

CEEC-ED

Engineer Technical  
Letter No. 1110-2-307

20 August 1987

Engineering and Design  
FLOTATION STABILITY CRITERIA FOR  
CONCRETE HYDRAULIC STRUCTURES

1. Purpose. This ETL provides guidance for evaluating flotation stability of concrete hydraulic structures.
2. Applicability. This ETL applies to all HQUSACE/OCE elements and field operating activities having civil works responsibilities.
3. References.
  - a. EM 1110-2-2200, "Gravity Dam Design."
  - b. ETL 1110-2-256, "Sliding Stability for Concrete Structures."
4. Discussion. Hydraulic structures, such as U-frame locks, stilling basins, pumping stations, conduits, canal linings, and spillway sills and aprons, are subjected to buoyant forces which affect structural stability. This ETL provides guidance for determining if the structures are adequately stable with respect to buoyant forces.
5. Flotation Safety Factor. The flotation safety factor,  $SF_f$ , is defined as:

$$SF_f = \frac{W_s + W_c + S}{U - W_g} \quad (1)$$

where  $W_s$  = Weight of the structure, including weights of fixed equipment and soil above the top surface of the structure. The moist or saturated unit weight should be used for soil above the groundwater table and the submerged unit weight should be used for soil below the groundwater table.

$W_c$  = Weight of the water contained within the structure which is controlled by a mechanical operator (i.e., a gate, valve, or pump).

$S$  = Surcharge loads.

U = Uplift forces acting on the base of the structure.  
The uplift forces should be calculated in accordance  
with References 3a and 3b.

$W_g$  = Weight of surcharge water above top surface  
of the structure which is totally controlled by  
gravity flow.

When calculating  $SF_f$ , the vertical resistance mobilized by  
friction along the exterior faces of the structure should be  
neglected. The basic assumptions and general derivation of  
flotation safety factor are given in Enclosure 1.

6. Flotation Stability Criteria. Concrete hydraulic structures  
should be designed to have the following minimum flotation safety  
factors:

| <u>Loading<br/>Conditions</u>   | <u>Minimum<br/><math>SF_f</math></u> |
|---|--------------------------------------|
| Construction  | 1.3                                  |
| Normal Operation  | 1.5                                  |
| Unusual Operation   | 1.3                                  |
| Scheduled Maintenance (e.g., structure dewatered<br>with normal tailwater or normal lower pool) | 1.3                                  |
| Extreme Maintenance (e.g., structure dewatered<br>with maximum tailwater or maximum lower pool) | 1.1                                  |

Any relaxation of these values will be accomplished only with the  
approval of HQUSACE (CEEC-ED) and should be justified by a  
comprehensive study of the piezometric pressure data and  
engineering properties of the structure, foundation and backfill.

7. Design Examples. Design examples for calculating the  
flotation safety factors are contained in Enclosure 2.

FOR THE COMMANDER:

2 Enclosures



WILLIAM N. McCORMICK, JR.  
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