

curves and that curve is used in which the readings give the same moisture content. Many jobs in Ohio are now being controlled by this method. Likewise, in the absence of typical curves, curves from other projects can be used as long as the above-mentioned readings give the same moisture content.

After several years of application on large embankment projects, the Proctor test may be considered as a sound engineering method for controlling embankment compaction. Embankment stability is directly dependent upon the mapping of the soil conditions before the writing of the contract and upon providing for adequate design for the weak spots. Embankment materials occur in many variations, and energy must be spent in controlling the poorer materials. The better types of materials are of much less concern.

FUNDAMENTALS OF SPECIFICATIONS

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There are three distinct steps in the preparation of contracts—the making of preliminary surveys, the preparation of plans, and the writing of specifications. From the survey, information is secured from which the plans are prepared and the specifications are written. The plans show the various details of the work as it is to be constructed. There is no doubt concerning the need for careful surveys and properly prepared plans; but there is still greater need for carefully written and properly prepared specifications, because it is from the specifications that the bidder is able to determine the nature of the work to be done and to draw his conclusions as to the fairness of the persons writing the specifications, how well the engineer knows the details of the work contemplated, and what kind of treatment he may expect from those who will be in direct authority during the progress of the work. With good specifications the contractor can intelligently estimate the cost of the various items of work, and there will be a minimum of arguments as to requirements and therefore small probability of litigation, as well as a minimum of delays during construction, which are always an item of expense to the contractor.

It is through the requirements of the specifications that the engineer is able to exercise control over the work and to secure proper quality of materials and workmanship.

It is thus evident that both the contractor and the engineer derive benefit from good specifications. It is equally true, although less evident, that the public in general derive benefit from good specifications; better results are obtained at less cost than would be secured with poor specifications. Suitable specifications are the first safeguard of public funds.

CLEARNESS

The two most important requirements of good specifications are clearness and fairness. Any specification which is ambiguous, indefinite, or impertinent will cause uncertainties of interpretations and will result in the contractor's adding certain amounts to his bid as self-protection. These amounts will nearly always be in excess of what the cost would have been had the specification been definite. There should be no doubt or reason for argument regarding the exact and precise meaning of any word, clause, or sentence in the specification. No sentence should be so worded as to permit more than one interpretation.

To gain clearness, certain things are necessary. Words and technical terms should be defined and used in the sense which they have acquired through common usage. Legal interpretation is on this basis. It is unwise to substitute synonymous words; they never have exactly the same meaning, and the word having the exact meaning should be used as often as necessary. Repeat only when really necessary, and then be careful that the repetition clarifies rather than obscures the idea.

Prepare an outline. It is difficult to write good specifications without one. An outline prevents needless repetitions and contradiction in repeated clauses, out of which grow legal tangles, and also prevents omission of important clauses. All parts of the specifications are not equally important, but some parts are of such importance that their omission would affect the usefulness or validity of the entire specifications. An outline will prevent illogical arrangements of clauses.

Avoid the use of long sentences; short, concise, exact ones are better. Be careful in the use of punctuation. A misplaced comma may reverse the entire meaning of a sentence.

Use words with which the average intelligent foreman is familiar. The use of pronouns should be held to a minimum. It is better to repeat the noun for the purpose of clearness.

Specifications serve as instructions to both the contractor's and the engineer's representatives, telling them the requirements which are to be met. When a clause is not clear, it becomes the duty of the engineer to make a reasonable interpretation, and in so doing he may reverse the decision of an inspector, who can only enforce specification requirements, and may thus cause the inspector considerable embarrassment as well as impairing his usefulness on the particular contract. Specifications should, therefore, be written so clearly that all parties reading them will interpret them with the same meaning and understanding. The contractor, his superintendent and foreman, the engineer, and the inspector should all derive the same meaning from independent reading of the specifica-

tions. This prevents disputes, arguments, litigation, and ill-will, and adds to the efficiency and effectiveness of supervision and inspection.

FAIRNESS

The specifications must be fair. A reputation for fair dealing is a valuable asset to an engineer. It is more valuable than any reputation he may have for clever use of words or ability to enforce specifications rigidly. The engineer's duties are of three kinds: legislative, executive, and judicial. He is employed by one party of the contract and supervises the work of the other party of the contract. He is therefore in a position where it is sometimes difficult to be impartial and strictly fair to both parties.

The fair dealing of an engineer is not limited to the period after construction work has started. His first contact with the contractor is when he prepares the specifications. Most complaints are not directed against the engineer and his interpretations of the specifications but against ambiguous and unfair clauses in the specifications. Frequent sources of complaint are phrases such as "to the satisfaction of the engineer," "in a workmanlike manner," and "acceptable to the engineer." A contractor will naturally draw the conclusion from such clauses that the engineer does not have the ability to write a good specification, does not know the details of the work, or is just too lazy to write a good specification. Such clauses also give an unfair advantage to those contractors who know the engineer and his temperament and prejudices and therefore are able to predict what will be required under these clauses.

It is unfair, as well as unwise, to attempt to put all the risks on the contractor. The responsible bidder will add to his bid to take care of such costs; the irresponsible will disregard them and, if lucky, will make a profit; if not, the contract may be abandoned to the bonding company. It is desirable to warn the contractor of any dangers likely to be encountered. If the engineer knows of specific hazards, he should, in fairness to the contractor, inform him of these facts. If knowledge of such hazards is concealed by the engineer, serious trouble may develop during the progress of the work.

Do not include anything in the specifications that you do not intend to enforce. Non-enforcement of specifications may cause the disrepute of an engineer.

It is essential that the engineer be able to exercise control over the work in order to secure proper performance and completion in reasonable time, but the engineer should not endeavor to deal arbitrarily or unnecessarily with any part of the work. The responsibility for the management of the work rests with the contractor and should not be usurped by the engineer.

Determine in advance the character of all work which will be required and then describe each item clearly and accurately.

The contract prices should include every item which can be foreseen. Extra and force account work will thus be held to a minimum.

The specifications proper consist of two distinct parts: general clauses and specific clauses.

GENERAL CLAUSES

Since the general clauses usually occur first in the specifications, we will consider them first. The general clauses cover various phases of the work and certain possible contingencies under numerous situations which might arise during the course of construction and which must be provided for. Some of these will be only remotely connected with the actual construction work, but they do have a bearing upon the business and legal dealings of the parties who are concerned with the contract. These clauses are required mainly because the specifications are prepared before it is known who the contractor is to be. Many of these clauses are to keep the parties of the contract out of court, the intent being to prevent litigation if possible.

Define in clear terms the words and phrases used in the specifications. This will decrease the possibility of misunderstandings and argument as to what is meant. Define engineer, inspector, bidder, contractor, surety, proposal, plans, specifications, contract, and any other terms used in a special sense.

Describe the work proposed under the contract, noting its beginning and end in the case of a road contract, or giving number of spans, length, type, location, etc., in the case of a bridge contract.

Clauses should be included setting forth the contents of the proposal forms, how the proposals shall be prepared by the bidder, where and when proposals shall be delivered, whether or not proposals may be withdrawn, and where and when they will be opened and read. Provide for the rejection of irregular proposals, such as those showing omissions, alterations, additions not called for, or other irregularities.

Require the bidder to furnish evidence of his competency to perform the work contemplated. It should be a condition of the general clause that lack of competency, lack of responsibility as shown by past work, uncompleted work of a nature to hinder prompt completion of additional work, evidence of collusion among bidders or of dishonesty or lack of good faith will be sufficient cause for the disqualification of a bidder and the rejection of his bid.

Many instances occur involving inconsistencies between plans and specifications which, if taken to court, would be tedious and expensive. The duty of the court would be to determine the intention of the parties and rule accordingly.

Many of the details of the design cannot be described in both the plans and the specifications. It is therefore desirable to stipulate in the specifications that the plans and specifications are to be considered as mutually explanatory and supplementary, that features in one shall have the same effect as if shown in both, and that anything essential or vitally necessary to the proper completion of the work, even though shown in neither the plans or specifications, shall be done by the contractor without extra charge. A clause should be inserted setting forth which shall govern in case of discrepancy between the plans and the specifications.

Should the contractor be required to verify data furnished by the engineer? There are two courses open to the engineer when preparing specifications for work where the data is uncertain—throw the responsibility for verification on the contractor, or assume responsibility for the data furnished. If the data furnished prove insufficient, inaccurate, or incomplete, upon whom should the burden fall? Cover this contingency carefully in the specifications.

Outline carefully the duties of the engineer during construction. His principal duties are to lay out the work, to give necessary lines, references, elevations, etc., to make all measurements necessary to determine payments to the contractor, to interpret the plans and specifications in cases of doubt or uncertainty, and to check materials and workmanship, seeing that they meet the requirements of the specifications. It is customary to place all these matters in the hands of the engineer. In addition, the engineer is often made arbiter in case of dispute. This places the engineer in a peculiar position. In public work, since he is the employee of the owner, it is his responsibility to develop arguments for the owner's side of the case, which makes it difficult for him to be impartial in reaching a decision. From one point of view, justice indicates that the engineer should err, if at all, in favor of the public body which employs him. If he has erred to the disadvantage of the contractor, the contractor may protest or proceed with litigation. If, on the other hand, the engineer has erred to the disadvantage of the public body that employs him, the matter is settled and injustice is done to the public.

Insert a clause mentioning the representative of the engineer—the inspector—and his duties and authority as delegated by the engineer. His work is usually limited to inspection; other duties or authority are those specifically delegated to him by the engineer.

Include a clause requiring the contractor to respect and preserve all survey points. The engineer must give lines and grades as needed by the contractor, but the contractor should be required to give assistance in these operations. In order to enforce this requirement, it is well to specify that the cost of replacing grade or line stakes carelessly or wilfully de-

stroyed by the contractor shall be charged against the contractor.

Provide for the rejection of defective materials and the removal and replacement, at the contractor's expense, of work not done in accordance with the terms of the contract. Defective materials remain the property of the contractor and should not be mutilated or defaced and thus made unfit for other uses.

The contractor must be required to assume the responsibility of compliance with all federal, state, and local laws, ordinances, and regulations which in any way affect those employed on the work or which affect materials or equipment used in or upon the work. Require the contractor to secure, at his expense, all permits and licenses needed in connection with the work. Cover the use of patented devices, materials, and processes used in construction and require the contractor to pay the royalty fees or damages for infringement.

There should be clauses covering employment, discharge of employees, sale of intoxicants, sanitation, legal relations with employees, citizenship, hours of labor, wages, payment of wages, etc. There are specific laws covering some of these in connection with public work.

Personal and property damages must be carefully covered. The contractor must be required to erect barricades, signals, lanterns, etc., to safeguard against personal damage or injury. Property damage may be a responsibility of either the owner or the contractor. These must be carefully differentiated, and the specifications should specifically and clearly place upon the contractor the responsibility for accident due to carelessness or neglect.

Progress of the work should be covered by clauses fixing the time for the beginning of the work after the signing of the contract. A time limit should be fixed for the completion of the contract. In some cases a progress schedule is desirable. If work is to be prohibited on certain days, such as Sundays or legal holidays, if certain kinds of work are to be prohibited during the night because of noises, dangers, etc., or if certain work is to be suspended during unsuitable weather conditions, the specifications must include these requirements.

During the progress of the work, contingencies may arise making it necessary for the owner to request the contractor to suspend operations either wholly or in part. If such suspension is through no fault of the contractor, provision should be made for reimbursement for losses due to the suspension of work.

Extensions of time may or may not be justified. Some delays due to weather conditions or those due to the owner justify an extension, but delays caused by the contractor do not. Specify what will be considered legitimate reasons for extensions of time and what will not be so considered.

The contractor may fail to complete the work within the time specified in the contract. If nothing is contained in the specifications regarding this contingency, the recourse of the owner is to sue for breach of contract; but such a suit at law is unsatisfactory. To avoid court action, insert a clause in the specifications making the contractor liable for damages sustained by the owner because of the failure to complete the work on time. Common practice is to specify a certain per diem sum as "agreed and liquidated damages" suffered by the owner. Another method of assessing liquidated damages is to insert a clause making the contractor liable for actual expense incurred by the owner through the delay in completion. On road or bridge contracts such expenses are those due to engineering and inspection, temporary surfacing, temporary structures, maintenance of detours, etc. Be careful in wording the liquidated damage clause. Avoid the use of the word "penalty"; the courts are jealous of the use of this word and will seldom enforce a "penalty" clause.

Abandonment of work must be covered by very carefully worded clauses. Such a situation may be handled by declaring the contract null and void and the contractor discharged, or by letting the contract remain in force while the bondsmen or the owner complete the work at the contractor's expense.

The contractor may not desire to do all the work with his own forces. The specifications should cover very clearly the rights of the owner with respect to subletting and assignment—what parts may be sublet or assigned, and what parts may not be.

During the progress of construction it is often advisable or necessary to make changes in the plans or to require additional work which will require more labor and materials. If the particular item of work is covered by unit prices, the additional work requires only a simple adjustment. On "lump sum" contracts, or if the change in plans requires work not covered by unit prices in a "unit price" contract, a "supplemental agreement" will be necessary to cover the additional work. On public work, a supplemental agreement is open to criticism on the basis that there is no competition in the establishment of the prices in the agreement. Be careful in the wording of the clauses relating to such changes. In general, such clauses should cover the authority of the engineer to make reasonable changes, provide a method of adjusting differences in cost, and provide that the changes allowed shall not affect the contract and bond.

A clause should provide for "extra work" and specify that extra work shall be ordered in writing by the engineer. Require that "force account" work shall be paid for at cost plus a percentage, and that the contractor shall furnish all information, such as time books and bills, to enable the engineer to determine the correct cost.

Provision should be made for payment of earned money. This may be at fixed intervals or may be made in certain specified sums. The method of measurement of work for estimating the earned money due should be clearly set forth. The method of payment should be described, the percentage to be withheld should be noted, and provision should be made for deferring payment until the next period whenever the earned money is less than a fixed amount. The conditions for final inspection, final acceptance of the work, and the payment of the final estimate should be clearly set forth.

SPECIFIC CLAUSES

The specific clauses describe or define the materials and the various phases of the work from the standpoint of the engineer. They might more properly be called the technical clauses. These technical clauses which apply specifically to materials and work should be very carefully written so that they will be perfectly clear and will leave no chance for substitution of materials, nor any possibility of securing any kind of work except that which is best for the particular item of work involved.

The specific clauses should be given an appropriate heading and should be separated from the general clauses. For convenience they should be arranged in the order in which the work will be done. This does not imply that the contractor must follow this order in performing the work under his contract.

Each item of work should be covered by specification. In general, this should include a description of the item, the materials to be used, the methods of construction, how the item will be measured, and how it will be paid for.

In describing earth excavation, the cubic yard, which is the general unit of measurement, needs qualification. Measurement may be made in any one of three ways: measure in place before disturbing; measure in the transporting vehicle; or measure in fill. Different volumes will be secured by these methods and the exact plan of measurement must be known.

The difference between earth excavation and rock excavation should be carefully noted. Rock may be solid and hard, soft, or loose. The specifications should fully describe each class of excavation and define the method of measurement for each class. Use great care in writing the clauses relating to classification of excavation, for in connection with these items a great amount of unpleasant feeling and expensive litigation frequently occurs.

Be careful in writing the clauses relative to concrete. Specify exactly the proportions of cement, fine aggregate, and coarse aggregate. Is the proportioning to be by volume or by weight? There is considerable difference in the quantities of materials required. If measured by volume, is it to be loose

or rammed material? If these clauses are not specific, the contractor may bid according to one interpretation, and the engineer, during construction, require another, thus adding considerable to the cost. Be sure that these clauses can be interpreted in only one way.

Various materials, such as steel bars, lumber, pipes, and cables, are carried in standard commercial sizes. For the purpose of economy, these standard sizes should be used in plans and specifications whenever possible.

Do not specify special brands or patented articles. Such a specification will cause trouble, create a monopoly for the one material, suspicion on the part of others, and charges of collusion and graft. Give the contractor an option in the use of materials. Require materials of a certain grade or that meet certain test requirements, but not a certain brand.

Require good materials and good workmanship, but do not expect absolute perfection. Use material of a quality satisfactory for the work contemplated. Sometimes it is not economical to use the best grade of material, a lower grade of material giving satisfactory results at considerably less cost. For every purpose there is one most economical material which can be used; higher requirements will only add to the cost.

The aim of a specification is to secure a finished product, and it is therefore desirable to specify for results instead of methods. In so far as possible, leave the methods of work to the contractor. It is difficult to specify methods and then require results.

The essential and most important features of the plans should be given the most careful and complete treatment in the specifications. Items requiring great amounts of labor and expense should be given the most detailed explanation. Describe minor items in less detail.

Engineering specifications cover almost all phases of industrial activity, and therefore no one individual can be capable of writing, from his own knowledge and experience, suitable specifications for the numerous engineering works and processes for which specifications are needed. Even though the particular specifications to be prepared are within the experience and knowledge of the writer, and though he may have prepared similar specifications, there will be differences in conditions, improvements in methods, special economies possible, etc., which will require readjustment of ideas and change in clauses contained in previous specifications. New conditions or new methods require investigation of every available source of information, and even this may not disclose sufficient information to satisfy the requirements of a complete specification.

With properly written specifications, all portions of the work being carefully and explicitly covered therein, and with

careful performance of duty on the part of the engineer and his representatives, the work on the contract should proceed with little friction and few arguments between the contractor and engineer, and reach final inspection, acceptance, and final payment with the best of feelings by all parties to the contract.

FUNDAMENTALS OF SPECIFICATIONS

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A specification of which the plans are a part has for its objective a finished or completed project; therefore, it should contain only such information as will insure the best results under a given condition. Quite often too much space is used for unnecessary stipulations; especially is this true of county construction.

Specifications for state highway work must be of the highest type as to clarity and intent, and the best evidence of the value of such specifications is the completed work which is accepted by the state from year to year. However, there is a vast amount of construction work done in the state which does not come under the authority of the state highway commission, and such work also must be adequately specified and planned.

The great bulk of this latter type of work falls to the several counties of the state. Unfortunately, these units of government do not have the strength of organization or the facilities at their disposal to specify or plan as thoroughly or with such exactness as the state. This is because of the different nature and types of the road, bridge, and miscellaneous construction which is handled by these units.

At the present time, about the only revenue that the several counties have from which to construct roads, bridges, etc., is from the gasoline tax and the motor-vehicle-license fees. The counties' share of these funds is much less per mile than is the share of the state. Because of this lack of adequate revenue and since the counties are dealing with only secondary types of road and bridge building, they cannot emulate the state in the production of more detailed plans and specifications.

USE OF LOCAL MATERIALS AND CONDENSED SPECIFICATIONS

Under the present law, any county contemplating the building of a road or bridge costing more than \$1,500 per mile or per unit must file plans and specifications therefor with the State Highway Commission for its approval. With the limited funds allocated to the average county engineer's office, it is practically impossible to turn out such a complete