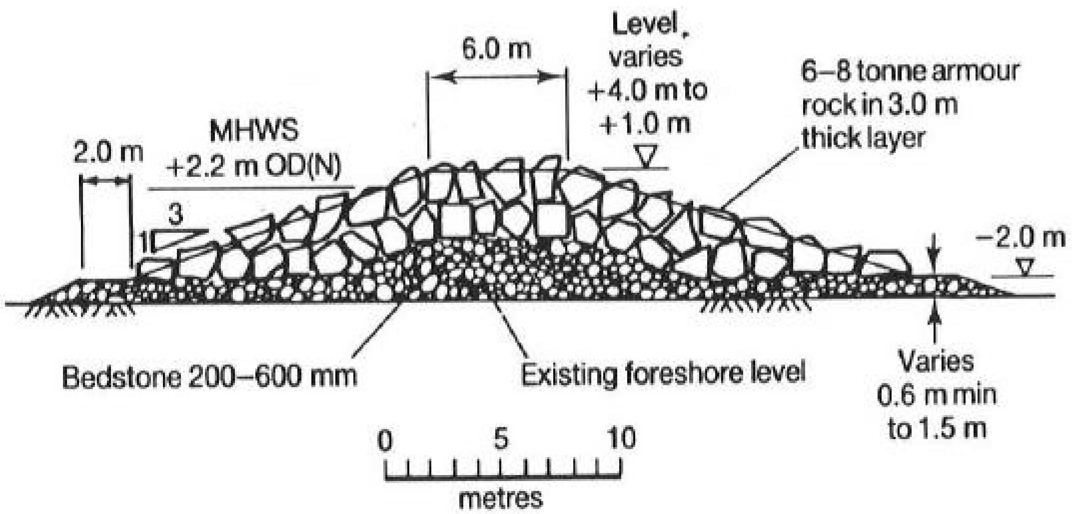
Anti-scour apron layout



Typical stone grading and gradient transition

Eastness Breakwater Clacton-on-sea





Some of the Experience

1. Wirral
2. Llanelli
3. Morecambe

Macro-tidal ranges, wide intertidal zones, significant bank and channel features.

Wirral Frame 1.1

Wirral Frame 1.2

Wirral Frame 1.3

Wirral Frame 1.4

Wirral Frame 1.5

Llanelli Frame 2.1

Llanelli Frame 2.2

Llanelli Frame 2.3

Morecambe Frame 3.1

Morecambe Frame 3.2

Morecambe Frame 3.3

Morecambe Frame 3.4

Morecambe Frame 3.5

Potential Opportunities

1. More sensitive interventions for shoreline evolution control.
2. Easier adaptation to actual exposure conditions during service life.
3. New design approach using staged reshaping of structures improving the efficiency of their littoral influence set against shoreline management objectives.

Potential Opportunities contd.

4. Temporary constructions to counter known periods of increased exposure especially in estuarial situations with options to move and follow the high exposure locations.

Strongpoints

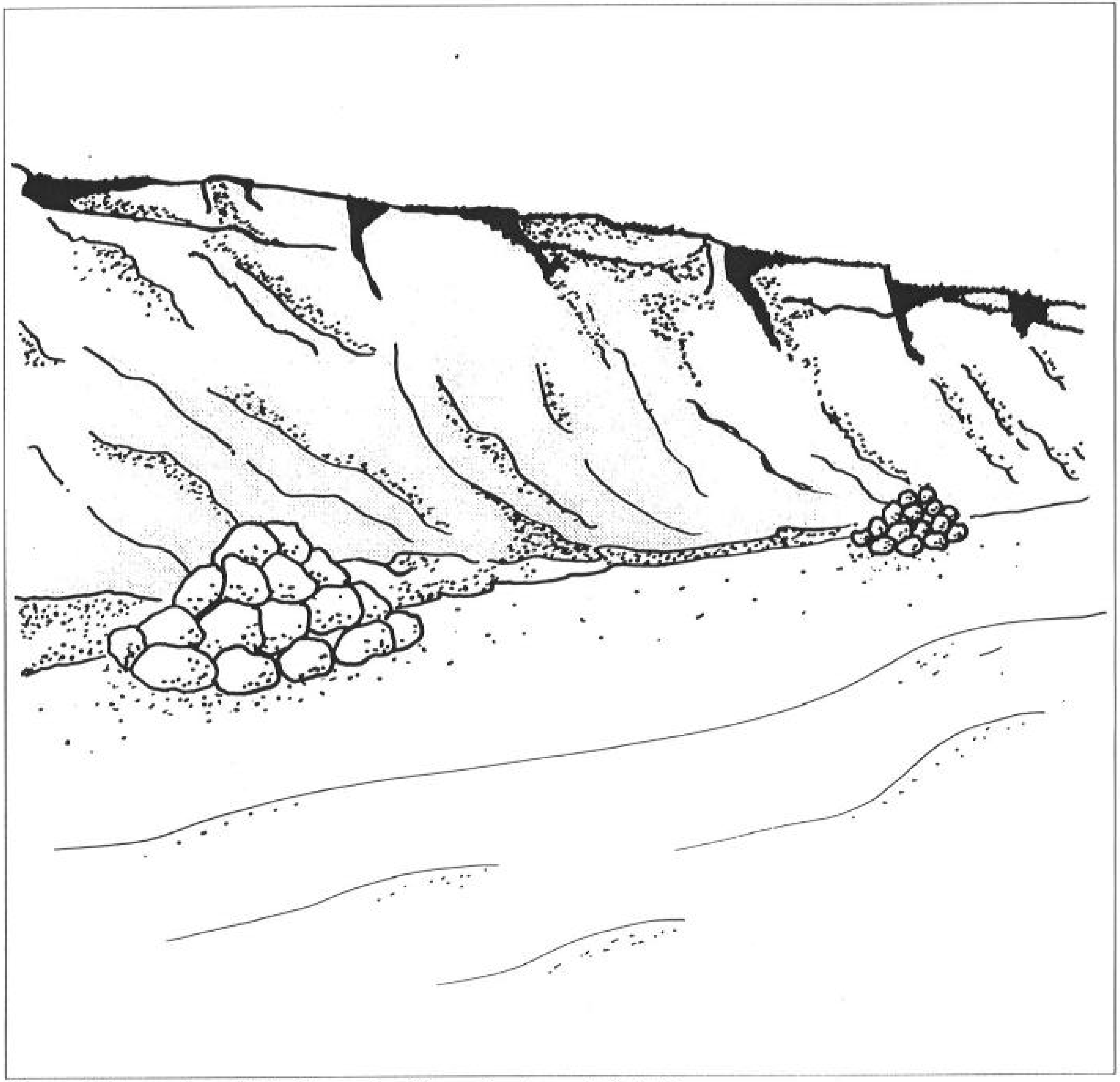


Figure 15 Strongpoints with the intervening cliffs eroding at a controlled rate

Rock Structures on Unprepared Foundations

Andrew Bradbury

Introduction

- Examples of UK practice
- Difficulties with conventional design
- Rationale for an innovative approach
- Assessment of structure performance

What do we want to get out of this?

- Examples of practice elsewhere
- Reasons for approach taken
- Design methods adopted
- Documentation of structure performance

CIRIA Manual on the use of rock in coastal and shoreline engineering

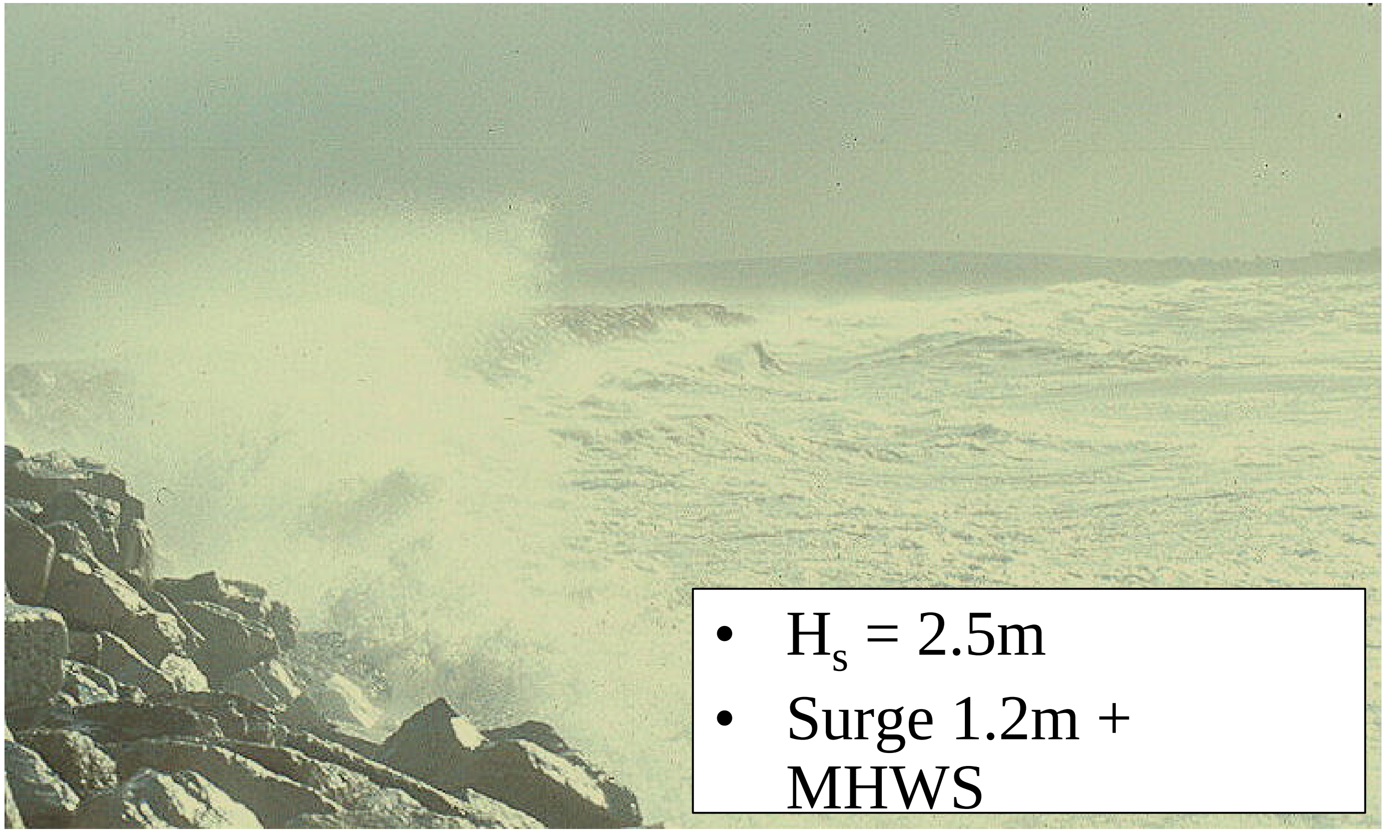
Possible causes of failure

- Inadequate foundation (clay beneath shingle)
- Inadequate armour size
- Steep slopes

Hurst Spit emergency works

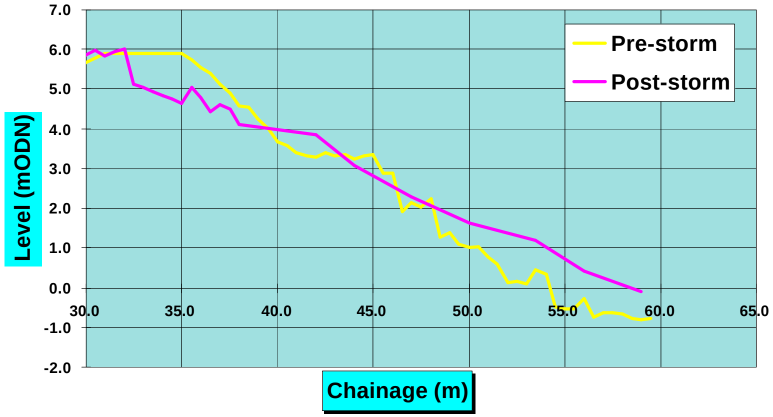
- 1963 emergency works on breached barrier – subsequently maintained
- No underlayer or geotextile
- Single layer armour

Storm conditions resulting in damage -1989



- H_s = 2.5m
- Surge 1.2m + MHWS

Storm response of rock revetment on an unprepared foundation



Damage S=7

Possible causes of failure

Single layer armour construction

Placement directly on shingle

Sub-size armour

Steep slope

Inadequate crest detail

Typical armour layer and underlayer construction

3-6 tonne 2 layer armour

60-300kg underlayer

Nicolon HD625 geotextile

Restricted toe construction in the intertidal zone

Tidal working at sites with narrow tidal range

Submerged foundation construction

Submerged foundation construction

Placement of submerged geotextile

Placement of submerged underlayer

Measurement of submerged underlayer

Structure Performance

Why not build rock structures with unprepared foundations ?

- Best practice guides and standards suggest prepared foundations are needed
- No design guidance is available for unprepared foundations
- Little documentation of structure performance

Best practice origins

- Best practice design methodology for structure stability is based upon small scale physical model testing
- Principles of filtering are based upon empirical methods developed in the SPM for deep water breakwaters
- Geotechnical aspects based on traditional soil strength analysis

Why have structures been built with unprepared foundations previously?

- Emergency works
- Danger of instability to existing structures
- Experimental structures
- Low risk structures
- Low or diminishing exposure

Emergency works - seawall failure

- Urgent support needed to seawall
- Tidal conditions unsuitable for geotextile placement

Emergency works

- Placement of armourstone and subsequent settlement

Undermined foundations

- Danger of structure collapse

Herne Bay - Eastcliff

- No geotextile used
- Limited settlement observed
- Future works likely to utilise geotextile

East of Hengistbury Head

- Relatively benign environment
- Originally built as experimental structures
- No discernable change

Highcliffe - Dorset

- 24 rock groynes since 1977 on Christchurch shoreline
- "Crude piles of rock"
- Sheltered site
- No geotextile
- No underlayer
- Wide grading
- Satisfactory performance

Blue Anchor Bay - Somerset

Blue Anchor Bay – Experimental L-groynes

Hayling Island

- 3-6t Armour placement on foreshore
- No geotextile
- No underlayer

Hayling Island

- Structures monitored
- No measurable change in level

Elmer

- Armourstone on bedding layer
- No geotextile
- Geotextile used on one island

Rustington

- Revetment against seawall
- No geotextile
- No underlayer

Seaford

- Low risk environment
- Placement as a secondary defence
- Subsequently covered by beach recharge

Structure performance

- Numerous structures with unconventional construction
- Limited data to support construction of structures
- Limited confidence in approach
- Need to work within best practice guidelines
- Need for better guidance on foundation requirements