INTRODUCTION TO BED, BANK AND SHORE PROTECTION

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Introduction to
Bed, Bank and Shore Protection

A little learning is a dangerous thing;
Drink deep or taste not the Pierian spring.
Alexander Pope (1688-1744)

Preface

Every book is unique. This one is because of a combination of two things:

- the coverage of subjects from hydraulic, river and coastal engineering, normally treated in separate books
- the link between theoretical fluid mechanics and practical hydraulic engineering.

On the one side, many fine textbooks on fluid motion, wave hydrodynamics etc. are available, while on the other side one can find lots of manuals on hydraulic engineering topics. The link between theory and practice is seldom covered, making the use of manuals without understanding the backgrounds a "dangerous thing". Using a cookbook without having learned to cook is no guarantee for a tasty meal and distilling whisky without a thorough training is plainly dangerous. Manuals are often based on experience, either in coastal or river engineering, or they focus on hydraulic structures, like weirs and sluices. This way, the overlap and analogy between the various subjects is lacking, which is a pity, especially in non-standard cases where insight into the processes is a must.
This book tries to bridge the gap between theoretical hydrodynamics and the design of protections. Understanding of what happens at an interface between soil and water is one of the key notions. However, this can only partly be derived from a textbook. Using one's eyes every time one is on a river bank, a bridge or a beach is also part of this process. In the same sense, a computer program never can replace experimental research completely and every student who wants to become a hydraulic engineer should spend time doing experiments whenever there is a possibility to do so.

Gerrit J. Schiereck
Dordrecht, June 2003

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Reminder I

Things you should remember before studying this book

1. $H = z + \frac{p}{\rho g} + \frac{u^2}{2g} = h + \frac{u^2}{2g}$ energy head = location + pressure head + velocity head = piezometric head + velocity head (Bernoulli)

2. $p = \rho g h$ hydrostatic pressure

3. $\Delta h = \frac{u^2}{2g} \rightarrow u = \sqrt{2g\Delta h}$ (Torricelli)

4. $\frac{p}{\rho g} = \frac{u^2}{2g} \rightarrow p = \frac{\rho u^2}{2}$ transfer of velocity into pressure

5. $\bar{u} = C\sqrt{RI} \left(C = 18 \log \frac{12R}{k_r} \right)$ (Chezy)

6. $u_f = kI$ (Darcy)

7. $\sigma' = \sigma - p$ (effective stress = total stress – water pressure)

8. $\left.\begin{array}{l} L = cT \\ c_0 = \frac{gT}{2\pi} \end{array}\right\} \rightarrow L_0 = c_0 T = \frac{gT^2}{2\pi} \approx 1.56 T^2$ (deep water wavelength)

9. $c_s = \sqrt{gh} \rightarrow L_s = \sqrt{gh}\, T$ (shallow water wavelength)

10. $\mathrm{Re} = \frac{uL}{\nu}$ (Reynolds number, inertia versus viscosity) for open channel flow, with $L = h$, flow is turbulent for Re > 2000-3000

11. $Fr = \frac{u}{\sqrt{gh}}$ (Froude number, kinetic versus potential energy)

    Fr < 1: sub-critical flow
    Fr = 1: critical flow (u = celerity shallow water wave)
    Fr > 1 super-critical flow

Contents

1 INTRODUCTION

Eroded coast (North Holland), courtesy Rijkswaterstaat

1.1 How to look at protections

1.1.1 Why and when

The interface of land and water has always played an important role in human activities; settlements are often located at coasts, river banks or deltas. When the interface consists of rock, erosion is usually negligible, but finer material can make protection necessary. In a natural situation, the interface moves freely with erosion and sedimentation. Nothing is actually wrong with erosion, unless certain interests are threatened. Erosion is somewhat like weed: as long as it does not harm any crop or other vegetation, no action is needed or even wanted. There should always be a balance between the effort to protect against erosion and the damage that would occur otherwise.

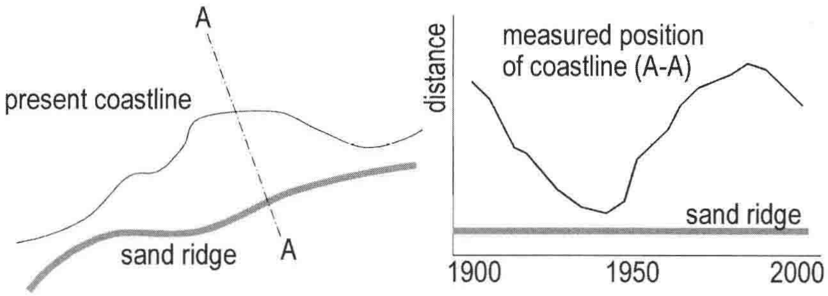

Figure 1-1 To protect or not to protect, that's the question

Figure 1-1 shows cyclic sedimentation and erosion of silt (with a period of many decades) seaward of a natural sand ridge. In a period of accretion people have started to use the new land for agricultural purposes. When erosion starts again, the question is whether the land should be protected and at what cost. Sea-defences are usually very costly and if the economic activities are only marginal, it can be wise to abandon the new land and consider the sand ridge as the basic coastline. If a complete city has emerged in the meantime, the decision will probably be otherwise. With an ever increasing population, the pressure on areas like these also increases. Still, it is good practice along a natural coast or bank to build only behind some set-back line. This set-back line should be related to the coastal or fluvial processes and the expected lifetime of the buildings. For example, a hotel has a lifetime of, say 50 years. It should then be built at a location where erosion will not threaten the building within 50 years, see Figure 1-2. So, in fact the unit for a set-back line is not meters but years! These matters are Coastal Zone Management issues and are beyond the scope of this book.

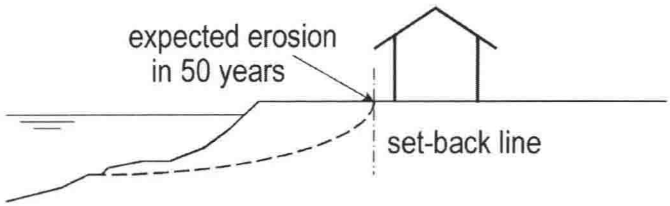

Figure 1-2 Building code in eroding area

Besides erosion as a natural phenomenon, nature can also offer protection. Coral reefs are excellent wave reductors. Vegetation often serves as protection: reed along river banks and mangrove trees along coasts and deltas reduce current velocities and waves and keep the sediment in place. Removal of these natural protections usually mark the beginning of a lot of erosion trouble and should therefore be avoided if possible. So, a first measure to fight erosion, should be the conservation of vegetation at the interface. Moreover, vegetation plays an important role in the ecosystems of banks. Chapter 12 deals with these aspects and with the possibilities of nature-friendly protections.

Finally, it should be kept in mind that, once a location is protected along a coast or riverbank that has eroded on a large scale, the protected part can induce extra erosion and in the end the whole coast or bank will have to be protected. So, look before you leap, should be the motto.

A lot of cases remain where protection is useful. Figure 1-3 gives some examples of bed, bank and shore protections. Along canals, rivers and estuaries, bank protection is often needed to withstand the loads caused by flow, waves or ships. Shore protection structures include seawalls, revetments, dikes and groynes. Bed protection is necessary where bottom erosion could endanger structures, like bridge piers, abutments, in- or outlet sluices or any other structures that let water pass through.

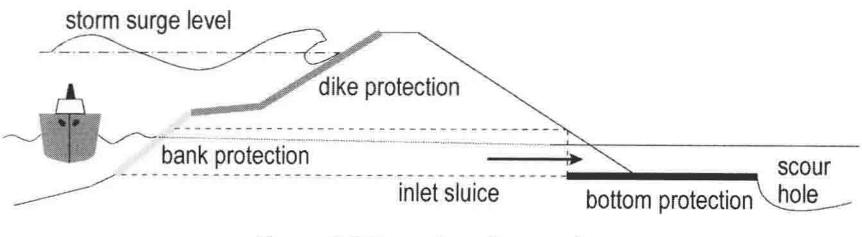

Figure 1-3 Examples of protection

1.1.2 Design

Protections of the interface of land or soil and water are mostly part of a larger project: e.g. a navigation channel, a sea defence system, an artificial island or a bridge. Therefore, the design of a protection should be tuned to the project as a whole, as part of an integrated design process, see De Ridder,1999. In general it can

be said that the resulting design should be *effective* and *efficient*. Effective means that the structure should be functional both for the user and the environment. This implies that the structure does what it is expected to do and is no threat for its environment. Efficient means that the costs of the (effective) structure should be as low as possible and that the construction period should not be longer than necessary.
A design that combines effectiveness and efficiency can be said to be "*value for money*". The intended value becomes manifest in the *terms of reference* (ToR) which contains the demands for a structure. This ToR has to be translated into concepts (possible solutions). Demands and concepts do not match one to one and a fit between the two is to be reached with trial and error. Promising concepts are engineered and compared. One comparison factor, of course, is costs. The designer's task to get value for money can be accomplished by compromising between four elements, see Figure 1-4.

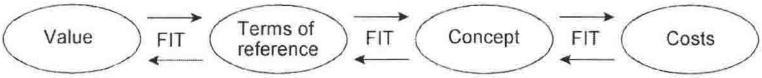

Figure 1-4 Value for money

The design process is of a cyclic nature because it is impossible to go directly from left to right in Figure 1-4. In the first phase, the designer works with a very general notion of the ToR and with some concepts in mind, based on his own or others' experiences. An integrated design process starts with a rough approach to all four elements in Figure 1-4, refining them in subsequent design phases. Effectivity can be evaluated in terms of functionality, environment and technology, while efficiency is expressed in terms of costs and construction although, of course, there are several overlaps and links between these aspects. They all play a role in each of the design phases, but the focus gradually shifts as indicated in Figure 1-5.

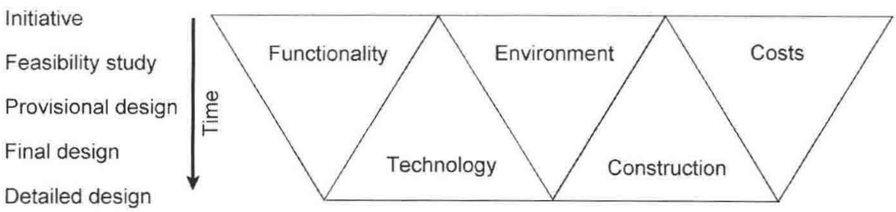

Figure 1-5 Focus during design process

Level of detail

In any project it is possible to discern various levels of detail. It is good to be aware of the level of detail one is working on and to keep an eye on the adjacent levels. An example of these levels (other divisions are, of course, possible):

1. System (Macro level)
2. Components (Meso level)
3. Parts (Mini level)
4. Elements (Micro level)

Examples of the macro level are e.g. a coastal zone, a watersystem (river, lake etc.) a harbour or a polder. On the meso level, one can think of components like a sea defence (dike, sea wall etc.), a river bank, a breakwater, a closure dam or an outlet sluice. On the mini level we look at dike protections, bank protections or bottom protections. The micro level, finally, consists of elements like stones, blocks etc. In this hierarchy, the title of this book indicates that it treats subjects on the third level. Level 1 should always play a role in the background, see e.g. section 1.1.1. Level 2 will be treated where and when adequate, while sometimes level 4 also plays a role e.g. when it comes to defining stone sizes. As a consequence of these levels, it can be said that the design of protections in a large project is usually more in the lower part of Figure 1-5, when it comes to the technical development of a plan.

1.1.3 Science or craftsmanship

Protections of the interface of land and water have been made for more than 1000 years. Science came to this field much later, as a matter of fact very recently. The second world war boosted the understanding of waves and coasts. In the Netherlands after 1953, the Delta project had an impact on the research into protection works. In the last decades, major contributions to the design practice have been made, thanks to new research facilities, like (large scale) wind wave flumes, (turbulent) flow measurement devices, numerical models etc. progress has been made in The scientific basis of our knowledge has progressed considerably, but even after 50 years, much of the knowledge of these matters is of an empirical nature. Most formulas in this book are also empirical, based on experiments or experience.
Working with these empirical relations requires insight, in order to prevent misconceived use. The idea underlying this book is to start with a theoretical approach of the phenomena, focussing on understanding them. In the design of protections, especially in the unusual cases, a mix of science and experience is required. Since undergraduates, by definition, lack the latter, a sound theoretical basis and insight into the phenomena is paramount. This book goes one step further than simply presenting empirical design relations; it aims to create a better understanding of these relations. Engineering is an applied science, which then, by definition, means that science is the basis but not the core. Creativity, experience and common sense are just as important.
Computer models play an increasing role in engineering. For a hydraulic engineer, however, a sheet of white paper and a pencil are still essential, especially in the