GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION

# GUIDELINES FOR PREPARATION OF DPR FOR COASTAL MANAGEMENT PROJECTS UNDER CLIMATE CHANGE SCENARIO

**Coastal Management Directorate**
**December, 2020**

## FOREWORD

India has 7,500 km of coastline on which developments are taking very fast on the land and at the same time, is subject to various pressures from the sea. The large number of existing and upcoming ports and the growing cityscape present enormous challenges to planners and engineers of India's coastal areas. The coastal zone regulations and the related environmental laws are playing an important role by balancing development and the environment in India. In spite of these, dealing with the ever-increasing erosion of the coastline is a huge task for the planners, scientists and engineers.

Central Water Commission issued "Guidelines for Preparation of Coastal Protection Projects" in 2003. Over the years, the situation has changed and it has become necessary to account the impacts of projected climate change in coastal protection and management.

With India's leading initiatives in contributing to reduction of global warming and in developing adaptation measures to climate change, the Department of Water Resources, River Development and Ganga Rejuvenation took up a program with Asian Development Bank (ADB) and Global Environment Fund (GEF) to develop a reference manual for climate change adaptation guidelines for coastal protection. "Reference manual on Climate Change Adaptation Guidelines for Coastal Protection and Management in India' was prepared by a team of international and national experts. The present publication titled 'GUIDELINES FOR PREPARATION OF DPR FOR COASTAL MANAGEMENT PROJECTS UNDER CLIMATE CHANGE SCENARIO' is based on this reference manual and it will supersede the earlier guidelines issued by the Central Water Commission issued in 2003.

I am sure that these guidelines will be of great use to coastal engineers and planners at different levels, both at the State and National level. I hope this will help all stakeholders in adapting measures for coastal protection and management. I appreciate the efforts made by the drafting team of Coastal Management Directorate in bringing out this publication.

**(R.K. Jain)**
**Chairman**
**Central Water Commission**

## PREFACE

India's coast is under threat from climate change impacts. These threats are over and above the present day wave, wind and physical coastal dynamics. There are also numerous indirect pressures and challenges such as man-made impact on delivery of sediment by the rivers to the coast, localized sedimentation, Coastal erosion and decreased water quality. These factors are all exacerbated by extreme weather conditions with climate change.

Central Water Commission through the Coastal Protection and Development Advisory Committee (CPDAC) provides guidance to the coastal engineering community about the policies, approaches and guidelines to be followed for coastal protection works. Department of Water Resources, River Development and Ganga Rejuvenation took up a project namely 'Climate Resilient Coastal Protection and Management Project' with the Global Environmental Fund and Asian Development Bank to study the climate change impacts on the Indian coast and identify solutions to contain the impacts. A publication with title "Reference Manual on Climate Change Adaptation Guidelines for Coastal Protection and Management in India" was developed under this project.

The present publication titled 'GUIDELINES FOR PREPARATION OF DPR FOR COASTAL MANAGEMENT PROJECTS UNDER CLIMATE CHANGE SCENARIO' has been prepared based on the reference manual for climate change adaptation guidelines for coastal protection. These guidelines contains various chapters on different aspects of project report would provide a great help for preparation of detailed project report for Coastal Management works and timely appraisal & clearance.

I would like to personally thank drafting team of Coastal Management Directorate Sh. R.P.S Verma, Director, Sh. Arpan Awasthi, Deputy Director, Sh. Ashish Kumar Ranjan, (AD), Sh. Vimal Vijayanath, (AD-II) under the leadership and Guidance of Sh. Reading Shimray, Chief Engineer (P&D) for their commendable and exceptional effort. It is hoped that these Guidelines will serve the purpose of guiding and assisting the state and union territory governments for planning and executing climate resilient and sustainable coastal protection and management projects in India.

**(R. K. Sinha)**
**Member, RM**
**Central Water Commission**

# INDEX

# Background

A substantial portion of the country's coast is affected by sea erosion. It is more extensive and severe in some States/Union Territories, while in others, it is observed in varying intensities at isolated stretches. Coastal erosion has resulted in loss of life, property, valuable beaches and adjacent coastal land used for habitation, agriculture and recreation. It has resulted in loss of precious natural coastal ecosystems. Coastal erosion is posing a serious threat to many important buildings, factories, monuments of historical importance, highways, bridges and strategic installations along the country's coast.

Coastal erosion occurs generally due to natural causes. This however, is being aggravated further by human activities which have been on the rise along the coast of the country. The coastal zone in many parts of the country has come under tremendous pressure due to high density of population, indiscriminate urbanization and development of industries related to tourisms, fishing, shipping, mining, aquaculture, petrochemicals etc. The activities of some of these coastal development sectors are affecting the stability of the coastline and sustainability of the coastal environment.

The maritime states and Union Territories have been implementing anti-sea erosion schemes depending on the severity of the problems faced by them. Considerable expenditure has been incurred and is being incurred almost every year in constructing protection measures, largely to handle emergency situations. In most cases, the protection works are planned, designed and executed in isolation with the sole aim of mitigating the erosion at the given site. The localized planning and design process for shore protection has adversely affected the adjacent coasts.

This publication brings out broad guidelines for coastal protection projects. Coastal protection project planning and design being an interdisciplinary task, needs inputs from coastal, geotechnical, hydrology, hydraulics, structural, meteorology, economics, environmental, geology, oceanography and other related disciplines. A systematic and integral approach for planning and developing optimum solutions to the problems of coastal erosion is necessary.

This publication aims to provide additional direction to the coastal engineers to design schemes for coastal protection and management in a climate change scenario. This document provides the holistic approach to address the manifold social, economic, management, scientific, engineering and environmental dimensions required to protect the Indian coastline and to mitigate climate induced impacts.

This guideline supersedes the "Guidelines for Preparation of Coastal Protection Projects" issued by the Central Water Commission in 2003.

# CHAPTER 1

# INTRODUCTION

The following important items and additional items, if any as relevant to the project shall be discussed briefly under this chapter;

1. Aim(s) of the project and description of works
2. History (Earlier proposals)
3. The surveys and investigations carried out for the various alternatives considered to justify the final choice of components of the project shall be discussed.
4. Stages/phases of development of the project
5. Cost and Benefit of the scheme
6. Public Cooperation and participation etc.

## CHAPTER 2

## SALIENT FEATURES OF THE PROJECT

| Sl No. | Particulars | Details | Appendix/Page No. |
|---|---|---|---|
| 1 | Name of Project | | |
| 2 | Estimated cost & Price level | | |
| 3 | Reference of State TAC clearance | | |
| 4 | Master Plan for the coastal protection, fitment of the project and priority | | |
| 5 | Name of State | | |
| 6 | Name of District | | |
| 7 | Latitude & Longitude of the project | | |
| 8 | Distance along with direction from nearby major district(HQ)/town | | |
| 9 | B.C. Ratio | | |
| 10 | Benefitted population in Nos. | | |
| 11 | Benefitted area in ha | | |
| 12 | Coastal Erosion affected area of the State in mha | | |
| 13 | Protected area of the State; so far in mha | | |
| 14 | Details of proposed works along with reach length | | |
| 14.1 | Seawall | | |
| 14.2 | Groyne | | |
| 14.3 | Offshore/Near shore Reef | | |
| 14.4 | Nourishment | | |
| 14.5 | Breakwater | | |
| 14.6 | Dune Restoration/care | | |
| 14.7 | others | | |
| 15 | Completion Schedule | | |
| 16 | Any other relevant information | | |
| 17 | Maps& Drawings | | |

* **Details of each item may be enclosed in relevant chapters/appendix**

# CHAPTER 3

## EXECUTIVE SUMMARY OF PROJECT

**Executive Summary of the project shall include following aspects;**

- Introduction.
- Need and objective of the project.
- Brief description of Shore Management Plan (SMP)/Master Plan for the coastal protection, fitment of the project and priority.
- Details of earlier executed/ongoing projects vis-à-vis master plan.
- Brief description of constraints if any,
- Location of the project.
- Description of the problem.
- Brief description of various agencies involved and their role.
- Formulation of Scheme
    - (i) The details of investigation carried out.
    - (ii) Coastal data available and used.
- Details of works proposed (i) Structural (ii) Non structural.
- Design features.
- Requirement of consultants and their role in planning, designing and execution of works, if any, shall be indicated.
- Basis of rates and cost estimate (Base Year).
- Benefit cost Ratio.
- Construction materials and Construction program.
- Socio-Economic Aspects.
- Environmental Aspects.
- Recommendations.
- Pre project and post project scenario description.
- Evaluation (Concurrent and Post project)

**Check list to accompany with the Detailed project Report**

(To be attached in beginning of DPR)

| 1. Planning | | | | |
|---|---|---|---|---|
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **1.1** | Master plan for overall protection of the Coastline been prepared and inter-se priorities for protection of various reaches identified? | | | |
| **1.2** | Does the scheme fit in the overall development of the Master plan in terms of priorities? | | | |
| **1.3** | Has the scheme been affected the adjacent reaches of the coastline? | | | |
| **1.4** | Have the various alternatives for providing adequate protection been studied? ( Beach Nourishment, groynes, off-shore breakwaters, sea walls etc) | | | |
| **1.5** | Is the present proposal superior to any other alternative? | | | |
| **2. Surveys & Investigations** | | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **2.1** | Have the topographical surveys of the area been carried out? | | | |
| **2.2** | Have the property surveys been carried out? If so, give details (No. of house, other important assets, Coconut trees-existing & destroyed over the years) | | | |
| **2.3** | Have regular measurements of the shoreline changes been carried out? If so, since when? | | | |
| **2.4** | Have these shoreline changes been plotted & enclosed with the report? | | | |
| **2.5** | Have the ground cross-section been prepared for various shoreline changes & appended with the report? | | | |
| **2.6** | Have any geo-morphological studies been carried out for this area? | | | |
| **2.7** | Have any observations of the wave climate been made? (Type of wave, wave height, wave direction, breaker distance from the shore etc.) | | | |
| **2.8** | Is the wave direction generally constant throughout the year? | | | |
| **2.9** | Have any observation with regard to littoral drift been carried out? | | | |

| | | | | |
|---|---|---|---|---|
| **2.10** | Is the littoral drift in one direction only or does it changes with the change in seasons? What is the net direction of littoral drift? | | | |
| **2.11** | Has an assessment of the quantity of sediment in the littoral drift been made? | | | |
| **2.12** | Has an assessment of littoral drift been made in respect of a stable reach i.e. in a reach where there is neither accretion nor erosion? | | | |
| **2.13** | If the areas subject to cyclonic storms, have the details of such storms over the 10 years & the specific damages occurring under the influence of such storms been appended with the report? | | | |
| **2.14** | Has classification of the beach material been given? | | | |
| | **3. Material Survey** | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **3.1** | How far is the quarry site from the project area? | | | |
| **3.2** | Is the quarry capable of yielding uniform quality material for construction of the protection work? | | | |
| **3.3** | In case of stones for the sea wall, does the quarry yield cubical stones? If not, are flat stones proposed to be used? Have any studies been conducted in the use of flat stones in the construction of sea wall? | | | |
| **3.4** | Have adequate investigations of filter material proposed to be used been carried out, as to its availability & suitability? | | | |
| | **4. Design** | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **4.1** | Have the detailed calculations of design components been appended with the report? | | | |
| **4.2** | Has any model studies been carried out to assess the adequacy of the proposed design? | | | |
| **4.3** | Is the design now proposed based on scientific calculations using actual data collected for the site? | | | |
| | **5. Estimate** | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **5.1** | Has the estimate been prepared as per the guidelines of CWC? | | | |
| **5.2** | Are the rate adopted in the preparation of the estimate latest & approved by the State govt? | | | |

| | | | | |
|---|---|---|---|---|
| **5.3** | Have the analysis of rates for various major items of works furnished along with the basis for such analysis? | | | |
| **6. B.C Ratio** | | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **6.1** | What is the B.C ratio for the scheme? | | | |
| **6.2** | Has it been justified on the basis of detailed analysis after collecting reliable data? | | | |
| **6.3** | Is the B.C ratio worked out on prescribed standard & annual loss supported by documents from the concerned govt departments? | | | |
| **7. Construction Plan and Man-Power Planning** | | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **7.1** | Are the major components of the work proposed to be done departmentally or through contractor? Will the work be done manually or by machines? | | | |
| **7.2** | Have the details of plants & Machinery, Spares etc. been worked out? | | | |
| **7.3** | Will it be necessary to import any equipment? | | | |
| **7.4** | Has the scheme been cleared by State TAC? | | | |
| **7.5** | Has the clearance of the State Finance Department been obtained? | | | |
| **7.6** | Is the scheme included in the State Development Plan? | | | |
| **7.7** | Has the Construction programme with physical and financial target been appended with DPR? | | | |
| **8. Environmental and social Aspects for schemes** | | | | |
| **Sl No** | **Particulars** | **Yes** | **No** | **Remarks** |
| **8.1** | Have the ecological aspects been discussed, particularly the adverse affects resulting from implementation of the scheme? | | | |
| **8.2** | Any improvement in the existing environment resulting from implementation of the scheme? | | | |
| **8.3** | Has Environmental Impact assessment (EIA) been done for the project? | | | |
| **8.4** | Has Socio-economic analysis been done? | | | |
| **8.5** | Does the scheme envisage acquisition of any private land temporarily or permanently for construction of the protection works? | | | |
| **8.6** | Does it involve any rehabilitation of the affected people? | | | |

**Reference of details may be mentioned (Page No. /Appendix) in Remarks**

# CHAPTER 4

# CLIMATE CHANGE ADAPTATION IN COASTAL PROTECTION AND MANAGEMENT PROJECTS

## 4.1 Need for Climate Change adaptation in Coastal Protection and Management

The primary goal of the Climate change adaption measures to be included in this guidelines for coastal protection and management is the development and fostering of sustainable methods to protect coasts in India, which can be adapted to climate change impacts through the engagement of decision makers, implementing agencies, coastal scientists, communities, and civil society.

All Indian coastal states and union territories are to some extent vulnerable to climate change impacts. Due to the absence of clear and officially endorsed guidelines, the planning of shoreline management and design of coastal protection measures in India still proceed largely according to current standards, which do not explicitly consider climate change related risks.

## 4.2 Guidelines for Climate Change adaptation in Coastal Protection and Management

A Technical Assistance (TA) programme was signed by Government of India with ADB for TA 8652-IND: Climate Resilient Coastal Protection and Management Project (CRCP&MP) to support mainstreaming of climate change consideration into coastal protection and management at the national level. The detailed background about TA 8652-IND is available in the Central Water Commission's (CWC's) **Reference manual on Climate Change Adaptation Guidelines for Coastal Protection and Management in India in two volumes,** available on the Coastal Protection and Development Advisory Committee's (CPDAC's) website **http://cwc.gov.in/CPDAC/ guidelines**

Volume 1 of this report is developed as a stand-alone document, while the more technical reader may refer to the numerous appendices in Volume 2, which contain the planning and design criteria for climate resilient coastal protection and management. This work has been considerably assisted by a Panel of Experts appointed by the DoWR, RD&GR with representatives from the coastal states and islands. The report was endorsed by the National Technical Committee (NTC) headed by Member (RM), CWC appointed by the DoWR, RD&GR.

A new concept called the Environmental Softness Ladder **(Appendix-1)** ranks protection works to aid decision making and approval. Practical topics focus on key methods of beach protection, from nourishment to offshore reefs, groynes, and seawalls.

The Guidelines are approached in two parts

**1. Regulatory Guidelines** bridge the gap between the existing CRZ regulations and the management of future events. The focus in the existing CRZ is on horizontal (rather than vertical) distances, except in the hazard line, where vertical dimensions are considered for deriving the distance from the High Tide Line (HTL). To allow for SLR and other factors causing elevated water levels, two concepts are introduced: the Minimum Beach Level (MBL) being the highest sea level that may occur at a coastal site, and the Minimum Floor Level (MFL) for buildings, identifying the safe floor level of building to guarantee a level of security defined relative to mean sea level. MBL and MFL vary around the Indian coast and the computations are explained in **Appendix-2**.The essential re-adjustments required to accommodate MFL in the existing CRZ are given in the Reference Manual on 'Climate Change Adaptation Guidelines for Coastal Protection and Management in India' which may be referred.

**2. Intervention Guidelines** incorporate an understanding of a range of soft and hard intervention strategies that can be considered to address climate change impacts at the coast. Soft and hard solutions with best global and Indian practices are considered, and an Environmental Softness Ladder is presented to enable the user to characterize the softness of existing or proposed coastal protection methods.

**States/UT's preparing DPR for Coastal protection projects under climate change scenario may refer the above manual on *''Climate Change Adaptation Guidelines for Coastal Protection and Management in India''* for proper guidance in planning, designing and execution of the projects.**

***Beach Nourishment – Softer solution for protection***

# CHAPTER 5

## SITE INVESTIGATION AND COASTAL DATA COLLECTION

The coastal protection scheme evolved by the state/UT Governments should be based on proper site investigation and collection of coastal data. It is necessary to identify causes of erosion properly and to take remedial measures based on these causes.

The details of site investigation conducted and coastal data collection carried out in formulation of the scheme may be included in this chapter. The general conditions required to be satisfied for coastal data collection survey is given in **Appendix-3.**

| Sl No. | Type of Survey and Investigation | Particulars/Details |
|---|---|---|
| 1 | Site Characterization Investigation | • Involves identifying, distinguishing qualities and features of a region that have a direct and indirect effect on the planning, design, economics, construction and maintenance of a coastal project. The total project area encompasses not only the physical limits of the problem area but also the area in which the project has an effect.<br>• Soil Explorations/Investigations data/ material characterization<br>• Hydrodynamic processes (waves, water level, currents), Seasonal variability of waves and currents, Storm Characteristics/ Meteorology, Topography & bathymetry, Geomorphology/Geometry and Sediment Characteristics, Littoral Drift and Sediment transport patterns, Shoreline Change Trends, Land/Shore Use, Geotechnical Requirements, River Discharge/Sediment Load etc.<br>• Studies using physical model, mathematical model, remote sensing etc done shall also be included. |

| | | |
|---|---|---|
| 2 | Material Survey | • Availability, Accessibility and Suitability of the various kinds of materials involved in the work.<br><br>• Background/Reason for the choice of materials |
| 3 | Available Coastal Data for the site/adjoining area. | • Field Measurements: Bathymetry, Hydrography, Topography Survey, Shoreline Survey, Geo-morphological studies. The details of data required is given below<br>(A project planner and designer should also be aware of the effects of the project on the adjoining coasts. The amount of data needed for a project varies with the type and scope of the problem.) |

For Coastal studies, data is normally needed across a range of categories:

- **Bathymetry -** Finding the depths around the region of interest, including offshore not only beach profiles. Bathymetry will often need to be recorded at least twice; at the end of the wet and dry seasons.

- **Wind -** Many of the processes are responsive to winds, including currents along the coast. Wind measured inland is usually not suitable.

- **Sea level -** Sea levels vary with tides and a range of other factors like storm surge, coastal trapped waves and direct wind forcing. Sea level is one of the primary factors determining the design of structures.

- **Currents -** Recording the currents both offshore and within the surf zone under a variety of weather and wave conditions.

- **Waves -** Measurements of waves are essential to predict longshore currents, longshore, sediment transport, design material sizes and to know the size and stability of a solution needs to be put in place.

- **Sediment dynamics -** Direct measurements of sediment fluxes on beaches are rare in India but they need to be made to confirm empirical equations and models.

- **Beach Morphology -** Beach-dune-sand bar transitions provide an important understanding of the cross-shore and longshore sediment dynamics. At inlets, the interactions that occur between waves and river / tidal flows are reflected on the beach morphology.

- **Grain sizes -** The sand size plays a critical role in predictions of sediment dynamics and needs to be measured along cross-shore profiles from the top of the beach to at least 10 m depth.

- **River flow -** River flows determine the delivery of sand to the coast and have a strong influence on the formation of spits, sand bars and deltas at the entrance.

- **Water Parameters -** Temperature, salinity, density and chemical contents are often needed to determine the state of the water quality.

- **Primary production -** While many coastal projects have no impact on primary production, some projects like power stations, hot water discharges and sewage discharges require good knowledge of the impact on phytoplankton and zooplankton, which underpin the marine food chain.

- **Beach and dune vegetation -** For beach-dune care or nourishment projects the information on native vegetation becomes very important.

**Near shore Coastal data collection is very important in formulation of scheme. Coastal data may be collected as per format in Appendix-4. Standard frequency of near shore Coastal data collection is given in Appendix-5.**

***Wave Rider Buoy deployed at sea***

# CHAPTER 6

# DESIGN OF WORKS

## 6.1 Introduction

The planning and design process should consider the various natural features and man-made structures in the vicinity of the site. It should be ensured that the proposed anti-sea erosion scheme does not transfer erosion problem to other areas. The dynamic coastal processes are constantly changing with time. The changes in coastal phenomenon observed at any site at the time of project implementation than what was at the time of project formulation should be accounted for and suitable modifications should be made. Both, structural as well as non-structural works shall be considered to minimize the investment required. Study of various alternatives for providing adequate protection shall be included.

Climate change scenario shall also be taken into account while designing Coastal structures. Reference manual on ‘’Climate Change Adaptation Guidelines for Coastal Protection and Management in India’’ may be referred for designing of the projects.

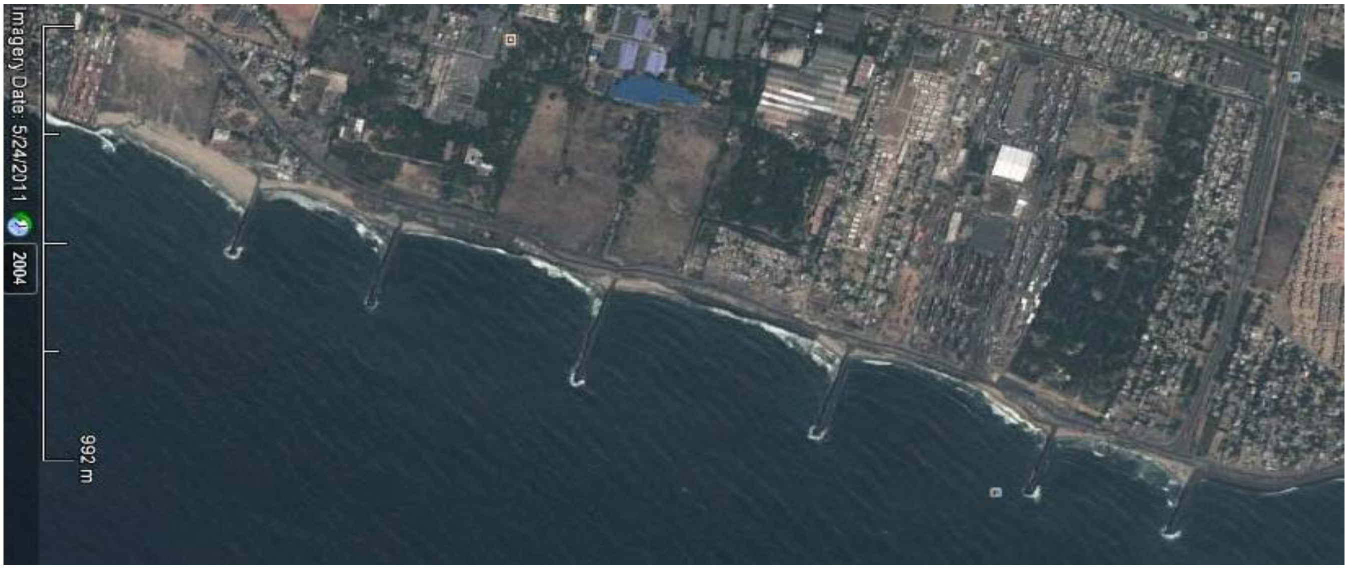
**The design of protection measures should be vetted by the Central/State Design organization/Research Institution. In complex cases, physical and mathematical modeling should be done to evolve the optimal solution.**

The design details of some of the coastal protection measures like Groynes, Seawall, Breakwater, Beach nourishment taken from the Manual on **“Protection and Control of Coastal Erosion in India” (2020)** prepared by NIO, Goa in association with CWC is given below for ready reference.

## 6.2 Design of Groynes

Groynes are structures placed perpendicular to the coastline to capture and hold sand that may be available in the littoral zone. Groynes are easy to implement and less costly than offshore structures.

Groynes are classified according to geometry of the Groyne and length of Groyne. Generally, Groynes are straight and perpendicular to the shoreline. However, they can also be curved, hooked or may have a T-shape towards the front end of the Groyne. Based on length, Groynes are classified as long and short Groynes. Groynes that traverse the entire surf zone are considered long, whereas that extend only part across the surf zone are considered short.




***Groyne field north of Chennai Fishing harbor***

The effectiveness of Groynes in maintaining the required beach area is related to their length, spacing, orientation and crest elevation. Groynes constructed on a shore where the littoral drift is high will result in sand accumulation and lee side erosion. Beach nourishment with Groyne construction is preferred in most of the recent projects (Basco and Pope, 2004).

The design of Groynes is mainly based on empirical formulae which are derived based on previous experience with Groynes performance and laboratory experiments and till now no standard design methodology is found.

Design of Groyne is governed by: 1) littoral processes (wind, wave and tide data, beach slope and grain size); 2) functional design criteria (length, spacing and height) and 3) structural design criteria (type of material and construction procedures).

**6.2.1. Functional Planning/Design**

The Groyne length may be taken as the seaward limit of the breaker zone at mean high water level (surf zone width). When the wave directions are variable, with equal longshore transport in either direction, the Groynes perpendicular to the shoreline is more suitable

Ten basic rules for Groyne design are summarized in Table 6.2.1. Rule “zero” is included to emphasize the fact that Groynes are only useful where longshore sediment transport processes are dominant. They are also successful if (1) agreement on the minimum, dry beach width, $Y_{min}$ is reached, (2) modern, numerical beach simulation models such as GENESIS and SBEACH are employed to study their design, and (3) a field monitoring effort is established to measure performance and adjacent beach impacts.

**Table 6.2.1. Basic rules for functional design of Groynes (Basco and Pope, 2004).**

| Rule | Description |
|---|---|
| 0 | If cross-shore sediment transport processes dominant, consider nearshore breakwater systems first. |
| 1 | Conservation of mass for transport of sediment alongshore and cross-shore means Groynes neither create nor destroy sediment |
| 2 | To avoid erosion of adjacent beaches width, $Y_{min}$ for upland protection during storm events as a measure to judge success. |
| 3 | Agree on the minimum, dry beach width, $Y_{min}$ for upland protection during storm events as a measure to judge success |
| 4 | Begin with S/L=2 to 3, where S is the longshore spacing and L is the effective length of the Groyne from its seaward tip to design shoreline beach fill at time of construction |
| 5 | Use a modern, numerical simulation model (eg. GENESIS) to estimate shoreline change around single Groyne or Groyne fields. |
| 6 | Use of cross shore, sediments transport model (eg. SBEACH) to estimate the minimum, dry beach width, $Y_{min}$ during storm events. |
| 7 | Bypassing, structure permeability and the balance between net and gross longshore transport rates are the three key factors in the functional design. Use the model simulation to iterate a final design to meet the $Y_{min}$ criterion. |
| 8 | Consider tapered ends, alternate platforms, and cross-sections to minimize impacts on adjacent beaches. |
| 9 | Establish a field monitoring effort to determine if the project is successful and to identify adjacent beach impacts. |
| 10 | Establish a 'trigger' mechanism for decisions to provide modifications (or removal) if adjacent beach impacts found not acceptable. |

### 6.2.2. Groyne length, height and Groyne spacing

Step 1: Initially, provide the length of Groyne (L) equal to surf zone width.

Step 2: Assume S/L ratio in the range 2 to 3 and calculate spacing between Groynes (S) in Groyne field.

Step 3: Length of the first Groyne ($L_1$) in the transition field is calculated by using the equation.

$$L_1 = \frac{1-\left(\frac{R}{2}\right)\tan 6°}{1+\left(\frac{R}{2}\right)\tan 6°} L \qquad \text{……….} \quad (6.2.1)$$

Where, L is the length of the previous Groynes in Groyne field
R is the ratio of spacing to length of the Groyne

Step 4: Spacing between last Groyne in Groyne field and first Groyne in transition zone is given by

$$S_1 = \frac{R}{1+\left(\frac{R}{2}\right)\tan 6°} L \qquad \text{………..} \quad (6.2.2)$$

Step 5: The length of remaining Groynes in transition zone is calculated using equation 6.2.1 and spacing of Groynes in transition zone is calculated using equation 6.2.2

Step 6: Height of the Groyne is to be equal to the derived level

Step 7: With the planned configuration, check whether the shoreline evolution using a numerical model (eg.: GENESIS, LITPACK). If the desired shoreline configuration is not achieved, then modify the length of the Groyne and repeat steps 2 to 7.

**6.2.3. Structural Design**

In the design of the rock armour structure, the following steps are considered.

1. Obtain the properties of the locally available stones with the range of size (gradation curve of a quarry).
2. Large fraction of the available stone can be used as material for the armour and the smaller fractions for core of the Structure.
3. Determine the shape and dimensions of the armour protection, which typically involves increasing the thickness of the armour layer, so that during design wave condition, a stable structure is obtained. This is to be verified using physical model studies. As the dimensions of the armour protection are determined, the relative Sizes of core material and armour material will vary to accommodate changes in the relative percentages of armour stone and core material required.
4. While designing the geometry of the cross-section of the armour, the availability of construction equipment at the location and the site characteristics are to be checked.

In most of the cases, rock is used as armor unit and the Groyne is designed for breaking wave condition. The details of design are available in Engineering Manual EM 1110-2-1100 (Part VI) of the US Army Corps of Engineers. Important steps are given below.

Step 1: Find out the Equivalent cube length of median rock using the equation

$$\frac{H}{\Delta D_{n50}} = A\varepsilon^2 + B\varepsilon + Cc \qquad \text{……………………} \quad (6.2.3)$$

$$\text{Where, } \varepsilon = \frac{\tan\alpha}{\left(\frac{H}{L}\right)^2} \qquad \text{…………………} \quad (6.2.4)$$

H = characteristic wave height (m)
$D_{n50}$ = equivalent cube length of median rock
$\rho_s$ = mass density of stone
$\rho_w$ = mass density of water

$$\Delta = \left(\frac{\rho_s}{\rho_w}\right) - 1 \qquad \text{......................} \quad (6.2.5)$$

L = Local wavelength at the toe of the structure
α = Structural armor slope
A, B, $C_c$ are empirical coefficients and the values are provided in Table 6.2.2.

**Table 6.2.2. Value of empirical coefficients used in Groyne design (EM 1110- 2-1100 Part VI) :**

| Armor Type | A | B | Cc | Slope | Range of $\varepsilon$ | Wave condition |
|---|---|---|---|---|---|---|
| Stone | 0.272 | -1.749 | 4.179 | 1V to 1.5H | 2.1-4.1 | Breaking |
| Stone | 0.198 | -1.234 | 3.289 | 1V to 2.0H | 1.8-3.4 | Non-Breaking |

Step 2: Calculation of weight of single armor unit.

Volume of unit armor unit = $D_{n50}$ X $D_{n50}$ X $D_{n50}$
Weight of Armor unit = Volume X Specific wt. of armor unit (W)

Step 3: Calculation of Crest Width

$$B = nk_\Delta \left(\frac{W}{w_a}\right)^{\frac{1}{3}} \qquad \text{....................} \ (6.2.6)$$

Where,

n =the number of stones
$k_\Delta$ = the layer coefficient (as per Table 6.2.3)
W = Primary armor unit weight
$w_a$ = Specific weight of armor unit material

Step 4: Similarly, thickness of cover layer and under layer is calculated using the formula,

$$r = nk_\Delta \left(\frac{W}{w_a}\right)^{\frac{1}{3}} \qquad \text{....................} \ (6.2.7)$$

r = Thickness of cover layer,

Layer coefficient value for different armour units are presented in Table 6.2.3

**Table 6.2.3. Layer coefficient value for different armour units (EM 1110-2- 1100 Part VI, Table No. VI-5-51)**

| Armor Unit | n | Placement | Layer Coefficient, $k_{\Delta}$ | Porosity P (%) |
|---|---|---|---|---|
| Quarry stone (smooth) | 2 | Random | 1.02 | 38 |
| Quarry stone (Rough) | ≥2 | Random | 1 | 37 |
| Quarry stone (Rough) | 3 | Random | 1 | 40 |
| Quarry stone (parallelepiped) | 2 | Special | .. | 27 |
| Quarry Stone | Graded | Random | .. | 37 |
| cube(modified) | 2 | Random | 1.1 | 47 |
| Tetrapod | 2 | Random | 1.04 | 50 |
| Tribar | 2 | Random | 1.02 | 54 |
| Tribar | 1 | Uniform | 1.13 | 47 |
| Dolos | 2 | Random | 0.94 | 56 |
| Core-Loc | | | | |
| Vol < 5 m$^3$ | 1 | Random | 1.51 | 60 |
| 5< Vol< 12 m$^3$ | | | | 63 |
| $12<Vol<22$ m$^3$ | | | | 64 |
| Accropod | | | | |
| Vol < 5 m$^3$ | 1 | Random | 1.51 | 57 |
| 5< Vol< 12 m$^3$ | | | | 59 |
| $12<Vol<22$ m$^3$ | | | | 62 |

Number of Armor units per unit area is calculated as

$$\frac{N_a}{A} = nK_{\Delta}\left(1-\frac{P}{100}\right)\left(\frac{w_a}{W}\right)^{\frac{2}{3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6.2.8)$$

n = the number of quarry stone or concrete armor units in the thickness. n=3
W = the weight of individual armor units
$K_{\Delta}$= the layer coefficient
P = the average porosity

Thickness 'r' of a layer of riprap is the greater of either 0.3 m or one of the following, whichever of three is greatest.

$$r = 2.0\left(\frac{W_{50}}{w_a}\right)^{\frac{1}{3}} \quad \ldots\ldots\ldots\ldots \quad (6.2.9)$$

$W_{50}$= Weight of 50% size in the riprap gradation or,

$$r = 1.25\left(\frac{W_{max}}{w_a}\right)^{\frac{1}{3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots.. \quad (6.2.10)$$

$W_{max}$ = Heaviest stone in gradation,

Riprap placing density,

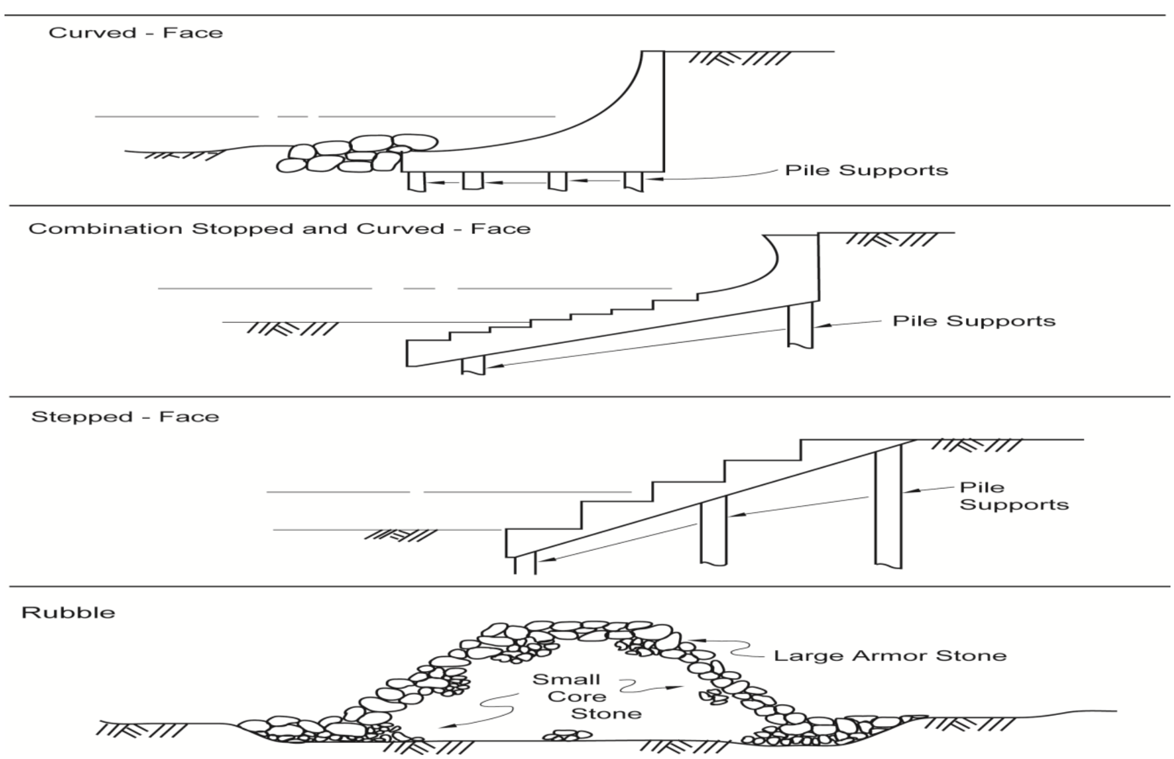
$$\frac{W_T}{A} = rw_a\left(1 - \frac{P}{100}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (6.2.11)$$

Where, P= Porosity

## 6.3 Design of Seawalls (Rubble mound and concrete) and Revetments

Seawalls are the structures primarily designed to resist wave action along high value coastal property. They are either gravity or pile supported structures made of either concrete or stone. Seawalls have a variety of face shapes. In India, the most widely used shore protection structure is the Rubble Mound Sloping Seawalls (RMS). As the RMS seawalls are flexible structures, they need regular maintenance.

The shape of the seawall is generally protected by rock armor. If the wave conditions are high and the rock size is not economically available in the nearby area, concrete armor units are used in place of rock armor. Rubble mound seawalls are designed like a rubble mound breakwater**.**



### 6.3.1 Functional planning

The weight of the armor units of the rubble mound seawalls is determined using the Hudson formula and the Van der Meer formulae. Hudson formula is widely used because of its simplicity and long period of application except for a low crest structure. But it does not account of factors such as wave period, angle of incident wave, wave spectrum, interlocking of armor units, size and porosity of the under- layer material.

Functional design consists of estimation of wave run-up, wave overtopping, wave transmission and reflection

The wave reflection coefficient can be reduced by a) using a sloping wall rather than a vertical wall, b) increasing roughness by using rip-rap and c) use of rock armour, rather than wall.

Hudson formula was derived from a series of regular waves test using breakwater models

$$W = \frac{\rho g H^3}{K_D \Delta^3 Cot\alpha} \quad \text{……………………} \quad (6.3.1)$$

Where ,
W = weight of an armor unit (N)
H = design wave height at the structure (m)
$K_D$ = dimensionless stability coefficient
$\alpha$ = slope angle of structure
$\rho$ = mass density of armor (kg/m$^3$) = 2600 kg/m$^3$ for rock
g = acceleration due to gravity (m/s$^2$)
Δ = relative mass density of armor = ($\rho$/$\rho$w) - 1
$\rho_w$ = mass density of seawater (kg/m$^3$) = 1025 to 1030 kg/m$^3$

The design wave height is $H_{1/10}$ at the site of the structure for non-breaking wave conditions. Where $H_{1/10}$ will break before reaching the structure, the breaking wave height or the significant wave height whichever has the more severe effect are used.

Kp values for rock armour at the trunk and head of structures under non-breaking and breaking wave conditions is given in Table 6.3.3.

Van der Meer formulae for plunging and surging waves are given below.

For plunging waves,

$$\frac{H}{\Delta D_{50}} * \sqrt{\varepsilon} = 6.2 P^{0.18} \left(\frac{S}{\sqrt{N}}\right)^{0.2} \quad \text{……………………} \ (6.3.2)$$

For surging waves,

$$\frac{H}{\Delta D_{50}} = 1.0\ P^{0.13} \left(\frac{S}{\sqrt{N}}\right)^{0.2} \left(\sqrt{\cot\alpha}\right) \varepsilon^{p} \quad \text{……………………} \quad (6.3.3)$$

where H = design wave height, taken as significant wave height (m)
$D_{50}$ = Nominal armour diameter equivalent to that of a cube (m)

$\Delta$ = relative mass density of armor = $(\rho/\rho_w)$ - 1
$\rho_w$ = mass density of seawater (kg/m$^3$) = 1025 to 1030 kg/m$^3$
$\rho$ = mass density of armor (kg/m$^3$) = 2600 kg/m$^3$ for rock
P = permeability factor (0.1 for relatively impermeable core to 0.6 for virtually homogeneous rock structure)
$\alpha$ = slope angle of structure
N = number of waves
S = damage level = number of cubic stones with a side of $D_{50}$ being eroded around the water level with a width of one $D_{50}$ = A/$D_{50}$2
A = erosion area in a cross section (m$^2$)
$\varepsilon$ = surf similarity parameter = tan $\alpha$ / √ $S_m$
$\alpha$ = average slope angle (degree)
$S_m$ = offshore wave steepness based on mean wave period = $2\pi H_s / g\, T_m{}^2$
$T_m$= mean wave period (s)

The limits of S depends on the slope of the structure. For a two diameter thick armour layer, the lower and upper damage levels have been assumed to be the values given in Table 6.3.1 (CIRIA (1991).

**Table 6.3.1. Damage levels for two diameter thick rock slopes**

| Slope of structure | Damage level S at start of damage | Damage level S at failure |
|---|---|---|
| 1:1.5 | 2 | 8 |
| 1:2.0 | 2 | 8 |
| 1:3.0 | 2 | 12 |
| 1:4.0 | 3 | 17 |
| 1:6.0 | 3 | 17 |

The start of damage of S= 2 to 3 is around 5% damage. Failure is defined as exposure of the filter layer.

The slope of the armor structure Cot $\alpha$ is to be between 1.5 and 6. Wave steepness Sm is to be within 0.005 to 0.06.

When value of surf similarity parameter is greater than $\varepsilon c = \left(6.2 P^{0.31}\sqrt{\tan\alpha}\right)^{\frac{1}{(p+0.5)}}$ the formula for surging waves should be used.

For Cot α ≥ 4, the transition from plunging to surging does not exist and for these slopes, only formula for plunging waves are to be used.

In general, the residual settlement after completion of construction is to be limited to not more than 150 to 300 mm depending on the type and importance of the structure and the site condition.

### 6.3.2. Location, height and length of structure

The crest elevation should be determined from wave run-up and overtopping considerations. An allowance for the settlement that will occur in the design life of the structure may also be included while determining the crest elevation.

The crest width should be sufficient to accommodate any construction and maintenance activities on the structure. For rubble mound breakwaters, the minimum crest determined from the following formula:

$$B = 3K_{\Delta} \left(\frac{W_a}{\gamma_a}\right)^{\frac{1}{3}} \quad \text{.......................} \quad (6.3.4)$$

Where $W_a =$ weight of an individual Armor unit(N).
$K_{\Delta}$ = Layer thickness coefficient.
$\gamma_a$ = Unit weight of Armor unit

### 6.3.3. Design

Design Procedure is as below:

1. Determine the water level range for the site.
2. Determine the wave height.
3. Select suitable armor alternatives to resist the design wave.
4. Select armour Unit size.
5. Determine potential run-up to set the crest elevation.
6. Determine amount of overtopping expected for low structures.
7. Design under-drainage features if they are required.
8. Provide for local surface runoff and overtopping runoff and make any required provisions for other drainage facilities such as culverts and ditches.
9. Consider end conditions to avoid failure due to flanking
10. Design toe protection.
11. Design filter and under layers.
12. Provide for firm compaction of all fill and backfill materials. This requirement should be included in the plans and in the specifications. Also, due allowance for compaction must be made in the cost estimate.
13. Develop cost estimate for each alternative.

Various formulae used for the design of vertical wall is presented in table 6.3.2 **(EM 1110-2-1100 part VI)**

**Table 6.3.2. Various formulas used for the design of vertical wall**

| Formula | Wave condition | Type of structure | Reference |
|---|---|---|---|
| Sainflou formula (1928) | Standing | Impermeable Vertical Wall | EM 1110-2- 1100 (Part VI) Table VI-5-52 |
| Goda formula (1976) | 2-D oblique | Impermeable Vertical Wall | EM 1110-2- 1100 (Part VI) Table VI-5-53 |
| Goda formula modified by Takahashi,Tanimoto and shimosako(1994a) | Provoked breaking | Impermeable Vertical Wall | EM 1110-2- 1100 (Part VI) Table VI-5-54 |
| Goda formula Forces & Moments | Provoked breaking | Impermeable Vertical Wall | EM 1110-2- 1100 (Part VI) Table VI-5-55 |

**Stone Revetment and Riprap:**

a) The design practice for stone revetments is basically the same as for rubble mound breakwaters.

b) Since the primary function is to Protect bank and preventing loss of upland material, more care should be exercised in filter design.

c) Application of geotextile filter is common.

d) Close attention should be paid to the hydraulic properties of the structure to prevent toe scouring, piping, bank instability and other hydraulically related failure modes.

e) Pressure build up in the soil behind the structure can result in leaching and loss of soil. Therefore, grading of the stone must be more tightly controlled than for breakwater design.

**Table 6.3.3 Stability Coefficient (breaking occurs before the waves reach the structure)**

| Armor Unit | No of layer (N) | Placement | Structure Trunk, $K_D$ | | Structure Head, $K_D$ | | Slope Cot α |
|---|---|---|---|---|---|---|---|
| | | | Breaking Wave | Non-breaking Wave | Breaking Wave | Non-breaking Wave | |
| **Quarry stone** | | | | | | | |
| Smooth Rounded | 2 | Random | 1.2 | 2.4 | 1.2 | 1.9 | 1.5 to 3.5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Smooth Rounded | >3 | Random | 1.6 | 3.2 | 1.4 | 2.3 | (c) |
| Rough Angular | 1 | Random | ( d ) | 2.9 | ( d ) | 2.3 | (c) |
| Rough angular | 2 | Random | 2.0 | 4.0 | 1.9 | 3.2 | 1.5 |
| | | | | | 1.6 | 2.8 | 2.0 |
| | | | | | 1.3 | 2.3 | 3.0 |
| Rough angular | >3 | Special | 2.2 | 4.5 | 2.1 | 4.2 | (c) |
| Rough angular | 2 | Special | 5.8 | 7.0 | 2.1 | 4.2 | (c) |
| Parallelepiped | 2 | Random | 7 – 20 | 8.5 – 24 | -- | -- | (c) |
| Graded angular | --- | Random | 2.2 | 2.5 | -- | -- | -- |
| **Tetrapod & Quadripod** | 2 | Random | 7.0 | 8.0 | 5.0 | 6.0 | 1.5 |
| | | | | | 4.5 | 5.5 | 2.0 |
| | | | | | 3.5 | 4.0 | 3.0 |
| **Tribar** | 2 | Random | 9.0 | 10 | 8.3 | 9.0 | 1.5 |
| | | | | | 7.8 | 8.5 | 2.0 |
| | | | | | 6.0 | 6.5 | 3.0 |
| **Dolos** | 2 | Random | 15.0 | 31.0 | 8.0 | 16.0 | 2.0 |
| | | | | | 7.0 | 14.0 | 3.0 |
| **Modified cube** | 2 | Random | 6.5 | 7.5 | -- | 5.0 | ( c) |
| **Hexapod** | 2 | Random | 8.0 | 9.5 | 5.0 | 7.0 | ( c) |
| **Toskanes** | 2 | Random | 11.0 | 22.0 | -- | -- | ( c) |
| **Tribar** | 1 | Uniform | 12.0 | 15.0 | 7.5 | 9.5 | ( c) |

Thickness of the Armour layer (t) is estimated using

$$t = nk\left(\frac{W}{\gamma}\right)^{\frac{1}{3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6.3.5)$$

Where W = weight of the individual Armour unit
n= number of Armour layers
k = layer thickness coefficient
$\gamma$ = Unit weight of Armour unit

Under layers and core

Weight of the under layer rock should not be less than one-tenth of the weight of the Armour. The size of individual under layer rock should be within ± 30% of the nominal weight selected. For concrete Armour units, the weight of under layer rock is to be as per British Standard, BS 6349 : Part 7. 1991 (BSI,1991).

This thickness of the under layer $t_u$ Should contain at least two layers of rock and may be determined from the following formula.

$$t_u = nk_{\Delta}\left(\frac{W}{\gamma_r}\right)^{\frac{1}{3}} \quad \text{………………….} \qquad (6.3.6)$$

Where W= Weight of a rock in the under layer (N)
N= Number of rock layer
$k_{\Delta}$ =Layer thickness coefficient, equal to 1.15 for rock
$\gamma_r$= Unit weight of rock (N/m)

While designing the filters, the following filter criteria (BSI, 1991) may be used to determine the size of the under layers in relation to the core.

$D_{15u}/D_{85c} \leq$ 4 to 5

$4 \leq D_{15u}/D_{15c} \leq$ 20 to 25

Where D is the nominal size of an equivalent cube
Suffix 'c' refers to cores
Suffix 'u' refers to under layer
Suffix '15' and '85' refer to the percentage of material Passing through that size

When applying the above criteria, some disturbances of finer material and possible migration through the overlying material due to varying wave induced water movements is still possible. A conservative approach should be adopted in the design of the filter.

When the rubble mound structure is protecting reclamation, adequate filter should be provided to prevent loss of fine material through the core. The following filter criteria are given in BS 6349: Part 7:1991.

$D_{15(larger)}/D_{85(smaller)} \leq$ 4 to 5

$4 \leq D_{15(larger)}/D_{15(smaller)} \leq$ 20 to 25

$D_{50(larger)}/D_{50(smaller)} \leq 25$

Where, D is the nominal size of an equivalent cube

Suffixes'15','50'and '85' refer to the percentage of material passing through that size.

The following points should be noted when designing the filter layer between the rubble mound structure and the reclamation fill.

- No filter layer should contain more than 5% of material by weight passing 63µm sieve and that fraction should be cohesion less.
- Filter material should be well graded within the specified limits and its grading curve should have approximately the same shape as the grading curve of the protected material

- Where the retained fill material contains a large proportion of gravel or coarser material, the filter should be designed on the basis of grading of that proportion of the protected material finer than a 20 m sieve.
- Where the retained fill is gap graded, the coarse particles should be ignored and the grading limits for the filter should be selected on the grading curve of the finer soil
- Where a filter protects a variable soil, the filter should be designed to protect the finest soil.
- The thickness of filter layers should be ample to ensure integrity of the filter when placed underwater. In practice, the thickness of filter layer at 1m below and 0.5 m above water level should be the minimum thickness of 40 $D_{85}$.
- The filter should cover the full depth of the structure.

**Slope of structure**

The slope angle of the structure depends on hydraulics and geotechnical stability, and should generally be not steeper than 1.

**Crest structures**

Usually the crest structure is constructed to provide access or act as a wave wall to prevent or reduce over topping. The underside of the crest structure may be keyed into the underlying material to increase sliding resistance.

**Toe protections and transitions**

Damage to a seawall initiates from the toe or the transition area. Wave action in front of the structure can cause turbulence at the seabed, leading to erosion of seabed material and sourcing of toe. The structural toe is designed to prevent layer sliding and toe scouring. Geo-textiles are more often used in revetment toe Structures.

Transitions are common in seawalls, mostly for cost Savings but also for accommodating different coastal Slopes. Discontinuities of pressure and permeability are likely to occur at the Joints, which make them the weak links. Material discontinuity also could lead to the development of seams and eventual separation and loss of material. The above concerns should be incorporated into the design. Overlapping layers are often used to soften the impact.

When currents are combined with Wave action, it is suggested that the weight of the rock for protection against wave scour should be increased by 50% (BSI, 1991). Alternatively, the shear stresses due to the combined effect of wave and currents may be calculated to determine the required toe protection. Fine material at the seabed is liable to be scoured. The design may include placement of rubble to act as falling apron for toe protection.

Gabions are made of polymer hawser laid ropes. A Special process to fabricate the gabions in various sizes appropriately weaves these ropes. Gabions are generally available in a prefabricated collapsible form with the bottom & four sides held together by appropriate binding and with a flip flop open top lid. The border & body ropes may be of different sizes ranging from 6mm to 12 mm. The sizes are selected depending upon the severity of the problem & the method of installation to be adopted.

**Gabion installation**

1) Slope shall be prepared to extend shown on the plans or as directed by the engineer. Prepare toe trench and anchor trench as specified. All loose or unwanted materials shall be removed. All depression shall be carefully backfilled up to desire grade and compacted to density at least equal to that of the adjacent foundation. Any buried debris protruding from the foundation that will impede the proper installation and final appearance of the gabion or gabion mattress shall also be removed and the void carefully backfilled and compacted as specified in the drawing.
2) Geotextile material with specified Properties shall be placed along the prepared slope before placing a gabion boxes or gabion mattresses.
3) Assembly of gabion boxes
4) Installation of gabion boxes. –
   - Place the fabricated gabions along the slope
   - Place corner bamboos or any support to avoid free-falling of empty gabions.

Stone filling operations shall be carefully proceeded with placement by a hand or machine to avoid damage to the polymer rope, to avoid between the filling material.

Undue deformation and bulging of the gabion mesh shall be corrected prior to further stone filling. To avoid localized deformation, the gabion units in any row are to be filled in stages consisting of maximum 300 mm courses. At no time shall any cell be filled to a depth exceeding 300 mm more than the adjoining cell. Max height from which the stone may be dropped in to the gabion shall not be more than 1m. Along all exposed faces, the outer layer of stone shall be carefully placed and arranged by hand if required to ensure a net and compact appearance. Last top layer of stone shall be uniformly overfilled 25 to 50 mm for gabions and 25 mm for gabions mattresses to compensate for the future settlement in rock but still allow for the proper closing of the lid and to provide an even surface, which is uniform in appearance.

Lids shall be stretched tight over the stone fill until the lid meets the perimeter edges of the front and end panels. The lid shall be tied with all edges of gabion.

Repeat the procedure up to the required height and length as shown in the design drawings

Precautions to be taken for construction of seawall with flexible gabions

1. During the execution of the work, the respective bench marks at both the sites should be utilized for correlating the levels of the designed sections

2. The trench for the toe should be excavated according to the designs
3. Geofabric filter should be properly designed considering the gradation of the beach material. During the placing of the filter care should be taken for adequate overlapping of the geofabric filter cloth
4. Gunny bags filled with coarse sand and gravel should be kept ready before placing the geofabric filter. It should be then placed over the already laid geofabric filter
5. Stones of recommended gradation should be placed in the trench over the gunny bags up to the designed level
6. The empty flexible gabions of 1 m* 1m *1 m size should be placed over these stones and filled with 20 to 40 kg stones
7. The open ends of the gabions should be secured according to the recommendations of the manufactures of the gabions. If, required, it is advisable to fuse the open faces of the gabions
8. It is possible to tie these gabions laterally also and the same should be tied accordingly.
9. Place the core stones according to the recommended design.
10. Cover this layer with the flexible gabions according to the procedure indicated above.
11. Complete the lee side of the seawall sections as recommended.

It is essential to create awareness amongst the local residents that this coastal protection works is being under taken for their own benefit and they should extend their full co-operation during and after the execution of work. It should be ensured that the residents do not cause damage to the structure by cutting of the ropes of the gabions or by removing the stones.

## 6.4 Design of Near-shore breakwater (also offshore breakwater)

Low crested and submerged structures such as detached breakwaters and artificial reefs are becoming common coastal protection measures. In some cases submerged structures are used in combination with the artificial sand nourishment.

Usually near-shore breakwaters or low crested submerged structures provide environmentally friendly coastal solutions. But the high construction cost and the difficulty of predicting the response of the beach are the two main disadvantages on use of near-shore breakwaters. Near-shore breakwaters are relatively expensive to construct.

Main function of the near-shore breakwater is to reduce the amount of wave energy reaching the shoreline. Near-shore breakwaters also reduce the offshore sand transport.

Design of the near-shore breakwater depends on the length of shoreline to be protected and the level of wave Protection required. If the length of shoreline to be protected is large, a number of nearshore breakwaters are protected with gap between the breakwaters. The submerged shore parallel breakwater is known as shore parallel near-shore sill. If the near-shore breakwater is constructed too close to the shore, a tombolo can develop and may block the longshore sand transport.

Numerical models have the advantage of simulating shoreline response to time varying wave condition.

Main parameters for multiple breakwater systems are length of the individual breakwaters, distance offshore, distance between the breakwaters and crest elevation.

Commonly the near-shore breakwaters built as rubble mound structures. Sand filled bags, timber sheet piles and sand filled pre-cast concrete boxes are used for sill construction.

The ratio of gap width to the sum of the break water length and gap width, known as the exposure ration, ranges from about 0.25 to 0.66.

With the planned configuration, the shoreline evolution is to be checked using numerical computer simulations

**6.4.1. Conceptual design**

Main parameters which control the shoreline response due to near-shore break water are:

- Distance offshore
- Length of the structure
- Transmission characteristics of the structure
- Beach slope
- Mean wave height
- Depth of the structure

- Mean wave period
- Orientation angle of the structure
- Predominant wave direction
- Gap between the structures in case of multiple breakwaters

For submerged structures the transmission coefficient (Kt) is estimated as given below (d'Angremond et al., 1996)

$$k_t = -0.4\frac{R_c}{H_i} + \left(\frac{B}{H_i}\right)^{-0.31}[1 - \exp(-0.5\varepsilon]C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.4.1)$$

Where, $\varepsilon = \tan\alpha / (Hi/L_o)^{0.5}$
α= seaward slope angle
Rc= Crest free board
$H_i$=incident wave height
B= breakwater crest width
C = 0.64 for permeable structures
= 0.80 for impermeable structures

Empirical geometrical criteria for layout and shoreline response of exposed offshore breakwater are given below (Harris & Herbich, 1986; Dally & Pope, 1986).

For Tombolo formation: Ls/X > 1 to 1.5

For Salient formation: Ls/X = 0.5 to 1

For Salient, in case of multiple breakwaters: G X/$Ls^2$> 0.5

Where Ls is length of breakwater
X is the distance to the shore and
G is the gap width between breakwaters

Empirical geometrical criteria for layout and shoreline response of submerged near-shore breakwater are given below (Pilarczyk, 2003).

For Tombolo formation: Ls/X > (1 to 1.5)/(1-kt)

For Salient formation: Ls/X < 1/(1-kt)

For Salient, in case of multiple breakwaters: G X/$Ls^2$ > 0.5/(1-kt)

In case of multiple breakwaters, the gap width is usually L ≤ G ≤ 0.8 Ls

Where L is the wave length at the structure = T (g d) $^{0.5}$

d is the water depth

After the carrying out the design through the above procedure, the morphological shore response needs to be simulated and tested using the numerical models (GENESIS, Mike21, Delft3D)

### 6.4.2 Design

For rubble mound structure, the Procedure on estimation of the weight of the rock is Similar to that followed for the Groyne structure.

Programs like CRESS, which is accessible in the public domain (www.cress.nl) can be used for the design of rubble mound breakwaters.

## 6.5 Design of Beach Nourishment

Beach Nourishment is the placement of new sediments on the eroded beach with sediments obtained from off-site or on-site sources, It has been widely used as a method of erosion control to maintain a wide beach for both coastal protection and recreation.

For beach nourishment volume calculation, the following steps are followed

Step 1:- Perform coastal measurements (for at least 10 years)

Step 2:- Calculate the loss of sand in cubic meters per year per coastal section

Step 3:- Add 40 % for losses.

Step 4:- Multiply this quantity by a convenient life time.

Step 5:- Put this quantity on the beach between the low water minus one meter line and the dune foot.

### 6.5.1 Source of Replenishment Material

The material for beach replenishment should have a similar grading or slightly coarser of the native beach. If finer material is used, material loss will be large. If the replenishment material is much coarser than the native material, a steep and more reflective beach may form and this can result in less sand on the lower part of the beach.

Proportion of fines (commonly < 0.1 mm) should be low to minimize turbidity at the placement site. If dredging is used to get the material, fines content is also important in considering the turbidity produced at the source site. Turbidity control methods such as bunding or silt curtains may need to be considered at source and deposit sites if fines content is high and better quality sand is not available.

### 6.5.2 Method of Replenishment

Generally the method of replenishment is using a trailer suction dredger with sand pumped on to beach. Another method is transporting from onshore beach accumulation areas for placement within and above the tidal beach. Collecting from near-shore or harbour entrance deposits by jet pump or adapted systems and pumping to deposit site is another method.

Operational issues for selection or assessment of suitable methods include:

- Wave and wind climate and potential dredge downtime.
- Depths of deposit for dredging and for discharge if using barges.
- The distance between source and discharge sites.
- Tides may limit beach width for along-beach trucking/pumping methods, and soft sand can present difficulties for trucks.

**6.5.3 Design**

The calculation of the minimum volume of material required is based on techniques with high degree of uncertainty. Repeated replenishment may be required and that the initial fill volume will be a compromise between delaying the need for a repeat replenishment and the high initial cost and possible loss rates from a large initial project.

The design may include hard engineering structures such as Groynes, seawalls, offshore breakwaters, or artificial reefs to improve the efficiency of the replenishment

Placement of material on specific portions of the beach (dune, beach berm, intertidal or near-shore), depends upon the requirement for replenishment and the methods/equipment available.

Frequency of repeat replenishments can be estimated. although is best assessed from monitoring of previous replenishment projects at the site. The effect of extreme storms or a net loss of sand by transport out of the system on actual timing of repeat replenishments is one of the uncertainties of beach replenishment and is an important aspect which needs to be recognized in the project management.

During beach replenishment, the following parameters need to be monitored.

- Near-shore and beach profiles to determine volume changes.
- Water quality at source and deposit sites.
- Monitoring of benthic/terrestrial environment and extent of disturbance. Ongoing monitoring and assessment of requirements for repeat replenishment are:
- monitoring sand volume changes across the active beach (dune, beach berm, intertidal and near-shore).
- buffer dune volume monitoring.
- development and application of trigger criteria for repeat replenishment.

***Tetrapods concrete Blocks***

# CHAPTER 7

# COST ESTIMATE

## 7.1 Preparation of Cost Estimate

**7.1.1** To work out the total cost estimate of the project in detail, the cost of various sub-heads as indicated under **Appendix-6** shall first be estimated. Only the relevant sub-heads of general abstract may be considered out of the sub heads listed in **Appendix-6** (to be updated as per Guidelines for Preparation of Detailed Project Report of Irrigation & Multipurpose Projects- 2010) as per specific requirement of the project.

**7.1.2** Cost estimate should be prepared on the basis of latest Schedule of rates of concerned State/UT.

**7.1.3** Analysis of rates of non schedule items should be worked out considering the cost of materials, carriage-handling-storing, labour, share cost of equipment involved in execution of work and profit and overhead charges over & above the prime cost of item of work so obtained.

The basic rates of material/hiring charges of equipments/Royalty charges etc. shall be adopted from the latest SoR of concerned state/UT exclusive of taxes and in case the rates are not available, then prevailing lowest market rate shall be adopted based on quotations.

The percentage provision towards profit/overhead/small T&P/water charges/carriage charges/loading-unloading to be considered in analysis of rates shall be adopted from the latest SOR

The GST shall be applied on total amount as per prevailing rates and shown separately in the estimate.

**7.1.4** The wages of workers are periodically revised by the State under the statutory labour law. Daily wage rates, therefore, shall be taken as those prevalent in the State at the time of formulation of the project. The daily wages generally fixed by the states after computing wages for 30 days and distributing the same to 26 days. Therefore, provision of weekly rest shall accordingly be finalized. Other hidden charges as per applicable local / statutory labour law shall be provisioned.

**7.1.5** For working out the use rates of machinery, the norms for life, depreciation, repair provision etc. should be adopted as per recommendation by the latest IS code 11590/ latest CWC Guide Book on use rate, hire charges and transfer value of equipment and spare parts. Price of various equipment preferably should be taken from SOR of concerned State if available, otherwise the same may be adopted on the basis of recent quotations/ price list of such equipment.

In case of specialized equipments, like, barges/tug boats/spud barge for which use rate analysis is not available either in CWC guidelines or State SoR, various component of use rate like ownership cost/fuel consumption shall be judiciously determined based on similarly executed earlier works in nearby area.

The duty factor corresponding to light duty may be adopted for estimating fuel consumption of all marine equipments, irrespective of tide & other effects.

**7.1.6** Provision for contingencies and work charged establishment should be considered up to 3% and 2% respectively of the item rates under the C-Works, K-Building and R-Communication sub heads only. These percentage provisions should not be considered on lump sum items and in case the submitted estimate is "contract estimate".

The contingencies shall also not be considered where there is no scope of variation/unforeseen items like hydro-mechanical works, concrete structures (tetrapods) etc. The percentage provisions of 2% towards W/C establishment shall not be taken, in case provision of supervisory staff/ foremen has already been made in analysis of rate under cost of labour.

**7.1.7** Quantity certificate regarding the correctness of quantities as per approved design and drawing should be provided by the project authority from the concerned Chief Engineer or equivalent rank.

**7.2 Preparation of detailed estimates of costs:**_For preparation of detailed estimates standard format of CWC may be used. The various heads under which estimates should be prepared are indicated below:

**I-Works:**

**7.2.1** **A-Preliminary**: The provision under this head covers relating to various investigations, surveys, Model tests etc. This shall be based on the actual cost likely to be incurred and shall be limited to 1-2% of the total cost of I-works.

**7.2.2** **B-Land**_: The provisions under this head covers acquisition of land etc. The provision shall be made as per actual requirements.

**7.2.3** **C-Works**_: The provisions under this head covers the civil costs of the all coastal protection works and strengthening of existing works or any similar works etc. This shall be based on detailed cost estimate per km length for typical sections of protection works like sea wall etc.

A separate provision for quality assurance or third party quality inspection may be added under this head.

**7.2.4 K-Building**: The provision under this head covers the construction of temporary buildings for residential/ Non-residential and stores shed etc during the construction period of the project. In addition to the cost of buildings, the provision for land development, fencing /boundary walls, security / observation booths, service connection such as water supply / sanitation drainage and electrification may be made as per norms fixed by the State Government. This should be based on the actual cost likely to be incurred and be limited to 2-3% of the total cost of I-works. The cost of store shed shall not be taken in case storage charges are included in material cost or rates are as FOR sites.

**7.2.5 M-Plantation:** The provisions under this head covers the requirement of plantation to augment the stability of coast. The provisions shall be made on lump sum basis keeping in view the experience of other projects or as per Environment Management Plan(EMP).

**7.2.6 O-Miscellaneous:** The following provisions are to be kept in this Sub head:

**(a) Capital cost of:**

(i) Construction power infrastructure subject to prevailing site conditions or provision in SoR/AoR
(ii) Water supply, purification and distribution
(iii) Sewage disposal
(iv) Fire fighting equipment

**(b) Maintenance and service of:**

(i) Electrification
(ii) Water supply, purification and distribution works
(iii) Sewage disposal and storm water drainage works
(iv) Security arrangements
(v) Fire fighting equipment

**(C ) Other items**:

(i) Contractor's All Risk Policy
(ii) Visits of dignitaries
(iii) Boundary pillars and stones, distance marks and bench marks
(iv) Misc petty items

**7.2.7 P-Maintenance** : Considering short duration of coastal work and major items to be executed under contract, the provision under this head may be kept with proper justification and should be limited to 0.5% of total cost of I-works less A-Preliminary, B-Land, O-Miscellaneous, M-Plantation, Q Special T&P and X-Environment & Ecology, Y-Losses on stocks and covers maintenance of all works during the construction period

**7.2.8 R-Communication**: The provisions under this head cover the construction of approach roads and quarry roads etc shall be made subject to conditions that no facilities are available at site and provision towards construction and maintenance of road are not taken in Analysis of Rate (AoR) of item of works.

**7.2.9 X-Environment and Ecology**: The provisions under this head cover the items concerning environment and ecological impact due to coming of the project.

**7.3 II-Establishment Charges:** In case works to be execute departmentally, the provision for establishment charges should be kept 8 to 10 percent of I-works excluding B-land. No establishment Charges should be provided if works are to be executed on contract basis. In both case, certificate should be provided by the project authority from the concerned Chief Engineer or equivalent rank.

**7.4 III-T&P**: The provision under this sub head covers survey instruments, camp equipments, office equipments etc. A nominal provision of Rs 20-25 lakhs under this sub head may be adequate.

**7.5 IV-Suspense:** Generally no provisions should be made under this sub-head unless necessary and well supported by facts and documentation.

**7.6 V-Receipt and Recovery**: This head is meant to account for estimated recoveries by way of resale or transfer of temporary buildings & vehicles shall be accounted for under this sub head. The recoveries in account of temporary buildings may be taken at 15% of the construction cost of building.

**7.7 Audit and Accounts Charges**: The provision under this Sub head should be made @ 0.25% of I-Work.

### 7.8 Miscellaneous points:

1. Generally these type of execution of protection works are of short duration and executed through contract and therefore
   a) Escalation shall be provisioned based on indices only when completion period for contract work is beyond two years.
   b) Nominal provisions under Q-Special T&P shall be provisioned with justifications
   c) Y-Losses on stock shall not be taken, as insurance costs are separately provisioned.

2. Specification of various items mentioned in Bill of Quantities/Estimate shall be concurred by the Designers like size of crates in gabion wall/size of mesh/geo-textile/tetra pod/boulders/compaction factor of filler material in different zones of embankment/sand nourishment etc.

3. Performance evaluation of the projects would be done by agencies like IIM, IIT, NITs, WAPCOS, State WALMI or any other agency identified by the DoWR, RD & GR/ State Govt. Both concurrent and post project performance evaluation should be carried out. Cost of Post project monitoring work should be limited to 2% of the total cost of the project which will be carried out for a period of 5 years after the completion of the project.

# CHAPTER 8

## BENEFIT COST RATIO

**Methodology of Calculation**

Benefit-Cost ratio for anti-sea erosion schemes shall be calculated as follows or any other economic analysis method.

**B. C. Ratio = Total annual damages/Total annual Cost**

**Total annual damages:**

Total annual damages is to be worked out as follows,

**(a) Average actual annual damages** (after adjustment of price level) on the basis of past 10 years damage data duly certified by concerned authorities, i.e, Revenue Department for land loss and Agriculture Department for loss of crops etc.

Average actual annual damage= Past annual damages/nos of years ------------ (a)

**(b) Average anticipated annual damages** shall be calculated for a period of economic life of project. While calculating the anticipated annual damages, extent of probable damages like cropped area, land use, type of properties etc. shall be duly certified by the competent authority. The annual anticipated damages should be worked out by dividing the total value of the all type of properties, which is likely to be damaged in absence of the project by economic life of project.

Average anticipated annual damage= value of properties likely to be damaged/no of years (economic life of project). ------------------------------(b).

**Total annual damage= Average actual annual damage (a) + Average anticipated annual damage (b)**

**Total Annual Cost**

The annual cost is to be worked out as follows,

i) Interest @ 10% of Capital Cost (Total estimated cost of scheme)
ii) Maintenance @ 5% of Capital Cost
iii) Depreciation @ 2% of Capital Cost

Thus the annual cost will be 17 % of the total estimated cost of the scheme.
B.C Ratio should not be less than one for economic viability of a scheme.

# CHAPTER 9

# CONSTRUCTION PLAN AND MAN POWER PLANNING

**9.1 General:** The construction planning for works envisaged in any Coastal protection works is a vital component for the timely completion of the works avoiding time and cost overrun.

**9.2 Construction Planning:** It is understood that construction planning is the key for in-time completion of the Coastal protection works. It is seen from the past experience that most of the projects are delayed in completion due to lack of proper construction planning.

The Implementation of project may involve following steps.

**9.2.1 Invitation of Tenders:** Model tender documents for procurement of materials should be prepared and used immediately after administrative approval of the project.

**9.2.2 Procurement of construction material:** Construction materials, required frequently in large quantities should be procured well in advance to save time. Any additional quantity as per approved DPR may be procured concurrent to execution of works

**9.2.3 Storage of construction material at site:** There should be proper space/shed for the storage of construction material. The storage space/shed should be such that, there is no risk of wear-n-tear and theft of the construction material till the works are over

**9.2.4 Testing of the material**: There should be arrangement of testing of the construction material before the start of the work. Provision for standard testing along with procedure of testing should be made a part of the tender document. All the construction material should posses qualifying standards before construction.

**9.3 Construction Equipment/Plant:** Type and nos. of equipment deployed with justification, construction schedule, capacity, fuel consumption, BHP/FHP, twin/single motors etc. along with working cost shall be included. Detailed specifications and working cost of any special plant which is proposed to be employed for construction should be given.

**9.4 Construction Material:** Results of experiments, if any, bearing upon the suitability of construction materials proposed, types of materials, locations from which obtainable, borrow areas, quantity available, facilities for manufacture, distance of work from the source of manufacture, nature of haul roads (whether in plains or hilly areas) should all be specified. Basic rates of steel and cement and other materials should also be given. A write up should be added indicating the quantities of key materials required for the project.

**9.5 Communication:** Average distance of carriage of heavy machinery, cement and steel etc. from the nearest rail head and communication facilities available for carriage of materials and suitability of existing roads and bridges for carriage of heavy plant and machinery should be described. Construction needs for new rail or road links should also be discussed

**9.6 Bar Chart and phasing of the project:**

**9.6.1** Bar chart showing activities related with execution of the project should be appended with the DPR.

**9.6.2** Phasing of the project comprising of physical progress along with financial progress should also be given in the DPR.

# CHAPTER 10

# ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

## 1. Environmental Monitoring Program

The primary aim of environmental monitoring program is to formulate a systematic, site-specific plan for monitoring the environmental parameters within the impact area, during and after commissioning of the project.

## 2. Environmental Impact Assessment (EIA)

The basic objective for Environmental Impact Assessment (EIA) is to predict environmental impact of projects, find ways and means to reduce adverse impacts and shape the projects to suit local environment. Comprehensive EIA including climate change impacts should be prepared before taking any construction approvals. The design must be site-specific and based on a clear understanding of the coastal processes for the entire 'sediment cell', the long-term stability or instability of the entire cell and the ecological impacts therein. A comprehensive EIA based on long-term monitoring of the 'sediment cell' has been recommended.

The Ministry of Environment and Forests (MoEF) latest notification declaring the Coastal Stretches as Coastal Regulation Zone(CRZ) and regulating activities in the CRZ shall be kept in view while framing the schemes.

**An EIA report shall have to prepare which should provide clear information on the different environmental scenarios without the project, with the project and with the project alternatives. An Abstract of the EIA shall be appended with DPR.**

## 3. Social Impact Assessment

Details of Social benefit, land acquisition and rehabilitation of affected areas/ people, if any may be appended with the DPR.

# CHAPTER 11

# MAPS AND DRAWINGS

11.1 Clear index map consisting of following in Arc-GIS/Autocad format on the basis of latest satellite imagery should be appended in the DPR.

11.1.1 Coastlines for past 2-3 years in different colours should be marked in the index map.

11.1.2 Nearby Executed works and proposed works along with reach lengths, orientation, layout etc as well as benefitted area should be marked on the index map with appropriate colours.

11.2 Sectional Drawings of the proposed works

# CHAPTER 12

## ANNEXURE AND CERTIFICATES

Following annexure & certificates should be appended in the DPR, if submitted for Central/External assistance.

1) CRZ Clearance/ Environmental Clearance from the concerned Central/State Agencies.
2) Concurrence from concerned Forest and Port Department, if required.
3) Minutes of latest State TAC meeting in which the proposal was cleared.
4) Documents for Benefit Cost ratio Calculation (damages data) from concerned State Department.
5) Quantity certificate regarding the correctness of quantities as per approved design and drawing from the concerned Chief Engineer or equivalent rank.
6) Certificate that separate schemes are not being proposed/ planned on the same reach of the coast.
7) Certificate of the State Finance concurrence.
8) Documents in support of examination of the design of protection measures vetted by the Central/State Design organization/Research Institution.

# CHAPTER 13

## PROCEDURE FOR SUBMISSION, APPRAISAL AND ACCEPTANCE FOR CENTRAL ASSISTANCE

CWC has launched the online platform e-PAMS (Project Appraisal Management System) for the submission and appraisal of the project. The DPRs shall be submitted by State govt/Project authority preferably through e-PAMS portal.

Procedure for Submission, Appraisal and Acceptance for Central Assistance is as follows;

- Preparation of DPR as per CWC Guidelines for Coastal management Projects.
- Submission of the Projects to field units of CWC after cleared by State TAC and other State/Central Agencies.
- Field units of CWC forward the DPR to Nodal office in CWC (HQ) for detailed examination after carrying out the preliminary investigation. (in the case of for major projects)
- The major projects are examined by nodal and specialized units in CWC (HQ).
- The medium and minor projects are examined and recommended by the field units of CWC.
- However, if the project is externally assisted then the DPR is to be submitted to Deputy Secretary, EA, Department of Water Resources, River Development and Ganga Rejuvenation (DoWR, RD & GR). DoWR, RD & GR forwards the DPR to CWC (HQ) for detailed examination.
- After examination by nodal and specialized units and compliance by Project authority and all the Statutory clearances having submitted by the Project Authority, an appraisal note will be prepared and put up to Advisory Committee of Department of Water Resources, River Development and Ganga Rejuvenation for consideration of techno-economic viability.
- The advisory Committee accepts or rejects the Proposal and if found acceptable recommends the Proposal for investment clearance.
- Proposal for investment clearance is to be submitted by Projects Authorities to CWC.
- The proposal is examined with reference to check list and guidelines issues by DoWR, RD &GR. If it is found acceptable, it is forwarded to DoWR, RD &GR with recommendations.
- The Ministry then considers the same in the Committee for accord of Investment clearance. If found acceptable, investment clearance for the same is issued by Ministry.

**Appendix-1**

## Environmental Softness Ladder

Environmental Softness Ladder (ESL) is to distinguish the potential environmental effects of sand-based solutions or construction-based coastal solutions rather than recommending preferences for favored methodologies. ESL as presented below is a process to be followed by proponents, rather than a point scoring system.

| Title | Methodology | Enviro-mental Impact | Category |
|---|---|---|---|
| Steep seawalls | Seawall/revetment to protect the land with front slope gradient >1:15 | 12 | Hard |
| Low gradient seawalls | Seawall/revetment to protect the land with front slope gradient <1:15 | 11 | Hard |
| Headland groynes | Groynes / headlands longer than 300 m with high crest | 10 | Hard |
| Long, high-crested groynes | Groynes longer than 100-300 m with crest above high tide | 9 | Hard |
| Short, high-crested groynes | Groynes with crest above high tide, but less than 100 m long | 8 | Hard |
| Low-crested groynes | Series of groynes with crests lower than high tide, and less than 100 m long | 7 | Hard |
| Nearshore reef | A reef built close to shore or on the inter-tidal beach | 6 | Moderate |
| Offshore islands / breakwaters | Emerged offshore structure | 5 | Moderate |
| Offshore reefs | Reef built offshore, normally in 3-8 m depth | 4 | Moderate |
| Nourishment | Major sand nourishment; sand source is offshore or external | 3 | Soft |
| Dune restoration | Sand nourishment: sand source is from the beach or surf zone | 2 | Soft |
| Dune care | Replanting, fencing, walkways on dunes | 1 | Soft |

Softer projects lower on the ladder are more desirable. All rungs on the ladder represent a stage. This means that options lower on the ladder must be considered first and eliminated with proper justification before proceeding to a harder protection methodology on higher ladder. With full adoption by the coastal states, projects at the top of the ladder will need considerably more studies and investigations than those at the base. The goal is to: (i) encourage the use of the softest possible solutions and (ii) ensure that softer options have been formally ruled out as unsuitable.

There are many shades between the two extremes of soft and hard and their combinations which make it difficult for inexperienced decision makers to distinguish the suitability of the various coastal protection methods. Thus, the ESL overcomes that difficulty. The ladder representation is a gentle reminder that the higher you go up the ladder, the harder it gets. The protection project will be seen as a nourishment solution on the ladder if the nourishment and re-nourishment is 'sufficient to maintain a natural beach locally and down drift over its life cycle'. Otherwise, the project will be ranked in the ESL by the structure.

Coastal protection solutions can be 'compound' at a single beach. Compound coastal protection solutions involve multiple structures, e.g., groyne field with seawall. In the Guidelines, environmental effects and efficacy of multiple structures will need to be considered individually and as a joint system to demonstrate the environmental, economic and social benefits of more than one structure. Most importantly, the proponent will need to carefully describe why more than one structure is needed.

Coastal protection solutions can also be 'hybrid, defined here as 'nourishment with structures'. Examples are groynes with nourishment in the compartments or reefs with nourishment to form the anticipated salient. Hybrid solutions are beneficial. Nourishment prevents the down drift effects associated with natural sand capture while the structures can minimize long-term re-nourishment needs.

**Appendix-2**

## Minimum Beach Level and Minimum Floor Level

The CRZ regulates construction over horizontal zones at the coast up to the hazard line, which is demarcated by the MoEF&CC (through the Survey of India), taking into account the tides, waves, SLR and shoreline change. With impending SLR and projected storm surge levels, the vertical dimension needs to be more formally incorporated while designing the coastal protection schemes.

MBL and MFL are introduced for this purpose.MBL is used to determine a safe beach / dune / seawall elevation to prevent overtopping and flooding of the hinterland during storms. MBL can be calculated for each site using physical process equations. MFL is the safe floor level of buildings to protect them and infrastructure in the coastal and low-lying areas from the risk of flooding. To guarantee a level of security, MFL must be higher than MBL. The safe elevation will vary between locations and should be determined and referenced in building permits.MBL can be calculated knowing the MSL, river flood levels, Sea Level Rise (SLR), storm surge, wave climate, wave set-up, swash levels, beach gradients, sand grain sizes and factors like continental shelf waves, coastal-trapped waves and local barometric pressure effects. MBL relates to conditions of a beach and hence will vary around the Indian coast. A typical diagram showing MBL computational scheme is shown below.

Steps for calculating MBL:

Step 1: Find the tidal height from the CCIS. For example, for Maharashtra the maximum tide height is 2.57 above MSL.

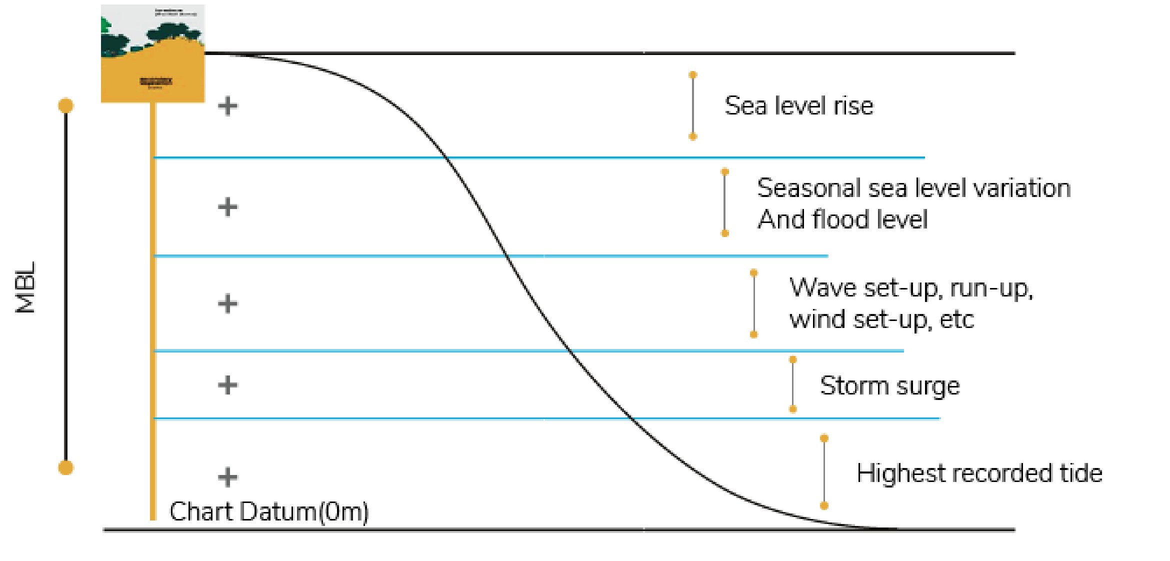
Step 2: Find the maximum surge height from CCIS. For example, for Maharashtra the maximum surge is 3.15 m.

Step 3: Find the predicted SLR from CCIS. For example, for Maharashtra the predicted maximum SLR is 1.17 m.

Step 4: Find the offshore wave height from CCIS. For example, for Maharashtra the maximum offshore wave height is 8.46 m.

Step 5: Transform the offshore wave height (Ho) to the breakpoint. In the absence of a computer model, the breaker height (Hb) can be estimated as Hb=1.2Ho. If the beach is sheltered the fraction 1.2 may be smaller.

Step 6: Determine the wave set-up using equations given in the 'Report'. For example, for a breaking wave height of 6 m, the set-up is 1.15m.




Step 7: Determine the wave run-up, which his is very sensitive to surf zone bathymetry and beach slope. The height needed for this calculation is the residual wave height at the beach face. This will be normally much less than the breaking wave height. For a 1 m wave height at the beach face, wave period of 12 s and beach face gradient of 1:10, the run-up will be 1.52 m. The minimum value should be 0.5 m. The run-up can be obtained with equation given in the 'Report'. As a rule of thumb, the beach face wave height will be 10% of the breaking wave height. But it may be much bigger in front of a seawall subjected to scour at the toe.

Step 8: Find the sum of the above, which gives MBL of a location. To obtain MFL for buildings and infrastructure a factor, depending on the general slope of the coast, needs to be added to the MBL.

**Appendix-3**

## General conditions for Coastal data collection survey

- The survey should cover the length of at least 500 m on both the sides of eroded area.
- Cross chainage profile should be taken at an interval of 50m along the base line.
- Cross chainage levels should be at 5m interval extending up to Low water line on sea side and up to habitation line or shore line i.e. the profile must extend at least 10 m beyond the highest elevation reached during highest high water on shoreward side.
- All levels are to be with respect to Chart Datum.
- The survey should be conducted before monsoon and after monsoon seasons.
- At least 4 geographical reference points are essential with respect to Latitude and Longitude.
- The levels (cross sections) are to be plotted at each cross chainage to the scale of 1:200 (on both X & Y axis).
- Contour map of the site is to be plotted in the scale of 1 : 1000 ( with 0.5 / 1 m contour interval as well as to be marked with and Low water line & High waterline.
- Any important features, monuments, coastal features, vegetations etc. need to be marked on the plan.
- Soil sample should be taken at least 50cm below the existing beach level for pre-monsoon and post-monsoon and Grain size analysis curve indicating $D_{15}$, $D_{50}$ & $D_{95}$ is to be plotted.
- Tide levels (with respect to Chart datum) like Highest High water level, Lowest Low water level, wave directions, maximum wave height, Wave period etc. are to be noted.
- Index pain & location plan of site need to cover all important features.

**Appendix-4**

# Standard Frequency of Coastal Data Collection

| Sl No. | Data | Frequency |
|---|---|---|
| 1 | Wave | Hourly |
| 2 | Current | 30 Minutes |
| 3 | Tide | 30 Minutes |
| 4 | Bathymetry | Once during Pre Monsoon and once during Post Monsoon |
| 5 | Coastal Sediment (Shore, Seabed and Suspended sediments) | Monthly |
| 6 | Wind | 15-30 Minutes |
| 7 | Riverine Data<br>(Discharge and Salinity) | Thrice a day (during low tide, mid tide and high tide), twice in a month ( Once during Spring Tide and Neap Tide), Once during Pre-Monsoon and Post Monsoon, Twice during Monsoon |
| 8 | Beach Profile | Monthly |
| 9 | Shoreline Change | Monthly |

**Appendix-5**

## Coastal Data Collection Format

| Sl No. | Description | | Information | | | |
|---|---|---|---|---|---|---|
| 1 | Field data of……………………………………… (Village, Taluk, Dist, State) | | Pre Monsoon/Post Monsoon | | | |
| 2 | Responsible agency for site | Division | | | | |
| | | Circle | | | | |
| | | Dept. | | | | |
| 3 | Date of Collection of data | | | | | |
| 4 | Tidal data | | HTL: | | LTL: | |
| | | | HFL: | | Storm Surge: | |
| 5 | Current Data | | Max Current (m/sec) : | | | |
| | | | Direction (Degree) : | | | |
| 6 | Wave Period (Sec) | | | | | |
| 7 | Wave Height (m) | | Max: | | Direction: | |
| | | | Min: | | Direction: | |
| 8 | Type of Bed Material | | | D85... mm | D50… mm | D15... mm |
| 9 | Bed Slope ( e.g 1:100 etc) | | | | | |
| 10 | Wind | | Speed (m/sec): | | Direction: | |
| 11 | Any other Collected data | | | | | |

**Appendix-6**

## Format for Abstract of Cost Estimate

**(Amount in .Rs Cr.)**

**(Price level. year ............)**

| **A** | **DIRECT CHARGES** | | **Remarks** |
|---|---|---|---|
| **I** | **I-WORKS** | | |
| 1 | A-Preliminary | | |
| 2 | B-Land | | |
| 3 | C-Works | | |
| 4 | K-Building | | |
| 5 | M-Plantation | | |
| 6 | O-Miscellaneous | | |
| 7 | P-Maintenance | | |
| 8 | R-Communication | | |
| 9 | X-Environment and Ecology | | |
| 10 | Y-Losses | | |
| | **I-WORKS** | | |
| **II** | Establishment | | |
| **III** | T&P | | |
| **IV** | Suspense | | |
| **V** | Receipts and Recoveries (-) | | |
| | **TOTAL DIRECT CHARGES** | | |
| **B** | **INDIRECT CHARGES** | | |
| (i) | Audit & Accounts charges | | |
| | **Total Cost including Direct and Indirect Charges (A+B)** | | |