How Strong is My Building Soil?

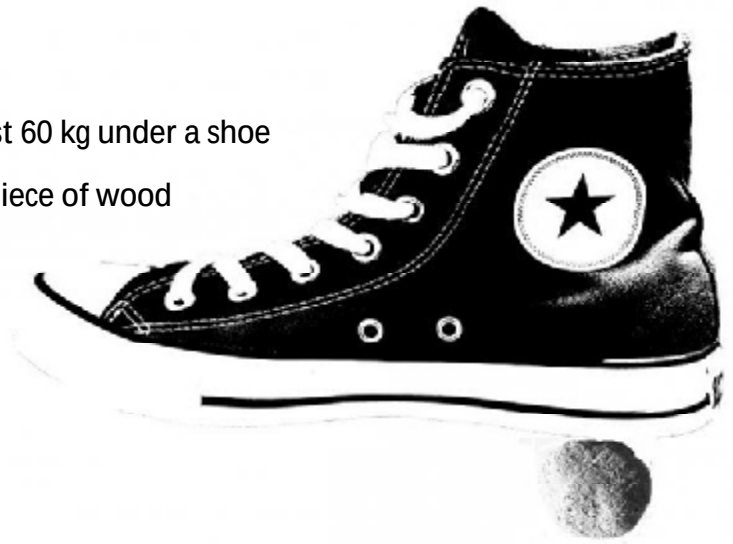
Build Simple Inc., www.BuildSimple.org , September 4, 2017

Estimate by Crushing Balls:

Standard: 30 mm balls can hold up almost 60 kg under a shoe

Special: Balls can hold up 30 kg under a piece of wood

Strong: Balls hold up almost 60 kg under a piece of wood



Check by Crushing Cylinders:

Standard: 40 mm cylinders can hold up 84 kg before breaking (or 10.5 kg on a 1:7 lever)

Special: Cylinders hold up 119 kg (or 15.5 kg on a 1:7 lever)

Strong: Cylinders hold up 133 kg (or 17.5 kg on a 1:7 lever)

More information about field soil tests are online at www.BuildSimple.org/soil-tests.php

ESTIMATE: BALL CRUSH TEST

Build Simple Inc., www.BuildSimple.org, September 2017

Shows a rough estimate of soil UCS (unconfined compressive strength)

YOU NEED 24 HOURS AND:

1.5 liters/ quarts of soil
A ruler with millimeters
A small flat piece of wood

MAKE SAMPLE BALLS

Pick out gravel 1/8 inch/ 3 mm or larger from your soil. Dampen soil. Stir well.

To make balls the same size, use a small plastic bottle cap. Fill the cap evenly. Take out the soil and roll the balls until very round. Try to make them 30 mm diameter.

Make 18 balls or more, so you can test at least 10. The balls should look round from above, but can be a little flattened on the bottom.

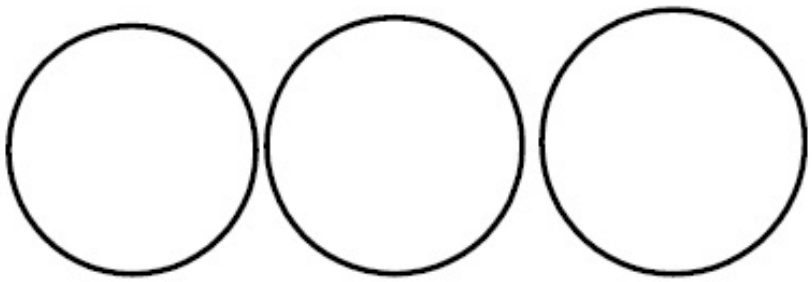
CURE BALLS

Dry the balls in full sun all day or in an oven at 210- 225° F/ 99- 107° C for 3 hours. Let them cool.

CHOOSE BALLS

Throw out cracked balls.

Use the circle guide below. Copy it bigger or smaller so they are 29, 30, 31 mm. Measure the circles with a good metric ruler. Write the diameter on your copy next to each circle.



Put a ball on a circle. Look straight down from above. The ball is this size if you can see some of the circle, but not all of it.

Throw out balls smaller than 29 mm or bigger than 31 mm.

CHOOSE A TESTER

Weigh people. Who is 60 kg/ 132 lb? Put rocks in their pockets if they are too light.

Or find someone who is not fat or skinny and is 1.57- 1.65 m/ 62- 65" tall. They will weigh about 60 kg/ 132 lb.

Someone with a lot of patience and shoes or sandals can test. Rubber soles may be better than hard leather soles.

MAKE A LIST

Get a list ready to write your results. One person should write all the results for the tester.

START THE TEST

Put the sample ball on a brick, cement floor, or a flat piece of wood.

Now, start the crush dance. Hold a wall or someone's shoulder to balance.

Stand on your toes in front of the ball. Lift up your other foot.

Gently put your foot down. When all your weight is on the ball or balls, let go of the wall or shoulder. Do not twist your foot.

Crushing while the toes are coming off the ground may take about half weight.

Don't stop if it cracks. Keep weight on until a ball breaks into many pieces.

BALL UNDER A SHOE

CRUSHES AT ALMOST FULL WEIGHT = « STANDARD

If the ball does not crush, but holds up the tester, very good!

BALL UNDER A PIECE OF WOOD

Now put a piece of wood on the ball, then stand on the wood.

Balance carefully so you don't twist on the wood.

BALL CRUSHES AT HALF WEIGHT = « « SPECIAL
BALL CRUSHES AFTER FULL WEIGHT = « « « STRONG

RESULTS VARY

Test many samples. Then find the average results.

If 5 or more balls (out of 10) are « « special with some balls stronger and some balls weaker, then this soil is really « « special strength.

Tell an engineer the approximate Mpa (megapascal) or psi (pounds per square inch) unconfined compressive strength your soil is. They can find out more in BSI's soil test information at https://BuildSimple.org/soil-tests.php.

« STANDARD = 1,3 MPA/ 190 PSI

« « SPECIAL = 1,8 MPA/ 260 PSI

« « « STRONG = 2,1 MPA/ 300 PSI

CHECK IT: TP TUBE TEST

Build Simple Inc., www.BuildSimple.org, September 2017

Shows approximate soil UCS (unconfined compressive strength) or compares different mixes.

YOU NEED 1 OR 2 DAYS AND:

2 liters/ quarts soil
Marker
A metric ruler or tape measure
Paper tubes from 5 rolls of toilet paper or 3 rolls of paper towel
Either: A wooden lever or some heavy people
A large bucket and a scale to 140 kg (310 lb)
Gravel, sand and/ or bricks
And a suitcase scale to 50 lb/ 23 kg

PEOPLE OR TOOLS?

Larger samples need more weight to crush. Small differences are easy to see. People who weigh 91 kg (200 lb) or 119 kg (262 lb) or 133 kg (293 lb) can stand on wood on a tube sample. Weight can be added in a bucket.

Or with a 1:7 lever you can use 9- 18 kg (20- 40 lbs) weight. This is less tiring to handle and easier to measure accurately.

MAKE SAMPLES

Fold paper tubes flat and cut 10 pieces that are 40 mm/ 1.5” long.

Pick big gravel out of your dirt. Add water until the soil is damp. Mix well.

Put soil in the tube in layers. Tamp firmly with your fingers as you add. Fill it up and scrape it off level. Squeeze gently to make it round.

Let the samples dry for 8 hours. Put them in the sun for 2- 3 days, or bake for 4 hours in a 210- 225° F/ 99- 107° C oven with the door cracked open.

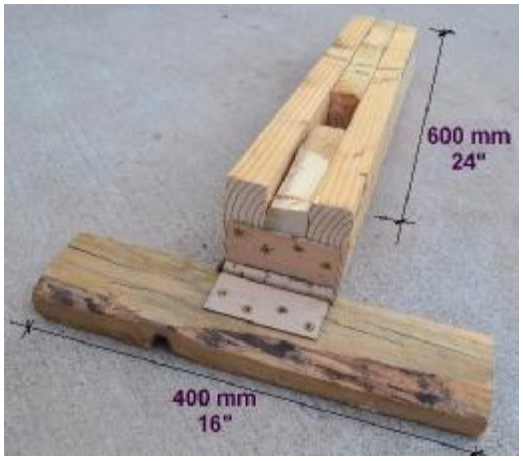
MEASURE SAMPLE WIDTH

Remove the cardboard. Rub samples with an uneven top gently on a brick to smooth. Write a number on each sample.

Measure the top of each sample in mm. Write the sample number and the top width on a list. For an oval sample, measure the widest and narrowest directions and average the two measurements.

Throw out any samples wider than 42 mm or smaller than 39 mm.

TP TUBE TEST



MAKE A LIST

Write down the sample number, width, and the weight needed to crush it.

MAKE A LEVER

If your wood is only 50 x 100/ 2x4, screw or nail three pieces together to make a 600 mm/ 24" long lever beam.

Attach the beam to a 400 mm/ 16" long board with a hinge.

Draw equal spaced marks 70 mm apart between the hinge and the end of the beam. Number these marks.

The hinge point is 0, and the weight must be centered over the 7 mark. Trace the size of your bucket on top of the beam, centered above the 7 mark.

USE THE LEVER

The lever beam must be level before you add weight.

Have a helper stand on the shorter hinge board. Lift the beam. Place the sample under the 1 mark.

If the samples are higher than the hinge board, Make the hinge board thicker.

If the hinge board is thicker than the samples are high, good! Find a thin piece of wood the right thickness to make the lever board level on the sample. Draw on it to locate the sample accurately each time.

After the lever beam is level, put an empty bucket centered over the 7 mark.

Add weight slowly. Don't let the lever bounce.

When the sample crushes into many pieces, weigh the bucket with a suitcase scale. Write down the crush weight for each sample on your list.

11 kg/ 24 lb	=	« STANDARD:
16 kg/ 35 lb	=	« « SPECIAL
18 kg/ 40 lb	=	« « « STRONG

FIND THE AVERAGE

If 5 out of 10 samples break under 11 kg weight, 3 others break under less than 11 kg, and 2 break under more than 11 kg, this is a « *STANDARD* strength soil.

The most accurate results come when you add all your crush weights together, then divide by the number of samples.

MORE INFORMATION

This test gives a conservative estimate of unconfined compressive strength. Your soil strength might be as much as 50% stronger than these results show. But it will not be weaker.

See the chart below to tell your engineer or building inspector what soil strength it is in Mpa (megapascals) or in psi (pounds per square inch).

USING WATER, BIG SAMPLES, OR THIN LEVER BEAMS

If you don't have a suitcase scale, you can measure water instead of weighing your bucket.

If you used samples of different sizes, use the column for the sample diameter that fits.

Toilet Paper Tube Crush Test				
	Weight or Volume of Water to Crush Each Sample Diameter			
	39 mm	40 mm	41 mm	42 mm
« Standard: New Zealand* Code Standard = 1.3 Mpa/ 190 psi	10.4 kg/ 22.9 lb/ 9.4 liters	11 kg/ 24.3 lb/ 10 liters	11.6 kg/ 25.6 lb/ 10.6 liters	12.2 kg/ 26.9 lb/ 11.2 liters
« « Special: Average for NZ Code Special = 1.8 Mpa/ 260 psi	14.7 kg/ 32.3 lb/ 13.7 liters	15.7 kg/ 34.6 lb/ 14.7 liters	16.5 kg/ 36.4 lb/ 15.5 liters	17.4 kg/ 38.3 lb/ 16.4 liters
« « « Strong: Minimum for New Mexico* Code = 2.1 Mpa/ 300 psi	17.2 kg/ 37.9 lb/ 16.2 liters	18.3 kg/ 40.4 lb/ 17.3 liters	19.3 kg/ 42.5 lb/ 18.3 liters	20.3 kg/ 44.7 lb/ 19.3 liters
*Why New Zealand and New Mexico Code Information? New Zealand's code shows how to plan safe buildings of these strengths. It has more information than any other earth building code or guidelines. New Mexico's code is simpler but many US engineers are used to working with this soil strength.				

If you made the lever with 2 instead of 3 pieces of 50 x 100/ 2x4 wood, it will take 0.6 kg/ 1 lb more weight or 600 mL more water at each strength level to crush samples. These crush weights also all assume a plastic bucket that weighs around 1 kg/ 2.2 pounds.

More About Soil

1 Subsoil Only!

Build with subsoil, not topsoil. Topsoil has organic matter like roots and decaying leaves that hold water and nutrients for plants. But in an earthen wall the organic material can decay, and your wall may shrink over time.

Topsoil may be darker brown than soil below. It often has a moldy smell that is different from mineral subsoil.

Prove it's Not Topsoil

It is easy to check that your building soil does not contain topsoil. Mix a handful in water and stir well. If a lot of stuff floats on the water (middle photo), dig deeper to the subsoil.

Organic and Inorganic Things in Soil

Some builders add fibers to soil to increase the strength of dried soil blocks. But straw may attract termites or other insects to your walls, especially if the roof leaks and the wall becomes damp. In areas where termites or chagas insects are a problem, use little straw, grass, pine needles, or organic materials inside earth walls.

Earthbag builders use polypropylene rice bags in their walls. These can last without damage as long as they are covered from the sun. Builders also use plastic geogrids (like plastic traffic fence), strips of rubber tires, steel wire (like barbed wire) or steel rebar for reinforcement.

Natural reinforcement of cane, wood, or bamboo works well but can also be destroyed by insects. If it is installed in the plaster layer, the owner can check its condition and possibly replace the reinforcement as needed.

Natural fibers in plaster are not a problem because the thin surface layer can always be replaced.

2 IMPROVE IT: MAKING SOIL STRONGER

Adding more clay often adds strength to soil.

This is most helpful if the clay is a strong one. Clay used for pottery is usually quite strong. A clay that shrinks and cracks when it dries is often strong.

Add clay to soil by soaking the clay for one day, stirring it well, then pouring it on the other soil.

SOIL PARTICLE SIZES

Soil is strongest when it has some particles of every different size so that the particles pack together well.

Sometimes adding a weak clay to soil can make the mix weaker. Sometimes adding sharp (not rounded) sand, ash, dung, or even silt can make a building soil stronger.

Many natural builders recommend stirring soil in water and letting it settle in a clear jar for a day. This shake test does not show anything about soil strength. But it will show if there are some particle sizes missing.

Clay is so fine that it looks like a smooth layer. You cannot see any particles. A soil with a lot of clay will have so much clay in all the water that you will not be able to see any different layers when it settles. But you can feel the silt like flour and the gritty sand with your fingers.

Sand is particles between the size of rock salt and fine table salt. Silt particles are smaller than sand. You can see silt particles with a hand magnifier.

If your soil is missing one size, try adding some particles of that size and retest this mix for strength.

TEST SOIL MIXES

To find out if something improves your building soil, make and test some samples of plain soil and different mixes. Make samples using 1 part of an additive and between 5 and 10 parts of plain soil. Measure carefully and stir well. Label samples and keep notes to explain.

3 IMPROVE IT: MAKING SOIL WATERPROOF

Gravel bags work well for footings and waterproof wall bases. Water from the ground does not cross the air spaces in the gravel bags. Broken bricks or sand can also be used, but a waterproof layer should be placed on sand bags.

Use waterproof wall materials in rainy climates as high as the rain splashes up on the wall. Earth walls are not damaged by being wetted if they can dry out all the way before being soaked again. Do not use plain or 'raw' earth in rainy climates where the lower part of outside walls often look damp or moldy.

4- 8% (measured by volume) of hydrated lime or Portland cement added to soil can 'stabilize' it. This means water will not longer soak deeply in and damage it.

Make one flat block of each soil mix and cure it. Measure how thick it is.

Lay the blocks on a screen or rack in a pan, or each on three thick coins. Fill the pan so the water rises 10 mm above the bottom of the block. Leave this for 4 minutes. Then drain it until the water barely touches the bottom of the earth blocks. Leave them just touching the water for 12 hours. Add water as needed.

Pour the water off. First measure how high the moisture has risen on the outside of the block. Next measure how thick the block is (if it has lost some thickness). Then cut the block in half and measure how high the moisture has risen inside the block.

Choose a mix that prevents damage from dissolving, or that sucks water up the least.

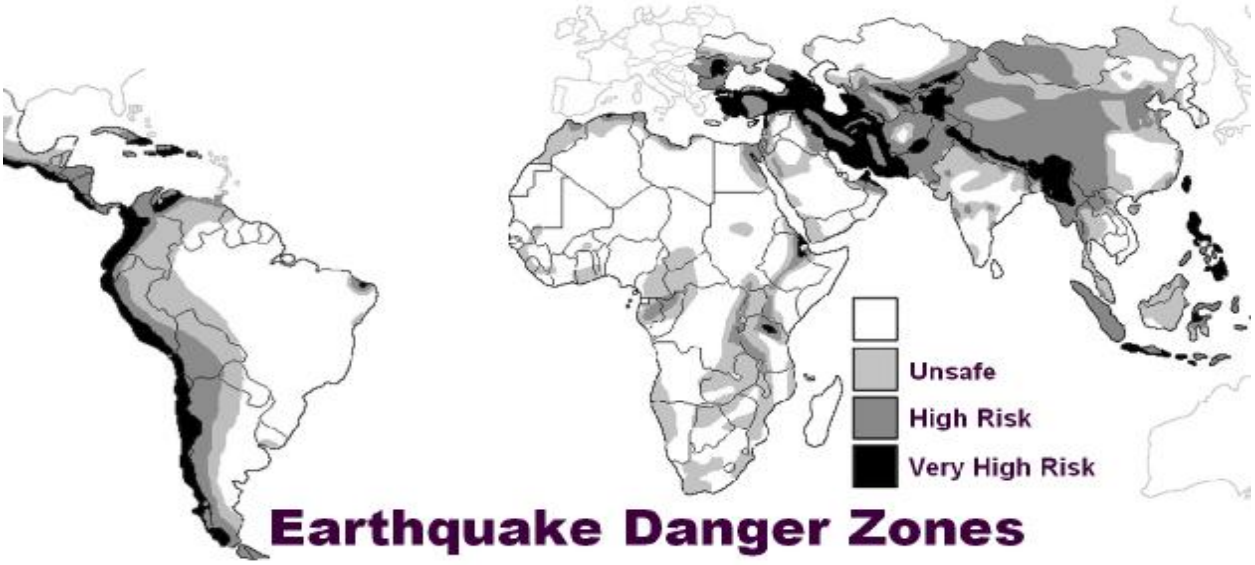
Either lime or cement makes soil harden more quickly.

Building soil with lime or cement added must be used up within 30- 60 minutes. It may also be impossible to hammer rebar through the wall after the material cures.

4 WHY TEST SOIL STRENGTH ANYWAY?

Most earth buildings are strong enough in places that have very tiny or no earthquakes, like the white areas on this map.

Where horizontal earthquake motions are no stronger than 0.25 g (1/4 as strong as gravity), almost any soil that holds together will do for earth buildings.



In low quake risk places, walls are sometimes damaged by landslides, motor vehicle accidents, or tsunamis. Using a stronger building soil can help a building to resist other hazards in addition to just earthquakes.

Many parts of the world have stronger earthquakes. Many earth buildings and unreinforced brick or block buildings are seriously damaged in mild quakes with 0.3 or 0.4 g motion.

STRONGER SOILS SAVE LIVES AND MONEY

In low, medium or high risk places, shown as gray or black, special earth buildings are needed.

Adobe and rammed earth can have containment of rebar, wood, tire strips, and strong mesh added on the inside and outside. If strongly connected it may survive 0.4 g motion.

Unreinforced wall damage in Nepal

'Low Risk' places are shown as

light gray on the map, labeled 'Unsafe.' Quakes may be as strong as 0.6 g there. Tested soil may help builders save money but create safer buildings.

Earth buildings can be strong enough for low risk when they are built very carefully with « Standard strength soil, a safe layout with enough bracing, a strong foundation, and very good quality work.

New Zealand's guidelines for unreinforced buildings show how to build adobe and rammed earth safely if you can afford a reinforced concrete footing. Good earthbag buildings of slightly stronger soil appear to be this strong even without a concrete footing.

'High Risk' places are shown on the map as dark gray. Quake motions may be 1.7 g, almost twice as strong as gravity. Reinforcement must be special, and stronger soil is very important.

'Very High Risk' places are shown in black. Earthquakes are likely here, and often are stronger.

Stronger Earth Walls

Where earthquake motions are stronger, stronger soils are very helpful. Buildings may need more costly reinforcement when built with weaker soils. Or buildings may need smaller window sizes to allow wider spaces between openings in the walls. Larger buttresses may need to stick out of building walls to brace buildings if building soil is weaker.

Soil Under the Building

Before building, ask engineers or colleges about the level of local risk. The map above is not really accurate. Also, find out how firm your soil is.

Rocky, hard ground or bedrock shakes less than soft ground. When it is hard to dig a footing the subsoil is good for a building.

Buildings planned where it is easy to dig the footing out should be stronger because soft soil amplifies vibration.

Buildings on soft soil that sometimes is wet may need special wide footings to prevent them leaning over or sinking if a quake happens while the ground is wet.

Learn More

Builders in hazardous areas can learn cheap ways to make buildings stronger. These include special reinforcement, special footings, and plans that have enough bracing walls to hold the building together in an earthquake. Please see the Build Simple website at www.BuildSimple.org to learn more about stronger natural building methods, including the Contained Earth (CE) type of earthbag.