

Roadworks

by Harris Hyman, P.E.

Ladies and gentlemen, start your pickups and drive across that open construction site. Sinking in mud up to the axles? Harsh! Time to build a road. But how?

The Physics of Mud

When you push on wet soil with sufficient stress — and it doesn't have to be much — the soil squirts out of the way. This is what happens with your trucks on a muddy job site (not that you ever actually do it): The wheels press on the wet soil, the mud pushes out of the way, and down you go.

The stress level needed to displace mud is about 500 pounds per square foot. The footprint of a truck tire is about 8 x 14 inches, and the loaded truck weighs about 4,000 pounds. Distributed between four tires, this gives a stress of: 8.93 lb. per sq. in., or 1,286 lb. per sq. ft. This is easily enough stress to move the soil.

Gravel to the Rescue

A "road" is no more than a device to spread out these wheel loads onto more surface. Since the load is on a larger area, the stress goes down. The vehicle stays on top, without sinking in.

The simplest way to make a road is to lay down 8 inches of gravel. The gravel should be compacted, packed tight to increase the density. This is often done with the crawler that is used to spread the gravel along the roadway. The crawler is run back and forth a few times over the "lift" or layer of gravel until the gravel tightens up.

The 1,000-pound load from each wheel of our truck sits on the top surface of the gravel, but the load spreads out through the gravel at about a 45-degree angle, as in the sketch. The bottom surface of the gravel presses on the

soil, but because of the 45-degree spread angle, this surface is 24x30 inches, much larger than the footprint of the tire. This larger surface places a stress of only 200 pounds per square foot, far below the squishing threshold (soil strength) of the ground.

There is a secondary positive effect of placing gravel, and that is to dry out the soil below. The gravel covers the soft subsoil and carries the surface runoff away. The subsoil is now dryer and somewhat stronger than the water-logged surface would be. So our road will take on slightly heavier vehicles than a light truck, and we're in paradise.

Making It Last

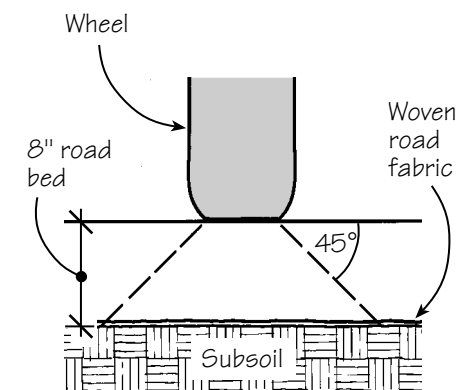
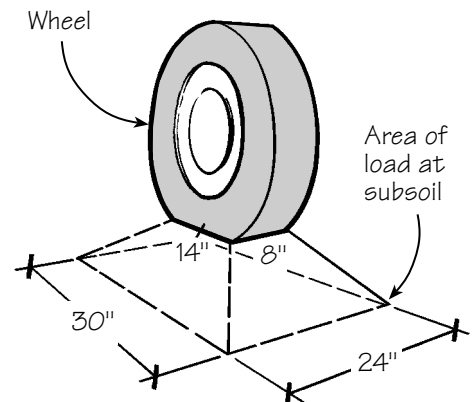
Well, almost. Even with the lighter loading, after a while traffic will push the lower layer of rocks in the gravel pad into the soft soil, particularly at the edges where the wheels track. In a couple of years the road is a mess. We need to do something to give the road some longevity.

The first thing is to create a denser roadbed so that individual stones do not feel the wheel loads. This is done by preparing a gravel mix consisting of large (2-inch) stones, smaller stones (3/4-inch), and "fines" — particles smaller than 1/64 inch (or (0.00004 microns).

The sketches on the next page might help give an intuitive idea of the compaction of a gravel mix. In the top sketch, there is a void among the circles, representing stones of a consistent size, that cannot be filled. The second sketch shows smaller circles in the voids, a far denser mix. This is the classic Macadam road, where a top layer of fine gravel is placed on the base layer of coarse gravel, and the fines are swept or washed into the larger stones of the base.

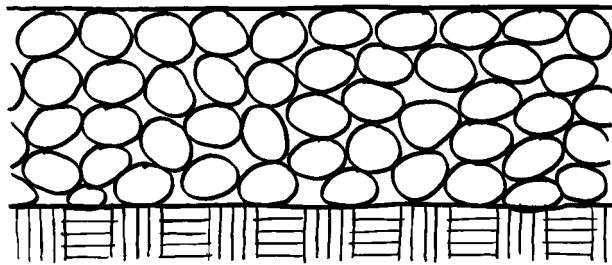
Then we get to the next problem, of the hard stones slipping against one another. There is no grip and the vehicle tires just toss the stones away. A proper mix of stone sizes helps to control this slipping, but often we have to add something to our mix to bind it together. This is usually a pulverized clay or sometimes even organic topsoil, maybe a cubic yard to each 4 yards of gravel.

Spreading the Load

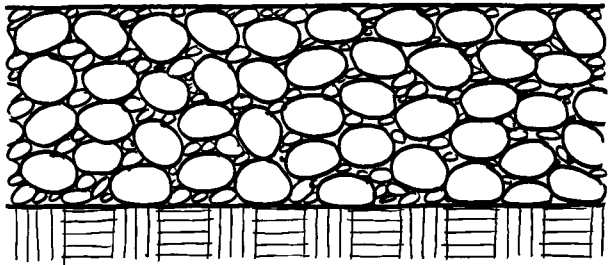


A road bed spreads the load from a tire over a larger surface area, reducing the stress on the subsoil.

Road Mix



Equal-sized stones



Mixed stones

A road bed made from stones of equal size will shift under the weight of vehicles. A dense mix of stones of different sizes and fines will compact under load.

Asphalt Topping

A road of this type starts to be longer lasting, both from its own strength and from the waterproofing it provides the subsoil. If we really want the road to last, a blacktop surface is added, placed hot by a specialized machine. This blacktop is bitumenized concrete, a mixture of asphalt and small stones, 1/2-inch or smaller. Here in the west we call it AC — asphaltic concrete. The AC for a residential driveway is typically a single lift 1 1/2 to 2 1/2 inches thick.

The AC becomes a hard, solid mass that spreads the load out somewhat better than the base gravel, so less material is needed for the job. However, AC costs about five times as much as gravel. The two materials are often balanced off against one another — more AC calls for less gravel. For a residential driveway, about 2 inches AC on 4 inches of gravel works well. For low traffic drives, a workable surface is 2 inches AC on 8 inches of gravel. Neighborhood streets (at least in my working area of Portland, Ore.) are paved with two 2-inch lifts of

AC on 8 to 12 inches of gravel.

When AC isn't in the budget, roads are often topped with 2 to 4 inches of a mix called "three-quarter-minus": 3/4-inch stones, fine stones, and a small amount of clay or organic topsoil for a binder. In thin lifts, this can be packed well with a crawler.

These suggestions are suitable for driveways in most areas of the country, on a variety of subsoils. Special consideration for drainage must be given to roads in areas of extremely cold temperatures to avoid frost heaving. In the desert, with almost no rainfall, the ground is packed hard and much of this is unnecessary. On collector roads and minor highways, the engineering becomes more significant, where subsurface soils are carefully evaluated and pavement design follows a careful technology.

Road Fabrics

About ten years ago, geotextile fabrics came into fairly wide use, first for airports and highways, but increasingly for small roads and driveways.

Conceptually, it's pretty simple: Throw a blanket on the ground and pile the road base gravel on top of it. The tension in the fabric spreads any loads on the surface over a wide area. Plus, it becomes impossible to push the rocks on the bottom layer into the mud, because they are restrained by the fabric.

Early problems tended to be with the chemistry of the fabric, which needs to be strong and non-deteriorating. These problems have been solved by the manufacturers, Contech (800/338-1122) and Mirafi (888/795-0808) among them. A layer of woven geotextile is now used on most projects, because of the increased strength of the road, allowable reduction in gravel, and low cost. The most widely used product in my area is a 20-mil woven polypropylene (6 oz. per square yard) costing about 66¢ per square yard.

This fabric really does a great job. With the blessing of the county and the Corps of Engineers, a geotech I work with has even put roads across wetlands. These roads had one layer of fabric directly on the native soil, 6 inches of 3-inch screen gravel, another layer of fabric, and a 6-inch mixed gravel surface. This technique was far more economical than the traditional excavation of 3 to 4 feet of muck to be filled with gravel. It was also attractive to the county environmental authorities because it avoided the dam which would have been created by the deep gravel fill, and allowed the wetland to continue to flow. It's been in about three years and still looks good.

If you're laying down gravel drives over soil that gets wet for part of the year, fabric will save the owner money in the long run. Try it.



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