Purpose:
The purpose of this calculation is to check the the structural integrity of a typical residential foundation for the potential to dry floodproof the foundations for the Glenview Setion 205 Project.

Assumptions:
1. The typical residential foundation to be checked will be an 8 ft unreinforced concrete wall. The majority of the residences will be assumed to have 8 ft below grade basement walls. Some residences will have taller walls and others could have 4 ft walls (crawl space and split level type homes), but for the purposes of checking the feasibility to dry floodproof, the standard 8 ft wall is checked.

2. Hydrodynamic loads are not checked. Assume velocities are less than 5 feet per second. EP 1165-2-314, sec. 602.2 indicates only hydrostatic loads be considered for velocities under 5 feet per second.

3. Relief of uplift pressures under the basement slabs by installation of an effective drainage system will be assumed IAW EP 1165-2-314, Sec. 611.3. It is assumed residences would need to have upgrades to the drainage systems to accomplish this. Sump pump sizing and estimated seepage for the anticipated flood elevation would need to be determined to validate this assumption.

4. Basement walls will require proper anchoring to the 1st floor diaphram.

References:
1. EP 1165-2-314, Flood Proofing, 15 December 1995.
2. FEMA P-259, Chapter 5D, Dry Floodproofing, Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures, January 2012

Conclusions:
1. The standard 8 ft basement wall is NOT adequate to resist hydrostatic loads. Structural strengthening of the walls will be required. Systems to consider include, permanent interior wall bracing or internally bonded steel plates or similar system (see photos here-in). Four ft basement walls appear adequate with minimal to no concrete wall strengthening required.
2. Drainage will need to be upgraded to alleviate uplift forces and this appears possible per recommendations in EP 1165-2-314. Pumping requirements and seepage rates should be checked to confirm.
3. Anchorage of the top of the basement walls to the 1st floor will likely be required. This can be accomplished with either special connectors or designed as part of the external floodproofing membrane.
4. Basement windows will require local flood enclosures.
5. Dry floodproofing above the 1st floor will require shields at doors or openings designed for the anticipated head. Strength of exterior walls will need to checked or incorporate membranes which strengthen the wall system to ensure structural integrity, i.e. steel plate membranes or similar.
6. Materials selected for dry floodproofing need to be responsive to the duration and depth of the flooding expected.

INPUT

$w_{conc} := 150 \cdot pcf$ $\gamma_w := 62.4 \cdot pcf$

$t_w := 8 \cdot in$ (thickness of basement wall)

$h_w := 8 \cdot ft$ (basement wall height)

$t_f := 10 \cdot in$ (footing thickness)

$b_f := 24 \cdot in$ (footing width, assume up to 24 inches wide... consv for uplift on footing)

$f'_c := 3000 \cdot psi$

Assumed Soil Conditions:

$\gamma_{sat} := 120 \cdot pcf$ $k_o := .6$

FEMA P-259 recommends the structure be checked as indicated in the below flow chart.

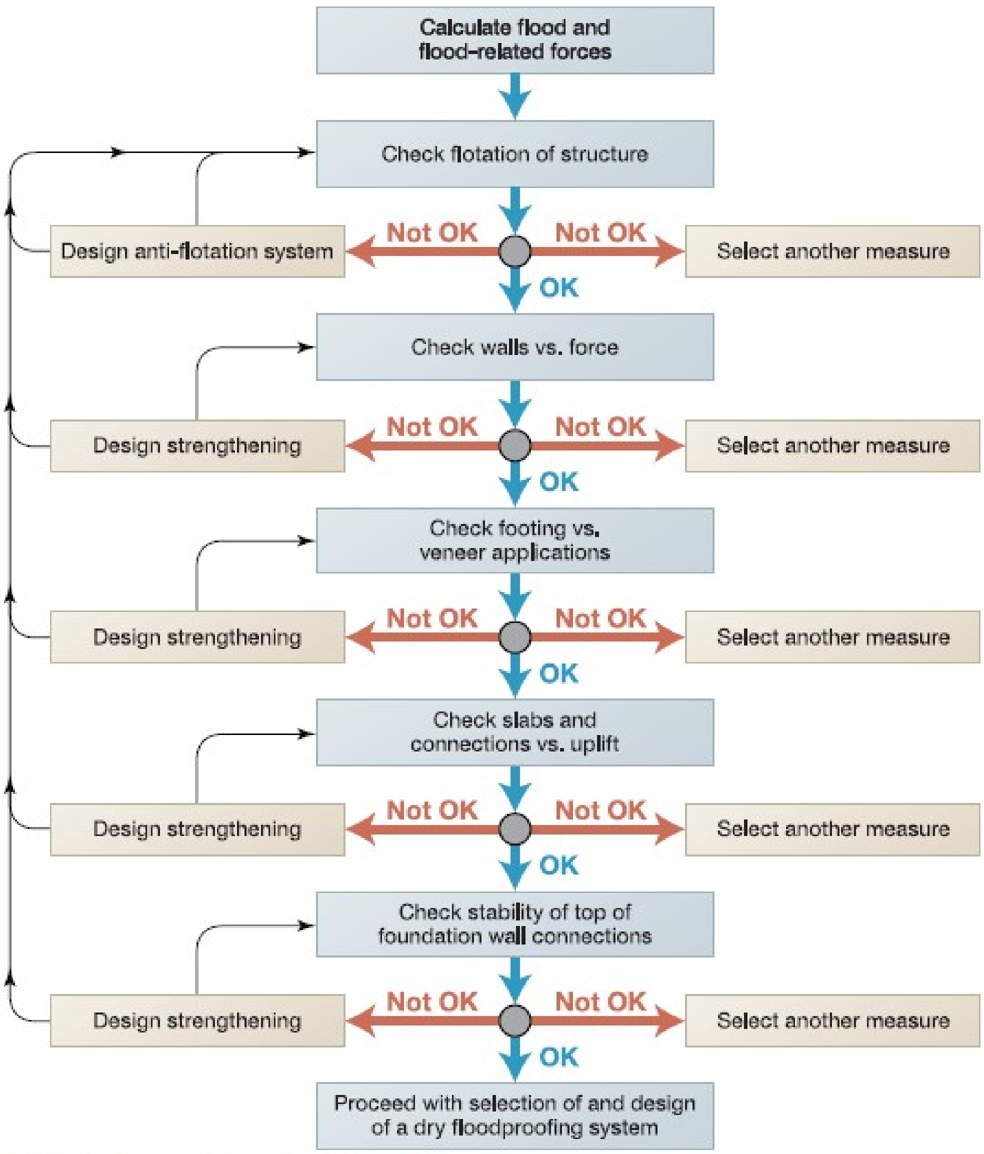
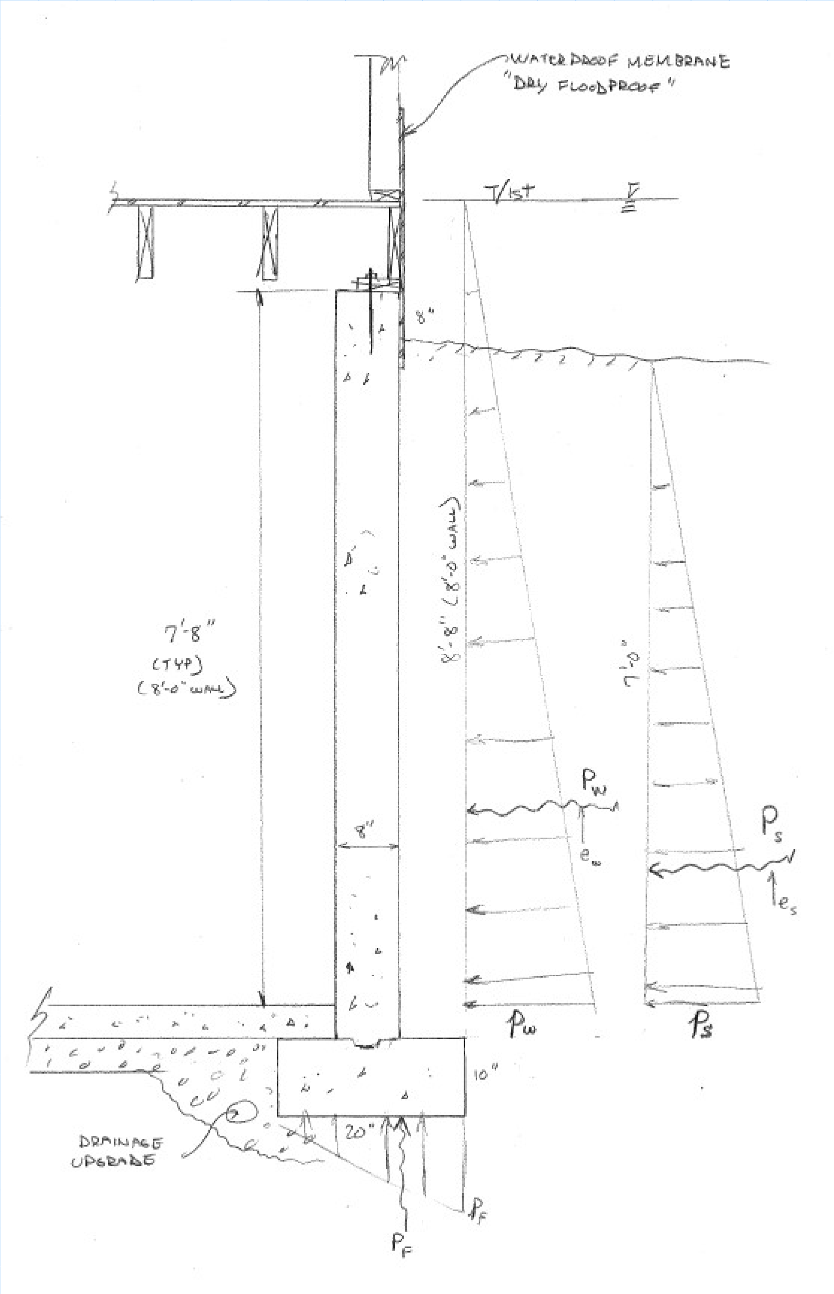


Figure 5D-10. Existing building structural evaluations

ENGINEERING PRINCIPLES AND PRACTICES for Retrofitting Flood-Prone Residential Structures 5D-11



Typcial Basement Wall - 8 ft

CHECK FLOTATION

It is assumed that the uplift pressures under the basement slabs will be achieved by upgrades to the drainage system and pumps to accomodate the increase hydrostatic head. This is consistent with EP 1165-2-314 as indicated in the below paragraphs. Thus, check uplift under the footings only.

Sec. 611.3 Foundation Drainage: Where impervious cutoffs are provided or where suitable foundation conditions exist, effective drainage and relief of uplift pressures under buildings and structures can be achieved. These foundation materials must be free-draining and have the desired degree of permeability. For the purpose of these Regulations, foundation drainage is intended to consist of the provision of drainage blankets, trenches, and in all cases, drain tiles or perforated drain pipes adjacent to footings and under floor slabs. Other methods of foundation drainage, such as by means of sumps, well points, or deep wells can be used for special applications. Drain pipes shall discharge into a sump or suitable collection structure, where the water is collected and ejected by sump pumps.

Sec. 1402.2 Basement Slabs: Under flood conditions, and often under normal non-flood conditions in cases where conditions of high water table prevail, basement slabs may be subjected to high uplift pressures. To overcome this condition, the slab can be made thick enough to have sufficient weight to counteract the uplift pressures. This solution is very seldom economical.

Sec. 1404.2.1: For relatively large, heavy structures, a more economical solution would be to design thinner reinforced concrete slabs that are tied into the footings, walls, and columns, such that the overall weight of the structure is utilized in resisting the uplift forces acting on the floor slabs. This type of construction would then provide the additional stability required to prevent flotation and overturning of the structure from other flood loads. The slab (commonly referred to as mat or raft type construction) must be capable of resisting all applied loads and distributed pressures, either when uplift pressures are acting at full intensity, as is the case during a flood, or when such loads are nonexistent, as could be the case under normal conditions. Integral slab construction can be utilized equally well for buildings supported on piles. In these cases, column and wall loads are supported by the piles, and the uplift pressures are transferred by the reinforced slab to the columns and walls so as to utilize the building loads (weight) as the downward resistive force.

Sec. 1404.2.2: In many cases, however, where uplift pressures are excessive, the most practical solution would be to relieve (or reduce) these uplift pressures under the slab by providing adequate and dependable drainage, combined where necessary with impervious blankets and cutoffs on the outside of the structure. Illustrations of foundation drainage methods that may be used for relief of uplift pressures are shown on Figure 6. Where it is found impractical to stabilize the slab and structure by one of the methods shown on Figure 6, or a combination thereof, it may be more expedient to anchor the slab and/or structure to

Check for water 2.5 feet above T/Foundation (i.e. 3 ft above grade):

$p_f := \gamma_w \cdot (8 \cdot ft + t_f + 2.5 \cdot ft) = 707.2\ psf$

$P_f := .5 \cdot p_f \cdot b_f = 707\ \frac{lbf}{ft}$

$W_{conc} := w_{conc} \cdot (t_w \cdot h_w + t_f \cdot b_f) = 1050\ \frac{lbf}{ft}$

$FS := \frac{W_{conc}}{P_f} = 1.5$

....flotation ok with concrete weight only and drainage for uplift under basement slab

<u>CHECK TYPICAL 8 FT BASEMENT WALL STRENGTH:</u>

Check wall for full hydrostatic loads as recommended by EP 1165-2-314, excerpt below:

Sec. 1404.3 Basement and Retaining Walls: Under normal or non-flood conditions, the primary loading on basement and retaining walls consists of lateral soil pressures caused by the backfill material. For selected granular backfills and normal heights of the wall, this load is relatively small. Other secondary or associated loads on walls are lateral loads resulting from surcharge conditions, loads resulting from frost action, and any vertical or other applied loads which the wall is intended to resist. Under flood conditions, by far the most significant load on a wall is that caused by lateral hydrostatic pressures. This load amounts to several times the intensity of the normal loads and as such will govern the strength and stability requirements for the wall. Provisions for backfill drainage are commonly used to reduce water pressure behind a wall and are known to be effective for groundwater control if carefully designed, constructed and maintained. In the case of walls subject to flood loading, a reduction in water pressure behind the wall is not considered practical nor dependable. When an infinite source of water exists and free water stands above grade, the most efficient drainage provisions are likely to be inadequate. For cases where the wall is protected by impervious membranes, blankets and cutoffs, even a minimal rupture, separation or failure of the membrane or blanket, or cutoff, can cause the attainment of full hydrostatic pressures on the wall and cause failure of an inadequately designed wall.

$h_{water} := 8.67 \cdot ft$ $\quad h_s := 7 \cdot ft$ $\quad$ (water to T/1st floor joist)

$p_w := h_{water} \cdot \gamma_w = 541\ psf$ $\quad P_w := \frac{1}{2} \cdot p_w \cdot h_{water} = 2.3\ \frac{kip}{ft}$ $\quad e_w := \frac{h_{water}}{3} = 2.9\ ft$

$p_s := (\gamma_{sat} - \gamma_w) \cdot k_o \cdot h_s = 241.9\ psf$ $\quad P_s := \frac{1}{2} \cdot p_s \cdot h_s = 0.8\ \frac{kip}{ft}$ $\quad e_s := \frac{h_s}{3} = 2.3\ ft$

$$M_{wall} := \left(\frac{P_w \cdot e_w \cdot (h_w - e_w)}{h_w} + \frac{P_s \cdot e_s \cdot (h_w - e_s)}{h_w} \right) \cdot 1 \cdot ft = 5728.8\ lbf \cdot ft$$

$S_{wall} := \frac{12 \cdot in \cdot t_w^{\,2}}{6} = 128\ in^3$ $\quad$ (section modulus of the wall)

Calculate Factored Tension due to bending, Service Load only (unfactored):

$LF := 1.2$ (minimum per ACI 318, could be larger, but use only for this check)

$M_u := LF \cdot M_{wall} = 6874.5\ lbf \cdot ft$

$\frac{M_u}{S_{wall}} = 644\ psi$

Calculate Compression in Wall which will reduce Tension:

$P_{conc} := (7.67 \cdot ft - e_w) \cdot t_w \cdot 1 \cdot ft \cdot w_{conc} = 478\ lbf$

$P_{dl} := 500 \cdot lbf$ (assume for end wall, no floor or roof loads)

$C := \frac{(P_{conc} + P_{dl})}{1 \cdot ft \cdot t_w} = 10.2\ psi$ (note, negligible)

$T := \frac{M_u}{S_{wall}} - C = 634.3\ psi$ (unfactored)

Check ACI 22.5.3, Plain concrete members:

$\phi := .65$

$T_{max} := 5 \cdot \sqrt{3000} \cdot \phi = 178$ (psi) $<< T$ .... no good!

..... Dry floodproofing not possible w/o wall Strengthening ......STOP!

Various methods to strengthen the wall will need to be considered and will require access to the existing concrete walls. One method is shown below:

Bracing Columns

Bonded Carbon Fiber or Steel Plates

CHECK TYPICAL 4 FT BASEMENT WALL STRENGTH:

$h_{water} := 4.67 \cdot ft$ $h_s := 3.5 \cdot ft$ (water to T/1st floor joist)

$h_w := 4 \cdot ft$ $t_w = 8\ in$

$p_w := h_{water} \cdot \gamma_w = 291.4\ psf$ $P_w := \frac{1}{2} \cdot p_w \cdot h_{water} = 0.7\ \frac{kip}{ft}$ $e_w := \frac{h_{water}}{3} = 1.6\ ft$

$p_s := (\gamma_{sat} - \gamma_w) \cdot k_o \cdot h_s = 121\ psf$ $P_s := \frac{1}{2} \cdot p_s \cdot h_s = 0.2\ \frac{kip}{ft}$ $e_s := \frac{h_s}{3} = 1.2\ ft$

$$M_{wall} := \left(\frac{P_w \cdot e_w \cdot (h_w - e_w)}{h_w} + \frac{P_s \cdot e_s \cdot (h_w - e_s)}{h_w} \right) \cdot 1 \cdot ft = 821.9\ lbf \cdot ft$$

$S_{wall} := \frac{12 \cdot in \cdot t_w^2}{6} = 128\ in^3$ (section modulus of the wall)

Calculate Factored Tension due to bending, Service Load only (unfactored):

$LF := 1.2$ (minimum per ACI 318, could be larger, but use only for this check)

$M_u := LF \cdot M_{wall} = 986.3\ lbf \cdot ft$

$\frac{M_u}{S_{wall}} = 92\ psi$

Calculate Compression in Wall which will reduce Tension:

$P_{conc} := (3.67 \cdot ft - e_w) \cdot t_w \cdot 1 \cdot ft \cdot w_{conc} = 211.3\ lbf$

$P_{dl} := 500 \cdot lbf$ (assume for end wall, no floor or roof loads)

$C := \frac{(P_{conc} + P_{dl})}{1 \cdot ft \cdot t_w} = 7.4\ psi$ (note, negligible)

$T := \frac{M_u}{S_{wall}} - C = 85.1\ psi$ (unfactored)

Check ACI 22.5.3, Plain concrete members:

$\phi := .65$

$T_{max} := 5 \cdot \sqrt{3000} \cdot \phi = 178$ (psi) > T .... ok

..... Dry floodproofing appears possible for 4' foundation wall, i.e. crawl space with minimal to no strengthening of the concrete wall.

CHECK SLAB UPLIFT:

Slab uplift is okay with proper provisions included for drainage and and pumping. This will also require back up generator.

CHECK ANCHORAGE AT TOP OF CONCRETE WALL :

Typical residential construction in the area has an anchored 2x6 pressure treated sill plate. This 1st floor joist rest on this sill plate with minimal to no nailing. A rim joist exist which may be nailed to the sill plate.

Additional anchorage should be assumed needed to connect the top of the basement walls to the 1st floor diaphram. This could be accomplished as part of the membrane installation, part of the wall bracing columns, or by designing a structural connection of the joist to the basement walls as shown below.