

CHAPTER 144

A Condition and Performance Rating System For Breakwaters and Jetties

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Abstract

This paper describes one aspect of a series of projects which the U. S. Army Corps of Engineers has undertaken to improve maintenance management of coastal and navigational structures. At the core of these projects is the development of procedures for more uniformly evaluating and describing the physical condition and functional performance of structures, and further, the development of methods where the condition and performance of structures, and their parts, can be expressed numerically to take best advantage of the benefits available from the use of microcomputers in maintenance management. These procedures are designed to allow the condition and performance of different structures to be more easily compared and more uniformly tracked over long time periods and to aid the repair budgeting prioritization process. This paper briefly

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describes the performance-based assessment method for breakwaters and jetties, primarily of rubble construction.

System Philosophy

The most important analysis within this system is on structure performance, with physical condition taking a secondary role. In this performance-based system, the difference between current structure condition and as-built (or "like new") condition is not, in itself, a deciding factor on the need for repair. Rather, it is a structure's documented loss of function as a result of structural deterioration which is most important. When performance is judged unsatisfactory, then repairs are considered which would raise performance back to satisfactory levels. Evidence of near-term structural instability is also an important consideration, as it could adversely affect performance.

The Eight System Steps

Table 1 lists the eight steps in the implementation and use of the system. A brief description of these steps is given below. A more complete system description is contained in Oliver, Plotkin, Lesnik, and Pirie 1996. This document will be referred to as the "system manual" in the rest of the paper.

Assigning Functions and Defining Reaches

The first step is to determine which functions the structure is intended to perform, according to the four main functional areas and nine functional rating categories, as listed in Table 2. These are described in the system manual which also contains a spreadsheet to assist in performing the complete functional assessment.

Generally, Harbor Area and Navigation Channel cover how well the structure controls waves and currents with respect to the categories listed for those areas. To avoid confusion and duplication of defect reporting, all sediment control aspects are grouped together under Sediment Management. Structure Protection refers mainly to how well a structure protects adjacent structures against attack by waves and currents. This function may apply to an outer breakwater protecting an inner breakwater, or to one jetty protecting the one on the opposite side of the channel.

Table 1. Eight Steps in the Rating System

Step Number (1)	Description (2)
	Steps 1-5 are Initial (One Time Only):
1	Determine What Functions Structure Serves.
2	Divide Structure into Major Reaches - by Function.
3	Establish Functional Performance Criteria.
4	Establish Structural Requirements.
5	Further Divide Reaches into Subreaches - by Structural and Length Criteria
	Steps 6 - 8 are Repeated as Required:
6	Inspect Structure - Produce Structural Rating.
7	Assess Functional Performance - Produce Functional Rating.
8	Review Structural Requirements.

The Toe Erosion and Trunk Protection categories serve as a useful reference but are not included in the Condition Index calculations, as their effect is covered by the structural rating categories.

Next is the initial step in dividing the structure along its length into reaches. The functions provided by different portions of the structure are determined, using the categories listed within the four main functional areas. Initial reach limits are set where functional changes occur. The head of a structure is always considered to be a separate reach.

Performance Criteria and Structural Requirements

Step 3 is to determine, for each reach and for each functional category which applies to it, what level of performance is expected. This performance expectation is

Table 2. Functional and Structural Rating Categories.

Functional Area (1)	Functional Rating Categories (2)	Structural Rating Categories (3)
Harbor Area	Harbor Navigation Harbor Use	Breach Core Exposure/Loss Armor Loss Loss of Armor Contact/Interlock Armor Quality Defects Slope Defects
Navigation Channel	Entrance Use Channel	
Sediment Management	Ebb Shoal Flood Shoal Harbor Shoal Shoreline Impacts	
Structure Protection	Nearby Structures Toe Erosion * Trunk Protection	

* Not included in Condition Index calculation.

indicated by the acceptable number of annual disruptions, or periods of disruption for each of the required navigation and related activities. The allowable disruption will vary not only with navigation activity, but also by size and type of vessel.

Performance is referenced to three levels of storm events:

1. Design Storm: This is the largest storm (or most adverse combination of storm conditions) which the structure (or project) is intended to withstand, without allowing disruption of navigation or harbor activities, or damage to the structure or shore facilities. The design storm is usually designated by frequency of occurrence or probability of occurrence.
2. Intermediate Storms (2X Design Storm Frequency): This level refers to storms (or combinations of adverse conditions) of intermediate intensity, which occur on the order of twice as often as the design storm. This level is intended to represent a midway point between the maximum storm levels (design storm) and small or minor intensity storms which may occur more frequently, especially during certain periods of the year.

3. Low Intensity Storm Conditions: This level refers to storms (or combinations of adverse conditions) of low intensity, which may occur frequently throughout the year, such as common rain storms or periods of above normal winds. This level is the next stage above normal non-storm conditions.

The design storm is the main reference point for establishing expected structure performance. Authorizing documents, design notes, project history, and current requirements are used to confirm the appropriate design storms for a project. For systems designed for seasonal use or for interrupted use, the expected non-use periods must be allowed for in arriving at a design storm. Design storm conditions include: wave height, direction, and period; water level; storm duration; and combinations of these factors.

The design storm typically varies from one project to another, and for different activities or areas within a single project. For example, disruption of cargo handling or limitations on channel entrance use might be tolerated more frequently than disruption in the harbor area. Thus the design storms for the navigation channel, damage to harbor facilities, vessel damage, and disruption of cargo handling are, or should be, at different return intervals.

For many harbor entrances, design depths and channel orientation are indications of design intent. For example, a 10 foot channel will have breaking waves at a wave height of 8 feet. At this wave height, about 4 feet of channel depth is lost at the wave trough and waves are steep enough to cause broaching of a craft with less than 5 feet of draft. Thus, with an 8-foot wave, the channel is impassable for all vessels due to either limited depth (for larger vessels) or excessive wave steepness (for smaller vessels). At this location, an 8-foot wave height can then be tied to a storm of a certain frequency or probability, and a tolerable frequency for closing the channel can then be determined. In a similar fashion, safety in the harbor berthing area and disruption to cargo handling could be analyzed.

When structure performance is rated later in the process, the ratings are based on storms of the greatest intensity which have occurred during the last rating period. Having three levels allows ratings to be produced during intervals when only storms of less than design intensity have occurred.

Once performance expectations are established for each function, it is then necessary to determine what structural requirements the structure must fulfill to allow performance requirements to be met. Seldom does a rubble coastal structure require full structural integrity to have continuity in function. In fact, most rubble structures are built with some allowance for damage before function is compromised, and many are overbuilt for constructability. Thus, structural damage does not automatically equate to loss of function.

Determining structural requirements involves estimating the minimum cross section dimensions, crest elevation, and level of structural integrity needed to meet functional performance requirements. Initial efforts in visualizing these dimensions can be aided by estimating the impact on functions if the reach under study were to be completely destroyed. Project history, authorizing documents, public input, and analysis may also be required to adequately determine these dimensions. As this is not an exact science, application of significant engineering judgment will be necessary to produce a reasonable estimate. Once this is done, these structural requirements are used to help identify sources of functional deficiencies in the existing structure.

Final Reach Division

At this point, the reaches which were initially divided according to function are now further divided according to the following two criteria:

1. By Construction: Further division is made based on changes in structural characteristics.
2. By Length: Where function and construction are uniform over a long length, divisions are made to keep reaches in the range of 60 to 150 meters (200 to 500 feet).

Divided in this fashion, the reaches now represent convenient-sized management units with similar properties. Reach definition is permanent, unless major changes are made to the structure.

At this point, all the initial steps in implementing the system are complete and need not be repeated. The following steps are then performed on a recurring basis, as needed.

Structural Inspection and Rating

Structural ratings are produced by comparing the current physical condition, alignment, and cross sectional dimensions of a structure to that of a "like new" structure which was built as intended and according to good practice, and with good quality materials.

For structural rating, each reach is divided into three cross sectional areas: the crest (or cap), the seaside, and channel or harborside. Each cross sectional area is given 0 to 100 ratings in five of six rating categories, as listed in the right-hand column on Table 2. (Slope Defects is not rated for the crest, and Breach is not rated for the two side slopes). These ratings are determined primarily from visual inspections of the structure, although additional information, such as hydrographic surveys, may also be used.

The system manual contains a rating table for each structural rating category. While these tables are specific to each category, they follow the basic format of the General Condition Index Scale shown in Table 3. Values are usually selected as multiples of 5 (60,65,70, etc). The system includes a field form for recording the ratings, inspector comments, and other information useful in producing a thorough inspection.

The ratings are then entered into the BREAKWATER computer program which calculates a composite structural index (SI) for each of the three cross sectional areas, a single SI for the whole reach, and finally an SI for the whole structure (Aguirre and Plotkin 1996). The SI value for a structure or structural component indicates its level of physical condition and structural integrity.

Functional Assessment and Rating

Functional assessment begins with a review of the functional performance criteria for the structure. Then, the environmental setting (wave and current energy, water level variability, sediment transport, etc.) is examined, followed by a review of the structural ratings, SI values, and comments made during the structural inspection. The intent is to determine the extent to which structural deterioration has adversely affected function.

As for structural rating, the system also contains rating tables for each functional rating category which likewise follow the general format of Table 3. After the

Table 3. General Condition Index Scale.

Observed Damage Level (1)	Zone (2)	Index Range (3)	Condition Level (4)	Description (5)
Minor	1	85 to 100	EXCELLENT	No noticeable defects. Some aging or wear may be visible.
		70 to 84	GOOD	Only minor deterioration or defects are evident.
Moderate	2	55 to 69	FAIR	Some deterioration or defects are evident, but function is not significantly affected.
		40 to 54	MARGINAL	Moderate deterioration. Function is still adequate.
Major	3	25 to 39	POOR	Serious deterioration in at least some portions of the structure. Function is inadequate.
		10 to 24	VERY POOR	Extensive deterioration. Barely Functional.
		0 to 9	FAILED	No longer functions. General Failure or complete failure of a major structural component.

ratings are chosen, a check is made to ensure that each rating is made based on how the structure itself (its presence or condition) has affected the rated functional categories.

The ratings are then entered into the BREAKWATER computer program which calculates a composite functional

index (FI) for the whole reach and then for the whole structure. The FI values for a structure or reach indicate how well it performs its intended functions. The FI values then lead to a condition index for the reach or whole structure.

Review of Structural Requirements

Finally, structural ratings and functional ratings are compared to the initial structural requirements. The intent is to perfect the relationship of performance to structural deterioration, which will occur over the long term through repeated analysis.

Budgeting for Repairs

Through use of the method outlined above, sufficient data and experience will be accumulated to track structure condition over time and properly relate physical condition with functional performance. At this point, general deterioration rates can be determined, along with minimum condition levels which will provide the required performance. From this information, the required repairs can be budgeted to the extent needed and at the appropriate timing.

While it is recognized that catastrophic effects of major storms can result in a clear need for immediate repair, these major events will not necessarily dictate the decision process or dominate a structure's overall long-term structural deterioration and accompanying loss of function. Even the repair of major storm damage is still appropriately assessed through the above method.

Conclusions

This system establishes a rational and systematic method for assessing the physical condition and performance of breakwaters and jetties. It emphasizes the need to establish performance expectations for coastal structures, and further, to relate the need for structural repairs to documented loss of function. The system for rubble breakwaters and jetties is currently being implemented throughout the U. S. Army Corps of Engineers. Similar procedures will also be developed for breakwaters and jetties of non rubble construction, and later, for seawalls, bulkheads, revetments, and groins.

Acknowledgements

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Appendix. References

Aguirre, R., and Plotkin, D. (1996). "BREAKWATER Computer Program User Manual," U. S. Army Construction Engineering Research Laboratory, Champaign, IL, (Draft Technical Report).

Oliver, J., Plotkin, D., Lesnik, J., and Pirie, D. (1996). "REMR Management Systems - Condition and Performance Rating Procedures for Rubble Breakwaters and Jetties," U. S. Army Construction Engineering Research Laboratory, Champaign, IL, (Draft Technical Report).