The Dual Footed Foundation; An Alternative to the Slab-on-Grade

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Introduction

With respect to residential construction, a return to sustainable building needs to commence with an appropriate foundation. A possible alternative to the popular slab-on-grade, steel reinforced, monolithic structure, is suggested with the approaching end of the Industrial Revolution[3]. With increasing cost of Portland cement and steel, an alternative foundation may be due to cost alone, but there are other reasons as well. The inherent weakness of the slab-on-grade, especially associated with expansive soils, is that the footer is in direct contact with the soil, and is resolved by two footings, one each above and below grade. Concern here is restricted to warmer climates, residential building in non-seismic zones.

The above grade, or top footer, either of stone or concrete, rests on a bottom footer, of nonconsolidated or non-cohesive fill; e.g., sand or gravel. Figure 1 is for a foundation for a compressed earth block (CEB) wall 14 in. wide, without plaster.

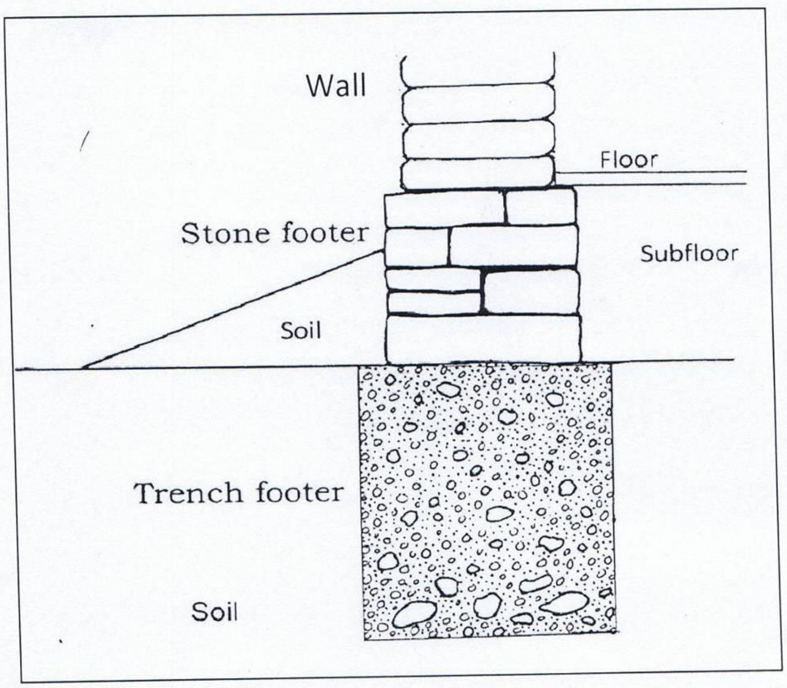

Figure 1. *Dual Footed Foundation.* Stone or top footer above grade; trench or bottom footer below grade with gravel infill. Note that the flooring will be a separate structural entity.

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[3] The end of the Industrial Revolution is especially marked when global demand exceeds global production of petroleum. We are running out of cheap oil; not oil *per se*. For the first time oil becomes the seller's market.

Construction of the Dual-footed Foundation

The preceding Figure 1 illustrates a dual footed foundation with a stone footer. Any noncohesive material will work as infill, generally sand, gravel of all variety, small stones, broken concrete and brick or crushed stone. The following are general guide lines for construction. 1). Width of the trench to be about 1.5 to 2 times the width of wall and two inches wider on either side then the top footer. 2). The trench, when in expansive soil, should slope to daylight to ensure drainage. 3). Infill of sand should be tamped down every 6 inches; all other fill to be tamped down every 8 inches. 4). A rebar reinforced concrete grade beam, when used, is set on top and directly in contact with the trench footer as in the case for a stone footer. For a stone footer, stones should be well mortared with first course of rock ¼ as thick as wide and extend the width of the footer. 5). To drain water away from the foundation a soil embankment around the perimeter of the trench is suggested to extend three or more feet out from the top footer. *See the Appendix for specific detail.*

Sand and Gravel

The essence of the trench footer is that the infill is non-cohesive material and thus remains collectively immobile to expanding soil. The dual footed foundation frees the top footer or bond beam from direct contact with expansive soils. In addition, no concrete or steel is utilized for the trenched footer and it need not be required in the above grade footer should stone, brick or CMUs be utilized. The trench filled footer acts to absorb the kinetic energy of expanding soils thus makes a superior substrate for a stone footing or grade beam on top. An inherent weakness of the slab-on-grade is its direct contact in, and with, the soil rendering it susceptible to the effects of soil expansion. There is nothing completely new in the dual footing as here envisioned; but rather an explicit focus on the great advantages of using non-cohesive material in the foundation substrate. It is, in part, a return to past construction methods. As such, for insight into the subject, I turn to the past voices of authority; architectural and engineering masters. In so doing I will use direct quotes. One such noted authority is Frank Eugene Kidder, C.E., and Ph.D. He authored numerous engineering and architectural classics on building at the end of the 19th century. One, herein cited, went through a dozen or so editions. Certainly, nothing said by them that follow is novel, but rather needs repeating and emphasis. The following concerns the nature of sand and gravel as foundation material.

With respect to gravel and its use, Kidder[4] (1898, p.18) commented that "...gravel gives less trouble than any other as a foundation. It does not settle under any ordinary loads, and will safely carry the heaviest of building if the footings are properly proportioned. It is not affected by water, provided it is confined latterly." And, as for sand, Kidder[5] (1895, p. 134) contended that "In all situations where the ground, although soft, is of sufficient consistency to confine the sand, this material may be used with many advantages as regards to the cost and the stability of the work. The quality which sand possesses, of distributing the pressure put upon it, in both a horizontal and vertical direction, makes it especially valuable for a foundation bed in this kind of soil; as the lateral pressure exerted against the side of the foundation pit greatly relieves the bottom." Kidder proposed emplacing sand in layers on the trench floor of about nine inches in thickness, and each layer rammed before the next is applied. Further, "The total depth of sand used should be sufficient to

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[4] Kidder, Frank Eugene, 1898. *Building Construction and Superintendence*, Part I, *"Masons' Work"*, 3rd ed., p. 18. This publication, and many others of similar note, are now available as reprints. With a return to sustainable building there is a need for a return to relevant classics of the past.

[5] Kidder, Frank Eugene, 1895. *The Architect's and Builder's Pocket-Book,* 12th ed. John Wiley & Sons.

admit of the pressure on the upper surface of the sand being distributed over the entire bottom of the trench."

Baker (1888)[6], a foremost authority of his day as an architectural engineer, noted: "The sandy soils vary from course gravel to fine sand. The former, when of sufficient thickness, forms one of the finest and best foundations…". He comments further that, "Sand when dry, or wet sand when prevented from spreading laterally, forms one of the best beds for a foundation. Porous, sandy soils are, as a rule, unaffected by stagnant water, but are easily removed by running water; in the former case they present no difficulty, but in the latter they require extreme care at the hands of the constructor." Baker continues: "Compact gravel or clean sand, in beds of considerable thickness, protected from being carried away by water, may be loaded with 8 to 10 tons per square foot with safety. In an experiment in France, clean river sand, compacted in a trench, supported 100 tons per square foot."

In so far as the above grade footer is concerned Kidder (1898, p. 63) commented, "For a building of moderate height stone footings are generally the most economical, and if they are carefully bedded, answer as well as concrete." Today, the economic concern is even more applicable favoring a stone footing over concrete at least in some regions of the country. In much of Texas, limestone is the most abundant geological outcrop and available at prices that allow construction for considerably less than with the use of concrete.

Dry Wall Footing or Rubble Trench

Frank Lloyd Wright[7], while proclaimed by the *American Institute of Architecture* in 1991 to be "The greatest American architect of all time" has failed to escape criticism, at times severe, from the engineering community. However, I know of no instance of criticism from such quarters related to what Wright called his "dry wall footing", sometimes referred to as a rubble trench, presumably due to the fact it worked as Wright contended. He used this foundation throughout his building career. But, just what is Wright's foundation? It is clearly a variant of the dual footed concept of a foundation well suited for exceptionally cold climates. He admits to having learned it from a Welsh stone mason during the construction of *Taliesin East* and had been using it since 1902.

In Wright's own words: "Instead of digging down three and a half feet or four feet below the frost line, as was standard practice in Wisconsin, not only terribly expensive but rendering capillary attraction a threat to the upper wall, he dug shallow trenches about sixteen inches deep and slightly pitched them to a drain. These trenches he filled with broken stone about the size of your fist. Broken stone does not clog up, and provides the drainage beneath the wall that saves it from being lifted by the frost." He called it a "dry wall footing", as he explained it, "…the wall stayed dry, the frost could not affect it. In a region of deep cold, to keep a building from moving it is necessary to get all water (or moisture) from underneath it. If there is no water there to freeze, the foundation cannot be lifted." It is evident why broken rock was used as it was much more porous that either sand or gravel and permitted water to quickly drain down and out of the trench. Water would be removed more quickly and efficiently than if a perforated drainage pipe were used.

Functioning of the Dual Footed Foundation

Just how does the trench footer work? As previously noted, unconsolidated material, such as sand or gravel absorbs, or dissipates, the kinetic energy associated with expansion of soil by clay

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[6] Baker, Ira O., 1888. Bearing Power of Soils. *The American Architect and Building News.* Vol. XXIV, No. 671, pp 206-207.

[7] *Frank Lloyd Wright Collected Writings*, Vol. 5, pp. 113-114, edited by Bruce Brooks Pfeiffer.

material penetrating the outer margins of the gravel or sand in the trench as noted in Figure 2. The infill of the trench is thus strongly integrated with the sides of the trench and remains immobilized.

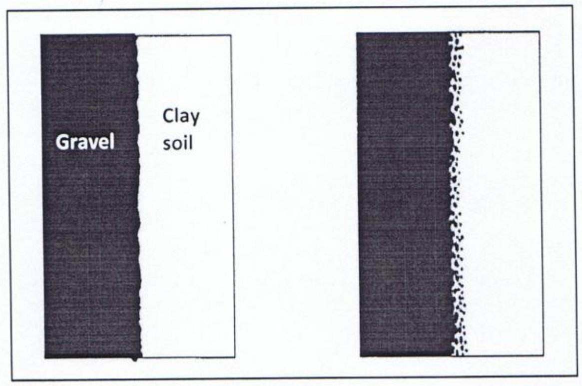

Figure 2. *How the trench footer works.* Left: the infill, gravel or sand, rests loosely against the trench walls. Right: Later, soil expansion, noted by arrows, expends kinetic energy by clay entering the voids of the outer most layer of infill. The trench infill remains immobilized -- there is no vertical movement of infill. The gravel, or sand load, is largely supported by lateral forces against trench walls. The above-grade footer thus remains stable.

What movement there is in the trench is dominantly marginal and lateral related to individual clasts --- not vertical, as will be the case with the footing of the slab-on-grade. Subsequent drying of the soil the clay, associated with the margins of the infill mass, will lose the moisture and contract slightly but remain in place to again expand with the penetration of moisture.

Slab-on-Grade Foundation

However, the slab-on-grade, with the footer directly in an expansive soil, is obviously vulnerable to soil heave. Clay is both a lubricant when moist and a binder when dry as noted in Figure 3. In the course of expansion due to moisture, kinetic energy will be mechanically applied against both sides and bottom of the footer. Lateral pressure will not "hold", or effectively resist the footer against vertical pressure from below; i.e., there is *minimal lateral resistance to vertical rise*.

In another comparison of the dual footer and slab-on-grade is exhibited by a pressure point on the bottom of the trench footer and the footer of the slab-on-grade. The vertical movement is resisted by the trench footer by lateral cohesion of the infill with the sides of the trench. While with the slab-on-grade footer, lateral resistance is minimal and any vertical movement at all results in vertical movement of the entire load.

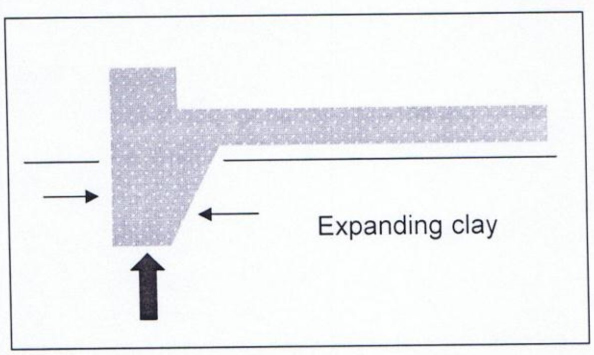

Figure 3. *Slab-on-grade:* The footer extending into, and surrounded by, an expanding soil. The vertical kinetic force is greater than the lateral compression due to resistance in part to the lubricant qualities of moist clay and the smooth sides of the footing.

With the entire foundation and floor and footing tied together as a single unit, vertical movement at any point affects the building as a whole.

Kelemens and Nasvik[8] note the difficulties of slab construction relate to improper design, specification, material, and workmanship combined with inadequate communication and slabs left exposed to the elements collectively produce problems that "... keep law offices in business." However, most such problems seemingly evade permanent solution. There are also comments that complications result from the number players involved: owner, architect, engineer, general contractor, concrete contractors, ready-mix producer, aggregate supplier, cement supplier, admixture supplier if utilized. In prolonged dry periods the foundation may require "watering" by a soaker hose around the perimeter of the foundation. All such concerns are largely avoided by the dual footed foundation.

Residential Construction

A region where the dual footed foundation is urgently needed concerns housing for colonias in the borderlands of Texas and Mexico. Housing of residents is a major concern where colonias themselves number in the thousands. These settlements are concentrated in the Lower Rio Grande Valley of south Texas, noted for exceptionally high temperature and high humidity and thus experiencing the most severe mold problem in the United States.

Currently, the use of post-and-beam foundation for wood frame homes is the choice mode of construction for the colonias. Residents are provided financial assistance for home construction with the stipulations that the owner, or occupants to be, are to provide so many hours of labor assisting in construction. A post and beam foundation is favored both for reasons of being less expensive than concrete-on-grade and for ease of construction. But, be that as it may, wood framed building, in an environment so conducive to mold, are not sustainable for any length of time not to mention the fact they are combustible and subject to high insurance costs. For this reason, there is growing interest in resorting to the use of adobe construction that is both sustainable, easy to work with, and immune to mold problems. However, in doing so, it is assumed that one must resort to the use of slab-on-grade foundations. Clearly, this is not the case. The dual footed foundation eliminates the need for foundation contractors and the expense of steel reinforced concrete; thus a saving in both material and labor.

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[8] Klemens, Tom and Joe Nasvik, 2004. In *Concrete Construction,* Feb 1, 2004.

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APPENDIX

1. If drainage of rainfall from the aggregate filled trench footer is necessary, in order to mitigate the potential moisture effect on the clay soil of the foundation, the bottom of the perimeter trench needs to be sloped to one low point on the surrounding ground surface for discharge. It may require a drainage pipe to carry the captured water to a surface location for discharge.

2. Construction of the Stone Footer will require mortar to bond the stone units together and prevent their movement. I suggest a similar activity for the CEB. Rather than a sand-cement mortar, I would propose that a moist clay mortar be used to bind the CEB units together. This filling of the void spaces between units will also help maintain the desired interior temperature.

3. Where Stone Footers may not be acceptable, I fully support the use of bamboo reinforced concrete. However, the smooth surface of the bamboo will not bond well with the concrete. Large diameter, split bamboo, may be the best way to create a bonding of this proposed reinforcement.

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