I have been asked to discuss the construction of an inter-state highway project, so I will try to briefly give you some idea of the data we need in order to bid, as well as, some of our thinking in organizing and operating one of these projects.

As a preamble to my remarks, let us go back and quickly review the subject of highway construction, how it has led up to the present time and how it affects us today. Highways constructed during the road building boom of the twenties were largely based on construction methods and a background of engineering that dated back for several centuries. In many instances our finished products were very inferior to those structures produced centuries ago. It is really quite a tribute to our engineering profession, the designers and builders that our roads have served as long as they have under loads and conditions that were not, and could not have been anticipated.

One of the many stumbling blocks confronting the designer of thirty years ago was the limitation of equipment to do work economically. It is quite true, that if we neglect the element of time, that people with the most primitive of methods could do almost any construction job. To illustrate what I mean: during a trip I made into the interior of the most backward part of Africa, I witnessed one of the local government's road building projects. This work was being done with slave labor and the natives being forced to work for no pay. Here long lines of men were making a fill of dirt being transported from the cut in baskets carried on their heads. The dirt was dug with a crude hoe and loaded into the baskets with bare hands.

I saw a rock cut being made by building huge fires on the rock, and when it was hot, water was poured on it causing it to crack and flake off. Again the crude hoe was used to pry off the loose pieces. This rock was also carried to the fill on top of someone's head. I saw one such rock cut over ten feet deep that was made in this manner. No one that I could find could say how long it had taken to make the cut. These were people who had not advanced far enough to even know the use of a wheel. As an experiment, we gave them a wheelbarrow without bothering to explain how to use it. Much to our amazement and amusement they promptly filled it with dirt and then two men lifted it up and a third man got under it. He then trotted off to the fill with wheelbarrow, dirt and all on top of his head. I knew all along that a wheelbarrow was a complicated piece of equipment, yet I never expected to see one operated that way.

Such methods as these, of course, would not permit the volume or scope of work which has been done and which must be done on our highways. Yet, this was the beginning of what some day may be a super-highway system in Africa. And, just as the number of people available, and their skill, set a limit on the amount of work that can be done by hand, just so the limit of work that can be done by machines is based on the number of machines, their power and efficiency.

The basic principle in the development of road building equipment today is power and capacity. New methods and new materials have been developed and have replaced the old. As a result you are seeing bids for earth moving that are comparable to those of twenty or thirty years ago, although labor and all the other elements of cost have doubled. As a direct result of these developments it is possible for you to design, and for the contractor to build, roads to a standard of
surface, grade and width that would not have been considered a few years ago. We hear engineers talking in terms of maximum grades, degrees of curve and structures that would not have been considered from a cost standpoint twenty years ago. So you see with this evolution in the entire concept of highway construction that it is up to us in the contracting industry to provide the proper tools and to use our manpower and equipment in the most efficient manner in order to produce the highways you propose to build under the Intra-State Program.

Right here, I would like to point out that there is a decided difference in the building of an intra-state project as compared to a regular state project. The projects are larger, the specifications are more rigid, more emphasis is placed on compaction. The plans are different: it being up to the contractor to balance his own yardage; he must utilize all suitable excavated material, regardless of the length of haul; he must furnish his own borrow and waste areas, and in order to meet time requirements, much more equipment and personnel are mandatory.

Speaking of our experiences with this program, we have submitted bids on most of the projects let in Kentucky and have been the successful bidder on the Clark County project and one section in Kenton County. The Clark County project was let on August 8, 1958 and construction started on September 14. At the present time the project is forty-eight percent complete, with the grade work being sixty-two percent complete. It is our experiences on this project that I shall use as a basis for my remarks.

As soon as we received plans on this project it was noted that rock lines were shown on the cross sections and that in almost every cut that there was a bench in the slope at the top of rock. After looking over the plans it was decided that it would be well to test drill the project. This was to be done for three reasons: to check the elevation of the rock, to determine the hardness and condition of the rock and to determine if the cuts were wet.

To do this a six inch diameter auger drill was used, putting down a hole on each ditch line and one on the center line every hundred feet in each cut. With this drill it was learned that, at approximately the rock elevation shown on the plans, there was a layer of rock from two to four inches in thickness. Beneath this there was from three to six feet of dirt and shale before solid rock was encountered. The auger drill would not penetrate the solid rock, so a six inch rotary drill equipped with a rock bit was brought in and every cut drilled to grade.

From this drilling it was learned that the rock was a laminated limestone, but with very few heavy ledges or layers. It was of sufficient hardness, which together with the laminated condition dictated the use of a percussion type of drill rather than a rotary or auger type. It was found that the rotary drill would not cut the rock fast enough to make its use economical, then too it is believed that better breakage can be obtained in a laminated rock if a percussion type drill is used. I can possibly get a lot of argument here, but the theory behind this is that a rotary drill cuts a clean hole with the dust being blown out the top of the hole, leaving the laminations and crevices fairly clean. With the combination of pounding and blowing of a percussion type drill these crevices become sealed with dust, and thus confine the force of the explosive and shatter the rock, rather than have its force expended through the laminations and leave the rock in large unbroken pieces.

Also from this drilling it was possible to determine the type and amount of explosives that would be required. Since the rock was highly laminated it would be extremely difficult to protect the slopes and prevent the benches from breaking out. This meant the drilling next to the slopes would have to be done with small drills and delay exploders used in the blasting to relieve the pressure on the slopes. I will discuss this in more detail later on, but you can see that all these things, together with length of haul, grades and the seasons during which the project will operate, affect the cost, and are data that any contractor must have in order to properly plan a job.

On this project there was 1,950,467 cubic yards of roadway excavation, four
bridges and three box culverts, in addition to one or more lines of culvert pipe in every fill. From the beginning it was recognized that the key to the rapid movement of large quantities of excavation was to rush the construction of box culverts and culvert pipe, thus keeping ahead of the excavation. Likewise, since the project was starting in September and since the job contained fifty-eight per cent rock, it was up to us to get the rock uncovered before bad weather set in. The rock could then be moved during the winter months. To do this 850,000 cubic yards of common excavation would have to be moved, in addition 45,300 yards of topsoil would have to be stripped from areas to be covered by fills. All the box culverts would have to be complete and approximately 12,000 feet of culvert pipe placed with headwalls and inlets built. All of this would have to be complete by the middle of November: a period of two months. As you can see this presented a problem of organization for mass production.

Knowing that the solid rock was at a lower elevation than shown on the plans and, as a result, the benches would no doubt, have to be lowered and slopes changed, it was decided to set slope stakes on the rock slope projected to the surface of the ground. In other words they were set on a three quarters to one slope from the ditch line to the surface of the ground. The excavation was then made on this slope down to solid rock. After the bench elevation was thus actually determined, slope stakes could again be set and the dirt slope and bench excavation made.

It was also decided that in every case where we had a positive projection on the pipe, that is, pipe to be laid either at or slightly above the original ground surface, that we would prepare the fill first, then excavate for the pipe and lay it as a negative projection. The reason for this is that it was felt that a better job would be obtained if the fill were made of selected materials and placed and compacted with heavy equipment. The trench is then cut and the pipe laid and backfilled. By using this method there is less backfill to compact with mechanical tampers. Also by the material being confined in a ditch it is possible to obtain better compaction with less danger of the pipe being disturbed or the joints cracked.

In organizing the job, we set up a crew with two scrapers, dozers and compaction equipment that were to go through strip topsoil and construct the fills where pipes were to be laid. The pipe work was divided into four operations, with a crew for each operation. First there was a crew using backhoes that went through and made the excavation. Then came a crew placing and compacting the porous bedding. Next was a crew that laid the pipe and last came a crew backfilling. To some this may seem like too much organization but it must be remembered that to carry the job on as planned that the drainage had to go in as quickly as possible, thus the assembly line method. As soon as the pipe was laid, inlet and outlet ditches were cut and head walls and inlets constructed.

As soon as the dirt and loose rock had been removed down to solid rock, drilling operations were started. Let me digress here and talk a little about a subject that I touched on previously, that is the rock elevation and the elevation of benches. As the excavation proceeded we found the material to be just as shown by our drilling, except that there were numerous large flat rocks mixed with the dirt, especially just above the solid rock. None of this material was suitable for benches, which means that the benches must be lowered with a resulting increase in yardage. If the benches had been left at the original elevation water would have seeped down through this material causing it to slough off and create a maintenance problem. Already this winter, where this loose material had not been removed, freezing and thawing action has created several slides. While on the subject of rock elevations, on every structure we had to go extra depths to find suitable foundation rock. In some instances footings had to be re-designed and we ended up with spread footings.

Before any drilling was started in a cut our engineer set drill stakes showing the limits of drilling and the depths to be drilled. In this manner we were able
to drill to the proper grade for super-elevated sections and for the depressed median at the same time as the rest of the cut was drilled. From the drill stakes we could also determine how much of the cut should be drilled with the big drill and how much should be drilled with the smaller air track drills. The four and a half inch drill was used on all drilling deeper than ten feet, with the smaller drills used on the shallow sections.

In order to obtain the best possible breakage all of the drilling was done on a staggered pattern, with the spacings varying with the depth. With the big drill the pattern varied between a ten by twelve and a maximum of twelve by fourteen feet. It was found that if a larger pattern was used that good breakage could be obtained in the top of the cut, but that the bottom would not be broken, requiring some secondary drilling and shooting. With the smaller drills the pattern varied from a six by six to a seven by nine.

The most economical type of blasting was with ammonium nitrate or fertilizer. In order to be sure that the fertilizer would be detonated it was always used in holes larger than three inches in diameter, and it was never used in wet holes. In the smaller holes regular dynamite was used. The fertilizer was column loaded with the detonating charge placed in the bottom of the hole. This held true except in the deep holes where a booster charge was placed about two thirds of the way up in the hole. The detonating charge consisted of sixty per cent dynamite fired with electric blasting caps. In order to protect the slopes mulle-second delay explosives were used. By using instantaneous exploders in the center of the cut with four periods of delays toward the slopes and two periods of delays toward the back of the shot it was generally possible to stack the material in the center of the cut, leaving the slopes broken to clean solid lines. The delays toward the back of the shot left a solid face in which to drill for the next shot. The rock, being laminated to begin with, caused it to break up into very small pieces and enabled our shovels to work at maximum capacity all the time.

To prepare for bad weather, layers of rock were placed on all fills as quickly as possible. In some instances where we felt that it would be winter before we could get into the area to move rock, we hauled rock extra distances in order to get an all weather haul road through the entire length of the project.

Organized in this manner and working single shift up to the first of October and double shift thereafter, we were able by November twenty sixth to lay 13,132 feet of pipe and move 962,500 yards of excavation. In this same period all of the culverts were completed and two of the bridges started. By preparing for winter as we did, it has been possible to keep working all winter, and as a result all of the excavation is now complete except for the material left in the slopes and benches, and that left under detour roads.

As designed, this project needed 100,619 cubic yards of borrow, obtained by the designer using an over all shrinkage factor of three per cent. When we balanced the yardage we used a twenty per cent shrinkage factor on dirt and fifteen per cent on rock. With these factors we ended up with 9,000 yards of borrow. However, events proved that both sets of factors were wrong, for before we were half through with the excavation it was all too apparent that we would end up with rather large quantities of waste. In other words, due to the amount of loose rock, and large flat rock in the common excavation, we actually got swell rather than shrinkage. This in turn created the problem of securing waste areas.

All of this brings up the subject of compaction. We used two types of compaction equipment. On the dirt fills we used the Buffalo-Springfield Compactor, with flat pads on the wheels, that exerted a pressure of 580 pounds per square inch. Excellent results were obtained with this roller, for not only did it produce the required compaction, but the action of the flat pads always kept the surface of the fill well sealed so that it would drain readily. Water could not easily penetrate fills on which this roller was used, and in almost every case we were able to continue work in a minimum length of time after a rain. This was not always true where a sheep foot roller was used, as water had a tendency to pocket in the indentations left by the feet.
On the fills where there was a goodly amount of shale or large flat rocks we used an extra large sheep foot compactor which was capable of exerting 750 pounds per square inch. The action of this roller in conjunction with the action of the tractor treads running over the fill had a tendency to break down the large flat rocks and make a compact fill.

It must be remembered, however, that different soils require different types of compaction equipment. For the sandy or porous soils rubber tired compactors work best, and in some types of soils the vibrating rollers produce quicker results. On one project that we had the material was very light and silty with traces of gravel. Here we tried every type of roller made and were unable to meet compaction requirements until we tried a thirteen wheel rubber tired roller. Operating this roller at from ten to fifteen miles per hour we obtained densities much greater than when it was operated at slower speeds.

I have talked a lot about organization and equipment, however you will remember that at the outset it was said that the amount of work that could be done was in direct proportion to the number of machines available. That one item of keeping the equipment available and running is generally the biggest problem of any contractor. As a usual thing it is figured that due to stoppages, down time for repairs and servicing that we get about fifty minutes of productive work out of every hour. By placing mobile radios in all of our foremen and mechanic's trucks we are able to have a mechanic sent to a piece of down equipment in a matter of minutes. The mechanic can call in to the office on his radio and order parts thus reducing costly down time. In a like manner, equipment can be shifted where necessary very rapidly. It is believed that this device alone has enabled us to increase our effective time from fifty minutes per to possibly fifty five minutes per hour. There are numerous other ways that this system can help out, in fact, our resident engineer accuses us of using it as a grapevine to warn everyone of his approach.

There is one other factor that has played a most important role in the progress of this job, that is, the close co-ordination and co-operation between the contractor and engineer. This is brought about to a large degree by our use of a project engineer. This man acts as the liaison between the resident engineer and the project superintendent. He can keep the details of the job in mind, co-ordinate and schedule the need for survey stakes and can set stakes himself when necessary. In this way he automatically checks the work of the survey parties and any errors can be quickly corrected before they become major in nature. In addition to these things, he frees the superintendent of a lot of details so that he can give his undivided attention to keeping the project moving. In short, I believe that it takes very close team work between the contractor and the engineer to make any job go.

What I have said is simply my observations and experienced with one intrastate project. If the program goes on as planned, there will be many more projects, more engineers, more contractors, more problems and more decisions to make. And just as our construction methods and equipment are continually changing, with power and speed being the keynote, just so it is up to all of us to keep ahead of the equipment in our thinking, planning and decisions. In this way our projects will be completed on time or ahead of time, with the result that the people of Kentucky will get full value out of this program.