Field Tests for Strength of Building Soils

Build Simple Inc., www.BuildSimple.org

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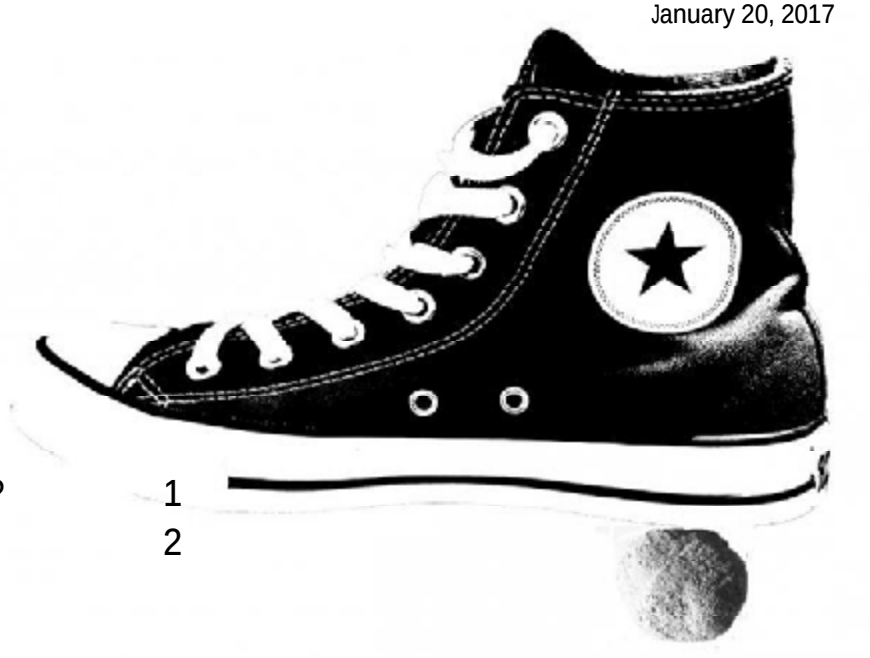


PART I: ABOUT SOIL TESTS

1 WHAT DO WE NEED TO KNOW?

Do Soil Tests Matter?

Stronger soils make stronger earthen walls. *INCREASING SOIL COMPRESSIVE STRENGTH BY 25% MAY DOUBLE WALL SHEAR STRENGTH* for earthbag buildings (Stouter 2017).

Many earthen walls have enough compressive strength to hold up roofs and/ or lofts or second stories in low-risk areas. But under horizontal stresses from earthquakes, landslides, or tsunamis, heavy earthen walls collapse at low force levels. Unreinforced earth can be a killer.

Right: Earthquakes can cause this type of damage to even well-reinforced contained earth walls

Strong soils hold onto strong reinforcements better than weak soils, and delay or prevent structural damage. Barbed wire barbs and rebar can twist more and move more in weak soil.

Builders in risky areas get the safest buildings (or need less reinforcement) with stronger soils.

Don't Builders Know Their Soil?

Adobe and rammed earth builders use sandy soils so that their blocks or walls will not crack when curing. Weak soils also chip too easily at the edges of blocks or wall sections, so they choose medium to strong soil. But the qualities they notice as they work the soil do not show exactly how strong it is.

Earthbag or contained earth is a family of modern techniques that use fabrics with small amounts of metal in earthen walls. Tamping the wall during construction allows the separate units to cure without cracking even if made of heavy clays. The corners don't chip either because the earthen wall material is usually protected by a layer of bag or tube fabric and another layer of stucco or plaster.

Earthbag can use a wider variety of soils than other earth buildings. So, earthbag builders may know even less about the quality of their building soil than adobe or rammed earth builders.

What Are We Looking For?

The color or the type of soil will not tell us the strength.

Earthbag trainers often teach that soil should contain a certain proportion of clay. But different clays are weaker or stronger. The proportion of clay does not tell the strength.

Right: A sandy soil with weak clay crushes easily

To know soil strength, special tests that use measured force to crush or twist cured samples are needed.

Strong, smooth soils should also be tested to be sure the soil will not shrink too much when curing

2 WHICH STRENGTH TEST?

Engineers who check plans to make sure buildings will be safe in risky places want to know the compressive strength of the soil. These tests are usually done on a full-size sample by a powerful machine in a laboratory. Get these tests if you can. In the US these tests can cost several hundred dollars to check one soil.

If you can't afford or find compressive strength lab tests, builders can find out approximate compressive strengths with simpler tests.

Do you want to make samples as big as an egg, a fist, or a rice bag? Are you in a hurry for results?

When you test small samples you need to make more of them. You need to make them carefully. But they cure quickly and are easy to store. With an oven to dry them, the small tests can be done in a day.

The big test is simple but slow since it needs to dry for at least a month in the sun or in a dry climate.

Some tests take more care, some need more equipment, and some produce more precise results than others. For any of these tests you need a good tape measure or ruler.

CHOOSE A STRENGTH TEST						
Test Name	Size	How Many Samples?	Easy?	Accurate?	Time Needed	Equipment Needed:
Ball Crush	Egg	12- 18+	ü ü	ü ü	12- 24 hours	§ Person who weighs 132 lb/ 60 kg § Soft-soled shoes § Plastic soda bottles § Small piece of wood § Oven to cure samples
TP Tube Lever Crush	Fist	8- 10+	ü	ü ü ü	24- 30 hours	§ Wooden lever made from two 18"/ 460 mm pieces, 2 nails or screws, and some washers § Tubes from toilet paper rolls § 5- 6 gallon/ 19- 23 L bucket § Accurate gallon/ 4 L container § Water § Oven to cure samples
Unit Drop	Rice bag	6+	ü ü ü	ü	1 month	§ 3 or more boards § Hard surface (Standards NZ 4298 p. 64)

Adobe builders may use these field tests as well as contained earth builders. Adobe blocks of a soil are probably almost as strong as tamped contained earth units.

UNIT DROP TEST

FOR STRENGTH

NEEDED:

Eight 5 gallon/ 19 L buckets of soil
Six boards
A hard surface
Optional: a marker or crayon

PROCESS:

Tamp and cure 6 large samples for 1 month
Lift to the right height
Drop on a corner on a hard surface

MAKING SAMPLES

The simplest test uses full-size units. For best results wet your soil 24 hours before you make the samples.

Fill 6 or more 18"/460 mm wide bags a little more than half full with damp soil. Tamp each one until it is 15"/ 380 mm wide and at least 5"/ 125 mm thick. The finished sample should be between 15- 30"/ 380- 760 mm long to produce accurate test results.

Place each one on a separate board to finish tamping.
During curing you can move these heavy samples without breaking them. Soil samples are strongest if they cure in the shade for 3 days. After that leave them in the sun, but don't let them get wet.

After several days see if the edges feel firm. Turn the tamped unit over gently. If you turn a weak soil sample too soon, it cracks (see photo at upper right right).

These samples will each weigh about 80 lb/ 36 kg.

Curing

The sample will be completely cured when it does not get any lighter. If you can't use a dieter's scale or a shipping scale to check it, let it cure at least one month in a dry location.

Before testing measure 4"/ 100 mm from one corner and mark on each sample.

UNIT DROP TEST (PAGE 2 OF 2)

DOING THE DROP TEST

Hold a sample up with the marked corner pointing down above a hard surface. As you drop it, step back to get out of the way!

To test for NZ Standard soil strength of 190 psi/ 1,3 MPa, hold the sample 35"/ 900 mm above pavement or hard ground (see at right).

A sample passes the test if no more than 4"/ 100 mm breaks off any corner, and it does not break in half.

Left: This sample failed by breaking in half

Below left: This sample passed because it stayed whole and less than 4"/ 100 mm broke off the damaged corner

You cannot test a sample more than once- even if it looks whole, it has been damaged.

To test for NM soil strength of 300 psi/ 2,1 MPa, hold the sample 56"/ 1,4 m above the pavement or ground (see at right).

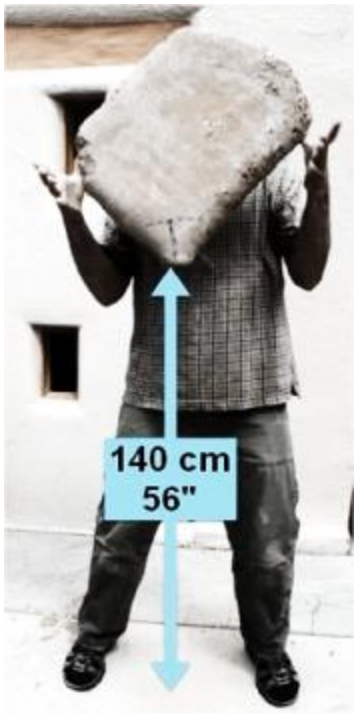
Test at least 6 samples.

Test 3 samples for NZ standard grade. If they all pass, test the last 3 for the higher NM strength.

If any of the first 3 fail the test for standard grade, drop all of the rest from the lower height. You want 2/3 of them or 4 out of the 6 samples to pass the test.

NZ STANDARD GRADE

NM STRONG SOIL



BALL CRUSH TEST

FOR STRENGTH

NEEDED:

1.5 quarts/ 1.5 liters of soil
Plastic bottles and tops
A baking tray or piece of metal
A small flat piece of wood
Some paving or a second piece of wood
Shoes for your 132 lb/ 60 kg person
Optional: a table knife or spackle blade

PROCESS:

Pick large gravel out of soil
Make and cure 18 small balls in 24 hours
Speed cure in an oven if needed
Find a tester the right weight
Stand with shoes on two balls
Stand with shoe on one ball
Find the average crushing strength

MAKING SAMPLE BALLS

You can only find soil strength from egg-size small balls by making 18 so you have at least 12 to test. Let someone who is careful or fussy make your sample balls. Your test will be more accurate if the balls are the right size.

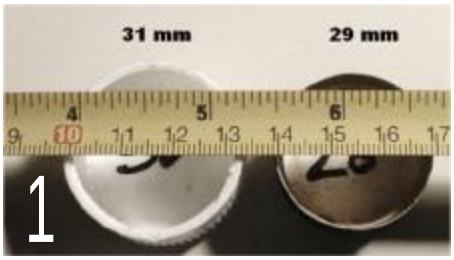
Find two bottle caps. One should be 31 mm across the inside, the other 29 mm (see photo 1). Try pint/ 450 mL cola bottles. Mark the size inside (photo 2).

Spread the soil out. Pick out gravel 1/8 inch/ 3 mm or larger.

Mix in just enough water to dampen your soil. Add a drop or two until you see the water shine for a moment. Stir well. Make up your samples within an hour.

Cut off the end of the plastic bottle. Squeeze and push your soil through it to make a uniform snake (see photo 4).

Measure and cut enough soil to make the ball (see photo 5). Check a few balls for size in the bottle caps- it can fit either one of them or be in between in size (photo 6).



WHICH SOIL BALLS TO USE?

Let your soil balls dry for a few hours. Then cure them in an oven at 225° F/ 107° C for 3 hours. Let them cool.

Measure your soil balls. Look straight down at a ball inside your bottle cap. If a ball barely fits in the larger cap, write the cap size. If a ball sits up on the cap, how many mm wider is it? (see photo 1) If the ball leaves space in the cap (photo 2), try in the smaller cap. It is much easier to measure on a circle than with a tape measure.

This test result charts are for balls that are 29- 31 mm in diameter. Take any cracked balls away, and any balls that are smaller than 29 mm or larger than 31 mm.

It does not matter if a ball is a little bit oblong, or a little flat, as long as the top is rounded (see photo 3). Estimate the average diameter for an oblong ball.

CHOOSE YOUR TESTER

If you can use a shipping or a doctor's scale, find out who weighs 132 lb/ 60 kg[1]. If someone is a little too light, put a can of food or two in their pocket.

The tester should wear shoes with rubber soles. Bare feet will not break balls at the same weights.

TEST TWO SOIL BALLS

Start with two balls at once. Each will only have to hold half of the tester's weight.

Place the balls about 12"/ 30 cm apart on a hard floor or on a piece of wood.

Stand on your toes in front of them, and hold a wall or a shoulder to balance well. Do not twist around on the balls or they will break at a much lower weight. Gently place a heel on each of the two balls (see photo 4).

Slowly rock back to put all your weight on the balls under your heels (see photo 5). When you are steady, let go of the wall or shoulder to prove all your weight is on the balls.

[1] A young man 5'2- 5'3" / 1.57- 1.6 m tall with no fat, or a thin woman who is 5'3 to 5'4"/ 1.6- 1.63 m tall should weigh 132 lb/ 60 kg.

Ball Crush Test

(page 3 of 4)

The tester should move very slowly and gently as he or she shifts her weight.

A sample that fails will not just crack once, but will be crushed or broken into many pieces.

Test One Soil Ball

If the two soil balls hold up the tester, take one ball at a time and have the tester put their weight on the single ball. Make sure that the heel of the shoe is not touching the ground at all. The tester has to lift the other foot up to balance on the foot resting on the sample ball (see photo 1.

If one soil ball holds up the tester, have the tester step on a piece of wood on the soil ball (see photo 2). It might be easiest to tie the wood to the tester's foot.

If a ball does not break under a piece of wood with the tester's full weight, it may break under a piece of metal (see photo 3- this is the same ball from the middle photo, finally crushed flat).

Mark down the results. At the end, find the average soil strength for all your samples.

BALL CRUSH TEST (PAGE 4 OF 4)

Check every row that applies to each sample. Circle the highest test result for each sample.

After testing all the balls, add up the soil strengths for all the samples and divide by the number of tests.

RESULTS

ID Number of 29- 31 mm Sample												Result	Soil Strength
1	2	3	4	5	6	7	8	9	10	11	12	Testing Two Balls:	
												Both crush easily	80 psi/ 0,6 MPa
												Both crush with most of tester's weight	120 psi/ 0,8 MPa
												Both do not crush under the tester's shoe	150 psi/ 1,0 MPa
												Testing One Ball:	
												Crushes easily	150 psi/ 1,0 MPa
												Crushes with half or more of the tester's weight	Standard (NZ) 190 psi/ 1,3 MPa
												Does not crush under the tester's shoe	Special (NZ) Average 260 psi/ 1,8 MPa
												Crushes under a piece of wood with half the tester's weight	
												Barely crushes under a piece of wood with all the tester's weight	Strong (NM) 300 psi/ 2,1 MPa
												Doesn't crush under a piece of wood with all tester's weight	320+ psi/ 2,2+ MPa
Using psi or MPa?													
Number of samples this strength: _____												x Strength _____	= total: _____
Number of samples this strength: _____												x Strength _____	= total: _____
Number of samples this strength: _____												x Strength _____	= total: _____
Number of samples this strength: _____												x Strength _____	= total: _____
Number of samples this strength: _____												x Strength _____	= total: _____
Number of samples this strength: _____												x Strength _____	= total: _____
Add all numbers of samples tested (A): _____												Add all strength totals together (B): _____	
B divided by A : _____ = AVERAGE SOIL STRENGTH													

Toilet Paper Tube Test

(page 1 of 5)

For Strength

Needed:

2 quarts/ 2 L soil
Paper tubes from 5 rolls of toilet paper
A simple lever made of scrap wood
An accurate size gallon/ 4 L container
A 5 or 6 US gallon/ 19- 23 L bucket
A marker
Optional: A baking tray or egg carton
A fish (hanging) scale

Above: Wood lever setup

Process:

Cut tubes into small lengths
Fill 10 tubes firmly, dry 24 hours, oven cure if needed
Make a lever
Mark a bucket for gallons or liters
Set the first sample under the lever board
Hang a bucket on the board
Slowly fill the bucket with water until the sample crushes

Making Samples

Remove any gravel that is 1/4"/ 6 mm or larger.

Fold the tube flat. Draw a line and cut it neatly to 1.5"/ 40 mm lengths (see photo 1).

Wet the test soil and mix well. Make samples immediately. Add damp soil to the tube in layers. Tamp it firmly with your fingertips as you add more (see photo 2). Fill it right up to the top and scrape it off level.

Place the sample where it can dry undisturbed. Squeeze it gently to make it round (photo 3 and 4).

Let the samples dry for 8- 12 hours before moving. They may take 2- 3 days to cure completely.

If you have different types of soil fill, set them on labels, and mark the tubes when dry.

For quicker testing, finish by baking for 4 hours in a 225° F/ 107° C oven to complete the curing.

MAKING A LEVER

A lever test will allow you to see smaller differences in strength than the ball crush test. With a lever test you can accurately compare different mixes of soil to decide whether adding small amounts of clay or sand can improve the strength and/ or workability of your soil.

This lever base is made of two 18"/ 460 mm long boards. Make the top board out of strong wood. Saw a small notch near the end of the lever board to hold the bucket handle in place (see photo 1).

The picture shows some 1.25 x 3"/ 31 x 76 mm boards because these were leftover hardwood. Use the strongest wood you have.

File or saw an angle on one edge of a small block of wood. Attach this to the bottom board.

Use two long, strong screws or nails with washers to fasten the end of the top board loosely to the center of this block. Don't fasten it tight. Leave a ¾"/ 20 mm gap so the lever board can tilt a little (see photo 2). Make sure your samples fit with a little extra room.

Carefully measure the distance between your screws or nails and the notch on top of the lever board. Divide that distance by 6. Draw equal spaced marks between the attaching point and the notch. If the attaching point is 0, your sample gets placed at 1, and the notch should be at 6.

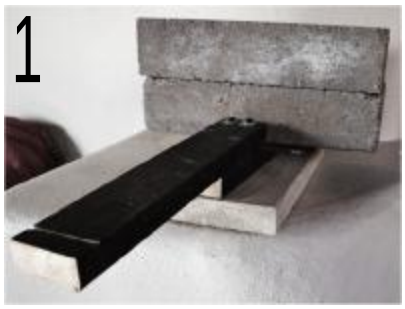
This is a 1:6 lever, with the weight hanging 6 times as far away as the sample.

If you have very strong soil and your screws or bolts start to bend, you may want to make a sturdier lever. Look at page 24 for several different ways to make a simple lever.

TP Tube Test

Lever Height

Find a flat wall or table high enough to hang the bucket underneath. Place heavy blocks or a full bucket of water on the bottom board to hold it still (see photo 1).



Measure Sample Width

First take the cardboard tube off.

Sometimes samples are bumpy on the top. Rub a bumpy side gently on a brick to smooth it a little. The sample top should be the smoothest side (like the left sample in photo 2).

Measure the diameter of the top of each sample (in photo 3 this sample is 41 mm diameter). Metric is easier than inches for accuracy. Discard any larger than 43 mm or smaller than 39 mm.

Measure the widest and narrowest directions of any oval tops. Write down the average of the two measurements.

Setup

If the top of the sample is not lining up level with the lever plank, rotate the sample.

The lever plank must be level when you start the test. If your sample is not tall enough, set it on a piece of wood or shingle (photo 4).

Add Weight

Hang an empty bucket on the notch. Add water slowly. Don't let the lever bounce. Fill a gallon/ 4 liter container full and use it to pour. Write how many gallons/ liters crushed the sample.

When Is It Crushed?

Some soils pulverize. Stronger ones may crack in pieces but still stand up (see photo 5).

Add just a little more weight until the sample loses its shape (see photo 6).

RESULTS

Choose the table below that matches your measuring container. For the size of your samples, find out how much water is needed to crush different strengths of soil with a 1:6 lever.

For strong soil when the hanging bucket is full, add a smaller bucket on top of the lever board centered over the notch. Have a helper touch the sides of the small bucket to keep it from falling off. Slowly add more water to the upper bucket and add up how many total gallons or liters.

TABLE 1: METRIC WATER VOLUME/ Toilet Paper Tube Crush				
	Sample diameter			
Soil Strength	39- 39.9 mm	40- 40.9 mm	41- 41.9 mm	42- 43 mm
Minimum: NZ Code Standard 1,3 MPa	13,7 liters	14,7 liters	15,6 liters	16,1 liters
Medium: Average for NZ Code Special 1,8 MPa	17,3 liters	18,4 liters	19 liters	20,5 liters
Strong: Minimum for NM code 2,1 MPa	22,7 liters	23,7 liters	25,1 liters	26,5 liters

TABLE 2: US WATER VOLUME/ Toilet Paper Tube Crush				
	Sample diameter			
Soil Strength	39- 39.9 mm	40- 40.9 mm	41- 41.9 mm	42- 43 mm
Minimum: NZ Code Standard 190 psi	3 gallons, 2.5 qts	3 gallons, 3.5 qts	4 gallons, 0.5 qt	4 gallons, 1 qt
Medium: Average for NZ Code Special 260 psi	5 gallons, 0.5 qts	5 gallons, 1.5 qt	5 gallons, 3 qt	6 gallons
Strong: Minimum for NM code 300 psi	6 gallons	6 gallons, 1 quart	6 gallons, 2.5 qt	7 gallons

TABLE 3: IMPERIAL WATER VOLUME/ Toilet Paper Tube Crush				
	Sample diameter			
Soil Strength	39- 39.9 mm	40- 40.9 mm	41- 41.9 mm	42- 43 mm
Minimum: NZ Code Standard 190 psi	3 gallons	3 gallons, 1 qt.	3 gallons, 1.5 qt	3 gallons, 2 qt
Medium: Average for NZ Code Special 260 psi	4 gallons, 1 qt	4 gallons, 2 qt	4 gallons, 3 qt	5 gallons
Strong: Minimum for NM code 300 psi	5 gallons	5 gallons, 1 qt	5 gallons, 2 qts	5 gallons, 3 qt

More detailed tables are on pages 20- 22 if you want to know the exact strengths in between these standard strengths.

RESULTS (CONTINUED)

Use this chart to record results and figure out your average soil strength.

Soil Strength from TP Tube Crushing Test			
Which measuring system? US gallons _____ Imperial gallons _____ Metric liters_____			
Sample Number	Sample Diameter in mm	How Many Gallons or Liters to Crush?	Use Table 1, 2 or 3 to see which strength level each soil sample reached or passed: Minimum/ Medium/ or Strong?
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Cross out the sample that tested the weakest.			
AVERAGE Add all the rest gallons*/ liters			Divide total by number of test samples added up:
Check Table 1, 2, or 3 for your average strength:			
· Remember there are 4 quarts in a gallon. It is easier to add gallons and quarts when you use fractions. 1 quart = 0.25 gallon, 2 = 0.5 gal., 3= 0.75 gal.			

Shrink Test

For Expansion

Needed:

Handful of soil
A 10 cm x 10 cm square of metal or plastic
A little oil

Process:

Pick gravel out of soil
Rub a little oil on your square
Spread damp soil on the metal or plastic square and dry

When Should You Test for Expansion?

Don't test very gritty soil this way. If you are not sure, wet a little soil until it is runny. Rub a tiny bit between your thumb and finger (see photo 1). If it feels like salt, you do not need to test. If it feels smooth, or like flour, you might need to test.

Take a larger pinch of damp soil between your thumb and finger. Pinch and open. If a lump sticks to your finger, this soil has a lot of clay (see photo 2). You should do this test.

If the soil mostly stays on your thumb, it has more silt than clay (see photo 3). You do not need to do this test.

Making the Sample

Remove gravel 1/8"/ 3 mm or larger. Wet soil well. Soak for hours if needed. Mix soil well.

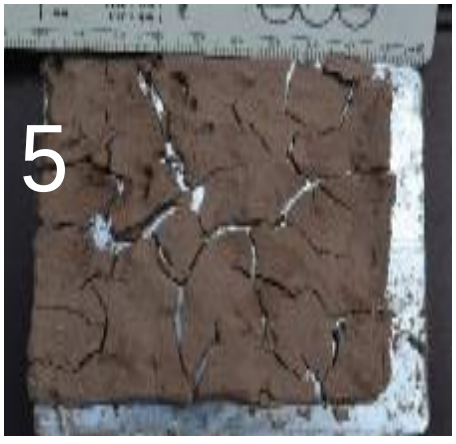
Oil your form. Spread soil 1 cm thick (photo 4). Dry.

Check for Shrinking

If the sample cracks, push the cracked pieces together. Push the soil so it lines up on two sides with the edges of the form (see photo 5).

If 3 mm of the form shows on two sides, the soil shrinks 5%.

If more shows, this might shrink enough to damage contained earth walls. Adding some sand or less sticky soil can reduce shrinking. Measure a new soil mix and try again.



PART III: INFORMATION FOR DESIGNERS

3 HOW STRONG SHOULD SOIL BE?

In risky areas, building soil should be as strong as possible. The plans should also be carefully checked for strength.

Get a rough idea of the risk level in any country with the GSHAP maps online. Or use more up-to-date local maps.

Right: Details of the year 2000 global GSHAP map (Global Seismic Hazard Assessment Program).

The low risk areas, where unreinforced earth is safe, appear white and light green in these maps. Dark green is moderate risk. More risky areas appear yellow and orange while high risk is reds to brown or black.

Earth Building Codes: New Mexico

In New Mexico, US, quake risk is mostly in the low range. The earth building code (NM RLD) is very simple. Adobe or rammed earth buildings keep openings away from each other and corners, and use very strong soil.

Earth Building Codes: New Zealand

New Zealand (southeast of Australia) has many earth buildings and strong earthquakes.

The NZ code requires certain footings, bond beams and lintels, and checks plans to be sure that heavy earthen walls have enough bracing. Following this code, adobe and rammed earth buildings can be safe without reinforcement up to 0.58 g force levels (Miller), the middle of the dark green areas on the maps. Conventional earthbag should be safe in this area also, with standard strength soil.

New Zealand allows reinforced adobe and rammed earth in higher risk areas. In areas shown yellow or red, use stronger soils and the best reinforcement you can afford. Always have a professional check your plan for safety.

Engineers and building designers can use the NZ codes to check plan safety for reinforced and unreinforced buildings. BSI will be publishing comparison information about contained earth strength early in 2017. Some types and soil strengths of contained earth walls proved as strong or stronger than the adobe walls tested for the NZ code (Stouter 2017). But *THE AMOUNT AND TYPE OF REINFORCEMENT ARE CRITICAL.*

SOIL STRENGTHS:
STANDARD/ NEW ZEALAND: 188 PSI/ 1,3 MPA
SPECIAL/ NEW ZEALAND: 260 PSI/ 1,8 MPA
STRONGER/ NEW MEXICO: 300 PSI/ 2,1 MPA

4 Quicker Tests

Unit Drop Test: Curing

Remove the bag after two days to speed curing (see photo 1). When it feels firm, lean the sample up on its side.

Place samples near a heat source to cure more quickly, like a furnace or a bake-oven. Aim a fan at them.

After four days in shade, samples can be cured under glass in a cool, sunny climate but only if air blows past them. A hot but enclosed area will actually slow curing. Samples that are not fully cured will not show actual strength (Minke 28).

Bake in an oven or kiln. Place bricks or stones under the center of the rack so it does not sag. The temperature should stay below 300° F/ 150° C.

The surface of samples begins to rise above the boiling temperature of water as moisture inside is lost. This can take 6 or more hours for a partly dry large sample. An infrared thermometer (contractor's heat gun to test radiant heat) will give some indication of the curing process, but the interior may not be fully cured when the surface begins to heat up.

Unit Drop Test: Testing

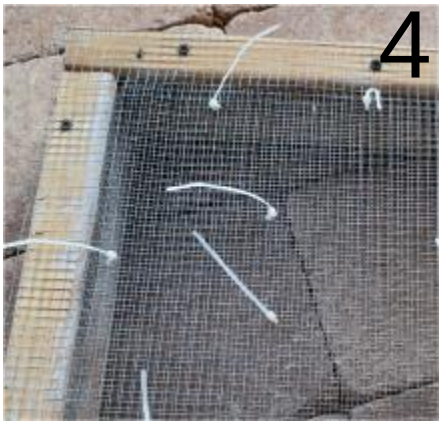
Place a pin on your tester's clothing at the height from the ground to lift the sample. A second person crouches in front and tells the tester when the sample is high enough.

Ball Crush Test: Preparing Soil

Using a sieve to remove the aggregate is quicker than picking it out by hand. But kitchen sieves and most window screen are too fine. They remove the coarse sand particles and will change the test results.

Someone who tests a lot of soil may want to buy a gold sifting tool classifier pan with 1/8"/ 3 mm screen (see photo 3).

Another option Is to overlap two ¼" mesh screens and fasten them securely to a frame. Tie the two layers together with wire or zip ties at many points (see photo 4). Some stones will still stick in between the mesh.



Dry soil must be completely dry to sift, and completely crushed.

With strong soil it is hard to break the smaller soil particles off of the aggregate. Sifting soil with clay attached to the aggregate will remove a lot of your clay and give you false results. For strong soil always sift soil after dissolving in water. After sifting, shake off the screen very well. Spread out your very wet soil in the sun or a hot place to dry. Don't try to make samples while it is too soft.

Ball Crush or TP Tube Crush Test: Curing

Weigh small samples to be sure they are ready to test. Weigh them after every hour in the oven. Weigh them one at a time, or weigh the whole batch together on a small postal or kitchen scale (see photo 1).

Earth gets lighter as it cures. If the weight doesn't go down after an hour in the oven, they are fully cured.

Store small samples in an egg carton. Be sure to label any different batches. You can write on the cardboard or directly on the soil with a marker.

TP Tube Crush Test: Preparing Soil

A 1/4"/ 6 mm wire mesh screen will quickly remove aggregate.

But dry soil must be completely dry to sift. For strong clay soils with aggregate, sift soil dissolved in water. Shake all the clay off the screen onto your soil carefully. Let the soil dry a day before making samples.

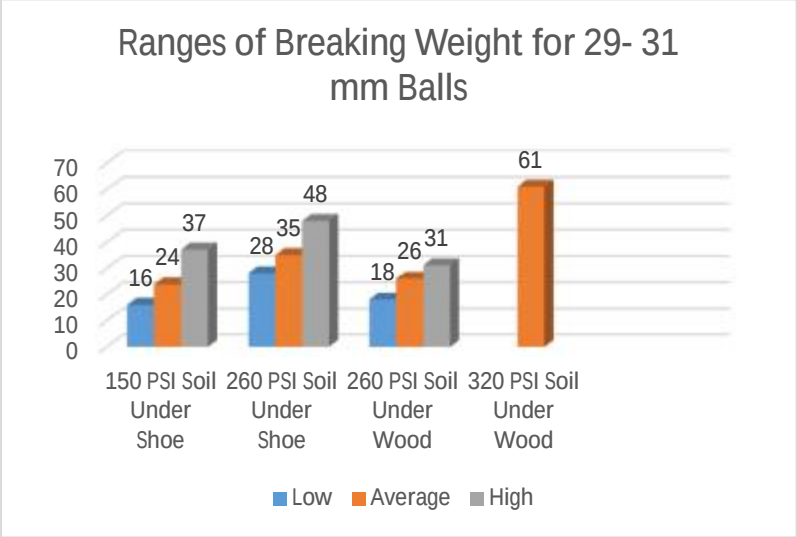
TP Tube Crush Test: Testing

Use seven bottles that are 1 gallon or 4 L size. Mark each one to show what level is completely full. Also mark the separate quarts or liters on the side of the bottles.

Fill them all with water before you start testing each sample. When the sample is crushed, count how many gallons and quarts/ liters are left. You will not have to measure the water in the bucket (see photo 2).

5 More Accurate Tests

Soil purchased at different times or dug from different locations may be very different. At least test samples mixed from different parts of the soil piles or dig areas.



Why So Many Samples?

Small samples and simple tests don't give you exact results. Although building soils have a natural variation in strength, small samples vary even more in strength than full-size samples.

If you only test one or two samples you don't know if your sample is a stronger than usual weak soil ball or a weaker than usual medium soil ball. By testing many samples and finding the average strength, you get a better glimpse of how strong the soil may be in a full-size wall.

Ball Crush Test: Making Samples

To make balls just the right size, try this BSI technique:

Use a bottle cap that holds about 2.5 teaspoons/ 12 mL. First just make one ball:

Lay a piece of plastic bag in the cap. Fill the cap firmly with soil. Scrape it off level (see upper photo at left).

Turn the cap over on a baking tray. Hold the plastic and lift the cap off (see middle photo).

Then peel the plastic off your lump of soil. In a few minutes, gently roll it. What size is the ball?

If this makes a ball between 29 and 31 mm use it. If not get another cap and retest. When you have one that gives you the right size, make them all at once.

Make lumps of soil using the caps (see bottom photo at left).

If the little lumps all have the same amount of soil, they will roll into the same size balls. Let them rest 5 minutes, then squeeze gently, roll into balls and place on a piece of metal to dry.

If your soil feels gritty when you roll the balls and tends to crack slightly, gently squeeze the balls as you shape them. This soil may be a little stronger when tamped in a normal size unit than these small ball tests will show. If a gritty soil tests lower than you expect, retest with TP tube samples.

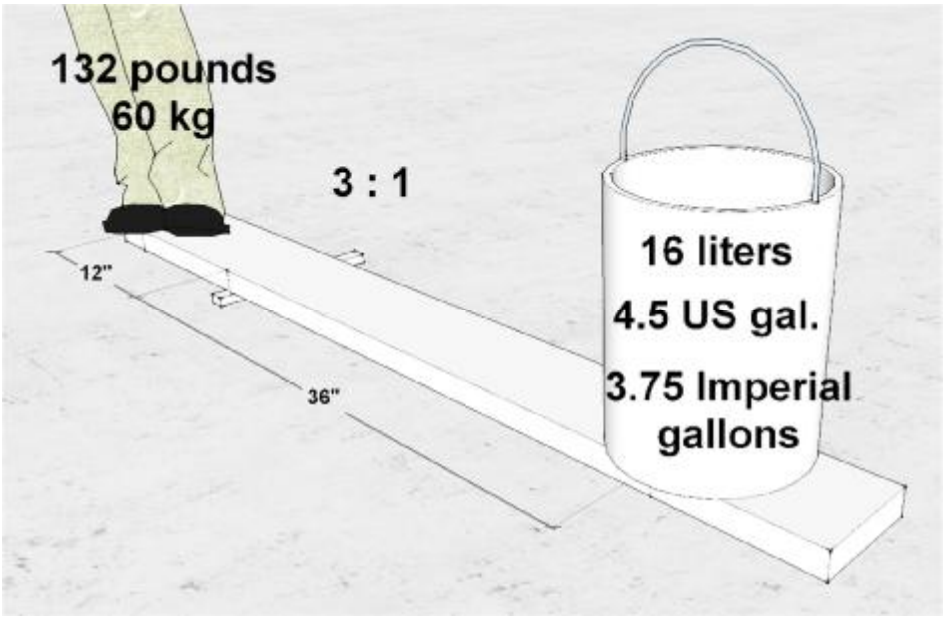
Bucket Weights

A liter of water weighs 1 kg. A US quart of water weighs a little less than 2.1 pounds. An Imperial quart of water weighs about 2.5 pounds.

In any tests where a 5 or 6 gallon/ 19 or 23 L bucket is placed on or hung from the lever, it should weigh 2 pounds/ 0,91 kg. A small bucket should weigh 1 pound/ 0.45 kg. If your buckets are lighter, add that much more weight. If they are heavier, add less water.

Ball Crush Test:

Testing



Check your tester's weight. If they cannot visit a doctor's office or a business with a shipping scale, use a lever. You need a strong board that is 5'/ 1,2 m long.

Fasten a pipe or a thin strip of wood 15"/ 380 mm from one end of the board. Mark 12"/ 300 mm from that pipe near one end, and 36"/ 900 mm from the pipe near the other end.

The tester stands on the 12" mark on the short side of the board. Place a bucket of water centered over the 36" mark.

If the tester weighs 132 pounds, the bucket will tip the board level when it holds 4 US gallons and 2 quarts, or 3 Imperial gallons and 3 quarts. If the tester weights 60 kg, the board will lift the tester when the bucket holds a little more than 16 liters.

Know exactly how big your balls are. Print a circle template and write exactly how large each circle is to the outside edge. Place your ball on one circle. If much hangs over past the circle edge, the ball is bigger than that circle. Try it on a bigger circle.

Go slow on the first test! The first test in a series you have no idea how much weight is needed.

TP Tube Crush Test: Testing

If you fill the bucket and the sample is not broken, add a heavy block hanging next to or under your bucket. This is easier than adding a bucket on top (see photo at left).

Then start pouring water slowly into the bucket again.

But you must find out how many liters or quarts are equal to the weight of the block.

For best accuracy, figure out the crushing strength of each sample, and then add them together to find out the average strength (copy the table below).

Average Soil Compressive Strength from TP Tube Crushing Test				
Sample Number	Sample Diameter in mm	How Many Gallons or Liters to Crush?	Compressive Strength from Table 4, 5, or 6 (next page)	Comments
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Circle the lowest strength, then add all the other strengths together:				Note: this size sample with most of its gravel sometimes fails too soon. Don't count the weakest sample.
Divide this by the number of samples added in:				
Average soil strength =				

Use the information in Tables 4, 5 or 6 to figure out strengths of each of your fist-sized sample tests. But don't forget to figure out the average of them all!

TABLE 4: APPROXIMATE COMPRESSIVE STRENGTH OF TP TUBE SAMPLES
Metric Water Volumes with a 1:6 Lever

39- 39.9 mm			40- 40.9 mm			41- 41.9 mm			42- 43 mm	
Crushes at	MPa		Crushes at	MPa		Crushes at	MPa		Crushes at	MPa
9 L =	1,06		9 L =	1,01		9 L =	0,96		9 L =	0,91
10 L =	1,15		10 L =	1,09		10 L =	1,04		10 L =	0,99
11 L =	1,23		11 L =	1,17		11 L =	1,12		11 L =	1,07
12 L =	1,32		12 L =	1,26		12 L =	1,20		12 L =	1,14
13 L =	1,41		13 L =	1,34		13 L =	1,28		13 L =	1,22
14 L =	1,50		14 L =	1,43		14 L =	1,36		14 L =	1,29
15 L =	1,59		15 L =	1,51		15 L =	1,44		15 L =	1,37
16 L =	1,67		16 L =	1,59		16 L =	1,52		16 L =	1,45
17 L =	1,76		17 L =	1,68		17 L =	1,60		17 L =	1,52
18 L =	1,85		18 L =	1,76		18 L =	1,68		18 L =	1,60
19 L =	1,94		19 L =	1,84		19 L =	1,76		19 L =	1,67
20 L =	2,03		20 L =	1,93		20 L =	1,84		20 L =	1,75
21 L =	2,12		21 L =	2,01		21 L =	1,92		21 L =	1,83
22 L =	2,20		22 L =	2,10		22 L =	2,00		22 L =	1,90
23 L =	2,29		23 L =	2,18		23 L =	2,08		23 L =	1,98
						24 L =	2,16		24 L =	2,06
									25 L =	2,13

TABLE 5: APPROXIMATE COMPRESSIVE STRENGTH OF TP TUBE SAMPLES
US Water Volumes with a 1:6 Lever

39- 39.9 mm		40- 40.9 mm		41- 41.9 mm		42- 43 mm	
Crushes at	PSI	Crushes at	PSI	Crushes at	PSI	Crushes at	PSI
2 g, 2 qt =	136	2 g, 2 qt =	129	2 g, 2 qt =	123	2 g, 2 qt =	117
2 g, 3 qt =	148	2 g, 3 qt =	140	2 g, 3 qt =	134	2 g, 3 qt =	127
3 g =	159	3 g =	151	3 g =	144	3 g =	138
3 g, 1 qt =	171	3 g, 1 qt =	163	3 g, 1 qt =	155	3 g, 1 qt =	148
3 g, 2 qt =	183	3 g, 2 qt =	174	3 g, 2 qt =	166	3 g, 2 qt =	158
3 g, 3 qt =	195	3 g, 3 qt =	185	3 g, 3 qt =	176	3 g, 3 qt =	168
4 g =	207	4 g =	197	4 g =	187	4 g =	179
4 g, 1 qt =	219	4 g, 1 qt =	208	4 g, 1 qt =	198	4 g, 1 qt =	189
4 g, 2 qt =	231	4 g, 2 qt =	219	4 g, 2 qt =	209	4 g, 2 qt =	199
4 g, 3 qt =	243	4 g, 3 qt =	230	4 g, 3 qt =	219	4 g, 3 qt =	209
5 g =	254	5 g =	242	5 g =	230	5 g =	220
5 g, 1 qt =	266	5 g, 1 qt =	253	5 g, 1 qt =	241	5 g, 1 qt =	230
5 g, 2 qt =	278	5 g, 2 qt =	264	5 g, 2 qt =	252	5 g, 2 qt =	240
5 g, 3 qt =	290	5 g, 3 qt =	275	5 g, 3 qt =	262	5 g, 3 qt =	250
6 g =	302	6 g =	287	6 g =	273	6 g =	261
		6 g, 1 qt =	298	6 g, 1 qt =	284	6 g, 1 qt =	271
				6 g, 2 qt =	295	6 g, 2 qt =	281
				6 g, 3 qt =	305	6 g, 3 qt =	291
						7 g =	302

TABLE 6: APPROXIMATE COMPRESSIVE STRENGTH OF TP TUBE SAMPLES
Imperial Water Volumes with a 1:6 Lever

39- 39.9 mm			40- 40.9 mm			41- 41.9 mm			42- 43 mm	
Crushes at	PSI		Crushes at	PSI		Crushes at	PSI		Crushes at	PSI
2 gallons =	131		2 gallons =	124		2 gallons =	118		2 gallons =	113
2 g, 1 qt =	145		2 g, 1 qt =	138		2 g, 1 qt =	131		2 g, 1 qt =	125
2 g, 2 qt =	159		2 g, 2 qt =	151		2 g, 2 qt =	144		2 g, 2 qt =	137
2 g, 3 qt =	173		2 g, 3 qt =	165		2 g, 3 qt =	157		2 g, 3 qt =	150
3 g =	188		3 g =	178		3 g =	170		3 g =	162
3 g, 1 qt =	202		3 g, 1 qt =	192		3 g, 1 qt =	183		3 g, 1 qt =	174
3 g, 2 qt =	216		3 g, 2 qt =	208		3 g, 2 qt =	195		3 g, 2 qt =	187
3 g, 3 qt =	230		3 g, 3 qt =	219		3 g, 3 qt =	208		3 g, 3 qt =	199
4 g =	244		4 g =	232		4 g =	221		4 g =	211
4 g, 1 qt =	259		4 g, 1 qt =	246		4 g, 1 qt =	234		4 g, 1 qt =	223
4 g, 2 qt =	273		4 g, 2 qt =	259		4 g, 2 qt =	247		4 g, 2 qt =	236
4 g, 3 qt =	287		4 g, 3 qt =	273		4 g, 3 qt =	260		4 g, 3 qt =	248
5 g =	301		5 g =	286		5 g =	273		5 g =	260
			5 g, 1 qt =	300		5 g, 1 qt =	285		5 g, 1 qt =	272
						5 g, 2 qt =	298		5 g, 2 qt =	285
						5 g, 3 qt =	311		5 g, 3 qt =	297
									6 g =	309

6 Other Ways to Make Levers

A lever multiplies force. This is very useful for testing.

Right: simple lever for small samples

A lever fastened with screws or nails is very simple, but will have limited strength.

Hinge Lever

You can also make a lever with a metal hinge. Find a location that is out of the way. It is safer to locate a lever next to a wall than to keep the lever board tied up (since it might drop by accident).

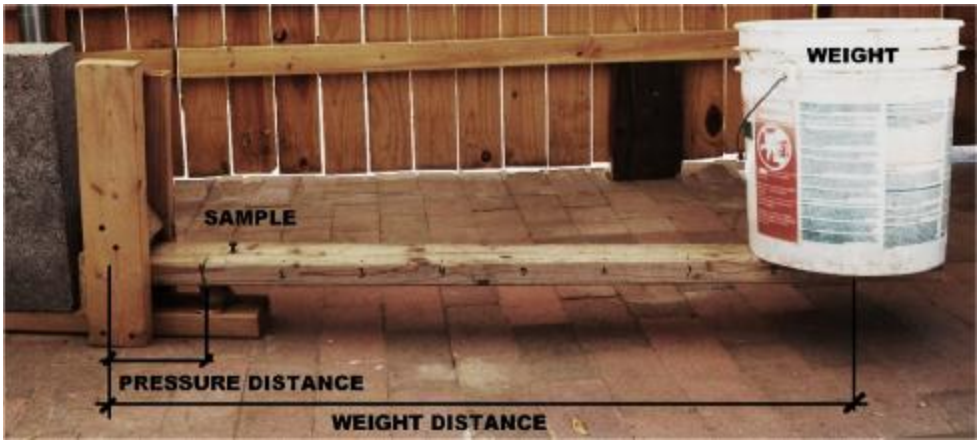
Attach a strong shelf bracket to a post at a convenient height. Leave room for your test samples, and a half- ¾"/ 12- 19 mm spacer block. Attach the hinge to the post and to the lever board with strong screws.

Left: a Hinge lever screwed to a post

Using a Lever

Always make sure the lever board itself is a strong piece of wood. It should hold the full weight needed without bending much. A small pressure distance allows a shorter lever, which will bend less.

The sample being tested is always centered at the pressure distance. When you put weight further away than the pressure point, the lever multiplies the effect of the weight.



If your weight distance is 6 times as long as your pressure distance, the

force on the sample will be 6 x the weight. The total weight for your test includes weight you place on the lever board- and *HALF THE WEIGHT OF THE LEVER BOARD*.

The weight of the lever board has already been added into all the tables you use to calculate your results. We assumed it would weigh about 6 pounds/ 2.7 kg. If it is much heavier, divide the weight by 2. Then add enough less water weight to be equal to a 3 pound force on the lever. If it is much lighter, keep a separate weight on top of the board to equal the 3 pounds that we assumed would be pressing on the sample from the lever board.

An end support is always helpful, but leave an air gap on top of it. If your board bends with higher weight, keep removing bricks so that there is still a small gap. The end support keeps the weight from falling off the lever board when your sample fails.

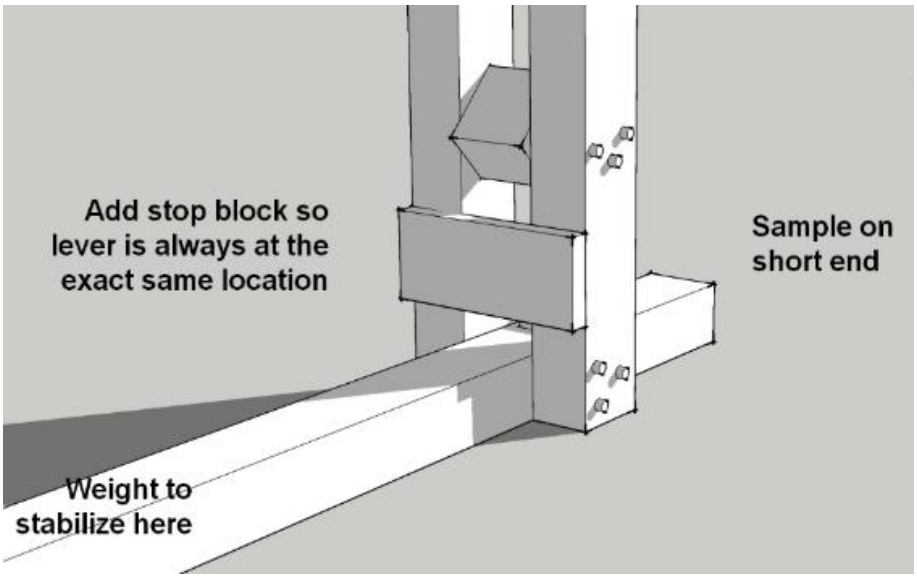
NEVER PLACE YOUR FINGERS UNDER THE LEVER NEAR THE END SUPPORT.

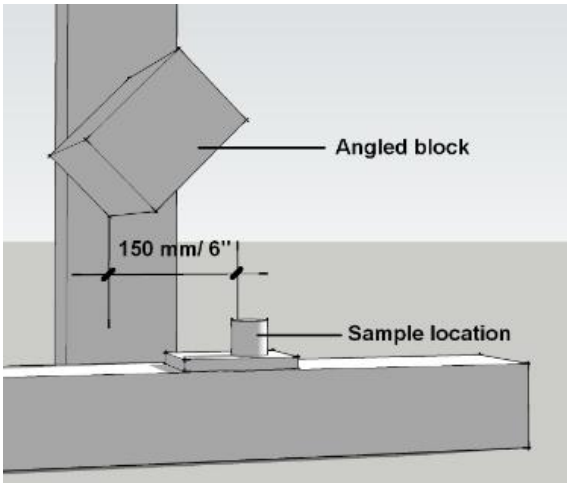
LOOSE LEVER BOARD

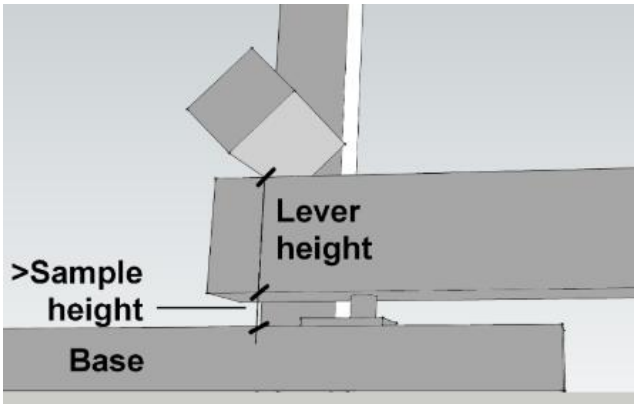
A small lever can also be made out of only scrap wood by a careful builder.

To build a lever without a hinge, fasten an angled block between two upright boards. Make sure it is high enough that your sample and the lever board will both fit under the angled block.

The next page shows photos of a simple wood and nails lever.







Above: Frame with weight and sample; Above right: back of frame with stop block; Below: Lever board in the frame with weight in the bucket

LEVER TEST RESULTS

This test is adapted from instructions for tensile tests in the New Zealand Standards (SNZ 4298 p 68).

Lever Multiplier = Weight Distance/ Pressure Distance

For a 6" WD and a 36" PD: 36/6 = 6.

Add half the lever weight to your bucket and/ or block or person weight.

Force is the total weight x the Lever Multiplier.

$$\text{Crushing pressure} = \frac{\text{force}}{\text{area of the sample}}$$

Compressive strength = Pressure x 1.8 (approximately)

7 More Info About Soils, Soil Tests, and Earth Building

Engineers will want to read the companion booklet, Information About Field Soil Tests, online at BSI's Soil Test information page.

BSI has a series of soil testing instructions that will be changed during 2017 to include these new field tests. The slide shows include more information on the characteristics of different soils. Check them out online at http://buildsimple.org/soil-tests.php.

Always check BSI's resources page for the latest test results and related guidelines at http://buildsimple.org/resource-lists.php. Developing voluntary guidelines is a long process.

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