Implications of Life-Cycle Performance Specifications

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The professional, managerial, and legal implications of using life-cycle performance specifications are presented. Changes in the roles of the parties using life-cycle performance specifications are discussed. Life-cycle performance specifications are a cost-effective means of procuring highway pavements that will provide satisfactory service over their design life. This approach can improve quality, reduce costs, and expedite the construction process. The basis of the process is the development of models of expected performance. These models will be used to predict whether the pavement will perform as required over the life of the project. Tests are performed at the end of construction to determine whether the expected performance is likely to be achieved. Adjustments in payment can be made, based on the performance model predictions. The ramifications of adopting life-cycle performance specifications are discussed.

People want more for their money—better quality for the same amount or less. Life-cycle performance specifications have been proposed as a means of accomplishing this objective in highway pavement construction. Normally, highway pavements are constructed using prescriptive specifications. Prescriptive specifications define what is to be done, when and how it will be done, who will do it, and the materials to be used. Performance specifications can be either end-result specifications or life-cycle specifications. An end-result specification defines the desired properties of the component or project at the end of construction by means of a set of defined criteria. If the criteria are met at that point, the component or project is acceptable. A minimum acceptable level of roughness in a new pavement is becoming a common end-result specification in the pavement industry. Life-cycle performance specifications define the function of the component, facility, or pavement: what it is to be used for, what it must be able to do, the period of that performance, and an acceptable range of performance parameters that must be met during the life cycle or period of performance.

A major pitfall in using prescriptive specifications is that under the Spearin Doctrine (United States v. Spearin, 248 U.S. 132 [1918]), which is the prevailing law in forty-nine states and for federal construction, it is implied that the owner warrants the adequacy of the plans and specifications to the contractor. Where the component, facility, or project is constructed according to those plans and specifications, the owner has no recourse against the contractor over the quality of workmanship expected, even if the constructed product is unacceptable or will not function.

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Owners can avoid the implied warranty by specifying the properties desired with an end-result specification. By doing so, however, they lose control of the design. For example, end-result specifications are frequently used for air-conditioning and heating systems, where a set of desired performance criteria is furnished to the contractor, who is free to find a system that will meet those criteria. On a competitively bid, fixed-price contract, the contractor will undoubtedly find the system that will meet the specified performance requirements at the least cost to the contractor and to the owner. In these situations, it is imperative that owners properly define their minimum acceptable requirements, because they are rarely given more than they request.

With an end-result specification, performance is measured at the time of acceptance. After acceptance, the responsibility of the contractor for the performance of the system or component is limited to what was agreed upon in the contract, or to warranties provided by law. Moreover, if the system ceases to perform as specified, the period in which the owner can look to the manufacturer for relief is generally limited to the warranty period in the contract.

Life-cycle performance specifications have been proposed as means of enabling owners to ensure that acceptable performance is obtained over the intended useful life of the system, component, or facility. There are many difficulties associated with developing and using life-cycle performance specifications. One difficulty is how to ensure performance over a design life of 20 or more years. Others lie in establishing the acceptance criteria and, last, the testing procedures to be used to determine whether the criteria have been met.

NEED FOR PERFORMANCE SPECIFICATIONS

Owners may want to adopt a life-cycle performance specification approach for the following reasons:

1. To shift the risk of performance to the contractor. It is implied that the owner who provides plans and specifications to a contractor warrants the adequacy of the plans and specifications. This is commonly referred to as the "Spearin Doctrine." After construction is completed, if the project does not work, or does not work as desired, the contractor cannot be held accountable. By specifying performance, it becomes the contractor's responsibility to ensure performance.
2. To obtain the most cost-effective design. By specifying performance, the owner will receive competitive bids that will meet the performance requirements. The owner will thus have the performance he or she specified at the lowest cost.

3. To spend more time defining objectives and needs. Owners will devote their time to defining their objectives and needs, rather than on design and writing specifications addressing materials and procedures for the contractor to follow.

4. To select from the best thinking of several designers. The contractors can engage different designers to develop the best way of providing the specified performance at lowest cost. The owner will have the benefit of the thinking of several designers, rather than only one.

DRAWBACKS TO OWNERS

Loss of Control Over Design

While owners can avoid the implied warranty by specifying performance, they lose control of the design. The contractor is furnished a set of desired performance criteria and is free to find a system that will meet those criteria. On a competitively bid, fixed-price contract, the contractor will undoubtedly find the system that will meet the specified performance requirements at the least cost to the contractor and to the owner. It is imperative, in these situations, that owners properly define their minimum acceptable requirements, because the materials selection, structural design, and construction techniques are the responsibility of the contractor.

No Guarantee of Performance After Acceptance

With an end-result specification, performance is measured at the time of acceptance. Life-cycle performance specifications have been proposed as a means of enabling owners to ensure that acceptable performance is obtained over the intended useful life of the system, component, or facility. In the pavement area, with a long life and a volatile environment in which contractors come and go over the expected life of the pavement, the expected method of determining the life-cycle performance would be the use of predictive models. If the pavement properties at the end of the construction are placed in the model and the projected life is equal to or greater than required, based on a predetermined reliability level, the pavement would be acceptable.

Implementation Difficulties

There are several major difficulties associated with developing and using life-cycle performance specifications. One is in the area of contractor selection. Other major problems center on the development of procedures to ensure performance over a design life of 20 years or more, establishment of the acceptance criteria, and finally the testing procedures and equipment to be used to determine whether the criteria have been met.

Higher Design Costs

It must be stressed that owners will not avoid the cost of design; indeed, their costs may be higher for the following reasons.

- Owners will still have to go through the process of scope definition, specification preparation, criteria selection and definition, identification of testing procedures and methods, and possibly development of testing equipment, with either in-house staff or an outside engineering firm.
- The contractor will include the cost of design in the bid. Owners will pay for the cost of design and for the contractor's usual markup for overhead and profit attributable to the cost of design.
- Owners may have to pay for the cost of conceptual design for all bidders. Some contractors may be reluctant to bid competitively on performance specification work where they may have to bear the cost of initial or conceptual designs. A possible solution is to have the client pay for the expense of the conceptual design for all bidders. If this happens, owners will be obliged to develop a procedure to screen potential bidders to limit their bid list significantly and, thereby, limit their costs. The U.S. Department of Defense does this now in aircraft procurement competitions. However, this may prove difficult to do in public works where laws dictate that bids must be accepted from all responsible and responsive bidders.

NEW ROLES

If, with life-cycle performance specifications, the contractor determines what the final product will be, what are the roles of the owner, engineer, or designer?

Role of the Owner

Owners commission the work to be performed. They decide the scope of the work and specify the performance required. They must also define how the required performance will be measured.

Role of the Contractor

Contractors must now become the designers and optimizers. They must still develop the lowest price bid or they will not get the job. But they must now determine whether they can provide the performance specified and do it by the least costly means of accomplishing the work. It will be up to the contractor to decide how best to accomplish the work, the materials to be used, and whether it will be possible to meet the performance requirements within the cost parameters necessary to win the bid.

Role of the Engineer

An engineer may continue to work for the client, where his or her new role will be to determine when, where, and how to use life-cycle performance specifications for a project; or an engineer may work with or for a contractor in developing the design to meet the performance requirements specified.

Engineer for the Owner

The owner's engineer will not design that portion of the project to be procured by means of life-cycle performance specifications. Instead, he or she will have to determine what the owner really needs, envision the performance required, establish the criteria by which achievement of performance will be determined, identify models or predictors of desired performance, and develop acceptance procedures (tests, testing criteria, and testing procedures) to establish whether the performance criteria established for the predictors have been met. Another major task facing the owner's engineer will be the determination of predictors of long-term performance. This will involve a major long-term testing program examining many different roadway surfaces, designs, bases, and material components and the mix of such components under different environmental conditions. The engineer will then establish the performance requirements to be furnished to potential contractors for bidding purposes. In addition to furnishing this information to the contractors, the engineer will have to develop criteria to be used to select the best proposal. These criteria must also be shared with the contractors so that they may know the standards against which they are to be judged.

Engineer for the Contractor

The engineer's client may no longer be the owner. The contractor's engineer will do the design, as the owner's engineer did before. Because of the partnership with the contractor, however, it is expected that constructability will be incorporated into the design, as well as innovative concepts based upon a value engineering approach to design necessitated by competitive bidding. The engineer may also face conflicts of still owing a duty to the owner, even while working for the contractor. The contractor's demands on the engineer may affect decisions in critical areas of design. Engineers will have to make their decisions based upon their best professional judgment.

CONTRACTOR SELECTION PROCESS

The contractor's bid will include the cost of the work and the contractor's design. The owner's engineer will have to evaluate the designs to determine which are acceptable. The criteria for design evaluation must be included in the Invitation for Bids so the contractors will know what they must do to prepare an acceptable design. Designs that are unacceptable will be excluded from further consideration. The remaining bids can then be evaluated on the basis of cost. Since all of the remaining designs are acceptable, the low bidder would appear to be the obvious selection. Appearances, however, may be deceiving. The low bidder of all of the acceptable designs may not be the most cost-effective. The designs may not be equivalent; some will be better than others. Some of the better designs will cost more than some of the lesser designs. What will be needed will be a means to evaluate the designs on a comparable basis, since one design may give a longer performance prediction than another one that costs less. Unit costs are routinely used in prescriptive specifications; a cost per year of service standard could be applied, with some minimum life required.

DEFINING AND ENSURING PERFORMANCE

A major task in developing life-cycle performance specifications is devising what will be considered an acceptable product and ensuring that it is achieved. The simplest approach is to define required performance and require a warranty to cover the design life. For a flexible pavement, an example might be that the pavement would not reach a PSI of less than 2.5, develop ruts greater than ½ in., or develop fatigue cracking over more than 3 percent of the traveled surface in fewer than 5 million equivalent single-axle loads. There is no assurance, however, that the contractor will still be in business after 12 or 13 years, should problems develop at that time.

Another approach is to develop models that predict the performance of the pavement. These models must then reliably predict performance based on properties that can be measured at the end of construction. These could include a measure of built-in defects, such as PSI; as well as properties used in the predictive equation, such as a measure of strength; items that indicate durability, such as air voids; items that indicate environmental effects, such as temperature susceptibility; and so on. At the end of construction, the owner would measure these properties and use them in the model to determine if the desired life is predicted. If it is, then the pavement is accepted. This approach differs from the end-result specification in that any combination of the measured variable in the predictive model that indicates satisfactory performance is acceptable. The concept of using a predictive model requires that reliable performance of pavements be established on the basis of parameters that can be measured at the end of construction. The variance must also be established so that the owner can specify the life and define the level of reliability desired.

A warranty, however, is only as good as the entity standing behind it. It is apparent that the time span during which a contractor can be held accountable is limited. With a design life of 20 or 25 years, who is to say that the contractor will still be in business when something goes awry? A large equipment manufacturer might possibly have more staying power than the contractor; but again, nothing is certain. An insurance policy to pay for any needed repairs might be prohibitively expensive, and the cost of the premium for such a policy would be passed on by the contractor to the owner. A lump sum amount might be retained from the contract amount, placed in escrow at project completion, and invested to provide funds in the event of needed repairs. The profit margin in pavement construction, however, has historically been relatively low, and the cost of added retainment would probably be passed on to the owner.

To make life-cycle performance specifications work, it is necessary to incorporate the concepts of control theory into the specification. Control always begins with an objective (*1*, p. 12). The objective must be measurable, if possible. Development of a control strategy includes the establishment of the following components:

- Predictors of results. It is often possible, by means of analysis or experience, to say that a particular result or objective will come to pass if something happens, or fails to happen. If it does not rain in the Midwest in May and June, then the corn crop will be 60 percent of normal in September; if an

NFC team wins the Superbowl, the stock market will go up for the remainder of the year; and so forth.

- Par. Par is the measurable value established for each objective that indicates whether the objective is achieved or not. In golf, for example, par is the number of strokes necessary to get the ball into the cup for each hole. In highway construction, it may be that a particular test value is obtained when concrete is tested, in situ. If the test value is less than what is considered acceptable, then the concrete is considered to be below par. This test may be conducted in several different locations and possibly at several different times. The values obtained would be compared against a standard—the par for that test in the context of that particular project.
- Assignment of responsibility to achieve par.

Scope definition of a project establishes the functions that a facility or highway is to perform. The better the definition of the scope, the better the design and the better the plans and specifications.

It has been shown that most savings in a project are made as a result of changes during the design period. It is difficult to value-engineer a project during design. Performance specifications and competitive bidding can be used to achieve similar results. The contractors will develop novel means of achieving the desired performance, and because they are bidding against each other, the price of achieving the performance will be low.

NO FREE LUNCH

Contractors will not prepare designs to meet performance specifications at no cost to the owner. The contractor's costs incurred in preparing the bids will be charged to the owner in the bid price of the successful bidder. The design costs of the unsuccessful contractors will be paid by other owners in the form of higher overhead costs.

INSPECTION AND TESTING

Who Does the Testing?

Testing can be performed by the owner (or the owner's agents), by the contractor, or by an independent testing laboratory.

Cost of Testing Equipment

The cost of testing equipment may be the determining factor in who is to do the testing. If the equipment cost is so high that it would be unlikely that one contractor would be willing to purchase it, or that a group of contractors would each be willing to purchase such equipment on a one-time basis, the owner or an independent testing agency would need to conduct the tests. Leasing the equipment may be possible, but the leasing company would obviously want to be sure of having enough business to justify their expenditure.

DUTY TO INFORM—WARN

After the results of tests during construction, does the owner have a duty to tell the contractor that the contractor's final product will not be acceptable? Does the answer depend on the stage at which the tests were conducted—that is, at a point where it is too late to make changes or one where changes to make the product conform can easily be made? Where the owner had knowledge that would have made a significant difference in the contractor's actions and, hence, the end result had the owner passed that knowledge on to the contractor, will the owner be estopped from raising the issue that the product will not meet the specification?

Duties are created by

- Contractual agreement,
- Gratuitously volunteering to undertake, and
- Operation of law, a requirement of statute.

In this instance, the owner may or may not undertake a contractual duty to keep the contractor informed of the quality and/or status of the work as it progresses. A court could find an implied duty on the part of the owner to tell the contractor if the product is unsatisfactory before the contractor proceeded too far. The question of whether the owner is correct or not may arise. In this discussion, "correct" refers to the interpretation and conclusions drawn from the test results, rather than to the values obtained in the test results. If the owner mistakenly tells the contractor that, based on the tests, the work is unacceptable, then the contractor may have a cause of action against the owner for negligently interfering with the conduct of the work.

CONVERSION TO PRESCRIPTIVE

The contractor has the ultimate responsibility for the final product when dealing with an end-result or performance specification. The specification defines the quality, which is defined as what is specified. In a prescriptive specification format, the contractor agrees to provide the material specified and workmanship of journeyman quality. Within a performance specification, the only testing required is at project completion, when a determination is made that the work performs or does not perform as specified. Testing by the owner prior to completion may result in undesirable legal consequences. If the owner tests during construction and the contractor does not meet the required performance stipulated in the contract, two consequences may result. The contractor may argue against having to meet the necessary performance standards because the owner knew that it was not performing acceptably and did nothing about it. The argument is that the owner's inaction constituted a waiver of the requirement. The obverse of this position is that if the owner advises the contractor of the deficiencies and then, human nature being what it is, offers advice on how to correct the situation, the contractor will argue that this action constituted a conversion of the performance specification into a prescriptive specification. The conversion from performance specification into prescriptive specification shifts the risk of failure to perform as desired from the contractor to the owner. Requiring testing by the contractor during construction or by an independent testing organization, with results to be provided to the owner, would not alter the preceding scenarios, since the contractor could still argue, convincingly, that the owner had knowledge that the performance requirement was not being met and that this constituted a waiver, or that the owner told the contractor what to do and that this constituted a conversion to a prescriptive specification. The better approach would be to tell the contractor what tests the owner will conduct at completion and to allow the contractor to run these tests if desired prior to testing by the owner.

Does this mean that no testing should be completed during construction? No, it indicates that testing during construction is the contractor's responsibility. Assuming that the pavement will be judged acceptable, or nonacceptable, based on test results used with the performance model, the contractor must ensure the achievement of the desired test results. This means that the contractor must be able to conduct tests during the materials selection, design, and construction phases that will reliably predict the end desired inputs to the performance model. This is the contractor's only means of ensuring that the final product will be acceptable.

PAYMENT FOR PERFORMANCE

Payment for work done under a performance specification may be an issue. Under conventional procedures, payment is made for work in place. With a performance specification, the work is not accepted until it is tested and the performance criteria have been met. This could create a cash flow problem for a contractor, so it may be necessary to provide for advanced payments rather than progress payments. Advanced payment is an alternative form of project financing instead of payment for work completed. Advanced payments are advances of money by the owner to the contractor before, in anticipation of, or for the purpose of complete performance under the contract. These advanced payments would be liquidated from payments due the contractor incident to the performance of the contract. Advanced payments differ from partial, progress, or other payments based on costs incurred by the contractor as work progresses. Controls are necessary to avoid abuses of an advanced payment clause in the contract.

ACCEPTABILITY

When using performance specifications, acceptability is dependent upon test results; and test results often vary. The contract should define in advance what is acceptable. What is acceptable may be stated as a value with upper and lower bounds. These bounds will constitute a minimum acceptable value and should be based on reliability concepts.

HANDLING NONPERFORMANCE

One of the major objections to using an end-result specification is that large quantities of material may be found to be defective and the cost of correction is high (*2*). The contract should define what will happen if the minimum acceptable test value is not achieved; for example, the section will be torn out and replaced; or remedial action will be permitted or not permitted or will be required, depending on whether the expected final result will exceed the minimum acceptable value. The cost of such additional work would be borne by the contractor. The cost of additional testing may also be assessed to the contractor by the owner. An alternative might be to reduce payment to the contractor because the pavement will not last as long as was envisioned when the contract was executed. The reduction in payment to which the contractor would be entitled would be established in the contract as a schedule for payment. There is a concern that the contractor may view the payment penalty as the cost of a license to avoid meeting the performance requirement.

PERSPECTIVES

The ultimate performance specification is a design-build contract. Some contractors may not want to bid competitively on jobs that approach being design-build in character. This is partly because they must pay an engineering firm to prepare an initial design as a basis upon which to prepare their bids.

Potentially Higher Overhead Costs

If the contractor is not the low bidder, then the expense of the design is added to overhead costs and must be recovered on other successful bids. The higher overhead costs will mean greater difficulty in winning other jobs. Moreover, the added expense of design is then borne, not by the original intended client, but by others.

Ethical Problems for Engineers

The creative contractor may decide to ask an engineer to work on the design on a contingent fee basis, with the understanding that the engineer will be engaged to complete the detailed design if the contractor has the low bid. The engineer receives no compensation if the contractor's bid is not low. This raises the issue of whether engineers are engaged in competitive bidding. Moreover, the contractor may ask several engineers to submit conceptual designs in order to price them and select the design that will give the lowest cost. The design cost has now been passed on to the engineers. This also raises the question of whether the engineers must limit the submission of their design to one contractor or can submit it to several in the hope that one combination of their design and the contractor's cost will be the winning combination.

Supervision and Control of Design

When contractors assume the design function, they either undertake to perform the design process in-house, subcontract it to an engineer subcontractor, or conduct it through a joint venture with an engineering firm. Contractors who propose to use the engineer as a subcontractor may then request design proposals from several design firms, selecting the design that they believe will provide the specified performance in combination with what they consider will be the lowest price.

CONCLUSIONS

Use of performance specifications can offer owners significant benefits, but not without significant costs. There will be changes in the way owners do business. There may be drastic changes in the composition of engineering staffs and functions. The process of procurement will shift from one of single-stage competitive bidding to one of double-stage competitive bidding. The cost of the engineering staff may increase as the size of the staff decreases. The educational and experience levels of the engineering staff may be significantly different. Fewer but more experienced and better qualified engineers will be needed to specify what needs to be done, while those whose function was primarily design may no longer be needed. They will be replaced by people who can define performance requirements and specify performance criteria and the means of measuring their achievement, and who will test the performance. The contract cost will appear to increase because the contractor has been asked to do the design. The contractor will have to hire engineers or contract with a design firm to be able to bid the work. The number of engineers may not be different, but the people who employ them will be. Owners will attain their objective, performance, at the lowest contract cost. The question remains of whether owners, contractors, and engineers are ready and willing to undergo a significant revolution in the way they do business, with all the accompanying dislocations to people and institutions, in order to achieve performance at lowest contract cost. If it is necessary to remain competitive in the marketplace, industry will do it. Change is inevitable. The more rapid the change, the more painful the dislocations. Tough-minded management, however, will seek and adopt those means that they perceive will enable them to achieve their goals, without regard to dislocations. Tough-minded management will ask whether they can achieve the performance they desire at the lowest total cost by means of performance specifications. If the answer is in the affirmative, the revolution will begin.

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