SECTION 01 81 16.13 – SEISMIC DESIGN CRITERIA

1.01 SUMMARY:

[A8]A. **Preamble**: [A13]This Section covers [A13] the structural systems for the new locks, the filling/emptying systems, Water-Saving Basins, [A11]approach structures, [A11] rolling gates, and their connections to the lock walls, as well as the anchorage of associated mechanical, electrical, and plumbing systems. Seismic design of building structures and associated mechanical, electrical, and plumbing systems shall be in accordance with ASCE 7-05, using site-specific ground motions. [A13]The design of Borinquen Dams shall be in accordance with the requirements of Section 35 73 00 (*Borinquen Dams 2E, 1W and 2W, and Dry Excavation North of Pacific Locks*). [A13]

[A17]B. **Explanation of Terminology Used in this Section**:

1. **Classification**:

   a. The "critical" components and equipment are the electrical and mechanical works whose malfunction could interfere with the safe and continuous operation of the Canal. Any structural element whose failure could result in the collapse of, unrepairable damage to, or malfunction of "critical" components and equipment; or the collapse of, unrepairable damage to the new locks, or the loss of Gatun Lake, is "critical". These components are as described in Volume II, Part 1.

   b. An "important" component is one whose failure could significantly impair operation of the new locks or require lock closure in order to restore its functional capability.

   c. All other structural components are considered "secondary." [A17]

   d. "Essential" and "Normal" structures are described in Section 01 81 16 (*Lock Structures*).

2. The "**Lock Structures**" are as [A17]described [A17] in Section 01 81 16 (*Lock Structures*).

3. Within this Section, a "**performance objective**" states the desired performance level for the structure for the seismic-design level. Performance objectives couple expected or desired performance levels with possible seismic-hazard levels.

4. The "**return period**" is the inverse of the annual probability of occurrence.

5. Whenever it is more economical to repair structural damage than to rebuild the damaged structure, the term "**repairable damage**" is used.

[A8]C. **Ground Motions**:

1. Seismic ground motions for the design earthquakes are defined in [A13]Volume VII, [A13] Part 3 (Seismic Design Criteria Data). These ground motions have been developed at 5% [A11]damping [A11] for oscillator periods between 0.01 and 2.5 seconds.

2. The ground acceleration time histories consist of three ground motion components, two horizontal components and one vertical component. All horizontal components for crustal earthquake records have been rotated into fault parallel (FP) and fault normal (FN) orientations. The horizontal components of the subduction record (from the Michoacan earthquake) are oriented along N-S and E-W directions and have not been rotated into FP and FN directions.

3. The average fault strike direction for the crustal faults are:

   a. Pedro Miguel-Limón Fault – Fault parallel azimuth 175, Fault normal azimuth 265.

   b. Gatun – Fault parallel azimuth 255, Fault normal azimuth 345.

4. The data provided represents basalt outcroppings at the Pacific Site and Gatun outcroppings at the Atlantic Site. [A8]

1.02 [A17]REFERENCES: [A17]

A. **Comité Européen de Normalisation** (**CEN**):

EN 1998	Eurocode 8. Design Provisions for Earthquake Resistance of Structures.

B. **Junta Técnica de Ingeniería y Arquitectura** (**JTIA**)**, Resolution** (**Panama**):

REP-04	Reglamento para el Diseño Estructural en la República de Panamá, 2004.

C. **U.S. Army Corps of Engineers** (**USACE**)**, Engineering Manuals and Other Documents**:

EM-1110-2-2100	Stability Analysis of Concrete Structures.
ER-1110-2-1150	Engineering and Design for Civil Works Projects.

ER-1110-2-1806	Earthquake Design and Evaluation for Civil Works Projects.
EM-1110-2-6050	Response Spectra and Seismic Analysis for Concrete Hydraulic Structures.
EM-1110-2-6051	Time-History Dynamic Analysis of Concrete Hydraulic Structures.

D. **International Code Council**:

IBC 2006	International Building Code.

E. **American Society of Civil Engineers**:

ASCE 7-05	Minimum Design Loads for Buildings and Other Structures.

1.03 DESIGN REQUIREMENTS:

A. Seismic Design Levels and Performance Objectives: Two levels of earthquakes and associated performance objectives shall be considered for the design of the new lock structures covered under this Section and identified in 1.01 A. These levels relate to safety, economics, and the desired performance of the new lock structures as described below.

1. **Level I Earthquake**:

a. The design earthquake represents ground motions for which the essential and normal structures as described in Section 01 81 16, and critical components and non-critical components of the system as described in Subparagraph 1.01 B. of this Section are expected to sustain no permanent damage, and the normal structures and non-critical components may sustain damage that can be repaired without interruption of operations.

b. Under this earthquake loading, displacements of the gates and lock heads shall be limited so that there is no leakage through any seal, joint, or opened crack.

c. The [A11]lock system[A11] shall be able to operate without interruption. All the gates and mechanical components shall be able to operate immediately after the event without any loss of serviceability.

d. The structural response shall remain essentially elastic under this earthquake loading.

e. The ground motions used for the Level I design shall correspond to the 475-year return period ground motions indicated in [A13]Volume VII[A13], Part 3.

2. **Level II Earthquake**:

[A13]a. This earthquake represents ground motions for which the gates and valves will retain their structural integrity (no collapse) and other critical components and equipment of the system may experience damage that requires replacement.[A13]

b. [A11]For normal structures, although there is no collapse, permanent offsets may occur. Damage consisting of cracking, reinforcement yield, and major spalling of concrete is possible. These conditions may require temporary[A11] closure of the locks to repair the damage. The foundations must have sufficient capacity to withstand the earthquake loading without any damage.

c. [A11]For essential structures, normalized residual horizontal displacement (displacement / wall height) of the lock walls shall not exceed 0.25%. The residual tilting of the lock wall toward the chamber shall not exceed 0.5 degrees. The peak response in the structure may be inelastic, but shall not exceed the prescribed[A11] residual deformations. Walls shall remain stable for the usual loading condition described in Section 01 81 16 (*Lock Structures*) under the permanently deformed state.

d. [A11]Essential structures[A11] may exhibit some visible damage, but shall be limited to narrow flexural cracking of concrete and the onset of yielding in steel.

e. Following the seismic event, gates shall retain the ability to fully retract into their Recess to allow for repairs.

f. The structures shall be checked for the 1,000-year return period ground motions described in [A13]Volume VII[A13], Part 3.

B. **Analysis and Modeling Requirements – Lock Structure**:

1. Analysis and modeling shall, as a minimum, be in accordance with the following parts of Section 8 Concrete and Steel Structures and Substructures of ER-1110-2-1806:

a. Part e: Analysis Methods.

b. Part g: Analysis Progression.

c. Part h: Seismic Design Principles.

2. Load combinations shall be consistent with codes implemented for design.

3. The final design shall use either response spectrum or time-history methods.

4. The results of the dynamic analysis shall be used to obtain motions for the seismic design of the gates and their electrical and mechanical components.

5. [A11]**Design at the Tender Stage**: [A11] The design and analysis shall provide sufficient detail to support the submitted design. Particular attention shall be paid to the interaction of the rolling gates and the lock-head structures under seismic and operational loads. The analysis shall include soil-structure interaction and horizontal and vertical components of the earthquake excitation.

6. **Intermediate and Final Design** [A17]**Requirements**: [A17] Linear elastic behavior shall be [A11]assumed and verified for the Level I earthquake and may be assumed for Level II earthquake,[A11] but three-dimensional (3-D) models (focused on joints between lock heads and walls, changes in foundation materials/support conditions, areas of maximum stress concentration, gates, and gate enclosures for rolling gates) shall be utilized. Finite-element models shall be utilized to represent the structure. The fluid, the lateral backfill, Soil Structure Interaction (SSI) effects (if identified), and the foundation shall be represented in the model in a manner that is consistent with the level of sophistication of the analytical techniques. At a minimum, response history analyses with two horizontal earthquake components and a vertical component shall be performed.

C. **Mechanical Electrical Plumbing** (**MEP**) **Equipment**:

1. **Seismic-Resistance Requirements**: Seismic protection and anchorage for MEP equipment and systems shall, as a minimum, conform to IBC 2006.

2. **Protection**: Upon the occurrence of the design-level seismic event, critical MEP equipment shall be protected from impact and damage by falling structural, mechanical, or architectural components.

[A13]D. **Buildings**:

1. As specified in Subparagraph 1.01 A. of this Section, the seismic design of building structures and associated mechanical, electrical, and plumbing systems shall be in accordance with ASCE 7-05, using site-specific ground motions. Bidders shall follow the design procedure outlined in ASCE 7-05 using the appropriate values corresponding to the 475 years return period for the construction of the appropriate design spectrum, based on the given accelerations. [A13]

1.04 DESIGN LOADS:

A. **Lock Structural Design Loads:**

1. The design calculations shall identify critical structural elements from Section 01 81 16 (*Lock Structures*), Section 01 81 19 (*Lock Gates*), and Section 01 81 23 (*Culvert and Conduit Valves*) and shall consider their possible failure modes. All other structural components are considered as "secondary components."

2. The intermediate and final designs shall identify the seismic-load paths and redundancy in the completed lock structures at the [A11]two design-earthquake levels.[A11]

3. The design shall evaluate and define the location and level of structural damage that is anticipated for Level II earthquakes and identify recommended repairs.

B **MEP Equipment Loads**:

1. Seismic requirements for the design of anchorages and components of identical equipment shall be determined for the most-severe case and repeated at all other locations.

2. Seismic restraint for MEP equipment shall be in accordance with ASCE 7-05, Chapter 13, Seismic Design Requirements for Nonstructural Elements.

1.05 SUBMITTALS: These shall conform to Section 01 33 00 (*Submittal Procedures*), Section 01 81 16 (*Lock Structures*), Section 01 81 19 (*Lock Gates*), and Section 01 81 23 (*Culvert and Conduit Valves*).

1.06 QUALITY ASSURANCE:

A. The Contractor, through his quality manager, shall verify conformance with the requirements of this Section. All requirements in Section 01 40 00 (*Quality Requirements*) shall apply to this Section.

B. **Independent Design Review**: The Employer reserves the right to conduct an independent review of all aspects of the design. If made, the review will verify:

1. That the design documents satisfy the engineering and functional criteria.

2. That the design assumptions are correct.

3. That the level of engineering is sufficient to substantiate the design.[A7]

END OF SECTION