CORDUROY ROADS

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Introduction

Corduroy is a process where slash or logs are used to cover over soft ground to increase the load bearing capacity. Although the road may only be used for a short period of time they can remain a servicable road for many years.

By using corduroy for road or landing construction on weak soils the roading engineer can have a road which can be used immediately after construction, does not require specialist techniques, and the builder can be confident that gross road failure is unlikely.

The expense of corduroying varies and is dependent on two main factors. The first one being the cost of the corduroy itself; if the raw material used is not waste, then the cost could be high. The second factor is the amount of aggregate which is used. Aggregate depth is reduced because the load is distributed over a larger area by the corduroy and the aggregate is used to create a running surface over the corduroy.

Corduroying as a method of road construction still has a place in modern roading practice as it provides the forest manager with another stabilisation option which, in many cases, can be applied to a multitude of problem areas and is not limited by soil types, weather, or consolidation time.

This method of building roads with corduroy or fascine material has been around for longer than many people care to remember. As early as commercial logging of the indigenous forest began in New Zealand, the problems of mixing weak soils and water have plagued the roading engineer. The West Coast of the South Island has been using this technique for years and still use it today to cross flat poorly drained Pakihi swamps. In Southland corduroy continues to be used to strengthen skid sites and roadways in poor strength clay soils, much the same as the East Coast of the North Island.

In Indonesia and other countries in South East Asia, the use of corduroy road construction has been common. In all areas around the world where this method of road building is used, there are a number of factors in common. Namely, there is a combination of weak soils and water.

Why does it Work?

The overall effect of corduroying is to float the road over any soil of low bearing capacity through the distribution of the vehicle weight over a wide area.

Corduroy is essentially the forerunner to modern geotextiles and as such performs much the same functions. These are:

1. Separation Layer

A layer of slash, branches or logs between a weak subgrade and roading aggregate serves to stop combining of the two and ensures that the load bearing functions of the base course are performed without hinderance from the weaker subgrade. It has always been said that 100mm of good material over 900mm of poor material equals 1000mm of substandard material. It is this effect that the separation layer prevents.

2. Reinforcement

The effect of corduroy laid across the formed carriageway is to carry out a load dispersion function.

On weak soils with less than adequate surfacing, a normal highway loaded front axle can cause shearing of the surfacing material and rutting along with penetration of the gravel into the subgrade.

A loaded logging truck sunk to the axles in a road is no fun but a hauler which has many times the axle loading of a loaded logging truck can cause a little more concern when it's buried to the running boards in your road.

A normal log truck front axle carries approx 5 tonne and with a tyre pressure of 6.2 bar gives a ground pressure of 4.8kg/cm^2 per tyre.

By corduroying the road the same axle on a 20cm diameter piece of pulp can reduce the ground pressure to .5kg/cm^2

3. Improved Drainage

This creates a permeable layer between the running course and the subgrade, which would allow water to move out from under the road. This is especially important in clay soils on the East Coast where springs and seeps of water can occur on the top of ridges, the normal place for roads.

Construction Process

In forest and road construction corduroy is normally used in two scenarios:

1. Where wet swampy ground with deep soils is identified prior to the road construction process.
2. Where construction of roads and landings has occurred and failure is eminent.
3. Where the road is needed urgently.

Indonesia and the West Coast of the South Island have common areas of wet swampy ground which is roaded over.

In Indonesia typically they will cut all the vegetation down, 50 metres on either side of the road, and lay it over the ground where the road is going. This practice is now being discouraged because of environmental reasons. All the merchantable wood is removed and heads, saplings and branches are all tossed onto the roadway without the removal of soil or other vegetation. Trucks then dump roading aggregate onto the vegetation and a small dozer or excavator will spread the material.

On the West Coast, the most use of corduroy is in crossing areas of Pakihi swamp.

If soils are too deep (up to 2m)to remove and back fill and still maintain good drainage, then branches, saplings and heads are combined to make the corduroy mat, then the road aggregate is dumped and spread with a small dozer. There is still a requirement to have 500mm of aggregate over the corduroy to give the required road strength.

In Otago/Southland, Wenita Forests, City Forests and Rayonier NZ all use corduroy as a method to strengthen their skids and roads.

Mostly on skids the corduroy is placed where the tracked excavator runs up and down beside the stacks to give better support. On roads where weak soils have been identified pulp material is typically used to cover the worst parts. Approximately 80 cubic metres of pulp material is used per 100m of roadway. Pulp has been used predominantly because of the lack of a pulp market and utilisation of pulp is seen as the cheapest option to increase the roadway strength.

In effect corduroy material can be saplings and waste, pulp logs or even sawlogs, mill slabs or boards.

In my experience on the East Cost with building and maintaining logging spur roads for all year round harvesting, I only use corduroy as a last resort, with the exception of strengthening skids.

This is due to the disruption to harvesting that occurs if your roads become impassable and the wet winters with sodden clay soils are not conducive to repairing roads.

I have found that a reasonable knowledge of the soil properties is important for the area you are working in.

The two forests which I have personal knowledge of are Patunamu and Wharerata. Both forests soils are very different from each other. Wharerata has a cemented sandstone base with a covering of volcanic ash and then top soil. Typically the volcanic ash is two to three metres deep with a mid winter California Bearing Ratio (CBR) value of 6% which reduces to CBR 3% under a Works Consultancy 4 day soak test. This material does not react with either cement or lime stabilising.

Patunamu is blessed with a light coating of Taupo pumice over volcanic ash typically from the Waimahia and Rotoma eruptions over a siltstone base.

Unfortunately during the eruptions there was very fine material held up in the atmosphere to later drop and be blown into isolated pockets in between the ash.

This fine material is tightly compacted and knitted together in mid summer, so much so that you usually have to rip it with a dozer before cutting it with a blade. In mid winter, this same material has absorbed so much water that you can pick out a handful from a cut batter and have the material dribble out between your fingers.

During road construction this material must be removed and because it is normally in isolated pockets it has to be identified and dealt with as the road is constructed.

Not only is this material found in this situation but at times it has mixed with other ash material. This mixture retains the white ash characteristics of absorbing moisture and if used as a fill, can result in a very wet low strength section of road.

Corduroy of Roads Patunamu

Case Study 1:

December 1992 was exceptionally wet as far as summers go near Wairoa, and a hauler had just made a shift to a landing at the end of a ridge top road.

Previous construction in February 1992 using a dozer to form the road and landings and an excavator to dig 400mm deep water tables for drainage had encountered few problems. The road was hard during the spreading of straight haul river run gravel as a surfacing.

The hauler had moved onto the landing and when the third truck load of logs had gone out, the road was closed due to each truck having to be pushed out by the excavator loader along the level roadway for 200m before getting to solid roadway.

Basically the subgrade had absorbed enough water to give it the consistancy of wet putty. A 6mm rod could be pushed into the centre section of the road up to 600mm deep before taking the weight of a person. The compacted river run gravel had sheared, mixed with the subgrade and could not support the truck.

A cleg hammer reading of the roadway from on top of the metal gave an approximate CBR rating of 2-3%.

Weighing up options of what to do was not difficult. With 1500 tonne of wood on the ground, a 60 tonne hauler at the end of a road which couldn't even carry the weight of a logging truck, the only option was for repairing the road.

Using a shorts trailer from a logging truck we loaded pulp from the landing stockpile and towed the trailer through the mud to start corduroying from the good part of the road back to the landing. The 600mm wide tracks of the loader track rolled the collapsed surface of the road to level it and then placed the logs side by side across the run of the road. They were then track rolled into the mud to try and fill some of the voids. As the logs will take the weight of the truck there won't be much movement of mud upwards after the logs settle.
All stubs and branches were removed flush with the logs.

Straight haul river run gravel was dumped from the good end of the road and spread with a rubber tyred front end loader.

A total of 197m^3 of gravel was used to cover the corduroy, with an average depth of 50-100mm over the logs, and filling voids or voids containing mud.

The end product after 8 hours work was a completely usable road which to repair in any other method would take weeks because of the drying out period.

Breakdown of Costs:

Log Loader	$600
Log Trailer	$360
River Run Gravel	$3169
Front End Loader	$228
Payment to Logging Crew (wood produced)	$2856
Loss of Revenue for pulp	$1302
	$8515

= 10.60/m^2 or $42.00 per lineal metre

Usual road construction cost average around $30 per lineal metre.

Case Study 2:

A road was required to log some minor species for a market which had just developed. Roading was taking place in June, the soils were already saturated and had no chance of drying within a couple of months.

A section of this road, approx 20m length, failed everytime the gravel truck tried to spread the river run. Approximately 56m^3 of river run had already been poured into the weak soils and still the 20m section could not support a loaded gravel truck. Each time the truck drove over the stone the front wheel sank 150-200mm into the gravel. Basically the road would not take logging traffic as it was.

The road was corduroyed with P.taeda from beside the road and 18m^3 of river run spread over the total 20m length and the road was ready to use. The major cost was the opportunity cost of the logs and the 56m^3 of gravel that had already gone in. In this case it was far cheaper to use the logs than continue to pour more gravel into the weak soils.

Breakdown of Costs:

Excavator	$255.00
18m^3 gravel	$166.50
Logs	$1,000.00
Wasted gravel	$518.00
	$1,939.50

= $24.00/m^2 $96.00 per linial metre

Use of Corduroy

Corduroying roads and landings has been the main form of repair to roads I have used. Other methods are totally dependent upon how bad the failure is, but the repair should be started when the first shadow appears in the road rather than wait until total failure occurs.

My goals in road construction have been to construct the road once, and construct it right first time. To not build outside of the construction season, November-April. To assess the time of year we were expected to be using the road - try and gauge the risk of failure and plan accordingly.

Roads can be damaged by a number of reasons which can result in compacted road surfaces opening up, allowing water into the subgrade.

Most common causes were:

1. Tracked or rubber tyred machines driving up and down the road, worst offenders were tracks with grousers and tyres with cleats.

2. Shearing of the road surface, mostly from the road unable to take the weight of tracked haulers.

3. Logging trucks getting stuck on roads and machinery having to be used to push them out.

4. Total failure of sections of the road to carry normal logging traffic flows.

5. Continual work areas such as where the roads enters the landing.

I rarely used corduroy during road construction if it occurred at the correct time of the year. I'd prefer to remove the undesirable material and back fill with good compacted material.

If springs were found in the road I would shape the road to allow the water to run into a deep water table. Then cut manuka (approx 4m high, up to 25cm diameter) and group into 300mm diameter bundles tied with baleing twine. These were then top and tailed across the road and 150mm of gravel spread across it.

So mostly I used corduroy as an emergency method to make a road trafficable immediately where there is adequate drainage of the subgrade. There is no other method I have used which worked as well to repair damaged or heaving roads with wet weak soils, in wet cold conditions.
In Mangatu where sometimes roading across active earthflow is required, corduroying can be a cheap option. Some work undertaken when logging first started there in 1989 used this method and costs of $9 per lineal metre were achieved. These road are still in use today.

Current roading practices there tend to be the same as I have used, with utilizing the best subgrade material available on site and removing those which have poor characteristics.

The benefits of corduroy can only be assessed in what it costs you through the options you have available, such as the costs of leaving wood on the ground; standing down machinery on high gang day costs; other road repair techniques; getting machinery out of impossible areas or using alternative methods.

The disadvantages are normally the costs. If you totally cost the operation out including the opportunity costs of the material, it is quite expensive but by comparing to the costs above can seem insignificant. $10,000 to fix a road is only 2.5 days daily rate for todays hauler crews.

Raw material can be a problem to obtain but most forests have areas planted in minor species which can be utilized, and districts with no pulp market may find that the use of the pulp is the cheapest option.

Corduroying can be used in construction or reconstruction of the road. To know if you should use corduroy or not is a matter of experience with the different options and soil conditions you work with, as well as an assessment as to the size of the job failure. Small sections of road can cost a lot per lineal meter but are a small cost in the overall picture.

In the first instance the standard options should be explored, namely; pour on more rock; dig out and backfill with good material, then resurface with stone; use textiles or geogrids.

Benefits to the Forest Industry

Corduroying as an operation will benefit the users every time. There is little or no chance of failure and the results give an immediately trafficable road. There is no need for specialised equipment or techniques and there is no movement of undesirable material which would otherwise be sidecast and could possibly contribute to sediment movement.

Using corduroy in an emergency will cause minimal disruption to operations, contractors, and truck operators are the one's most impacted when roads fail as invariably trucks end up being pushed or pulled through the collapsed sections of roads or everything is closed down.

The logging contractor can utilize corduroy to support his haulers. With an integral tower, such as the Madill 009, log ends are placed under the foot pad of the tower to give extra support from the compression force of the tower.

Corduroy in the Future

This method of road construction is going to continue to be a tool used for as long as equipment use the ground to support their activities. It will continue to be used more as a repair option during the wettest times of the year in weak strength soil, drained topography and as a construction process in poorly drained, flat topography. It is not a method to take the place of proper forest road construction practice. There may be a place to use it in environmentally sensitive areas where minimum soil disturbance is required. A very light track could be cut, corduroy placed and covered. After us it can be removed.

Weyerhauser in the State of Washington use sawlogs for their corduroy and uplift the wood on completion of their settings.

Alternative Methods

A number of alternative products could be used in road construction. (Takallou etal 1987)

<u>Biogradeable materials:</u>

Bark chips, wood chips and sawdust have been used to stabilize roads built in slide-prone areas. Bark and wood chips are an inexpensive method of construction temporary logging roads.

<u>Chemical stabilisation:</u>

Lime, Portland cement, emulsified asphalts, fly ash, sodium, calcium or magnesium chloride, and lignin sultonate can be used to alter the following soil properties strength, compressibility, premeability, volume stability, plasticity, and durability.

Geotextile and geogrid:

Geotextiles are mainly used in roads to separate the surface or base from poor subgrade. Geogrids which are high-strength polymer structures, stabilize weak soils.

Marginal aggregates:

Marginal aggregates are those that do not meet standard specifications for road use and may require some type of additive or special treatment. The types of marginal aggregates include cinder, pumice, rhyolite, coquina, decomposed sandstone, marginal sand, pit-run gravel, sand-clay shale, baked shale, chert, and marine basalts. Marginal aggregates can be used for logging roads that require a life of approximately 1 to 3 years.

Sand-sealed subgrades:

One application of emulsified asphalt on natural subgrade followed with a sand topping which waterproofs a subgrade soil. Sand-sealed subgrades are most effective in areas that have good subgrade and high-cost rock, but that have a plentiful source of low-cost sand.

Metal mats:

Metal mats are surfaced panels prefabricated from material such as aluminium and steel. The mats come in various panel sizes and can be connected together to form a continuous road surfacing.

Reusable aggregate without geotextile separation:

The recovery and reuse of high-quality aggregate on several projects may lower the construction cost. The reuse of the high-quality aggregate can be most effective for the projects that have high rock cost, short duration of logging, short hauling distances between projects, and projects about equal size. About 70 to 75 percent of the aggregate can be recovered each time for future use. This assumes the roadway has not heaved and subgrade has not mixed with the aggregate.

Membrane-encapsulated soil layer (MESL):

The MESL concept maintains the moisture content of the subgrade soils at a desired level by encapsulating the soil in a waterproof membrance to prevent water infiltration. The MESL should generally be used with fin-grained soils that are susceptible to strength loss if wetted.

Geoweb stabilisation (expandable grids):

Geoweb opens like an egg crate divider into an 8-ft by 20-ft panel. The expanded panels are set in place and the cells are filled with sand. The sand is compacted and the surface is sprayed with a liquid asphalt.

LIMITATIONS OF THE ALTERNATIVE SURFACING SYSTEMS

(Takallou etal 1987)

Potential Surfacing Types	Subgrade Soil Type	Geometrics of the Roadway	Expected Life
Wood and Bark Chip	None	Not recommended on steep grades	1 to 3 years
Chemical Stabilisation	Depends on chemical	None	3 to 5 years chemical
Geotextile and Geogrid Separation	Effective on weak subgrade	None	Same as quality aggregate
Marginal Aggregate	None	None	2 to 3 years
Sand Seal Subgrade	Not on weak subgrades	Not recommended on steep grades or sharp curves	3 years
Metal Mats	Not recommended on very weak soils (CBR 3)	Not recommended on steep grades or sharp curves	31000 tonnes
Reusable Aggregate without Geotextile	Recommended for firmer subgrade	None	Same as quality aggregate
Reusable Aggregate with Geotextile Separation	None	None	Same as quality aggregate
Membrane Encapsulated Soil Layer (MESL)	Works best on organic clay, wet and fine-grained soils	Not recommended on steep grades	Unknown
Geoweb Stabilisation (Expandable Grids)	Works best on weaker sand soils	Not recommended on steep grades	Unknown
Lignin Sulfonate	Clayey sand (SC) to sandy gravel	None	3 to 5 years

As can be seen from the table on limitations the only alternative which can be successfully used on steep grades are:

- chemical stabilisation
- use of geotextiles
- use of aggregate

All of these are best used during road construction at the optimum time of the year.

The use of these systems is variable as a repair option after road failure.

Chemical stabilisation has varied results when conducted in winter with wet subgrade on anything other than the optimum medium to stabilise. It is very expensive and normally requires transportation of specialised equipment onto the site.

Geotextiles is a good system but with a heaving road the geotextile gives no added strength and works only as a separation layer. The amount of aggregate required to cover it is in response to the CBR value of the heaving road.

Use of aggregate on its own can result in huge amounts of material being poured into failed sections with most times poor results. The use of oversize clean stones (greater than 150-200mm diameter) as a base may form a platform to build upon but once again the results are varied.

Use of aggregate on its own during normal construction is the most widely used practice and requires a firm subgrade and gravel thickness in response to the CBR value of the subgrade.

Conclusion

Corduroy on roads is a viable option to repair damaged roads. There is also nothing better then to have constructed the roads correctly in the first instance and consider that to be the cheapest option to the roading engineer.

We will continue to see corduroy used by the forest industry in road construction and if rut depth and compaction on haul tracks in our cutovers becomes a concern then there could be a return to its use in the cutover.

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