CHAPTER VI-1

Introduction to Coastal Project Element Design

TABLE OF CONTENTS

List of Tables

CHAPTER VI-1

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VI-1-1. Introduction to Part VI. Part VI is the second of two engineering-based parts oriented toward design of coastal projects. Part V (Coastal Project Planning and Design) focuses on aspects related to overall coastal project design and development, whereas Part VI contains specific information and procedures for designing the structural elements used in coastal navigation and shore protection projects.

a. Part VI Overview. Part VI contains eight chapters as described below.

(1) Chapter VI-1 briefly overviews and summarizes the contents of each Part VI chapter and provides overall guidance on using the design procedures.

(2) Chapter VI-2, "Types and Functions of Coastal Structures," begins with brief descriptions of the various types and functions of coastal structures most often used in coastal projects. Typical cross sections and layouts are illustrated in the second section along with descriptions of the usual construction for each structure type. The third section introduces the types of concrete armor units used on coastal structures. The chapter ends with a comprehensive overview of failure modes associated with each structure type. Understanding potential failure modes is critical for design, and this understanding is aided by many figures in the chapter illustrating the various failure modes.

(3) Chapter VI-3, "Site-Specific Design Conditions" focuses on site-specific design information that may need to be considered during preliminary and final design. Whereas several project sites might experience similar design wave and water-level conditions, there may be unique conditions at each site that could significantly influence final design. Site specific design conditions and considerations discussed in this chapter include foundation and geotechnical requirements, seasonal profile variation, structure flanking, seismic activity, ice, environmental considerations, aspects related to construction, maintenance, aesthetics, etc.

(4) Chapter VI-4, "Materials and Construction Aspects," begins with a section discussing general requirements of materials used in coastal projects such as material properties, durability, adaptability, cost, availability, handling, and maintenance requirements. More detail and specific design guidance and considerations are given in individual sections for earth and sand, stone, concrete, steel and other metals, wood, geotextiles, and plastics. Each section overviews typical use of the material in coastal projects, lists the physical and mechanical properties of the material, and discusses placement considerations and potential environmental impacts.

(5) Chapter VI-5, "Fundamentals of Design," is the heart of Part VI, and contains most of the guidance and methodology needed for designing coastal structure cross sections (with the exception of hydrodynamic criteria, which are presented in Part II, "Coastal Hydrodynamics"). A brief introduction is followed by a section giving guidance related to the hydraulic response of the waves at the structure (i.e., wave runup, overtopping, transmission, and reflection). Next are two sections containing methodology for determining loading and response for sloping-front

rubble-mound structures and vertical-front structures, respectively. Foundation loads are also reviewed in this chapter. The intention is to generate awareness of when geotechnical aspects should be considered in the design process. Estimation of scour for different situations is covered next along with procedures for designing scour protection. Methods for estimating wave forces on slender cylindrical piles are followed by the final section, which summarizes briefly impact forces and ice forces that might occur at structures.

(6) Chapter VI-6 introduces reliability-based design of coastal structures. Familiar deterministic design equations are cast into the form of "failure functions," which can be evaluated in terms of random loading and response variables. Sophisticated probability methods are overviewed, but application requires the distribution of the random variables be reasonably well established. The partial safety factor system is presented that permits a less rigorous, but still useful, reliability analysis based on tabulated coefficients for specific design formulas. Overall system reliability can be analyzed based on failure probability of system components.

(7) Chapter VI-7, "Example Problems," illustrates application of design guidance and formulations given in previous chapters through case studies and example problems. The examples cover the most common applications such as wave runup, wave overtopping, armor layer stability, and stability of vertical-walled bulkheads and caissons, and forces on cylindrical piles.

(8) Chapter VI-8 begins with an overview of coastal project maintenance followed by a section on project monitoring and inspection. Condition monitoring occurs over the life of the structure whereas performance monitoring is usually short-term monitoring to access project performance. Each type of monitoring has different elements, but often shares the same instrumentation or techniques. Coverage includes evaluation of structure condition, types of instruments, and monitoring plan considerations. Repair and rehabilitation of rubble-mound structures after damage or deterioration is needed to assure continued functionality. Techniques for different levels of repair are discussed.

b. Comparison between Part VI and the *Shore Protection Manual*. Part VI corresponds mainly to the topics covered in Chapter 7 of the *Shore Protection Manual* ("Structural Design: Physical Factors"). Part VI is substantially larger than the equivalent portions of the older document, with most topics receiving expanded coverage. Several topics not included in the *Shore Protection Manual* have been added to Part VI. Table VI-1-1 shows the main topics of Part VI and how coverage compares with similar content in the *Shore Protection Manual*.

(1) The two main organizational differences between the *Coastal Engineering Manual* and *Shore Protection Manual* relate to presentation of design guidance and example calculations. Much of the design guidance in the CEM is presented in the form of tables. Each table applies to a specific design formula or procedure. Typically the table includes all the information needed for applying the formula or procedure to a specific structure type including necessary coefficients, variables, range of applicability, and when necessary, a cross-section or planview sketch illustrating the specific structure for which the methodology applies. The tables contain only minimal discussion and background information about the methodology so that Part VI

could be kept to a manageable length. If additional information is needed, see the provided reference to the original source material.

Table VI-1-1
Topic Coverage in Part VI Compared to *Shore Protection Manual* (1984)

Section	Topic	Changes from *Shore Protection Manual* (1984)
VI-2-1	Structure types	Similar coverage
VI-2-4	Failure modes	New topic
VI-3	Site-specific design criteria	Revised/updated
VI-4	Construction materials and procedures	New topic
VI-5-2	Wave runup and overtopping	Revised/updated
VI-5-2	Wave transmission and reflection	Revised/updated
VI-5-3	Rubble-mound structures	Revised/expanded
VI-5-4	Vertical-front structures	Revised
VI-5-5	Marine foundations	New topic
VI-5-6	Scour and scour protection	New topic
VI-5-7	Forces on piles	Same/revised
VI-5-8	Other forces on structures	Revised
VI-6	Reliability in design	New topic
VI-7	Design of specific project elements	Same/new examples using new guidance
VI-8	Monitoring, maintenance and repair	New topic

(2) In the *Shore Protection Manual*, some of the design guidance was immediately illustrated by example problems embedded in the text at that location, whereas in the *Coastal Engineering Manual* example applications of various design formulas are collected separately in Part VI-7. Separation of examples from the tables of design guidance is part of the modular design of Part VI. Many of the *Coastal Engineering Manual* example problems use the same conditions given for the corresponding problems in the *Shore Protection Manual*. This allows side-by-side comparison to show how the new guidance of the *Coastal Engineering Manual* differs from the older *Shore Protection Manual* results.

(3) Even with the increased number of pages, there are several instances where specific guidance contained in the *Shore Protection Manual* has not been included in the *Coastal Engineering Manual*. Decisions on whether or not to include certain material were based on considerations of guidance reliability and usefulness, with priority given to more common design needs. For those few situations where no guidance is included in the *Coastal Engineering Manual*, it should be acceptable to use the older guidance found in the *Shore Protection Manual* (or other sources) subject to the restrictions and caveats noted and provided improved procedures are not available in other design manuals. For example, the *Shore Protection Manual* contains provisional guidance for estimating slamming forces on vertical walls caused by breaking waves (Minikin method). This procedure produces high forces, and it is viewed with skepticism by some. Because no commonly accepted procedure was available at the time of writing to replace Minikin's method, it was decided to not include this topic. In other cases, the guidance was

deemed sound, but the application was considered fairly rare compared to the included procedures. These were tough decisions, but the important point to remember is that the *Coastal Engineering Manual* is not all-inclusive; and just because a particular design formula or procedure is not given in the *Coastal Engineering Manual*, this does not imply that it is not valid. That judgment must be made separately based on available information. However, where design guidance provided in the *Shore Protection Manual* differs from newer design methods contained in the *Coastal Engineering Manual*, strong justification is needed before choosing the *Shore Protection Manual* guidance over the preferred *Coastal Engineering Manual* recommendation.

c. Logical Connections to Other *Coastal Engineering Manual* Parts. Part VI is most closely linked with Part V, "Coastal Project Planning and Design" and Part II, "Coastal Hydrodynamics." Part V guides the engineer in selecting and evaluating alternatives to solve coastal problems, and Part VI tells how to design the specific elements (structures) that comprise each alternative. For each alternative, functional project design results in planform dimensions and multiple design objectives related to the purpose and intended function of the structure types used in the project. Contained in these design objectives are specific structure performance criteria such as whether to allow overtopping, permissible wave transmission, allowable damage levels, etc. Some information on general design criteria related to individual structure types can also be found in Part V.

(1) Hydrodynamic loading (i.e., wave parameters, design water levels, currents, etc.) related to specific structure geographic location and exposure are estimated using information provided in *Coastal Engineering Manual* Part II. These estimates form the hydrodynamic design criteria for each structure that is part of the coastal project. Hydrodynamic input requirements are specified for each design formula, and some parameters may vary between formulas. For example, design waves may be specified as significant wave height (H_s or $H_{1/3}$), zeroth-moment wave height (H_{mo}), or some other statistical representative wave height such as $H_{10\%}$ or $H_{1\%}$. Therefore, it is necessary to determine from Part VI what form the hydrodynamic criteria take when estimating the criteria from Part II.

(2) **Important note:** Part II was authored several years before Part VI, and in Part II-7, "Harbor Hydrodynamic," older guidance related to wave reflection and transmission was included that has since been superseded by the updated design guidance provided in Part VI. Although the older guidance provides reasonable estimates, using the formulas for wave reflection and transmission provided in Part VI-5-2 is recommended.

d. Using Part VI in the Design Process. In some cases more than one procedure is available for estimating the result of wave loading on a specific structure type, and separate tables are given for each methodology. Usually, similar results are produced by the different methods, but the range of applicability may differ. Therefore, it is important to first verify the appropriateness of a selected procedure for the specific design problem. If more than one set of guidelines is appropriate, it is wise to perform the calculation by both methods and compare results. Results that are nearly the same indicate either method can be used with confidence. In cases where answers from two methodologies diverge, the engineer must investigate further the background of the competing methods with primary focus on extent and range of experimental measurements on which the method is based, and the general acceptance of the method in the

coastal community. For example, one method might be based primarily on shallow water conditions, whereas the other method examined deeper water conditions. An older formula might be based on monochromatic wave experiments, but cover a wide range of incident wave conditions, whereas a newer formula might have been developed with a small number of irregular wave observations. At the end of the day, engineering judgment based on past experience may be needed, and that is acceptable provided concerns and caveats are made known to those with a stake in the project.

VI-1-2. References.

Shore protection manual. (1984). 4th ed., 2 Vol, U.S. Army Engineer Waterways Experiment Station, U.S. Government Printing Office, Washington, DC.

VI-1-3. Acknowledgements.

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VI-1-4. Symbols.

H_{mo}	Zeroth-moment wave height
H_s or $H_{1/3}$	Significant wave height (length)
$H_{10\%}$ or $H_{1\%}$	Statistical representative wave heights