Chapter 1
General

1-1. Purpose

This manual establishes and standardizes stability criteria for use in the design and evaluation of the many various types of concrete structures common to Corps of Engineers civil works projects. As used in this manual, the term "stability" applies to external global stability (sliding, rotation, flotation and bearing), not to internal stability failures such as sliding on lift surfaces or exceedance of allowable material strengths.

1-2. Applicability

This manual applies to all USACE commands having responsibilities for civil works projects.

1-3. References

Required and related publications are listed in Appendix A.

1-4. Distribution Statement

Approved for public release, distribution is unlimited.

1-5. Mandatory Requirements

Designers performing stability analyses of concrete structures are required to satisfy specific mandatory requirements. The purpose of mandatory requirements is to assure the structure meets minimum safety and performance objectives. Mandatory requirements usually pertain to critical elements of the safety analysis such as loads, load combinations and factors of safety. Mandatory requirements pertaining to the guidance contained in a particular chapter are summarized at the end of that chapter. No mandatory requirements are identified in the appendices. Instead, any mandatory requirements pertaining to information contained in appendices is cited in chapters which refer to those appendices. Where other Corps guidance documents are referenced, the designer must review each document to determine which of its mandatory requirements are applicable to the stability analysis. Engineers performing the independent technical review must ensure that the designers have satisfied all mandatory requirements. Waiver procedures for mandatory requirements are described in ER 1110-2-1150. This reference also indicates that deviation from non-mandatory provisions should be rare, and are subject to approval by the engineering chief in the design district.

1-6. Scope

This manual covers requirements for static methods used in stability analyses of hydraulic structures. The types of concrete structures addressed in this manual include dams, locks, retaining walls, inland floodwalls, coastal floodwalls, spillways, outlet works, hydroelectric power plants, pumping plants, and U-channels. The structures may be founded on rock or soil and have either flat or sloped bases. Pile-founded structures, sheet-pile structures, and footings for buildings are not included. When the stability requirements of this manual conflict with those in other Engineering Manuals or Engineering Technical Letters, the requirements of this manual shall govern. These requirements apply to all potential failure planes at or slightly below the structure/foundation interface. They also apply to certain potential failure planes within unreinforced concrete gravity structures. This manual defines the types and combination of applied loads, including uplift forces due to hydrostatic pressures in the foundation material. The manual defines the various components that enable the structure to resist movement, including anchors to the foundation. Most importantly, the manual prescribes the safety factors which govern stability requirements for the structure for various load combinations. Also, guidance is provided for evaluating and improving the stability of existing structures.

1-7. Background

a. General. Engineer Manuals published over the past 40 years have set stability requirements for the different major civil works structures. For sliding and bearing, the stability requirements have been expressed deterministically in terms of an explicit factor of safety that sets the minimum acceptable ratio of foundation strength along the most critical failure plane to the design loads applied to the failure plane. The analysis for determination of the resultant location in prior guidance has been termed an *overturning stability analysis*. This is a misnomer since a foundation bearing, crushing of the structure toe, and/or a sliding failure will occur before the structure overturns. This manual replaces the term overturning stability analysis with resultant location.

b. Intent. The basic intent of the new guidance specified herein is summarized below:

- Provide new standard factors of safety as replacement for the somewhat variable factors of safety previously specified in other Corps guidance documents.
- Establish basic structural performance goals for each loading condition category.
- Provide tabular summaries of the structure-specific loading-condition check lists found in the other Corps guidance documents in order to properly categorize each loading condition as either usual, unusual, or extreme.
- Require the use of higher factors of safety for conditions where site information is not sufficient to provide a high degree of confidence with respect to the reliability of foundation strength parameters, loads information, and analytical procedures used in the stability analysis.
- Permit the use of lower factors of safety for existing structures when there is a high degree of confidence, based on records of construction and in-service conditions, that the values of the critical parameters used in the stability analysis are accurate.

The process used to standardize factors of safety is based on the premise that the traditional factors of safety specified in the recent guidance for Corps concrete hydraulic structures, for the most part, provide adequate protection against stability failure. The standardization process recognizes, as did previous Corps guidance, that lower factors of safety can be assigned to those loads and loading conditions designated as *unusual*, or *extreme* because the probabilities of those loads and load conditions occurring during the life of the structure are significantly less than the probabilities for *usual* loading conditions. The following elements were part of the safety factor standardization process:

- Traditional factors of safety specified in previous Corps guidance documents were used as a basis for establishing new factors of safety, which are re-formatted to be consistent with other Corps guidance that has probabilistic based requirements.
- The guidance incorporates past practices of assigning lower factors of safety to *normal* structures, as compared to those traditionally used for *critical* structures,.
- The guidance incorporates past practices of categorizing maintenance and construction loads as *unusual* loads.
- The guidance defines the loading condition categories of *usual, unusual*, and *extreme* in probabilistic terms to provide standardization as to which category various structure specific loadings should be assigned.
- Provides a consistent set of safety factors, which account for loading probability, critical structures, and the knowledge of site information used in the stability analysis.

c. Factors of safety. Factors of safety are needed in stability and structural analyses because of the potential variability in loads and material strengths. The factor of safety assigned to a particular stability design or

investigation reduces the risk of unsatisfactory performance due to loads being greater than assumed for design and the risk of unsatisfactory performance due to material strengths being less than assumed for design. This guidance makes no attempt to quantify the reliability of the safety factors prescribed for use in the design and evaluation of Corps structures other than that they are traditionally accepted values that when used with prescribed simple assessment procedures have produced structures which have performed satisfactorily for many years. The minimum-allowable safety factors described in this manual assume that a complete and comprehensive geotechnical investigation has been performed. Higher safety factors are required when site information is limited. When concerns about stability exist, the designer should take all measures necessary to quantify load and material strength variability and use the most comprehensive analytical tools available to evaluate the capacity of the structure to meet performance objectives.

d. Sliding stability. Sliding of a structure on its foundation represents the most difficult aspect of a stability analysis, especially in those instances where the foundation is jointed, and where the strength properties vary throughout the foundation. The approach to evaluating sliding stability is one that uses the limit equilibrium method with the linear Mohr-Coulomb failure criterion as a basis for estimating maximum available shear strength. The greatest uncertainties in the analysis are those associated with shear strength determination. The safety factors used are consistent with current foundations and explorations procedures, and with current analytical methods. The guidance recognizes that there are foundations where design shear strength parameters are highly variable because foundation conditions change from one area of the foundation to another and because the foundation may be comprised of both intact rock, and jointed rock with clean or filled discontinuities all with differing shear / displacement characteristics and possibly with strain-softening characteristics which make overall strength a function of displacement. A combination of experience and judgment is necessary to confidently determine that the strength and load parameters used in the stability analysis will provide structures that meet performance objectives.

1-8. Coordination

Even though stability analysis of concrete structures is a structural engineering responsibility, the analysis must be performed with input from other disciplines. It is necessary to determine hydrostatic loads consistent with water levels determined by hydraulic and hydrological engineers. Geotechnical engineers and geologists must provide information on properties of foundation materials, and must use experience and judgement to predict behavior of complex foundation conditions. To ensure that the proper information is supplied, it is important that those supplying the information understand how it will be used by the structural engineer. To ensure that the information is applied appropriately, it is important that the structural engineer understand methods and assumptions used to develop this interdisciplinary data.