Livingston Engineering Associates LTD.
© Thomas G. Livingston, P.Eng.
59 Horton Crescent
Yellowknife, Northwest Territories, Canada, X1A 3B8
867-445-7590
info@livingston-engineering.com

Information Paper No. 2
CONCRETE FOUNDATION WALL DESIGN

Yes, we design and stamp foundations. Foundations generally consist of two structural parts: a footing and a below-grade wall. The footing is a wide element that transfers the load from the house to the ground (which could be either bedrock or soil). The foundation wall is designed to be strong to resist lateral (sideways) pressure and be impervious to water ingress. In order to keep your wooden stud wall from being damaged, it should also extend above grade by at least 200 mm (8"). Figure 1 shows a traditional foundation – one that might be used where permafrost is not present, and where a below-grade area such as a basement is desired. Another kind of foundation commonly found is called variously a *slab-on-grade, a thickened slab-on-grade, or a raft foundation.*

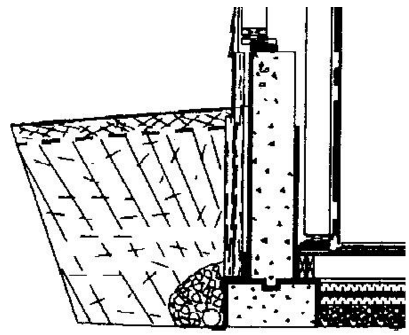

Figure 1: Traditional foundation (not in permafrost)

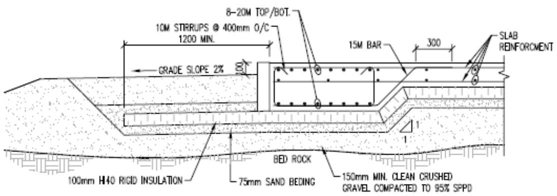

Figure 2: Slab-on-grade foundation

Concrete foundations can be either reinforced or not. The latter are called "plain concrete" (more on that later).

Besides the quality of concrete employed, designers of all well-designed foundations must pay attention to two simple issues of flow:

1. The flow of water (keep water OUT)
2. The flow of heat (keep heat IN)

Figure 3: This stepped footing actually is the foundation wall as well, because the bedrock is competent, so a spread footing is not needed to transfer loads.

1. Water: Good drainage is essential. Water must be enabled to reach the lowest part of the foundation system and then must be carried away from the building quickly. For traditional basements such as shown in Figure 1, this is the purpose of the standard perforated drainage pipe around the perimeter at the base of the footing, and back-till that is porous enough to allow any surface water to get to the drainage pipe fast. If the backfill grades away from the building and has a clayey top layer, very little surface water will penetrate anyway. But subsurface water is a different matter! Slabs-on-grade can rely on the under-layer of coarse compacted granular material that prevents water from accumulating under the slab and causing problems. Drainage tile may also be utilized where it is deemed necessary.
2. Heat: In our cold climate we need our concrete to be insulated in such a way that the heat that is generated inside our building stays inside for as long as feasible. In areas of permafrost we generally do not want the permafrost to melt (i n some areas of discontinuous permafrost there may be

exceptions to this rule, however). Because a piece of concrete, if properly insulated to the outside, can act as a large and surrounding lump of thermal mass, it is often advantageous to insulate the outside portion of concrete foundations. For slab foundations, the principles are the same: we want to isolate the flow-path of heat loss, so we insulate under the slab. A good practice that slows the flow around the edges is to add sloped rigid foam insulation along the perimeter as shown in Figure 2.

Figure 4: An example of a thickened slab. The "thickening" is actually a cast-in-place footing to support line loads directly above.

The other type of foundation commonly used is a pile foundation. In essence, piles are a carefully-distributed forest of long posts buried to specified depths in the ground (or socketed to competent bedrock if we are lucky). Nowadays, piles are usually hollow steel sections, but can be timber (tree trunks) or reinforced concrete. They may be anchored to rock or can use the friction between the ground and the soil and the pile to provide bearing capacity.

The type of foundation chosen for your project will depend on many factors. Each type has its place in certain circumstances. We can discuss the pros and cons of all of them with you during the Conceptual Design Phase of your project.

Figure 5: An example of a concrete pile foundation

To reinforce or not?

Reinforcement is generally not needed in a traditionally-formed foundation wall that is 7.5 ft. high or less. Part 9 of our National Building Code is quite clear on such design issues. However, the Code does assume good building practices are followed: thus water must be directed away from all parts of the foundation as discussed above. A key to really knowing what is going on is to understand that concrete, although good where compressive strength is needed, is not nearly as good when it is bowed, as it would be if placed under excessive pressure from the soil on the sides. Normally the lateral pressure of well-drained soil is all that plain concrete of the usual 8" to 10" thickness should be made to safely withstand. Table 9.15.4.2.A of our Code provides various options for plain concrete foundations that are allowed to be built without the stamp of a structural engineer. As can be seen by looking at Figure 6, even a 12" thick, 20 MPa plain concrete wall can be no higher than 7.5' from basement floor to grade (provided it is supported by the basement floor and its joists at the sill line).

Table 9.15.4.2.A.
Thickness of Solid Concrete and Unreinforced Concrete Block Foundation Walls
Forming Part of Sentence 9.15.4.2.(1)

Type of *Foundation* Wall	Minimum Wall Thickness, mm	Maximum Height of Finished Ground Above *Basement* Floor or Crawl Space Ground Cover, m	
		Foundation Wall Laterally Unsupported at the Top(1)	*Foundation* Wall Laterally Supported at the Top(1)
Solid concrete, 15 MPa min. strength	150	0.8	1.5
	200	1.2	2.15
	250	1.4	2.3
	300	1.5	2.3
Solid concrete, 20 MPa min. strength	150	0.8	1.8
	200	1.2	2.3
	250	1.4	2.3
	300	1.5	2.3
Unreinforced Concrete Block	140	0.6	0.8
	190	0.9	1.2
	240	1.2	1.8
	290	1.4	2.2

Figure 6: From Part 9 example of the 2005 NBCC

As Figure 7 shows[1], if a lateral force is placed on a foundation wall, it tends to bow. One can easily imagine the "fibres" of this wall being subjected to compression on the face nearest to the force and to an equal tension on the opposite face. While concrete is very good at resisting compressive forces, it is very bad at being able to withstand forces that pull it apart. This is why the old parlor trick of breaking a plain concrete bar with one's bare hands works so spectacularly. Anyone can do it. The remedy is to add something that will be able to counteract the tensile forces on the "far side" of the wall. This "something" is called steel reinforcement – ribbed

[1] Yes, yes, for those of you who are nit-pickers, we are well aware that the lateral force is modelled as a triangle and the point of the resultant is at the one-third point from the base. However, we are simply trying to illustrate a basic idea here…

to increase its ability to resist pulling out along its axis as the tension increases. Thus, beyond some fairly simple and small loading conditions, reinforcement is needed near the tension face of all foundations. And the phrase, “near the tension face” is extremely important, for a misplaced re-bar is next to useless.

What kinds of lateral pressure are we talking about? Foundation walls are subject to lateral pressures and must be designed to resist whatever is expected to be found in nature. There are three kinds of lateral pressures that we must design for:

1. The pressure of the (dry) soil itself. It is important to understand that the deeper the soil, the greater is the pressure. Different soils exert different pressures due to their own density and to their ability to compact.
2. Hydrostatic pressure (the extra pressure of water sitting against a foundation) adds greatly to the problem. That is why it is so important to design a foundation so that no water will ever accumulate.
3. Surcharge loads such as parking spaces adjacent to a foundation, or a garage ramp that undergoes periodic loading. These surcharge loads simply increase the overall “design” pressure of the soil column and any hydrostatic pressure that may be present.

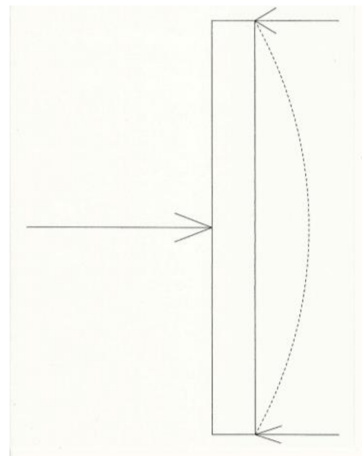
Figure 7: Foundation wall bowing under an idealized lateral force.

As can be seen from the table in Figure 6, Part 9 of our Building Code does not allow for un-reinforced concrete foundations that are greater than 7’-6” high (unless a structural engineer approves). For some of our foundations in hilly Yellowknife, we can readily see that concrete walls can often be far higher than seven and a half feet. We have seen them as high as 14 ft.

These foundations must be dealt with by sound engineering principles whereby we calculate the pressures on the foundation wall and make sure the reinforcing and the concrete strength and design mix are sufficient to resist what is being thrown against the wall.

There are many manufacturers of insulated concrete forms (ICF) who vie for market share. These systems have advantages and disadvantages. One thing to bear in mind is that since it is the vertical bars that are modelled to carry the tension load, their placement with regard to the tension face is crucial. With the ICF type foundations it is difficult to understand how it is possible to control the exact placement of vertical steel as it is fed from above. We await enlightenment by the ICF industry.

We hope this Information Paper has been useful to you.