

Road Building 101

By Captain Thomas S. Bowers

For Marine Corps combat engineers, road-building missions generally consist of constructing combat roads and trails to enhance the mobility of our forces. This construction involves clearing trees and other obstacles, rough grading the surface, and possibly compacting the surface. Depending on the time available, drainage ditches may be added. By doctrine, road building for Marine combat engineers is not very complex.

This article describes how the Engineer Operations Division constructed Ordnance Point Road at the Marine Corps Air Station, Cherry Point, North Carolina. This project was more than a simple combat road. Because of its location, it had to meet Department of Transportation specifications.

For the sake of simplicity, I break the construction project into seven phases and discuss the techniques used in each. My intent is to highlight how we resolved some of the problems encountered.

Mission and Design

The mission was to construct an 1,800-foot improved-surface road to connect two ammunition supply magazines so that ammunition could be moved within the storage areas without having to exit onto a main road. The completed road required appropriate drainage and erosion-control measures to limit environmental impacts on the surrounding area.

The design called for the first 1,100 feet of the road to be straight and the next 300 feet to include a super-elevated S-curve. Coming out of the banked curve, the last 400 feet would be straight. The curve would be located over the main culvert to help ensure proper drainage. The road was to be a series of cuts and fills. The first 1,100 feet would have cuts from 2 to 6 feet deep, which would provide the fill required to bring the rest of the road up to grade. The only problem we encountered with the design was that it changed many times during construction. The initial time line for this project was three months, but because of all the changes, it took nine months to complete.

Clearing Operations

In the planning phase, clearing the roadway seemed to be a simple task, but many problems surfaced. The area was a dense forest with most of the trees more than 100 feet tall, and their removal was difficult. My first concern was for unit safety. We cleared the area with D7G Dozers and chain saws and used various types of heavy equipment to load and haul timber to the landfill.

About this time, station environmental protection representatives informed us that we were operating in an environmentally sensitive area and could not continue clearing. Even though we had the required permits and were



Marine engineers dig a trench to emplace a 150-foot culvert.

constructing a base-approved project, work was delayed. No endangered species were in the work area, but it was considered environmentally sensitive because of a small stream that ran across the site. From this point on, environmental constraints impacted every phase of the project.

Culvert Emplacement

The most difficult part of the project was emplacing 150 feet of 6-foot-diameter culvert in the 70-foot-wide by 20-foot-deep natural swale. All water in the surrounding area filtered down to this swale and into a stream that ran across the middle of the road. After surveyors staked out the culvert location, we diverted the stream to one side of the swale. The stream was not a problem, but the swale was a mud pit. We tried using both wheeled and tracked equipment to get down the embankments to dig out the culvert trench, but we only succeeded in getting the equipment stuck. Then the S3 Operations Officer, the only Marine in the squadron with road-building experience, suggested building a series of three steps down the embankment to serve as platforms from which the equipment could work.

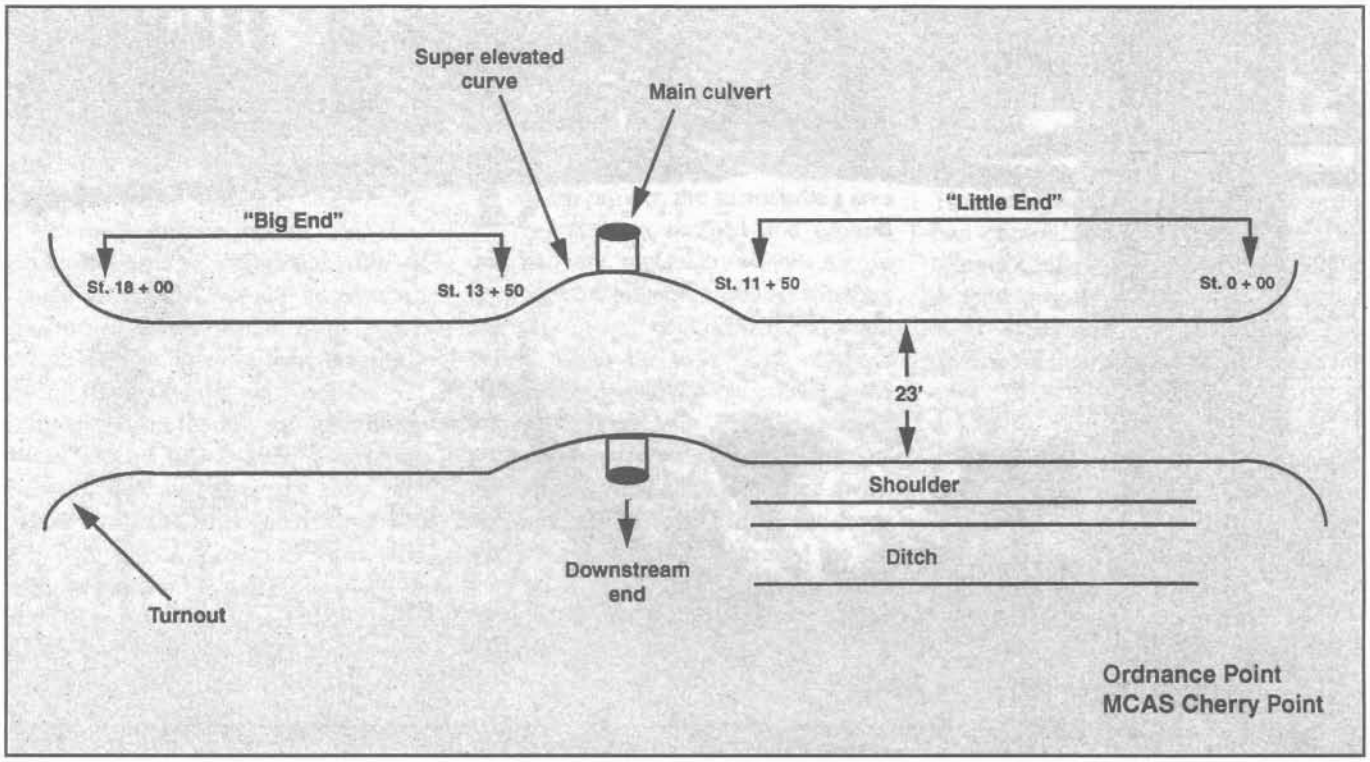
The area was covered with about three feet of muddy topsoil on top of a sand and clay base. As we scraped off the topsoil, subsurface groundwater percolated to the surface and degraded trafficability. Eventually we cut steps into the embankment, but we could not excavate the culvert trench from them because the heavy equipment sank into the mud. We used rolls of fiberglass reinforcing mat, called *Momatting,* from our rapid runway repair kit to stabilize the surface. Covering the steps with the mat allowed the vehicle's weight to spread over a larger area.

An excavator with a ditching bucket was used to dig a trench 150 feet long by 8 feet wide by 4 feet deep. This took about two days because the excavator could dig only a small section before it had to be moved. The culvert's base was a 3-foot bed of gravel, which trucks dumped into the trench and combat engineers spread with shovels. A high-speed, high-mobility crane emplaced each 50-foot section of culvert, and we sealed and bolted them together. To backfill the trench, we emplaced a 1-foot lift of gravel and five 1-foot lifts of suitable fill. Between each lift, we compacted the fill. The operation was slowed because only two mechanical compactors were available. In addition, rain filled the trench with water, which hindered compaction.

Fill for the swale was supposed to come from the first section of the road, but due to inclement weather and poor drainage, none could be generated. There were no stockpiles on the base; however, two runways were being resurfaced on the other side of the base, and the old asphalt was being stockpiled for removal by a contractor. The Environmental Affairs Section determined that we could use the asphalt as fill without adversely impacting the environment.

The five dump trucks in our squadron could not haul enough asphalt to support the backfill operations, so we borrowed trucks from other squadrons. The area around the culvert required 21 feet of fill to bring it up to the required subgrade. Again, each 1-foot lift was emplaced and compacted before the next lift was added. Although this was time consuming, it enhanced the California Bearing Ratio (CBR) of the road.

The two major problems in this phase of construction were terrain and



weather. Poor trafficability of the existing soil and frequent rains caused this phase of the project to take almost two months.

Preparation of the Road Surface

The temporary drainage ditches eliminated flooding on the existing road surface. We began working on the "big end" (St. 13+50- St. 18+00), which was mainly a fill area. After shaping and leveling the ground, we layered crushed asphalt to bring the road surface up to the required subgrade and cut in the shoulders and rough ditching.

As work on the big end neared completion, surveyors marked the cut and fill locations on the "little end" (St. 0+00- St. 11+50). Since this part of the project would generate a surplus of fill, we suggested to the facilities engineer that we not make all of the cuts but just level the 1,150 feet and improve the drainage. This plan would not adversely affect trafficability or the CBR of the road and would speed up the operation. The idea was rejected because new ammunition bunkers were being constructed in another part of the storage area and the fill to cover them would have to be purchased. If we could generate the required fill, it would save the Marine Corps Air Station thousands of dollars.

After attempting to make the cuts with D7G and 1150E Dozers, then pushing the fill into a pile and moving it with our TRAM scoop loaders to the stockpile site adjacent to the road, we realized that this operation could take months. We needed a piece of heavy equipment that could both cut and move large amounts of fill. The 621B Scraper can do this, but in 1993 the Marine Corps decided that Marine Wing Support Squadrons did not need such equipment, so they removed our two scrapers. The 8th Engineer Support Battalion at Camp Lejeune, North Carolina, loaned us one for the duration of the project.

The bowl of the 621B Scraper has a capacity of 18 cubic yards. We used the



Excavation continues.



Erosion-control measures included lining the ditches with riprap.

push-loading method: a D7G Dozer pushed the scraper to fill the bowl, since the scraper lacked the power to make cuts in the muddy terrain. Two passes with the scraper equal about four passes with a dozer.

Drainage

The drainage plan included adding ditches along each side of the road, installing several culverts, and constructing two swales to channel water flowing out of the ditches and into the surrounding forest. Since a small stream is channeled through the 150-foot culvert we installed, extensive erosion-control measures were required. The 3-foot bed of gravel that the culvert rests on prevents the ground from eroding away, which would cause the culvert to shift or sag and the road to fail prematurely. The gravel bed also ensures that groundwater below the streambed is released before it filters up to the road subgrade. In theory, once the ground is tightly compacted, groundwater will filter upward. By providing a relatively uncompacted layer of stone below the surface, water moves on the horizontal axis and exits at the end of the culvert. To ensure that the gravel bed would not become as compacted as the surrounding soil, we placed a layer of synthetic geotextile fabric in the trench before laying the gravel. The multilayer weave of the fabric allows water to pass through it and keeps sand and silt from building up on the gravel. This fabric is the primary erosion-control measure under the entire road surface, and it lines the drainage ditches and swales.

When the road was at subgrade, we added two 18-inch-diameter culverts 3 to 4 feet below the surface. One is at St. 17+90; it is a control measure to ensure that excess water from the upstream side of the road can flow under the road and into existing ditches. We emplaced the other culvert at St. 6+50 so that ditches on the upstream side of the road can drain before reaching the main culvert.

The ditches for this road are trapezoidal. A shallow "V" ditch would have silted up too quickly, and a deep "V" ditch would have been more difficult to emplace and tie into the existing terrain. The trapezoidal ditches have a front and back slope ratio of approximately 3:1, with the slopes meeting at the flat bottom of the ditch. We lined the ditches with riprap (5- to 7-inch pieces of coral), another erosion-control measure, which also slows the accumulation of silt throughout the length of the ditch.

Low areas in the surrounding terrain made ideal locations for constructing two swales, which allow the ditching away from the main culvert to empty back into the woods and help prevent overflow during severe storms. We used an 1150E Dozer to widen, flatten, and extend each natural swale and then covered them with riprap.

Our drainage and erosion-control plan may seem extreme, but since the road was constructed in an environmentally sensitive area, the potential effects of excessive silt runoff on a nearby lake were a major concern. We know that our drainage system works well, because during construction it rained almost every day. We could see potential problems and correct them before the project was completed.

Final Grade and Surfacing

The last construction phase involved bringing the entire road surface up to the final grade by adding additional lifts of "crush and run," which consists of crushed stone and small 1- to 2-inch stone. Even though we simultaneously spread it on the little end with the 621 Scraper and on the big end with dump trucks and a 130G Grader, completing the task was an extremely slow process. The area to be covered was 1,800 feet long by 23 feet wide. Each pass with the scraper covered about 40 feet. Then the scraper moved to the crush-and-run stockpile where it was loaded by a scoop loader. The dump truck and grader combination was no faster. As a 1-foot lift was completed at each end, a smooth-drum compactor made approximately 10 passes to ensure that the crushed stone was well-compacted. Some areas only required one lift, while others required two or three. At this point, rainy weather helped us in two ways:

- It controlled the dust from the stone and kept it from obscuring the operator's view.
- It facilitated the compaction process.

The last section of the road to be brought up to final grade was the main culvert area. We shaped the super-elevated curve over the main culvert with the last two crushed-asphalt lifts. Asphalt provides an excellent base material for the curve, since it increases resistance to the shearing effects of heavy loads. Asphalt is also easier to shape than crushed stone.

The main problem we had in this section of road was trying to spread stone with the grader while maintaining the super elevation. Once we spread the stone, the compactor had to roll the area without flattening the slope. When compacting was finished, we identified high and low spots and filled or cut them using a grader.

Completion

During the nine months spent on the project, the surrounding area had been scraped and plowed and had tire ruts everywhere. As we cleared more and more area for ditching and runoff, we stockpiled the fill and debris off to the side. Each of these piles had to be moved and consolidated into one large pile for the bunker project. Large tree stumps dug out during construction had to be hauled away, and damaged trees had to be cut down and removed. We also removed the silt fencing used to protect the stream during construction and cleared and graded approximately 40 feet on each side of the road.

In open areas, we sowed grass seed and covered it with straw. Where there were trees and bare topsoil, we added mulch for erosion protection. We placed riprap in the ditches and around the main culvert. A fencing contractor had installed gates at each end of the road about one foot above the final grade. From a security standpoint, the gates could be easily breached; in addition, they were not aesthetically pleasing. We pulled the corner posts, reset the gates to an appropriate height, and anchored them with new concrete. At last we were ready for a final inspection by the facilities maintenance engineers.

In the main portion of the inspectioa, the engineers compared the as-built plans with the original plans to ensure that changes made during construction were authorized by the design engineers. Once they were satisfied that the road was properly constructed, the engineers conducted a walk-through that emphasized the drainage and erosion-control measures. They were satisfied with the end product but added two more tasks:

- Dig out the silt buildup at the downstream end of the main culvert.
- Remove a small concrete culvert that restricted the flow of water upstream.

After completing these tasks, the road was officially finished, and it was time for the ribbon-cutting ceremony. The entire squadron witnessed the ribbon cutting and road dedication. The Marine Corps Air Station commanding general presented five Navy Achievement Medals for the hard work and dedication that went into this project.

Lessons Learned

I learned many valuable lessons from this project.

- Do not overestimate the capabilities of your unit. The squadron commander committed the engineer division to the project knowing that we lacked adequate training or experience. The positive effect was that the project allowed the equipment operators to become thoroughly trained. Some of these Marines had only a few hours of operating time on various pieces of heavy equipment when this project began. By the time we were finished, each operator had attained a high level of proficiency on several pieces of equipment.
- Learn to cope with various command relationships. Throughout the project it seemed that everyone on base was directing the project, including facilities engineers, environmental representatives, design engineers, and my supervisors. This was a case where using the chain of command was crucial. If someone outside of my chain of command wanted to change something, they first had to convince my commander. This allowed me to build the road as it was designed and retain control of what happened at the work site.
- When you are in charge of a project, manage your resources wisely. Adjust the time line to meet changing demands. Keep your unit informed about all aspects of the

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We cannot effectively do either of these functions without a comprehensive understanding of how terrain affects the movement of friendly and enemy forces. In our beginning education as young engineer lieutenants, we are taught how to site obstacles for the greatest effect. You could call this "Terrain Appreciation 101." No other member of the combined arms team receives such education. They may receive the basics in how to identify key and decisive terrain, but the nuances of how terrain affects the movement to and from that decisive terrain is taught only to engineers.

In reality, we practice our terrain visualization expertise every day, generally without giving it a second thought. Every time we advise a commander on the correct placement of an obstacle or obstacle belt to achieve the desired effect, or recommend shifting a battle position to achieve better engagement area coverage or gain increased survivability, we are using our terrain evaluation skills to assist the supported commander in "visualizing" terrain effects. In support of the offense, we help define where the enemy might set defenses based on the limiting effects of the terrain, or where he might emplace obstacles to create advantage from the opportunities afforded by the terrain. We do this throughout our careers at every level of command and staff. As a division engineer, both as a battalion commander and later as a brigade commander, the division commander expected me to study the area of operations and to advise him of the opportunities it offered for us to gain advantage over the enemy.

So, the idea of being the "Terrain Visualization Experts" for the Army is really nothing new. It is something that we, as well-trained engineers supporting our maneuver commanders, have always done, and it is an important contribution to countless successes on the combined arms battlefield. As the Army moves to the 21st century, this contribution will grow in importance as dispersed, noncontiguous operations and greater reliance on increased mobility expand the battlespace and increased tempo reduces the time available to see and understand battlespace effects. Maneuver commanders must know they can turn with confidence to their engineers to assist them in the critical function of "visualizing" the terrain. As the tempo of operations increases, our ability to modify the terrain to our advantage decreases.

Moving Ahead

On future battlefields, we will be forced to rely heavily on wielding terrain as it already exists as a combat multiplier. We can do this if we clearly understand the terrain and its effects on the men and machines that move on it.

The transition to digital topographic data and the increasing capability of our terrain-analysis tools will permit the technical experts (the topographic engineer warrant officers) to provide increasingly complex analysis products. These products will increase our understanding of the terrain and its effects. When coupled with our knowledge of friendly and enemy capabilities and intentions, these products will help us identify the terrain effects to be exploited. Then we must impart this knowledge to the commanders we support. We must help them visualize the terrain early in the planning process so our forces can exploit its effects to our advantage. That is the engineers' role. After all, we (the topographic engineer warrant officers and the combat engineers) are the experts!

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project, and ensure that they understand why something is done a certain way. When you must work on weekends to maintain the time line, be creative in your efforts to keep up morale. These are a leader's obligations.

- When planning a project, try to anticipate events or factors that may impede progress. Weather and terrain may influence construction projects dramatically. Building a road during the cold, rainy winter in North Carolina is not a good idea. The ground may be solid and dry during the summer, but it is muddy and flooded in winter. Be aware of training and deployment schedules. It would not be wise to begin a project and then lose half of the unit to a deployment.
- As a leader you must set the example. You must do anything that you ask your unit to do. You must be a teacher, a counselor, and a role model. You must earn their trust and confidence.

No one can control all of the factors that affect a construction schedule. During the construction of Ordnance Point Road, I had daily operations meetings to attend, formations and inspections to conduct, and concurrent projects to oversee. There will always be some resource constraints in any construction project. Personnel, time, and equipment are your most valuable resources. The success or failure of the project depends on how well you use these resources.

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