Chapter 4
Special Design Considerations for Rectangular Channels Lined with Retaining Wall Structures

4-1. General

The stems of retaining walls used to line rectangular channels are vertical or nearly vertical. These walls must retain the surrounding soil and contain the channel flows. Although rectangular channels are more expensive than trapezoidal channels, they are sometimes justified in highly developed urban areas. Limitations on economical right-of-way may not allow for construction of excavations with stable slopes. In such cases, rectangular channels are required.

4-2. Retaining Wall Types

Cantilever and I-type reinforced concrete retaining walls are commonly used to form the sides of rectangular channels. These walls are used with or without bottom channel paving as shown in Figure 2-2.

a. Cantilever walls. Cantilever walls are usually the inverted T-type or L-type. The inverted T-type wall develops additional stability because of the weight of the backfill material resting on the heel of the base slab. The base slab of the L-type wall does not have a heel. Hence, stabilization is provided only by the weight of the wall itself. The L-type wall requires less excavation for construction.

b. I-type walls. I-type walls are often used when right-of-way restrictions prohibit sloped excavations as discussed in paragraph 2-8. I-type walls often consist of driven piles or concrete drilled piers with attached concrete face wall. Concrete slurry walls are also an alternative. The walls should be designed to prevent movements which would result in settlements or loss of materials which would be detrimental to existing structures or essential environmental features.

4-3. Channel Bottoms

Paving of channel bottoms is often required to prevent erosion of the in situ materials when subjected to channel flows or to satisfy other environmental factors. Joints in channel bottom paving slabs should be avoided, when possible, by the use of continuously reinforced concrete paving. Guidance for continuously reinforced concrete paving is contained in paragraphs 3-4, 3-6, 3-7 and 3-8*a*.

4-4. Joints In Retaining Walls

Vertical contraction joints should be placed in the wall stem at a spacing of approximately 5 to 10 m (20 to 30 ft). Wall base slabs may be designed as continuously reinforced slabs. Horizontal construction joints should be provided at the base of wall stems and at vertical lifts of 2.5 to 3 m (8 to 10 ft) in walls. Guidance for joints in retaining walls is contained in EM 1110-2-2502.

4-5. Drainage Provisions

a. Drainage systems. Except for I-type walls, drainage systems should be provided behind channel retaining walls and beneath channel bottom paving slabs on soil foundations to relieve hydrostatic pressures whenever the permanent or fluctuating water table is above the invert of the channel. General information on the design of drainage systems is provided in paragraph 2-4. Since construction procedures do not permit the installation of a drainage system behind I-type walls, these walls should be designed for the unrelieved hydrostatic pressures which may occur throughout the life of the walls.

(1) Retaining walls. EM 1110-2-2502 provides information for the design of drainage systems to relieve hydrostatic pressures on retaining walls. Details of the drainage systems for rectangular channels, including those formed with retaining walls, are shown in Plate 2. Backfill material placed behind channel retaining walls should be a pervious, free draining, granular material to ensure the lowest level of saturation and to minimize horizontal earth pressures. The pervious backfill material should be covered with a layer of impervious material to prevent surface runoff from entering the backfill.

(2) Channel bottom paving slabs. When channel - bottom paving slabs are placed on rock foundations, the drainage system usually consists of a system of holes drilled in the rock and weep holes in the slab. The depth of holes required to achieve the required drainage effectiveness is dependent on the type and condition of the rock. The geotechnical engineer should be consulted in this regard. If paving anchors are provided, the depth of drain holes should not be less than the depth of the anchors. When drainage is required for channel bottom paving slabs on soil foundations, a drainage system as discussed in paragraph 3-3 should be used.

(3) Hydrostatic pressures. The intensity of the hydrostatic horizontal and uplift pressures on the structure is dependent upon the effectiveness of drainage system. The drainage system effectiveness is discussed in paragraph 2-4*e*. In past designs, it has been common to assume a 25 to 50 percent decrease in drain effectiveness. The design pressures must be based on these considerations. The design memoranda must provide adequate documentation to clearly show that the values used in the design are proper and result in an adequately conservative design. Appendix C provides methods for the design of the drainage system by the use of seepage analyses.

b. Pressure relief systems. Pressure relief systems should be provided for those areas where perched water is encountered during construction.

4-6. Structural Design

a. Loading conditions. The forces acting on rectangular channels should be defined to determine the design loadings as discussed in paragraph 2-3*b*. The following loading conditions are representative of the controlling conditions in which the design loadings are applied to cantilever and I-type retaining walls and the channel bottom paving slabs of rectangular flood control channels. Earth pressures on walls should be determined by using applicable criteria in EM 1110-2-2502, EM 1110-2-2504, and ETL 1110-2-322.

(1) Case 1, Construction loading (unusual condition). Wall and backfill in place; earth pressure; channel empty; compaction effects and construction surcharge loadings. See Figure 4-1a.

(2) Case 2, Design flood loading (usual condition). Wall and backfill in place; earth pressure; water level on the channel side at the design water level, plus freeboard; backfill saturated to normal-low ground water level, adjusted to reflect the design effectiveness of the drainage system. See Figure 4-1b.

(3) Case 3, Drawdown loading (usual condition). Wall and backfill in place; earth pressure; channel empty; backfill saturated to highest ground water level, adjusted to reflect the design effectiveness of the drainage system. See Figure 4-1c.

(4) Case 4, Earthquake loading (unusual condition). Wall and backfill in place; active earth pressure; water in channel to normal water level; backfill saturated to normal ground water level, adjusted to reflect the effectiveness of the drainage system; earthquake induced loads. See Figure 4-1d.

b. Stability.

(1) Cantilever retaining walls. Stability analyses should be performed to determine the horizontal, vertical, and rotational equilibrium of these walls to ensure safety against sliding along the base or any foundation medium below the base, overturning, bearing, or excessive differential settlement of the foundation and flotation. The criteria for performing stability analyses of T-type and L-type retaining walls, including the factors of safety for sliding and overturning, are contained in EM 1110-2-2502. The flotation factors of safety and the criteria for performing the flotation analysis are given in ETL 1110-2-307. Computer program X0153, CTWALL, may be used for the analysis of these walls.

(2) I-type retaining walls. Stability analyses for I-type walls should be performed using a model which depicts the loaded wall embedded in the foundation material. Stability is achieved by the resistive foundation pressures on the embedded portion of the wall. A pictorial description of the I-wall is shown in Figure 2-2c. Computer program X0031, CWALSHT, may be used for the analysis of these walls.

(3) Channel bottom paving. Flotation stability of the channel bottom paving shall comply with criteria in ETL 1110-2-307. Pavement on rock may be anchored to resist flotation with reinforcing bars grouted into holes drilled into the rock.

c. Reinforced concrete design. Criteria for design of reinforced concrete hydraulic structures are given in EM 1110-2-2104. For singly reinforced flexural members, the ratio of tension reinforcement provided should be $0.375p_b$.

(1) Cantilever retaining walls. T-type and L-type walls should be designed for the loading cases described in paragraph 4-6*a*, as applicable, and the foundation pressures obtained from the stability analyses.

(2) I-type retaining walls. I-type walls should be designed for the loading cases described in paragraph 4-6*a* and the resisting forces which develop on the embedded portion of the wall.

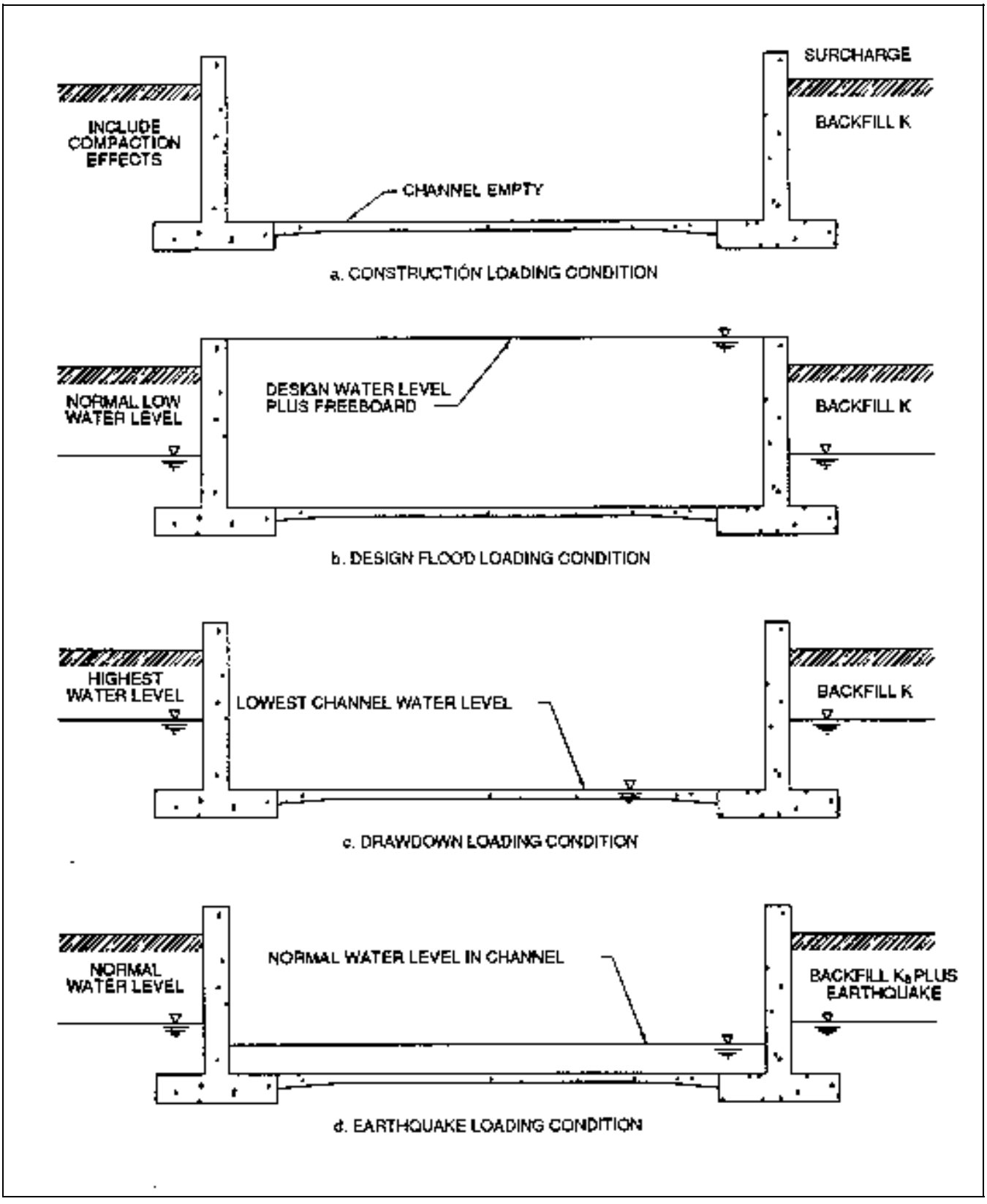

Figure 4-1. Loading conditions, rectangular channels with retaining walls

(3) Channel bottom paving.

(a) Minimum reinforcing. The minimum percentage of reinforcing steel should comply with Table 3-1 or Table 3-2, which ever is greater.

(b) Uplift loading. Channel invert paving should be designed for the maximum net uplift load. Pavement on rock which is anchored to resist flotation should be designed to span between the anchorage points. Anchors should be designed to provide a safety factor of 1.5 against the design uplift pressures.

(c) Isolated or buttress action. Paving slabs used in conjunction with retaining walls may be designed and detailed to act independently or as a strut slab to provide horizontal support to the wall.

4-7. Special Considerations During Construction

When retaining walls are designed for the paving slab to act as a strut to provide sliding stability, contract requirements should stipulate that the slab should be placed prior to the construction of walls. Contract specifications should define any restrictions on the backfill differentials required to comply with the design assumptions.