

Inspection and Control of Highway Construction

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For the last year and one-half, I have been unable to observe much of our construction work in Illinois because of the great amount of time and effort spent in getting underway the greatly accelerated highway program.

There are many problems to be solved concerning the location and preliminary engineering on interstate routes. There is also the rush of programming and expediting of plans for approval by the Bureau of Public Roads preparatory to advertising and awarding contracts.

We have found it necessary in many cases to resort to consultants for assistance in making surveys and plans, but after the contract is awarded we still look to our own engineers for staking and supervising the construction work. This has created a serious problem for the administrator of every highway department because there is a shortage of experienced construction engineers for such a large and rapidly expanded program. A few years back it was common procedure to assign four or five experienced engineers to one project. Now we are fortunate if the resident engineer has had three years of construction experience before he is assigned a million dollar project, and we all know that both the administrator and the field engineer must be ever alert to keep abreast of present-day design, construction methods, and equipment use. The road-building industry has made gigantic strides in the last 20 or 30 years. We have passed that era of building a narrow two-lane pavement on a narrow right-of-way, when we depended upon a plentiful supply of hand labor, and when engineers were available even for inspection of minor work.

This is an age of complicated design, freeways, divided highways, huge interchanges, multilevel bridges, great urban expressways—not \$30,000, \$40,000, or \$100,000 a mile as in the past but multimillion dollar projects. For example, modern Wacker Drive in Chicago cost \$1 million per city block. The layman does not realize the time and money consumed in underground work in the metropolitan areas that

precedes the construction work on the surfaces such as underground utilities to be relocated; construction of sewers or main drains, some built under air pressure; and siphons and water galleries, which must all be supervised by competent construction engineers.

The responsibility connected with the construction of a modern highway project is great and a real challenge to everyone connected with it. There are ever-changing problems caused by new developments, such as widening old pavements without forms; the slip form paver for base course construction; prestressed concrete bridge decks and precast slabs for bridge deck or bridge widening; vertical sand drains; vibrations of concrete and vibration of granular material in surfaces, bases, and sub-bases; winter construction of structures and the resulting fire hazards during curing operations, demanding new fire-proof techniques, such as insulated blanket protecting.

CONTROL OF CONSTRUCTION

It is only by rigid inspection and control of construction procedures that we can be sure of getting a finished highway product that is in accordance with the plans and specifications set up for the job thus insuring that the work will be of the best possible quality. For this control of the work we must depend on:

1. The qualification of the contractor to perform the work involved in the contract.
2. The adoption of adequate specifications covering all details of the work.
3. Inspection of the work as it is being done.

In Illinois we handle the formal qualifications of bidders in a manner which I believe is generally similar to that used in most states. We have about 500 contractors qualified and approved for highway work, many of whom are from out of the state. Bidder qualifications provides assurance that the contractor has the necessary equipment, organization, and experience to carry on the work.

All of our work is required to be done in accordance with standard specifications. Any requirements peculiar to one job and not contained in the standard specifications are specified in special provisions inserted in the proposal and contract. We try to write our specifications so that they will define the minimum necessary requirements relating to methods and equipment to produce a good quality of work and also permit the contractor as much latitude as possible to develop new methods, or equipment to do the work as economically as possible, without sacrifice in quality of the finished product. The specifications are based on experi-

ences and what we consider good engineering practice. Specifications are used so long as they produce satisfactory results and are modified to conform with modern requirements and modern methods of construction.

While work must be done in compliance with the requirements of the plans and specifications, the satisfactory completion of a highway project usually requires of the engineer much more than merely checking the work against the specifications. Conditions are encountered which cannot be anticipated in general specifications or on the plans. In pavement construction unsatisfactory soil or drainage conditions may be encountered. In bridge work the foundation soils or other conditions may be variable or different from those anticipated in the plans, and changes may be necessary. Therefore, inspection must be made not only to insure conformity to predetermined requirements but also to provide all the ingenious engineering abilities and principles so necessary for a successful completed facility.

In any kind of highway construction there are many details that must be watched continuously as the work is being done because a deficiency in any one may affect the completed work. In concrete pavement construction the engineer must inspect the compaction of the subbase, the preparation of the subgrade, the setting of forms, the installation of joints, placing of reinforcing steel, the spreading, consolidating and finishing of the concrete, and the curing. He must make slump tests, air entrainment tests, and flexural strength tests. He is required to take cross sections of the subgrade and pavement to determine the thickness of the slab at frequent intervals. He must straight-edge the completed pavement to check for smoothness. This is in addition to the preliminary examination and periodic checking of the batching and weighing equipment, hauling equipment, mixer timing device, water measuring equipment, and the dispensing device for air entraining admixture.

MECHANICAL OPERATIONS

Equipment such as the concrete spreader, vibrator, finishing machine, and longitudinal float must be adjusted before starting and checked at regular intervals to make sure the pavement will be struck off and finished to the required thickness and crowned surface. The placing of a concrete pavement is now an almost entirely mechanical operation and a serious deficiency in the finished surface may result from lack of proper adjustment in any of the mechanical equipment. These are examples of the many details that must be kept under control as the work progresses.

Because paving is mostly a mechanical operation, its control is chiefly a matter of specifying the right kind of equipment and being sure that it is kept in proper adjustment and is operated so that it will

produce the desired results. Starting with the proportioning plant, the materials for each batch must be handled and weighed expertly and accurately as called for in the mixture design. The placing of subbase material, setting forms, preparing subgrade, and the mixing, spreading, and finishing of concrete are all performed by mechanical equipment.

These mechanical operations keep the amount of hand work to a minimum and produce a more uniform product than could be achieved by manual skill. One of the chief duties of the inspector is to see that each piece of equipment is functioning properly and in coordination with the others. Proper control of the mechanized operations will insure uniformity in subgrade, uniform consistency of concrete and uniform consolidation and finishing, all of which are basic requirements in the production of a good pavement and smooth riding surface.

In concrete bridge construction the operations to be inspected include pile driving and measurement of pile bearing capacity, bearing strength of soil used to support foundations, construction of false work and forms, placing reinforcing bars and proportioning, mixing, placing, and finishing of concrete. In structural steel construction the inspection starts with tests of the steel, inspection of the fabrication at the shop, and inspection of the erection of the fabricated material at the construction site.

In Illinois, all federal-aid and state construction work is inspected by personnel of the Division of Highways. Exceptions occur on some of the expressway work in Chicago where some interstate and urban work (all federal-aid) is inspected by Cook County and the city of Chicago. Federal-aid secondary work and construction financed by state motor fuel tax, apportioned to counties, cities, and townships are inspected by the counties or cities under the general supervision of the state. Each district engineer of the Division of Highways is responsible for the state inspection work in his district. He also supervises the engineering inspection provided by the counties and cities. In 1957 about 600 contracts were awarded for construction on state and federal-aid work under the direct control of the state. When work is started on any project, an engineer who is qualified by education and experience to supervise the work is assigned as resident engineer. His job is to see that the construction will be in accordance with specification and contract requirements.

The Bureau of Materials handles all inspection of materials used in the work. This inspection may be made at the plant where the materials are produced or at the job after the materials are delivered, and includes the testing of samples submitted to the laboratory.

In the control and inspection of construction work the opinions and viewpoints of both the engineer and the contractor are necessary and vital to produce a good product. Sometimes their opinions may differ but both have the same ultimate objectives. Both are interested in getting the best construction possible. The contractor is by necessity interested in keeping the cost as low as possible because his business success depends on doing the work efficiently and economically. In many instances contractors have developed new equipment and methods to reduce their costs and these economies have in turn then reduced the cost of work to the state. In order to encourage the development of new methods for improvement of the work and reduction of cost, it is necessary that specifications be carefully written so that the contractor will be permitted to improve his methods or equipment with only such limitations imposed as are necessary to insure good construction practices.

There has been much discussion recently about whether specifications should control the methods of doing the work or only the final results. For practical reasons we feel that some control of the methods to be used and the equipment for doing the work is essential. However, the specifications should not include unnecessary restrictions and should leave to the contractor the greatest possible opportunity to use his ingenuity in the use of methods of construction which will improve the product or reduce the cost.

CONSTRUCTION TRAINING PROGRAM

From what I have said so far it is apparent that the inspection and control of construction work depends to a great extent on the work of engineers who are assigned to field construction. The resident engineer is directly responsible for the construction work on his project, and he is assisted by as many inspectors as may be needed. These inspectors may be technicians, of whom I will have a little more to say later, or they may be young engineers who start with inspection of small work and progress to bigger and more important jobs as they gain experience. In order to help the men assigned to field inspection of construction work we have carried on a training program for the past several years. This is done in connection with the general "in-service training program" for the younger engineers in all phases of highway work.

For the construction training program, pictures showing important details of all kinds of construction work are taken throughout the year. These are motion pictures or still pictures to be shown on slides. Then, during the winter when field construction is in a small seasonal lull, meetings are held at the district offices where these pictures are shown and discussed. The discussions are led by widely experienced engineers

from the Bureau of Construction or the district offices. These meetings not only give instruction to the young engineers but give them an opportunity to present for discussion any problems or new ideas they have encountered in field inspection work. We have found that ideas presented by the younger engineers who are in actual direct contact with the construction are often of great value.

To help carry the summertime work load we also employ 2- and 3-year civil engineering students. These summertime students render valuable assistance during the peak of the construction season. Many of these students, having become familiar with our policies concerning vacations, sick leave, salaries paid, our fine pension plan, and the chances for advancement, return to us after graduation. There is also another inducement. Those who have had a summer or two experience are, after graduation, started at a salary somewhat higher than a graduate without any experience in highway work.

Last year we realized that in order to properly supervise the increased volume of construction with the number of engineers available some means of relieving the graduate engineers of routine detail duties would have to be accomplished. We decided to ask the cooperation of the high school principals in selecting graduating students who were offered a chance to take a competitive examination that would qualify them to take an 11-week course at the university. From the results of the examinations we selected about 200 high school graduates. After the 11-week course, they were employed by the Highway Division. A few were sent to the central bureaus in Springfield, but most were assigned to the district offices nearest their homes. They are classified as engineering technicians, and we find that most of them are demonstrating their ability to perform a valuable service. After two or three years' experience, many will be capable of assuming responsibilities as technicians, thus releasing engineers for more important duties.

I believe this plan fits in well with the modern trend for the education and training of engineers. I understand that a greater emphasis in engineering education is being placed on the thorough knowledge of fundamentals and that the details of practice in a particular field are to be acquired by experience. As in the medical profession where doctors are assisted by various technicians, so it now appears that in the engineering profession the engineers will need the assistance of technicians who are trained in performing some of the routine and perhaps less important technical work. When there were more graduate engineers available than actually needed, engineers could properly be assigned to such duties as routine survey work, setting stakes, minor inspection, simple drafting, and plan preparation, plotting cross sections, and many

other duties. Now, however, with the shortage of engineering personnel the engineer's time must be conserved for work making greater demands on his professional training.

Field inspection of construction may be regarded as one phase of highway engineering, and it is certainly one of the most important. Good construction depends on the constant vigilance of men qualified by education, experience, and judgment to control the operations so that the completed project will be the best possible. When you consider that a modern paving outfit may place as much as \$40,000 worth of work in a single day, it is not hard to see why we regard the field inspection of construction work of greatest importance.

I have great faith in our construction field engineers. They cooperate to the fullest in working many hours a day in supervising the work on large projects and in many cases oversee adjacent projects which are manned with less experienced engineers. Day after day they are relied upon to coach the newly graduated engineers or the newly employed technicians. Each year when the new program is announced, there is concern in the districts over how these engineers can handle the work with the personnel available. They have however never failed to solve the problem in some way or another. Everyone absorbs additional duties or assigns the detailed minor technical duties to the engineering technicians, and the work is usually completed, provided weather permits and there is no shortage of material or strikes. The work is never delayed for the lack of services from the field engineers.

The difficulties inherent in a greatly accelerated construction program such as we are experiencing now are a challenge to both our design and construction engineers. The excellent job they are doing shows the resourcefulness of these people and the ability of conscientious and dedicated professional engineers to find methods of handling and solving any problem.