CONSTRUCTABILITY IN PUBLIC SECTOR

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ABSTRACT: Constructability is defined as the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. It should ideally be started early in the conceptual design phase of a project. Public sector owners, such as the U.S. Army Corps of Engineers, have difficulty accessing private construction expertise early in a project life cycle due to Federal Acquisition Regulations. This paper outlines a case study using a contractor symposium to enhance constructability during early detailed design on a project in Texas. It briefly describes the Sargent Beach erosion control project on which the constructability symposium technique was used. It then discusses the symposium process including its applicability, mechanics, and important considerations. The article then discusses the status of the project including actions taken as a result of the symposium. It concludes with a discussion of benefits, problems, and recommendations concerning this innovative technique.

INTRODUCTION

This article describes a constructability study undertaken by the writers on behalf of the U.S. Army Corps of Engineers' (COE) Galveston District office. The purpose of this study was to analyze the COE's Sargent Beach, Texas Erosion Control Project and to make recommendations concerning risk assessment, project controls, and contracting strategy to maximize the chances for overall project success, including cost minimization. Included in the paper is an in-depth discussion of the constructability symposium process used in conducting the study, including elements that are crucial to symposium success.

BACKGROUND

The following discussion outlines the current situation and the proposed solution to a serious beach erosion problem in southeast Texas.

Situation

The Gulf Intracoastal Waterway (GIWW) is a critical component of the inland waterway navigation system of the United States. In Texas, the GIWW extends along the entire coast of the Gulf of Mexico, and links, among others, the Houston, Galveston, and Freeport, Texas areas with such down-coast cities as Corpus Christi and Brownsville. It also links Texas' ports to much of the United States' industrial heartland by way of the Mississippi and other connecting waterways, and thus supports a significant sector of the United States' economy.

The GIWW was constructed in stages, with the last section being completed in 1949. In most of the Texas section of the GIWW, the waterway is well protected from Gulf of Mexico wave action by either barrier islands or inland canals linking major bay systems. The reach passing near the community of Sargent, Texas, however, was built relatively close to the coast and is protected only by a narrow strip of land. A vicinity map of the area is given in Fig. 1.

In the Sargent Beach area, rapid erosion of the silty material making up the barrier island separating the waterway from the Gulf of Mexico threatens the continued operation of this section of the GIWW. Along this approximately 12.87 km (8 mi) stretch, the shoreline is eroding at an average rate of between 7.6 and 10.7 m (25 and 35 ft) per year (U.S. Army Corps of Engineers 1992).

There are few, if any, dunes on this section of coast; the maximum elevation along this stretch is about 2.1 m (7 ft) above mean low tide (MLT). If the strip of land separating the GIWW from the Gulf becomes too narrow, then waves will overtop the beach with increasing frequency. As water flows into the GIWW, it will erode the soil and cause sediment to deposit in the navigation channel. Additionally, past observations show that when the barrier beach narrows to 91.4 m (300 ft), storm waves will throw beach side material as far as the GIWW channel. These actions will require more frequent maintenance dredging of the channel to keep it navigable. A recent aerial photo of the island is given in Fig. 2.

The possibility of the Gulf waters physically breaking through or breaching the remaining strip of land is a very real

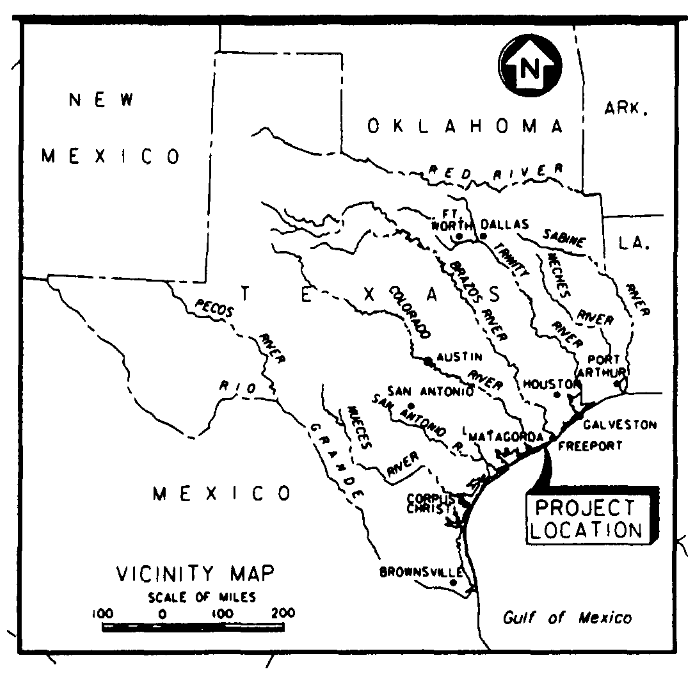

FIG. 1. Geographic Location of Project

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FIG. 2. Aerial Photo of Sargent Beach Looking Northeast, November 1991

threat to the GIWW. Such a breach would subject GIWW traffic to Gulf wave action and potentially dangerous currents, thus seriously impeding, if not stopping, such traffic. To keep the GIWW navigable, breaches would have to be plugged and the channel dredged to remove any shoals.

At the present rate of erosion, the COE estimates that the barrier beach will narrow to the point where serious maintenance problems will develop by the year 2000, and that by 2014 this section of the GIWW would permanently close to commercial barge traffic (U.S. Army Corps of Engineers 1992). Closure of this section of the waterway would seriously disrupt the present system of water transport and would have a severe economic impact on industries and communities along much of the Gulf coast.

Solution

In response to this alarming scenario, the U.S. Congress directed the COE to study the problem and devise possible solutions. Several alternatives were considered and after detailed technical, economic, and environmental analysis, the COE recommended construction of a stone revetment along the length of the island, with a design life of 50 yr. At the time of this study, the detailed design for the project was being performed by the COE's Galveston District, with assistance from the COE's Waterways Experiment Station in Vicksburg, Mississippi and a private consulting engineering firm.

The proposed structure is 12,799 m (41,992 ft) long and runs generally parallel to the GIWW. A plan view of the structure is shown in Fig. 3. Given the present rate of erosion, the crest of the structure will be located approximately 91.4 m (300 ft) from the south bank of the GIWW, as this is the minimum distance required to prevent serious wave overtopping and still permit construction to take place "in the dry" (i.e., on land, as opposed to in the surf zone). Eventually, the beach remaining between the structure and the Gulf will erode back to the revetment, at which point the structure will arrest the erosion, prevent excessive wave overtopping, and prevent the Gulf from breaking through to the waterway, thereby safeguarding the GIWW.

The cross section of the structure will vary according to soil conditions, but will be one of the following five basic types:

- 1 vertical (V):2.5 horizontal (H) sloping revetment
- 1V:5H sloping revetment
- Sheet pile wall section
- Transition section
- End section

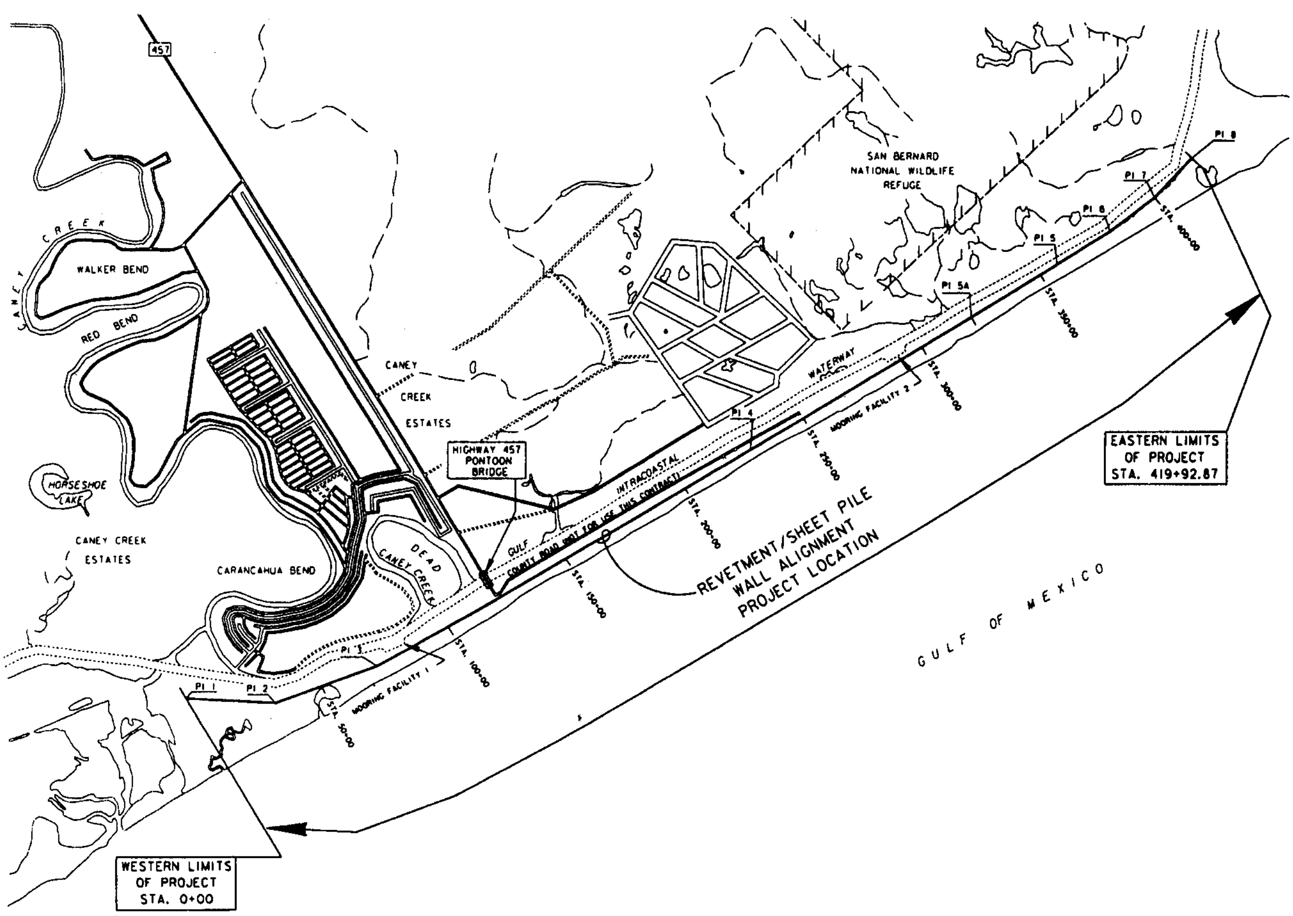

FIG. 3. Plan View of Revetment (0.305 m = 1 ft)

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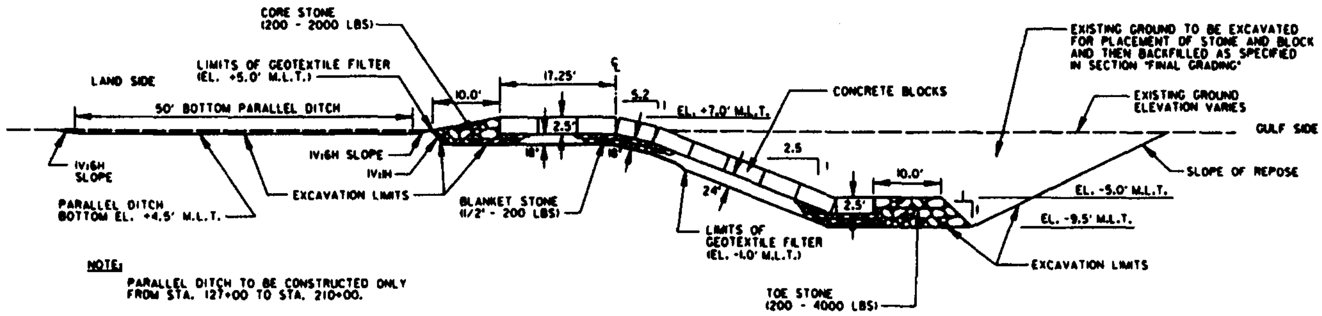

TYPICAL 1V:2.5H CONCRETE BLOCK REVETMENT SECTION

STA. 20+00 TO STA. 73+48
STA. 108+12 TO STA. 330+88
STA. 371+00 TO STA. 410+00
N.T.S.

FIG. 4. Typical Revetment Cross Section (0.454 kg = 1 lb; 0.305 m = 1 ft)

The cross section of the 1V:2.5H sloping revetment, which makes up approximately 75% of the project, is shown in Fig. 4 for illustrative purposes. Note that this is the cross section of the final design.

The toe element of this section will be at an elevation 3.0 m (10 ft) below MLT, with a 1V:2.5H sloping stone revetment, and a cap section of stone rising to an elevation of 2.1 m (7 ft) above MLT. The revetment armor consists of 1.75 × 1.75 × 0.76 m (5¾ × 5¾ × 2½ ft) precast concrete units weighing approximately 5,500 kg (6 tons) each. The armor units rest on a 0.6 m (2 ft) thick layer of blanket stone, defined as reasonably well-graded rock ranging in size from 13 mm (1/2 in.) to 90.8 kg (200 lb). The toe will be protected by toe stone consisting of material graded from 90.8 to 1,816 kg (200 to 4,000 lb) while the core stone, which will be used to make the cap, will range in weight from 90.8 to 908 kg (200 to 2,000 lb). Following stone placement, the excavated material will be backfilled over the toe and much of the sloping revetment to restore the area.

Poor foundation conditions require that one section of the revetment, approximately 823 m (2,700 ft) long, be built upon lifts of compacted clay backfill, and the revetment laid back on a 1V:5H slope. Even worse soil conditions in two other sections, one 1,049 m (3,440 ft) long and the other about 305 m (1,000 ft) in length, preclude use of the stone revetment altogether, and require that precast concrete sheet piling be used instead. Transitions of precast concrete armor units will be built to tie the different sections together. Vegetation will be restored along the length of the structure for aesthetic and erosion control purposes.

Construction of the revetment will require approximately 68,000 armor units, 2,110 sheet piles, 288,000 t of blanket stone, 63,000 t of core stone, and 157,000 t of toe stone. Over 836,000 m^3 (1,000,000 cu yd) of earth will have to be excavated and then backfilled to build the structure (U.S. Army Corps of Engineers 1992). As of this writing, engineering and design activities are complete and the project is in the construction phase.

Constructability Study

The COE realized that this project was unusual, unique, and posed special construction problems. To overcome these perceived problems, they desired to conduct a constructability study early in the detailed design phase of the project.

Constructability can be defined as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives" [The Construction Industry Institute (CII) 1986]. The constructability concept was born out of the realization that designers and contractors see the same project from different perspectives, and that optimizing the project requires that the knowledge and experience of both parties be applied to the project planning and design processes. Ideally, construction expertise would be incorporated from the moment of project inception during the preproject planning phase of a project.

The benefits that should accrue from the application of constructability during preproject planning include the following:

- Reduced cost
- Shorter schedules
- Improved quality
- Enhanced safety
- Better control of risk
- Fewer change orders
- Fewer claims

These benefits are the result of an expansion of front-end planning and the investment of additional effort to anticipate and prevent potential problems. Such efforts must be owner driven (CII 1987).

Private sector construction is generally well suited for employing constructability concepts. Private sector owners are usually free to select the contractor of their choice at any point in the project life cycle. As long as payment terms can be negotiated, the contractor can be required to participate throughout the planning and design process. In this way, the contractor's input to the project can be maximized.

Public sector owners such as the COE ordinarily do not have such latitude. Regulatory requirements for public agencies in the United States generally require that construction contracts be awarded using open competitive bidding, with award going to the lowest responsive and responsible bidder (The Federal Acquisition Council 1985). This competitive bidding requirement makes it more difficult for public owners to involve construction contractors in the planning and design process. In fact, if a construction contractor were compensated for involvement during the design process, that contractor would probably be precluded from bidding on the job due to the potential conflict of interest and perceived "unfair" advantage. Failure to exclude that contractor would almost certainly result in a protest by one or more unsuccessful bidders if the reviewing contractor was awarded the project.

Although public sector owners face additional hurdles to gaining contractor input, this does not mean that they cannot avail themselves of contractor expertise. It simply means that different approaches from those used by private industry must be employed.

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METHODOLOGY

To tap construction contractor knowledge for the benefit of the project, the Galveston District of the COE contracted with the CII at The University of Texas at Austin to perform a constructability study of the Sargent Beach project (CII 1993; Wood 1993; Flanigan 1993; Wood and Flanigan 1995). As determined jointly by COE and CII representatives, the purposes of the constructability study were (CII 1993) (1) the identification of planning, design, procurement, and field operations incident to the Sargent Beach project that could be improved through optimum use of construction knowledge and experience; and (2) the development of a study methodology that, if proven successful, would expand options available to public sector entities for exploitation of constructability techniques.

The scope of the study was developed jointly between the CII and the COE. Upon agreeing to undertake the study, the CII formed a study team. It consisted of the CII associate director for research in the capacity of study director, one postdoctoral scholar whose function was to perform computer simulation modeling for the project, two COE officer students, and one supervisory faculty.

At the time that the CII study got underway, the COE had completed the following actions regarding the Sargent Beach project (CII 1993):

- The feasibility study was complete and the optimum solution (from an economic and environmental standpoint) was identified
- The environmental impact statement was complete and approved
- Congressional project authorization had been received
- Conceptual design was complete, including physical model testing of the proposed design at the COE's Waterways Experiment Station at Vicksburg, Mississippi

The rapid rate of shoreline erosion and the possibility of storm-induced damage combined to make the entire Sargent Beach project very time sensitive. The COE was expediting its design efforts, and the constructability study was to be similarly expedited.

The idea behind conducting the constructability study was to convene a symposium of industry experts drawn from potential project bidders and to solicit their comments and recommendations concerning the proposed design and project management plan. These comments would then be analyzed and would form the basis for the written report submitted to the COE. This approach is illustrated in Fig. 5, which shows the symposium in relation to the design and construction of the project. Note that this approach had never been tried before by the COE.

In preparation for this symposium, study team members obtained copies of the proposed design, feasibility report, environmental impact statement, and related documents from the Galveston District and studied them to become thoroughly familiar with the project. It used the study scope developed previously with the COE to develop a proposed report outline, and assigned responsibility for each area to a study team member. Such assignment of responsibility eliminated the problem of effort duplication and ensured that all topics were covered.

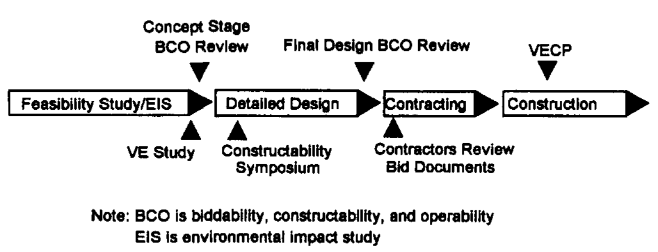

FIG. 5. Sargent Beach Constructability Symposium Timeline

The study director identified firms from the list of CII member companies that he thought had experience in heavy marine construction and might be interested in participating in the symposium. The Galveston District provided him with the names of additional firms that the district had worked with and which were capable of doing this type of work. He made initial contact with the firms by telephone, and extended formal invitations to those that had expressed interest in the symposium.

Each study team member developed a list of questions pertaining to his particular area of responsibility for presentation at the constructability symposium. The study director acted as the symposium facilitator and compiled these lists of questions into an outline to guide the discussion with contractor representatives. To maximize the productive discussion at the symposium, he sent a read-ahead package to each contractor representative who would be attending the session. This package contained the following items:

- Cover letter
- Meeting agenda
- Statement of meeting objectives
- List of desired products to come out of the meeting
- Excerpts of the project feasibility report describing the proposed design, including cross sections of the proposed structure

The purpose of the read-ahead package was to familiarize the attendees with the project. Doing so, it was thought, would greatly reduce the amount of time needed to explain the project, and thereby maximize the time available to get contractor response.

The Galveston District debated whether or not it could legally send representatives to the constructability symposium. The concern was that since the symposium was a closed forum (as it was not publicly advertised and specific contractors had been invited to attend), COE attendance might violate provisions of the Federal Acquisition Regulations governing free and open competition. After consulting with legal counsel, the district concluded that it could legally send representatives. The district decided, however, that these representatives would attend primarily as observers, rather than as active participants in the discussion with the contractor representatives.

The constructability symposium was held in Houston for 8 h on Feb. 12, 1993. Representatives from seven construction companies were present. Including study team and COE personnel, total attendance was 24. The attendance breakdown is shown in Table 1.

The study director, in his capacity as symposium facilitator, began the meeting with personnel introductions, reviewed the meeting agenda and the list of meeting objectives, and then provided a brief summary of the Sargent Beach project. Several contractor attendees had worked on projects in the area and were familiar with the site and the conditions likely to be encountered.

Following the introductions and summary briefing, the facilitator moved into discussion with the list of project issues

TABLE 1. Constructability Symposium Attendees

Organization (1)	Number of attendees (2)
Galveston District, COE	4
Contractor representatives	14
University of Texas, CII	6
[Total]	24

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put together beforehand. The general technique was for the facilitator to pose a question and then solicit comments from the contractor representatives. Because the meeting was not electronically recorded, two study team members took notes, which were used to produce meeting minutes. Contractor comments were summarized, without attribution, with particular emphasis given to key points of agreement or disagreement. Copies of the minutes were sent to the COE as well as to all contractor representatives who attended.

Because of the approach that the COE took to the symposium (i.e., choosing to attend primarily as observers rather than as active participants in the discussion), the study team found that most comments made at the symposium represented the contractors' perspective. It felt that numerous issues needed to be explored from the owner's side as well. For this reason, the team traveled to the Galveston District office in March 1993, to meet with lead designers and key project management personnel to solicit their opinions on some of what the contractor representatives had proposed. The study team and the design personnel met for approximately 4 h and then visited the project site with the district's engineering project manager.

Based upon the symposium and subsequent meeting with Galveston District officials, areas of concern for constructability were developed within the team. These areas and subtopics are shown in the affinity diagram in Fig. 6.

For most of the topics under study, several different courses of action were available to the COE. In some cases, the contractor representatives at the constructability symposium were in strong agreement as to which course of action they preferred. In other cases, there was no such consensus. The same was true for COE design and project management personnel.

The relative advantages and disadvantages were identified and subjectively weighed for each course of action. Recommendations were then made as to which course of action the COE should adopt to maximize the chances of project success. Where these recommendations depended in any way upon assumptions, these assumptions were identified to permit evaluation of risks associated with the decisions. A draft report was compiled and sent to the COE for review and comments. The study team reviewed the resulting comments and, in some cases, amended the report to reflect the additional information or revised design details. The final report was presented to the COE in August 1993.

The study team briefed contractor representatives who had attended the original constructability symposium on the team's findings and recommendations in Houston, Texas in September 1993. Each was given a copy of the constructability study at that time.

CONSTRUCTABILITY ISSUES

Significant constructability recommendations were made in the final report regarding the areas of risk reduction and assignment, project scope, contractual relationships, phasing of project work, and cash-flow management. Although many recommendations were made, the writers consider the following recommendations to be key:

- Implement project partnering for construction.
- Develop contract documents in such a way to minimize uncontrollable risks for the contractor (e.g., weather, transportation disruption, differing site conditions, and so forth).
- Test and expose site conditions to the best extent possible prior to bid, particularly dewatering and pile driving.
- Provide specific contractual guidance on quality control and acceptance criteria for placement of finish materials. Performance specifications should be used as much as possible and should be made as functional as possible.
- Mooring facilities to the island should be provided under a separate contract and should be in place before construction.
- The status and disposition of all permits should be specifically addressed in the contract documents.
- The contract should be drafted to maximize government payments in relation to contractor progress, specifically for mobilization, storm recovery, unit pricing basis, and so forth.

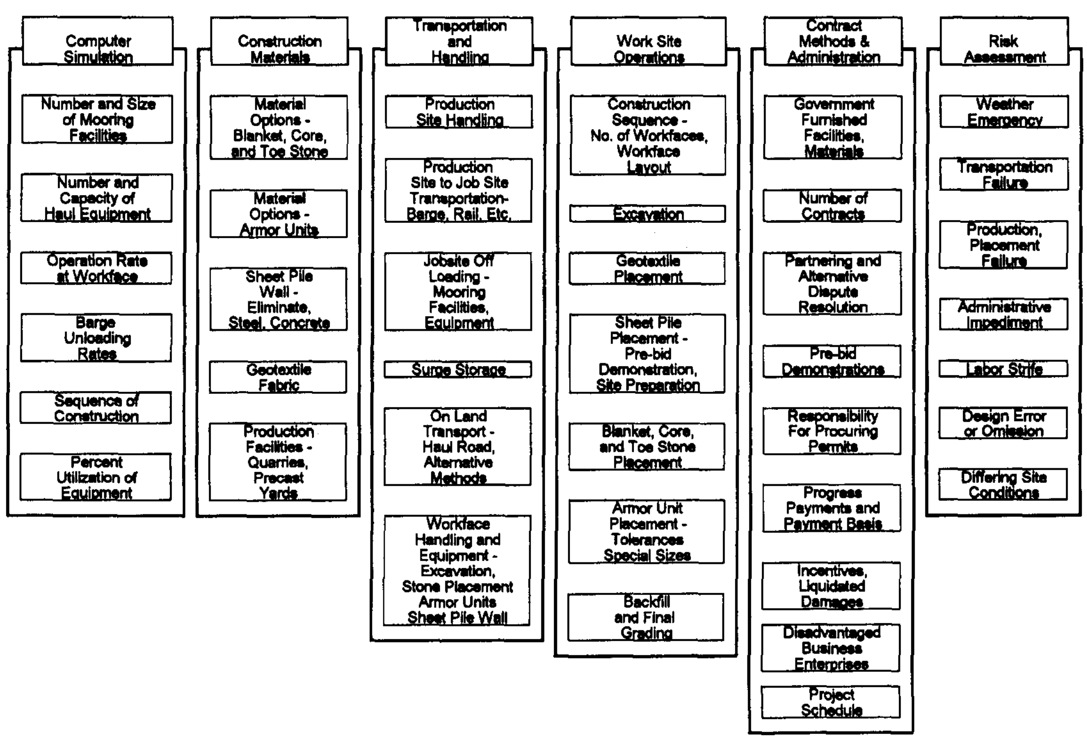

FIG. 6. Affinity Diagram of Constructability Categories/Areas of Concern

EFFICACY OF SYMPOSIUM

A survey questionnaire was sent along with meeting minutes to all contractor representatives who had attended the constructability symposium (Flanigan 1993). The purposes of the survey included (1) Learning more about what motivated the contractor representatives to attend; (2) Determining if they thought the symposium was a worthwhile effort; (3) Identifying what they thought were the most important factors in making a successful symposium; (4) Identifying areas that needed to be improved; and (5) Gauging their willingness to attend a similar symposium for a different project.

Based on their response to the questionnaire, the factors affecting symposium success were subjectively categorized, as shown in Table 2.

The constructability symposium technique is an effective method of soliciting construction contractor participation into the project planning and design process. The COE benefited from the constructability symposium by developing contractor interest in the project, gaining feedback on the proposed design and contracting strategy, and improving its relationship with contractors by demonstrating a willingness to change and by considering the contractors' point of view.

All the contractors who attended were interested in being included in future symposiums. Contractors who participated in the symposium benefited by getting a lead on potential new work, helping to produce what should be a more constructable design, which will benefit the contractor who is awarded the construction contract, and interacting with other contractors.

PROJECT STATUS

The project was awarded for construction in the spring of 1995. It had a government construction estimate of $62,385,066 based on the final decision that had incorporated many of the recommendations outlined in the constructability report. Competitive bids were opened on April 4, 1995, with 14 responsive bidders. The number of bids is indicative of a very aggressive bidding competition. The bid breakdown on the five lowest bidders is shown in Table 3.

Interestingly, the low bidder, the tenth place bidder, and the high bidder each had representatives at the constructability symposium. Four other contractors represented at the symposium did not bid.

Did the constructability study help? Obviously, the answer to that question will not be known until the construction project is completed and is in service. The difference in engineering cost estimate and the lowest bid does not tell the complete story either, but it is an interesting data point. Recommended measures that may indicate success after completion of construction could include the number of change orders processed, claims history, final quantity tabulation of in-place units versus design estimate, schedule achievement or improvement, partnering implementation, among other measures.

TABLE 2. Factors Affecting Symposium Success in Order

Importance (1)	Factors (2)
Very important	Owner takes action based on the issues
	Knowledgeable facilitator
	Quality "read-ahead" packet
	Selection of qualified contractors to attend
	Owner or A/E representatives with decision-making authority present
	Well prepared meeting agenda
Important	Project overview briefing
	Neutral agency sponsor (study team)
Not very important	Large number of contractors represented
	Quality of meeting facilities
	Neutral meeting site

TABLE 3. Sargent Beach Construction Bids

Contractor[a] (1)	Bid (2)
Low bidder[b]	$42,648,694
Second low bidder	$44,955,248
Third low bidder	$45,653,560
Fourth low bidder	$45,827,963
Fifth low bidder	$46,444,262

[a]14 Responsive bidders.
[b]Low bidder (under high bid: $30,615,288; under government estimate: $19,736,372; under next low bid: $2,306,554).

CONCLUSIONS

The COE's current standard project review does not provide for any contractor input until after the design is complete. While several reviews are built into the process, they are conducted by government or private design personnel who, regardless of the amount of construction experience they have, are still looking at the project from the owner's perspective; they lack the contractor's profit incentive. This situation is particularly true regarding unusual projects such as that described in this article. Suggestions that the contractor may make under the Corps' Value Engineering Change Program (VECP), if adopted, are typically limited and require design rework.

The methodology described in the present paper is a proactive, rather than reactive, approach to getting input from contractors in the formative stages of the project. It is key that the organizers of the symposium are well prepared and use the participants' time well. Having an agenda and a list of questions prepared in advance are very important.

While this project is admittedly a sample of one, constructability symposiums appear to benefit both owners and participating contractors. Owners benefit by developing contractor interest in the project, by gaining input on such things as the proposed design, risk management, or contracting strategy, and by improving their relationship with the contractors by demonstrating a willingness to listen to what the contractors have to say. Contractors benefit by getting a lead on potential new work, by helping to produce what should be a more constructable design, which is to their benefit if they get the job, and by networking with other contractors.

The Sargent Beach constructability symposium demonstrated that these forums are well suited to collecting contractor input on such things as the following:

- General sources of materials
- Likely modes of transporting or producing materials
- General sequence of construction activities
- Types and approximate numbers of construction equipment required
- Contractor preferences concerning government-furnished items
- Quality control standards
- Contract scopes and packaging
- Potential sources of claims and disputes
- Preferred method of dispute resolution
- Constructability of the proposed design
- Suitability of partnering

The study revealed that these symposia are not well suited to getting such information as detailed activity logic and durations and equipment cycle times.

The reason that these items cannot be collected is that the symposium participants are not likely to have sufficiently detailed knowledge of the project—even if they did, the project

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approach varies widely between participants. Additionally, full disclosure of these types of information by the contractor may give competitors insight into their strategy.

It is difficult to quantify the benefits obtained from sponsoring a constructability symposium. The costs, such as costs for consultant fees, reproduction costs, or meeting costs, for example, can be calculated readily. The ultimate benefit depends importantly on owner response to symposium recommendations leading to efficiency of design and improved operational characteristics of the completed facility. As noted earlier, the cost of the construction bids was much less than the engineer's estimate. The writers believe that this is due in large part to the effort described in the present paper.

RECOMMENDATIONS

The writers recommend that public agencies consider using constructability symposia, as described in the present paper, as a method of improving designs. The traditional design process for public sector projects does not inject construction knowledge early enough in the project. These symposia are particularly useful for projects that have unique features and difficult construction environments such as the Sargent Beach project.

ACKNOWLEDGMENTS

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