SOUTH LAFOURCHE LEVEE DISTRICT

DRAFT DOCUMENT ON
INTERIM DESIGN PROCEDURES
HURRICANE PROTECTION LEVEES

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Contents

1. Introduction

1-1. Purpose

The purpose of this manual is to present basic principles used in the design and construction of earthen levees for the South Lafourche Levee District.

1-2. Applicability

This manual applies to all levees to be constructed by the South Lafourche Levee District and/or its contractors.

1-3. References

Several publications are referenced in this manual. These publications shall be consulted where appropriate.

1-4. Objective

The objective of this manual is to develop a guide for design and construction of levees in the area governed by the South Lafourche Levee District. The manual is general in nature and not intended to supplant the judgment of the design engineer on a particular project.

1-5. General Considerations

a. General

(1) Numerous factors must be considered in levee design. These factors may vary from project to project, and no specific step-by step procedure covering details of a particular project can be established. However, it is possible to present general, logical steps based on successful past projects that can be followed in levee design and can be used as a base for developing more specific procedures for any particular project.

(2) The South Lafourche Levee District recognizes and is grateful for the assistance provided by the U. S. Army Corps of Engineers in the existing hurricane protection system. However, the South Lafourche Levee District feels strongly that the system as it exists is not adequate for the protection of the residents of South Lafourche. Since the authorization of the Larose to Golden Meadow levee project, there has been a great deal of subsidence in the South Lafourche area. Also, global weather patterns have necessitated a closer look at the levee system requirements. In particular, the South Lafourche Levee District feels as though the U. S. Army Corps of Engineers has not addressed the flood elevations recommended by the preliminary Flood Insurance Rate Maps for Lafourche Parish as published by the Federal Emergency Management Agency on July 30, 2008.

b. Levee Design Standards

(1) The primary goal of the construction of levee projects for the South Lafourche Levee District shall be to ensure that any new construction does not lower the strength and/or stability of the existing levee below acceptable standards. Any proposed construction shall be evaluated using sound engineering principles.

(2) The secondary goal of the construction of levees for the South Lafourche Levee District shall be to meet the latest design standards for levee construction put forth by the U. S. Army Corps of Engineers. The current U. S. Army Corps of Engineers guidelines are the Hurricane Storm Damage Risk Reduction System design guidelines. Each project shall be evaluated for reasonable project budget, sound engineering principles, and risk to the community. Even if the current U. S. Army Corps of Engineers guidelines cannot be immediately met, they shall be considered in the planning of the levee project. It may be possible to design the proposed levee section so that it approaches the current U. S. Army Corps of Engineers guidelines as it consolidates. New construction shall be designed so that these guidelines can be met in the future without tearing out a section of levee, therefore subjecting the area of South Lafourche to storm surges.

(3) The tertiary goal of the construction of levees for the South Lafourche Levee District shall be to meet previous U. S. Army Corps of Engineers guidelines for the construction of levees, as designated in the U. S. Army Corps of Engineers EM 1110-2-1913, 30 April 2000. These guidelines have produced levees that have withstood the effects of many hurricanes through the years. Since the existing South Lafourche levees were designed and built using U. S. Army Corps of Engineers guidelines, there should be no reason to construct a levee that does not meet these older guidelines.

c. Priority

The South Lafourche Levee District shall use several factors to determine the priority of the upgrades they construct:

(1) Current elevation of protection in a project area compared to the levee system as a whole.

(2) Cost of proposed project compared to funds available.

(3) Availability of suitable material near project site.

(4) Whether project is to bid out or constructed in-house.

(5) Location of proposed project.

(6) Length of proposed project.

2. Design Procedures

2-1. General Design Guidance

The following represents the typical procedure for the geotechnical design and analysis of levee embankments. The procedures stated herein, although considered typical, are in no way implied to eliminate engineering judgment.

2-2. Design Elevation of Levee Reach

The levees shall be constructed to withstand as high a flood elevation as is practical. The ultimate goal is to design the levees to withstand the flood elevations as recommended by the Federal Emergency Management Agency and the U. S. Army Corps of Engineers.

2-3. Geotechnical Field Investigation

Prior to any design, soil borings from previous construction projects shall be considered, if available. If there are no levees currently in the area, it would be helpful to review aerial photos to determine a preliminary layout. Based on this information, a soil testing program shall be put together.

2-3.1. Scope

In general, for levee design, centerline and toe borings should be taken at a maximum spacing of 500 feet along the centerline alignment of the levee. The spacing of borings should not be arbitrarily uniform but rather should be based on available geologic information. Borings can be laid out along the levee centerline but should be staggered along the alignment in order to cover more area. It may be most practical to have the soil borings alternate with the cone penetrometer tests. Borrow borings are typically taken at 500 feet along the centerline alignment of the levee. Consult geotechnical engineers when developing boring programs.

A testing system can be set up so that there is rolling set of four scenarios. For the first cross section scenario, a boring is taken on the centerline and a cone penetrometer test on the protected toe. For the second cross section scenario, a cone penetrometer would be taken on the centerline and a boring taken on the floodside toe. For the third cross section, a boring is taken on the centerline and a cone penetrometer test on the floodside toe. For the fourth cross section scenario, a cone penetrometer would be taken on the centerline and a boring taken on the protected toe. The order would repeat for further cross sections.

The soil borings taken along the centerline alignment shall alternate between 5” undisturbed and 5” general type soil borings or cone penetrometer tests.

Each of these soil borings shall be drilled to a minimum depth of three times the height of the proposed levee. Boring depths shall always be deep enough to provide data for stability analyses of the levee and foundation.

Additional borings will be required for any hard structures to be constructed. Borings at hard structure locations should extend well below invert or foundation elevations and below the zone of significant influence created by the load.

2-3.2. Testing

The guidance outlined herein assumes test results are from 5” diameter undisturbed samples; unconsolidated-undrained triaxial (Q) tests are the predominant tests and are supplemented by unconfined compression (UCT) tests.

The following laboratory tests shall be performed on all fine grained cohesive soils:

Visual classification and water content determinations	On all samples.
Atterberg limits	On representative samples of foundation deposits for correlation with shear or consolidation parameters, and borrow soils for comparison with natural water contents, or correlations with optimum water content and maximum densities.
Permeability	Not required; soils can be assumed to be essentially impervious in seepage analyses.
Consolidation	Consolidation tests shall be performed. In some locations, correlations of liquid limit and natural water content with coefficient of consolidation, compression index, and coefficient of secondary compression can be used satisfactorily for making estimates of consolidation of foundation clays under load.
Compaction	Perform standard 25-blow compaction tests.
Shear strength	Q triaxial tests appropriate for foundation clays, as undrained strength generally governs stability.

The following laboratory tests shall be performed on all pervious soils:

Visual classification	Of all jar samples.
In situ density determinations	Of Shelby-tube samples of foundation sands where liquefaction susceptibility must be evaluated.
Relative density	Maximum and minimum density tests should be performed in seismically active areas to determine in situ relative densities of foundation sands and to establish density control of sand fills.
Gradation	On representative foundation sands: *a*. For correlating grain-size parameters with permeability or shear strength. *b*. For size and distribution classifications pertinent to liquefaction potential.
Permeability	Not usually performed. Correlations of grain-size parameters with permeability or shear strength used. Where underseepage problems are serious, best guidance obtained by field pumping tests.
Consolidation	Not usually necessary as consolidation under load is insignificant and occurs rapidly.

Shear strength	For loading conditions other than dynamic, drained shear strength is appropriate. Conservative values of φ' can be assumed based on S tests on similar soils. In seismically active areas, cyclic triaxial tests may be performed.

2-3.3. Strengthlines

Strengthlines should be drawn such that approximately one-third of the tests fall below the strengthline and two-thirds plot above the strengthline. A line indicating the ratio of cohesion to effective overburden pressure (c/p) of 0.22 should be superimposed on the plot. The c/p line may be used to assist in determining the trend of the strengthline. A plot of centerline strengths under an existing embankment and another plot under natural ground to be used for toe strengths should be drawn.

2-4. Levee Embankment Design

2-4.1. Existing Condition

Using Method of Planes (in accordance with the U. S. Army Corps of Engineers Stability with Uplift program) with tested undrained shear strengths, determine the Factor of Safety of the existing section. At a minimum, the following analyses shall be performed for the Existing Condition:

- Design Hurricane Still Water Level (SWL)

  Applies to analyses failing toward the protected side for the Still Water Level condition (100-yr return period, 90% assurance, as authorized in the current design hurricane loading condition). Stability is analyzed for the as-constructed section with water at Still Water Level using drained strengths expressed in terms of effective stresses for free-draining materials and undrained strengths expressed in terms of total stresses for materials that drain slowly.

- Water at Top of Levee Section

  Applies to analyses failing toward protected side of the as-constructed levee or floodwall section for the water level at the top of the constructed levee under a short term hurricane condition. Stability for levee systems are analyzed using drained strengths expressed in terms of effective stresses for free-draining materials and undrained strengths expressed in terms of total stresses for materials that drain slowly.

2-4.2. Proposed Condition: Spencer's Method Analysis

In accordance with the U. S. Army Corps of Engineers Hurricane Storm Damage Risk Reduction System design guidelines, the proposed levee section is analyzed using Spencer's Method for Global Stability.

Spencer method shall be used for circular and non-circular failure surfaces since it satisfies all conditions of static equilibrium and because its numerical stability is well suited for computer application. These factors of safety are based on well defined conditions where: (a) available records of construction, operation, and maintenance indicate the structure has met all performance objectives for the load conditions experienced; (b) the level of detail for investigations follow EM 1110-1-1804, Chapter 2, for the Preconstruction Engineering and Design (PED) phase of design; and (c) the governing load conditions are established with a high level of confidence. Poorly defined conditions are not an option.

- Design Hurricane Still Water Level (SWL) 1.5

  Applies to analyses failing toward the protected side for the Still Water Level condition (100-yr return period, 90% assurance, as authorized in the current design hurricane loading condition). Stability is analyzed for the as-constructed section with water at Still Water Level using drained strengths expressed in terms of effective stresses for free-draining materials and undrained strengths expressed in terms of total stresses for materials that drain slowly.

- Water at Top of Levee Section 1.4 (1.5)

  Applies to analyses failing toward protected side of the as-constructed levee section for the water level at the top of the constructed levee under a short term hurricane condition. Stability for levee systems are analyzed using drained strengths expressed in terms of effective stresses for free-draining materials and undrained strengths expressed in terms of total stresses for materials that drain slowly.

  The required factor of safety shall be increased from 1.4 to 1.5 when steady-state conditions are expected to develop in the embankment or foundation. (The higher FOS only applies to the freely-draining sand stratums that can obtain the steady state condition).

If an adequate Factor of Safety cannot be obtained with typical levee sections, design stability berms, reinforcing geotextile, soil improvements, or some other means to produce an adequate Factor of Safety with regard to the current design criteria. The designer should check the final design section determined by the Method of Planes and the Spencer Method and present the Factors of Safety for both analyses. The minimum distance between the active wedge and passive wedge in an embankment should be 0.7H, where H is the vertical distance of the intersection of the active wedge with the ground surface and its intersection with the failure surface.

2-4.3. Proposed Condition: Method of Planes Analysis

If the proposed levee reach cannot be feasibly built using the Spencer's Method for Global Stability, the proposed levee section is analyzed using the Method of Planes.

Method of Planes shall be used as a design check for verification that levee and floodwall designs satisfy historic district requirements. Analysis shall include a full search for the critical failure surface per stratum since it may vary from that found following the Spencer method.

- Design Hurricane Still Water Level (SWL) 1.3

Applies to analyses failing toward the protected side for the Still Water Level condition (100-yr return period, 90% assurance, as authorized in the current design hurricane loading condition). Stability is analyzed for the as-constructed section with water at Still Water Level using drained strengths expressed in terms of effective stresses for free-draining materials and undrained strengths expressed in terms of total stresses for materials that drain slowly.

- Water at Top of Levee Section 1.2

Applies to analyses failing toward protected side of the as-constructed levee section for the water level at the top of the constructed levee under a short term hurricane condition. Stability for levee systems are analyzed using drained strengths expressed in terms of effective stresses for free-draining materials and undrained strengths expressed in terms of total stresses for materials that drain slowly.

The required factor of safety shall be increased from 1.4 to 1.5 when steady-state conditions are expected to develop in the embankment or foundation. (The higher FOS only applies to the freely-draining sand stratums that can obtain the steady state condition).

2-5. Seepage Analysis

Piping and seepage analysis shall be performed in accordance with U. S. Army Corps of Engineers EM 1110-2-1913, 30 April 2000, Design and Construction of Levees.

2-6. Adjacent Structures

Any adjacent structures (e.g., pump stations) shall be considered when analyzing the levee cross section.

2-7. Wall Design

Since it is much more difficult to raise the elevation of a wall (as opposed to a levee), all hard structures shall be designed in accordance with the latest U. S. Army Corps of Engineers guidelines.

2-8. Levee Tie-ins and Overtopping Scour Protection

Protection may be needed on a floodside slope to withstand the erosional forces of waves and stream currents. Protection may be beneficial on a protected side slope to withstand the erosional forces of overtopping waters. The required protection will vary, depending on a number of factors:

- The length of time that floodwaters are expected to act against a levee. If this period is brief, with water levels against the levee continually changing, grass protection may be adequate, but better protection may be required if currents or waves act against the levee over a longer period.
- The relative susceptibility of the embankment materials to erosion. Fine-grained soils of low plasticity (or silts) are most erodible, while fat clays are the least erodible.

- Structures floodside of the levee. Bridge abutments and piers, gate structures, ramps, and drainage outlets may constrict flow and cause turbulence with resultant scour.
- Turbulence and susceptibility to scour may result if levee alignment includes short-radius bends or if smooth transitions are not provided where levees meet high ground or structures.
- Requirements for slope protection are reduced when floodside levee slopes are very flat as may be the case for levees on soft foundations. Several types of slope protection have been used including grass cover, gravel, sand-asphalt paving, concrete paving, articulated concrete mat, and riprap, the choice depending upon the degree of protection needed and relative costs of the types providing adequate protection.

Performance data on existing slopes under expected conditions as discussed above are invaluable in providing guidance for the selection of the type of slope protection to be used.

Sometimes it may be concluded that low cost protection, such as grass cover, will be adequate in general for a levee reach, but with a realization that there may be limited areas where the need for greater protection may develop under infrequent circumstances. If the chances of serious damage to the levee in such areas are remote, good engineering practice would be to provide such increased protection only if and when actual problems develop. Of course, it must be possible to accomplish this expeditiously so that the situation will not get out of hand. In any event, high-class slope protection, such as riprap, articulated mat, or paving should be provided on floodside slopes at the following locations:

- Beneath bridges, since adequate turf cannot be generally established because of inadequate sunlight.
- Adjacent to structures passing through levee embankments.

Riprap is more commonly used than other types of revetments when greater protection than that afforded by grass cover is required because of the relative ease of handling, stockpiling, placement, and maintenance. Guidance on the design of riprap revetment to protect slopes against currents is presented in U. S. Army Corps of Engineers EM 1110-2-1601. Where slopes are composed of erodible granular soils or fine-grained soils of low plasticity, a bedding layer of sand and gravel or spalls, or plastic filter cloth should be provided beneath the riprap.

3. Construction Procedures for Quality Assurance / Quality Control

3-1. Classification of Methods

Levee embankments classified according to construction methods used are listed in the following table for levees composed of impervious and semipervious materials (i.e., those materials whose compaction characteristics are such as to produce a well-defined maximum density at a specific optimum water content). Where a levee has previously been constructed, compacted fill shall be used for the new levee project. Where there has been no previous levee project and multiple lifts are anticipated, semicompacted fill may be used for the levee project.

Classification According to Construction Method of Levees Composed of Impervious and Semipervious Materials		
Category	Construction Method	Use
Compacted	Specification of: a. Water content range with respect to standard effort optimum water content b. Loose lift thickness (6-9 in.) c. Compaction equipment (sheepsfoot or rubber- tired rollers) d. Number of passes to attain a given percent compaction based on standard maximum density e. Minimum required density	Provides embankment section occupying minimum space. Requires strong foundation of low compressibility and availability of borrow materials with natural water contents reasonably close to specified ranges. Used where field inspection is not constant throughout the project.
Semicompacted	Compaction of fill materials at their natural water content (i.e., no water content control). Borrow materials known to be too wet would require some drying before placement. Placed in thicker lifts than Compacted (12 in.) and compacted either by controlled movement of hauling and spreading equipment or by fewer passes of sheepsfoot or rubber- tired	The most common type of levee construction used in reaches where: a. There are no severe space limitations and steep-sloped Compacted embankments are not required. b. Relatively weak foundations could not support steep-sloped Compacted embankments. c. Underseepage conditions are such

	rollers. Compaction evaluated relative to 15-blow compaction test.	as to required wider embankment base than is provided by Compacted construction. d. Water content of borrow materials or amount of rainfall during construction season is such as not to justify Compacted compaction.

Construction control of levees may present somewhat difficult problems. Construction operations may be carried on concurrently along many miles of levee. This means that much time is needed to cover the operations on many levee jobs. In addition, levee inspection personnel generally operate out of an area office which may be a considerable distance from the levee project. Under these conditions, the inspectors used must be well-trained to observe construction operations, minimizing the number of field density tests in favor of devoting more time to visual observations, simple measurements, and expedient techniques of classifying soils, evaluating the suitability of their water content, observing behavior of construction equipment on the fill, and indirectly assessing compacted field densities.

Some of the things that can happen during construction that can cause failure or distress of even low embankments on good foundations are given in the following table.

Embankment Construction Deficiencies	
Deficiency	Possible Consequences
Organic material not stripped from foundation	Differential settlements; shear failure; internal erosion caused by through seepage
Highly organic or excessively wet or dry fill	Excessive settlements; inadequate strength
Placement of pervious layers extending completely through the embankment	Allows unimpeded through seepage which may lead to internal erosion and failure
Inadequate compaction of embankment (lifts too thick, haphazard coverage by compacting equipment, etc.)	Excessive settlements; inadequate strength; through seepage
Inadequate compaction of backfill around structures in embankment	Excessive settlements; inadequate strength; provides seepage path between structure and material which may lead to internal erosion and failure by piping

As a general rule levee embankments are constructed as homogeneous sections because zoning is usually neither necessary nor practicable. However, where materials of varying permeabilities are encountered in borrow areas, the more impervious materials should be placed toward the floodside of the embankment and the more pervious material toward the landside slope. Where required to improve underseepage conditions, landside berms should be constructed of the most pervious material available and floodside berms of the more impervious materials. Where impervious materials are scarce, and the major portion of the embankment must be built of pervious material, a central impervious core can be specified or, as is more often done, the floodside slope of the embankment can be covered with a thick layer of impervious material. The latter is generally more economical than a central impervious core and, in most cases, is entirely adequate.

3-2. Compaction Procedure

Within the crown of the levee, earthen fill shall be installed in lifts limited to 12” thick. Compaction tests are taken on every lift at no more than 500’ spacing.

Outside of the crown of the levee, earthen fill shall be installed in lifts limited to 12” thick. The compaction required outside of the crown of the levee should meet semi-compaction criteria established by the engineer. The berm material will consolidate over time. In all cases, the cross section of the levee shall meet the necessary stability requirements.

In cases where the berm is used as a temporary storage location for materials to be used in later lifts, no compaction tests are necessary. This material shall be placed so that water may drain.

3-3. Soil Testing Procedure

Soil classification and proctor analysis tests shall be performed on the earthen fill at no more than 500’ spacing.

3-4. Stockpiled Material

There may be cases in which it is economically feasible to excavate borrow material that will not be used until future lifts of the levee. Allowing this wet material to dry before placing it on the levee section, as opposed to hauling in dry material from outside sources, could save a great deal of money.

Stockpiled material shall be included in any analysis of the design section. There shall be no failure in the crown of the levee due to this stockpiled material.

In cases where the berm is used as a temporary storage location for materials to be used in later lifts, no compaction tests are necessary. This material shall be placed so that water may drain.