Troubleshooting LOW RETAINING WALLS

by Robert Randall

Inadequate footings, poor drainage, and the wrong backfill wreak havoc on masonry and timber retaining walls

In most parts of the U.S. you don't have to look far to find failed or failing retaining walls. They can lead to callbacks, unhappy customers, and even worse, damage to property or even serious injury.

Catastrophic failure (walls tipping over completely) is unusual, partly because the process often progresses slowly and corrective action is usually taken before the catastrophe can occur. But that's not always true. One rainy afternoon in about 1960, the harmless-looking wall in Figure 1 suddenly and spontaneously tipped over. Fortunately my three sisters and I were inside playing Monopoly instead of out playing in the yard. The shock of the impact of five tons of masonry against our house, followed by twenty tons of mud, was something none of us will ever forget.

What made that wall tip, and why so suddenly? The answers are really pretty straightforward. First, the wall was a simple — and very poorly designed — gravity wall that had only a very small footing and no reinforcing steel. In short, it was not much different from a tall stack of blocks. During a period of prolonged heavy rains, the soil behind the wall soaked up a lot of water, and became heavier and more fluid, increasing the force behind the wall. At the same time the ground under and in front of the wall became soft and slippery, undermining the stability of the footing and offering little resistance to the tipping wall (see Figure 2).

Clearly, water was the biggest factor in this failure. What could have been done differently? The single most important thing would have been to prevent the accumulation of water in the soil behind and beneath the wall. As the photograph in Figure 1 shows, there were occasional blocks placed sideways as well as gaps between blocks in the bottom course. These well-intended features, like the drain holes frequently seen in the face of retaining walls, were inadequate because water-retentive native soil was used as backfill.

Soils with more than a minimum of clay content (5% fines by weight) are generally water retentive and should not be used as backfill. Instead, place gravel or clean sand behind the wall, with footing drains similar to common foundation footing drains. Good practice is to separate the backfill from the native soil face of the excavation with geotextile fabric, often nothing more unusual than "weed mat."

Freeze Damage

The case described above was unusual in two regards: It ended in catastrophic failure, and the prime cause of failure was not freeze damage. In the northern half of the country at least, most retaining wall problems result from the expansion of wet soil when it freezes during cold weather. This type of failure is still an indirect result of backfilling with water-retentive soil and/or the lack of good drainage, but it is frost action that causes the damage.

Figure 3, on page 37, shows retaining walls suffering from tipping brought on by frozen soil. This kind of damage often occurs over a period of years. With each freeze, the soil expands and pushes the wall outward a little bit. Then, as the soil thaws, it settles down to take up the extra space. I call this frost ratcheting, as it progresses in small increments, and never reverses itself.

The best solution for frost damage is to use gravel or sand backfill and footing drains. In some cases, you may be able to use 2-inch extruded polystyrene foam insulation to help retain ground heat and thereby prevent freezing. Put the foam directly against the back of the wall from the footing to just below grade at the top of the wall, and horizontally across the top of the granular backfill, again just below grade. This strategy is appropriate where a large amount of granular backfill cannot be accommodated, such as a tight site where excavation is limited. Consider foam insulation anywhere you don't

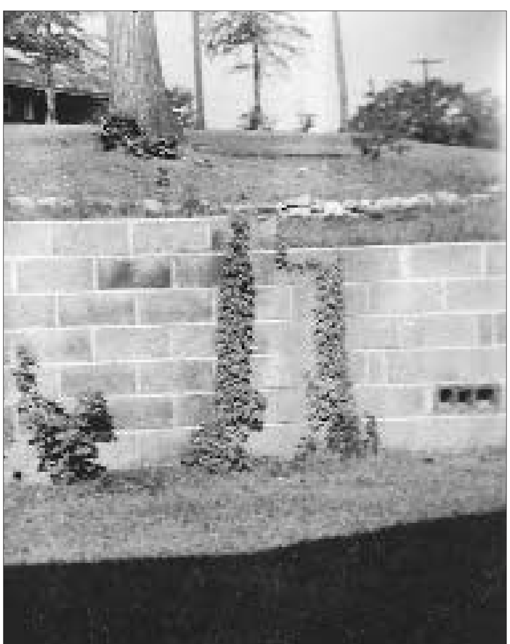


Figure 1. *This block wall, which on its face looks sturdy and well-built, collapsed during heavy rains because it had no reinforcing, too small a footing, and was backfilled with native soil.*

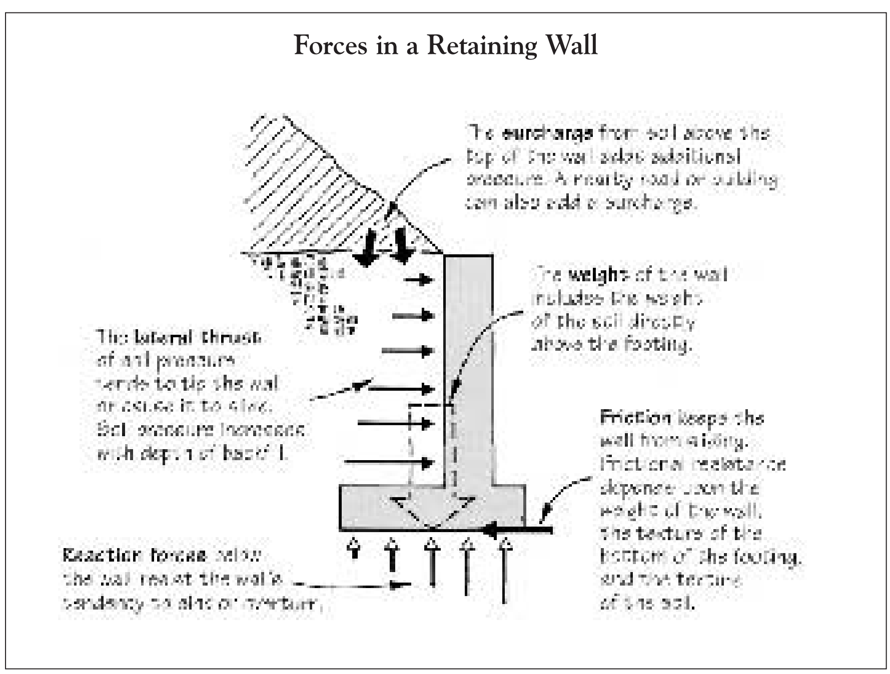
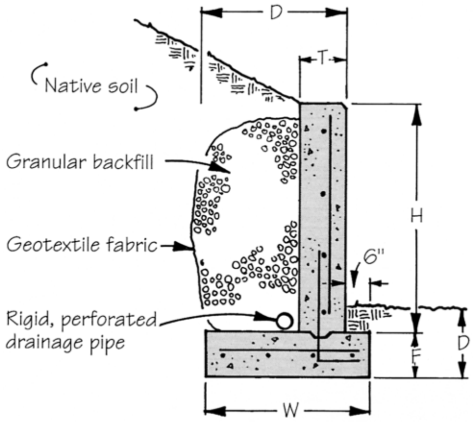


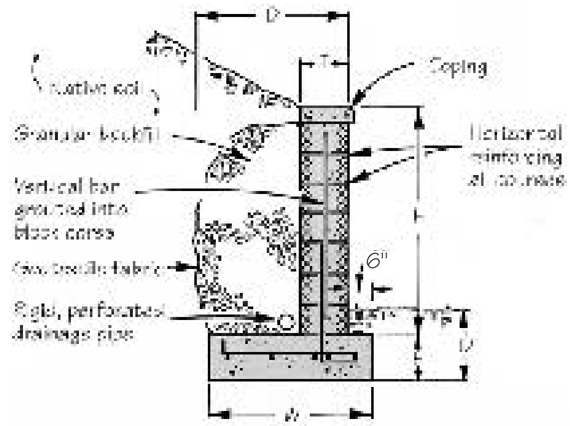
Figure 2. *The greater the depth of the wall, the greater the total lateral force of the soil. This exerts an overturning force that is resisted by the weight of the soil over the footing and the weight of the wall itself. Friction at the base of the footing keeps the wall from sliding.*

Retaining Wall Details

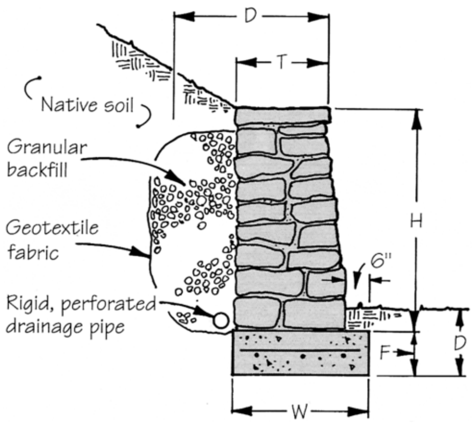
Masonry Retaining Walls



Poured Concrete



Concrete Block



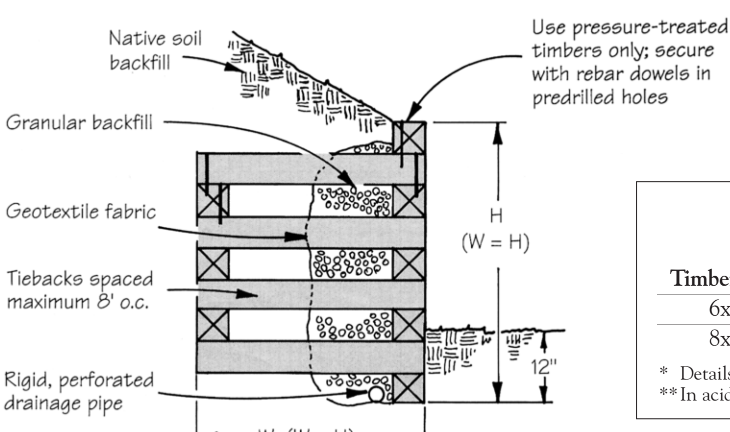
Mortared or Dry-Laid Stone

Recommended Dimensions for Low Masonry Retaining Walls*

H	W	Steel Rebar	Bar Spacing	F	T	D
2′	20″	#3 (3/8″)	2′-0″ o.c.	9″	8″	Local
3′	25″	#4 (1/2″)	2′-0″ o.c.	10″	8″	frost
4′	32″	#5 (5/8″)	2′-0″ o.c.	11″	10″	depth or
5′	42″	#5 (5/8″)	1′-6″ o.c.	12″	12″	12″-18″

*Suggested details for walls no higher than 5 feet where dense, coarse-grain soil exists below footings. Not for loose or soft sand, peat, or clay.

Timber Retaining Walls



Recommended Dimensions for Low Timber Crib Walls*

Timber Size	Dowel Size	Spacing of Tiebacks
6x6	1/2″ (#4 bar)**	6′-0″ max
8x8	3/4″ (#6 bar)**	8′-0″ max

* Details apply to walls no higher than 5 feet.
**In acidic soils, increase by 1/4" or use hot-dipped galvanized.

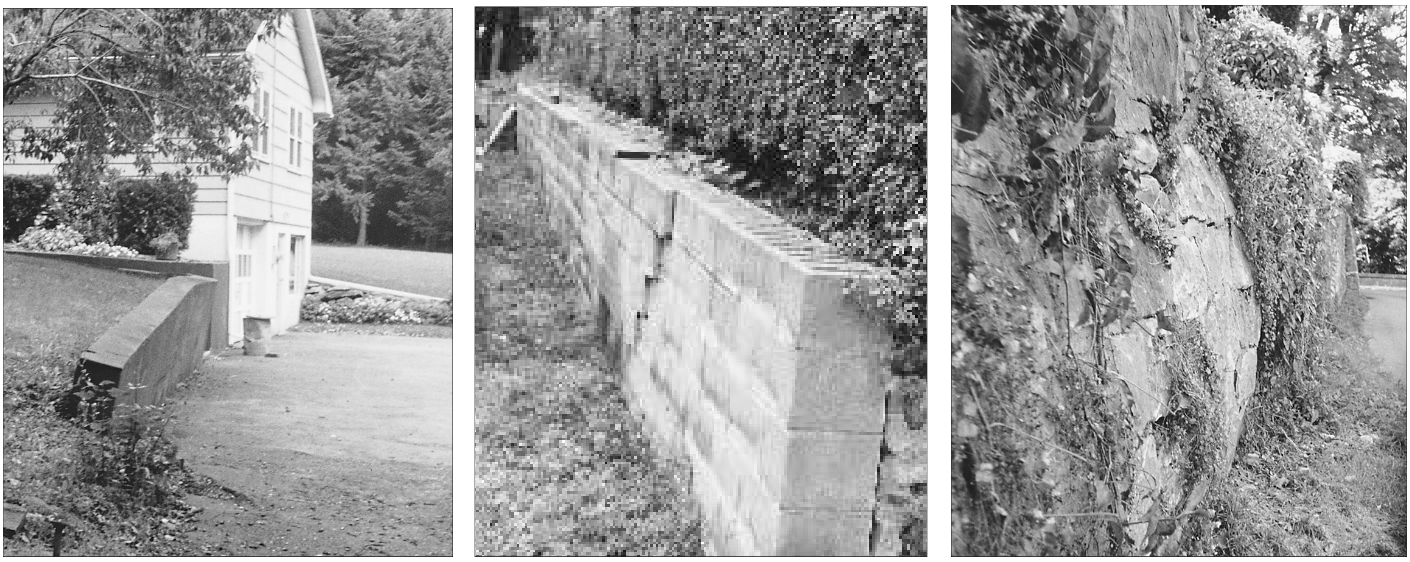


Figure 3. *In northern climates, the freeze-thaw cycle is the primary cause of retaining wall failure. Wet soil expands as it freezes, exe rting enormous force against the wall, pushing it outward. As the soil thaws, it settles into the space against the wall and the cycle is set to begin again with the next frost. With poured concrete walls, the entire wall often tips as a whole (left). In the case of block walls (center) or mortared stone walls (right), cracks and bulges may appear as sections of the wall tip.*

have room to place backfill all the way to frost depth.

To paraphrase from an engineering text, the forces exerted by freezing ground are too great to be resisted by any practical structural design. The only prevention is to eliminate the conditions which lead to freezing: water and cold.

Shear Failure

Figure 4 shows a relatively unusual condition known as shear failure. In this case, the upper part of the wall has managed to slide forward without tipping, along a failed mortar line. Mortar is not an effective glue; it usually fails under load unless there is a large compressive force such as the weight of a house sitting on it.

Sometimes the slippage occurs between the footing and the soil beneath (usually with clay soils), in which case the shear failure is also called a slipping failure. That's why you should always set footings 12 to 18 inches below grade and compact any fill between the toe of the footing and the footing excavation.

Other Problems

Look at Figure 5. Is this freeze damage or is it the tree? In a case like this it is hard to tell, because the forces exerted by growing tree roots are nearly as irresistible as the force of freezing ground. Don't plant large or fast-growing trees near retaining walls.

Figure 6 illustrates classic bad design, frost damage, and material deterioration. How could anyone expect a stack of railroad ties spiked together to resist ground forces? The leaning end of the wall should have been secured to the corner of the foundation or anchored with timber or steel deadmen back into the earth behind. If that had been done, and properly drained backfill used, this wall would still be serviceable. The drainage would also have helped retard the decay visible in the top tie.

When building timber crib walls, dowel the timbers together with lengths of rebar. Driving spikes is ineffective and often splits the timbers, sometimes long after the wall is built. Instead, drill holes the same size as the rebar dowels you are using. Be sure to treat all cut ends and holes with a preservative.

How to Avoid Failures

Like anything else you build, to avoid failure in low retaining walls you must design the wall right and build it accordingly. Here are the basic guidelines for walls no higher than 5 feet:

- Always use durable materials on sound footings. For poured concrete walls, use a 3,500 psi mix. For timber walls, use only pressure-treated timbers.
- Take into account local frost depth.
- Provide well-drained granular backfill with geotextile separation from native soil.
- Make the footings wide enough (see "Retaining Wall Details," facing page).
- Don't ever place footings on fill, no matter how much you compact it.
- Use proper reinforcement with masonry walls and tiebacks in the case of timber walls.
- Wherever you need to add fill in front of a footing, use good quality, compacted granular fill. This may help the footing resist slipping. However, to get any design "credit" for resisting slipping, you must pour the footing against the undisturbed face of the excavation trench.

Modular concrete an option. There are several excellent modular concrete block retaining wall systems that incorporate geogrid anchorage into the backfill, including Keystone (7600 France Ave. S., Ste. 110, Minneapolis, MN 55435; 800/747-8971), Unilock (287 Armstrong Ave., Georgetown, ON L7G 4X6, Canada; 416/453-1438); and Versa-Lok (P.O. Box 9116, North St. Paul, MN 55109; 612/770-3166). These products are similar in principle to the timber crib walls, and generally require more excavation and backfill than concrete walls. Where this can be accommodated, modular walls will probably be a competitive option. As with all retaining walls, success depends on good footings and drainage. Since they are unmortared, modular block walls are a little more forgiving than solid masonry to minor settlement or frost action. ■

Robert Randall, P.E., is a structural engineer in Mohegan Lake, N.Y.

Figure 4. *Shear failure occurs when the force of the soil causes the retaining wall to slide along a mortar joint, but without tipping over.*

Figure 5. *Tree roots can cause retaining walls to lean; keep large or fast-growing trees away.*

Figure 6. *Railroad ties stacked and spiked together, but without tiebacks into the earth behind, cannot resist the force exerted by wet or frozen soil. Poor drainage also accelerates rotting.*