8.0 STRUCTURE STABILITY

8.1 General

Stability analyses should be conducted to verify that the structure, or component thereof, is stable relative to a failure plane located at the structure-foundation interface, and the structure foundation is stable relative to a deep seated failure surface. This section only deals with the structure stability at the structure-foundation interface.

Structure stability is usually assessed in terms of the factor of safety, which is the ratio of the resisting (stabilizing) forces to the driving (destabilizing) forces under specified loads.

8.2 Geotechnical Parameters

Geotechnical parameters normally required to conduct stability analyses of structures include:

- Unit weight of foundation and backfill materials.
- Friction angles and cohesion for soil.
- Bedrock friction angles and dip.
- Friction angle at the concrete-soil or concrete-bedrock interface.
- Lateral earth pressure coefficients.
- Groundwater conditions.
- Seismic coefficients.

8.3 Sliding

Sliding along the structure-foundation interface is ordinarily assessed using the friction factor method with cohesion neglected.

The factor of safety against sliding is defined as the ratio of resisting forces to driving forces and, for a horizontal sliding plane, is expressed as follows:

$$FS = \frac{[\sum N - \sum U] \tan \phi}{\sum H}$$

where:

FS	=	Factor of Safety,
$\sum N$	=	summation of normal forces,

$\sum U$ = summation of uplift forces,
$\sum H$ = summation of horizontal forces, and
$\tan \phi$ = coefficient of friction at structure-foundation interface.

Typical values for the required factor of safety against sliding are provided in Table 8-1. However, appropriate values for a specific project should be established based on the specific condition being analyzed, the importance of the structure and the consequences of failure, degree of confidence in the geotechnical design parameters, and experience with similar foundations and structures.

Table 8-1
Sliding Stability - Factors of Safety for Various Conditions of Loading

Condition of Loading	Minimum Factor of Safety
Construction	1.3
Usual	1.5
Unusual	1.2 to 1.5
Extreme	1.0 to 1.2

For the various conditions, examples of possible loading combinations for various structures or structure components are included in the relevant sections.

8.4 Overturning and Foundation Bearing Pressure

Adequate resistance against overturning should be provided by designing the structure such that:

- Under Usual and Unusual Conditions, the resultant of all loads (forces) is located within the middle third of the base width of the structure (eccentricity less than one sixth of the base width). As such, the entire base area of the structure will be in contact with the foundation under elastic conditions. The maximum bearing pressure should also be kept below the allowable value.

- Under Extreme Conditions, the resultant of all loads (forces) is located within the middle half of the base width of the structure (eccentricity less than one quarter of the base width). As such, portions of the base may not be in contact with the foundation. The maximum bearing pressure should also be kept below the allowable value.

8.5 Floatation

Certain water control structures or components thereof that are not susceptible to sliding or overturning may, nonetheless, be subjected to buoyant forces that can affect their stability. Consequently, adequate resistance should be provided to prevent floatation from occurring. Examples of water control structures that may be subjected to destabilizing buoyant forces include conduits, gatewells, stilling basins, and pumping stations.

The factor of safety against floatation for such structures is generally defined as the ratio of resisting forces to driving forces and is expressed as follows:

$$FS = \frac{\sum N}{\sum U}$$

where:

FS	=	Factor of Safety,
$\sum N$	=	summation of normal forces (structure dead loads, earth loads, and hydrostatic loads), and
$\sum U$	=	summation of hydrostatic uplift forces acting against the base of the structure.

Normally, the possible resistance due to friction between the earth backfill and the structure is neglected.

The magnitude of the hydrostatic load contained within the structure may depend on its operational status (operating, non-operating, or maintenance mode), whereas the magnitude and distribution of the hydrostatic uplift forces acting on the base of the structure may vary depending on the status of any drainage systems (operating or plugged) that may have been provided.

Typical values for the required factor of safety against floatation are provided in Table 8-2. However, appropriate values for a specific facility should be established based on the specific loading condition being analyzed, the importance of the structure, and the consequences of failure.

Table 8-2
Uplift Stability - Factors of Safety for Various Conditions of Loading

Condition of Loading	Minimum Factor of Safety
Construction	1.3
Usual	1.5
Unusual	1.3
Extreme	1.1

Relevant design information on floatation stability of concrete water control structures can be obtained from USACE ETL 1110-2-307 (1987).

For the various conditions, examples of possible loading combinations for various structures or structure components are included in the relevant sections.