Construction Management Practices in Saudi Arabia

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ABSTRACT

Construction projects worth $270 billion have been executed in Saudi Arabia during the last 14 years. Widely varying construction management (CM) techniques have been used on these projects. Some special features that make the construction industry in Saudi Arabia different from that industry in the rest of the world include shortage of local contractors, local consultants, and local labor force; shortage of local materials; extreme climate; a working year of 305 days; and a multinational influence. The results of a survey conducted on the management aspects of 43 construction projects, in progress during 1984-1985, are presented. These 43 projects were studied through site visits and interviews with the project managers. The cost of these projects ranged from $1.6 million to $3,714.3 million, and the average cost was $226.9 million. The most popular organizational structure was the traditional architect/engineer (A/E) type used on 17 projects followed by the design/construction (D/C) manager type, which was used on 13 projects. Eight of the projects used the professional CM type of organizational structure, and four used the turnkey type. The performance of each project was measured in terms of timely completion, cost overruns, quality of work, and goodwill. It was observed that the professional CM type fared the best, followed by the D/C manager type, the traditional A/E type, and the turnkey type in that order. Project control methods, settlement of disputes, quality control, tender evaluation, changes and payments, delay penalties, project closeout, and other management aspects are also discussed.

During the last decade Saudi Arabia has experienced unprecedented construction activity that has attracted construction professionals from all over the world. During the second development plan (1975-1980), expenditure on construction projects totaled about $30 billion, 32 percent of the total government expenditure during this period. During the third development plan (1980-1985), an estimated $210 billion was spent. The construction industry employs 15 percent of the total labor force and consumes 14 percent of the total energy in the country.

Projects of all types and sizes have been executed: more than 400,000 housing units, 35,000 km of high-specification highways, more than 60 dams, two major international airports, seaports, refineries, a diplomatic enclave, and many ministry buildings. The demand for basic infrastructure and housing has largely been met and a shift has started toward construction of industrial and commercial projects. The two industrial cities of Jubail and Yanbu are examples of this shift. These two industrial cities, to be completed by the year 2000, will cost $135 billion and will employ 144,000 full-time workers. Details about these cities and other important projects are documented elsewhere (1). The physical facilities created so far will carry development forward and enhance the quality of life of Saudi citizens.

Widely varying construction management (CM) techniques have been used in Saudi Arabia depending on the contractor's background, public or private ownership of the project, the size and type of project, and so forth. Most of the CM techniques are well documented. However, the social attitudes and the forces that affect CM practices (local regulations, multinational influence, and the work environment) create a unique construction industry in Saudi Arabia. Some special features of the construction business in Saudi Arabia are

1. There has been a shortage of local contractors. Most consultants and contractors are foreign based, may not be in Saudi Arabia after the 1-year maintenance period, and will have no lien on the project after it is handed over. This situation has led the Saudi owner to select only those firms that have good international reputations and proven experience in their specific field of construction work.
2. Because both the consultant and the contractor are often foreign based, a joint venture of two or more firms from different countries is preferred to one reputable firm from one nation. Lately this concept has been extended to joint ventures between a Saudi firm and a foreign firm.
3. The emphasis in every phase of a project is on excellence. The words "biggest," "best," and "latest" sell. Sometimes the utility or worth is compromised in favor of the "best."
4. All unskilled and semiskilled labor is imported from Far Eastern and Middle Eastern countries. The extra costs of trips home, annual vacation, housing, transport, medical care, food, and insurance can be as much as 100 percent of base wages. These workers live in temporary labor camps without their families. They are readily available for overtime work.
5. The working time is 10 hr a day, 6 days a week. Annual holidays total from 6 to 10 days. This leaves a working period of about 305 days a year.
6. There are no organized labor unions and no strikes.
7. Inflation is minimal. In the last 4 years it has been zero and, on some goods, even minus.
8. Trust on the part of the owner is very important. To survive, a construction management company, a consultant, or a contractor has to work hard to create an impression of trustworthiness.

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9. Most sizable projects involve a major component of foreign equipment and engineering. As much as 40 to 50 percent of materials is imported, and therefore the proportion of material cost is relatively high. Poor material planning has been the cause of delay on some projects.
10. Safety and environmental requirements are minimal and of a quite basic nature. Institutions like the Occupational Safety and Health Administration (OSHA) in the United States do not yet exist.
11. Ten percent of the contract value is advanced to the contractor for mobilization expenses, at the time of the notice to start work, against a bank guarantee. This amount was 20 percent until 1984. This advance payment is recovered through deductions of the same percentage from progress payments.
12. The harsh climate reduces labor productivity and machine life. High day and night temperature differentials induce severe temperature stresses in structures during construction.

Management of construction projects cannot be standardized because it is largely a function of the ingenuity and experience of a particular construction company and depends on many project-related and other extraneous factors. The diversity in management methods has been further compounded in Saudi Arabia by the different national origins of the construction professionals. A review of the various CM methods followed on projects in Saudi Arabia appears to be necessary at this stage so that the various CM techniques can be evaluated. Such a review would provide guidance to those who are seeking efficiency in their management procedures. This paper is an effort in that direction.

DATA BASE

For the purpose of collecting data for this paper, 43 projects in progress were visited. A list of these projects and their costs is given in Table 1. In order to obtain survey results that could be generalized, different types and sizes of projects were selected. A questionnaire was prepared, and the project engineer or manager at the site was interviewed. Most of these projects were located in the central region of Saudi Arabia. Although some of the people interviewed were open-minded and gave information without reservations, many others were apparently suspicious of the effort and hesitated to answer some questions. In the early years some contracts were awarded after brief negotiations, in some cases with high unit costs, and under these circumstances the hesitation of the project managers to divulge all information, particularly financial, was understandable. Therefore, although 43 projects were studied, the results reported in this paper are based on fewer than 43 answers to each question.

DETAILS OF COST AND TIME AND CONTRACT TYPES

The tendered cost of the projects included in the survey ranged from $1.6 million to $3,714.3 million with an average cost of $226.9 million. The planned time of construction ranged from 6 months for a $7.5 million building project to 46 months for a $149.4 million road project; average time was 27.6 months. According to these figures, an average project spent $8.2 million each month.

One of the 43 projects was executed using an in-house design team and construction organization. This project included the construction of a shopping center. Information on the type of contract awarded was not available in two other cases. Types of contracts awarded on the remaining 40 projects are given in Table 2.

Two lump sum contracts had cost overruns on the order of 18 percent, and others had cost overruns of less than 5 percent. In the case of unit price contracts, one project overspent by 16.7 percent, four

TABLE 1 Construction Projects Included in the Study

Project Name	Estimated Cost[a] (million U.S. $)
Building Projects	
Arab security studies and training center	120.3
Al-Iftaa and Al-Dawa	26.1
Second housing for special security forces	125.7
General Organization for Social Insurance housing	42.8
Nammal compound in Rabwah	42.9
Residential area for unmarried people, Islamic University	54.5
Sport complex project	48.6
Internal security forces housing project site, Jeddah	375.0
KSU faculty housing, Phase II	133.3
Oleya shopping center	68.6
Sama head office building	171.4
Al-Nasr sports club, Class A	57.1
RSNF headquarters expansion	110.0
Al-Khozama plaza complex	54.9
Al-Mousa center	61.4
Security forces hospital, Phase II	157.1
SFD headquarters office building	31.4
MOFA staff housing project	54.6
Council of Ministers extension building	7.2
Vocational training facilities	69.6
King Faisal specialist hospital	—
Taif ordinance coprs facilities	117.1
New Riyadh passports building	37.2
Extension for the officers' club, National Commercial Bank	11.0
National Commercial Bank branch	1.6
New Ministry of Commerce building	18.9
Riyadh DQ international school	40.0
Sports club, Riyadh diplomatic quarter	34.3
Construction of new campus of King Saud University	3,714.3
PTT building project	143.0
Rush housing in Riyadh	285.7
Defense housing	1,142.0
Sewage Treatment and Water Supply Projects	
Riyadh sewage treatment plant	68.9
Sanitary and storm drainage system	137.1
Riyadh sewage pump station	45.7
Bridges	
Al-Khaleej Road bridge, Riyadh	111.7
Road Projects	
Riyadh Ring Road, east leg	61.7
Al-Jumah descent project	149.7
Riyadh, Dammam Expressway Contract D	60.7
Riyadh, Dammam Expressway Contract E	59.1
Miscellaneous Projects	
Trabah Dam in Taif area	34.7
TV center, Riyadh	342.8
King Khalid International Airport	3,142.8

[a]In cases in which estimated cost was not available, tendered cost has been given.

TABLE 2 Contract Types

Contract Type	No. of Projects
Lump sum	14
Unit price	18
Fixed price	2
Unit price with top ceiling	2
Lump sum with top ceiling	1
Lump sum with unit price for extra items and variations	3

projects overspent by from 5 to 7 percent, and others were completed within 4 percent cost overruns. In one case, in which a lump sum contract with unit prices for extra items and variations was followed, the project expenditure was 3.1 percent less than the bid amount. In another case, in which a lump sum contract with a top ceiling was awarded, the cost overrun was 14.1 percent.

ORGANIZATIONAL STRUCTURES

Almost all of the known forms of relationships among the owner, the designer, and the builder were followed with slight variations from classic forms in a few cases. The breakdown of various structures is given in Table 3.

TABLE 3 Organizational Structures Used on Surveyed Projects

Organizational Structure	Type of Project					
	Buildings	Sanitary and Water Supply	Bridges	Roads	Misc	Total
Traditional A/E	13	1		2	1	17
D/C manager	8	1	1	2	1	13
Professional CM	6	1			1	8
Turnkey	4					4
In-house						1

The traditional A/E contract situation, in which the owner signed separate contracts with the designer and the construction supervisor and the designer and the construction supervisor had no relationship, obtained on 40 percent of the projects. The D/C manager contract was used on 30 percent of the projects. The professional construction management contract was next in popularity and was used on 19 percent of the projects. Turnkey contracts were followed on building projects only. Two examples of organizational structures are shown in Figures 1 and 2. In most cases the contractual relationship among the owner, the consultant, and the contractor was designed to relieve the owner of responsibility for all technical matters and site supervision. The owner was responsible for financial matters like variations, change orders, time extensions, and progress payments.

The project managers were asked if they faced any bottlenecks or problems during construction. Projects following traditional A/E contracts were reported to experience delays caused by the supervising consultant at every stage. There were also many instances of design error. Projects following D/C manager contracts also reported design errors and delays in approvals. Projects following professional CM contracts or turnkey contracts did not report any approval delays or design errors.

The performance of each project was measured on four counts:

- Timely completion,
- Cost optimality,
- Quality of work, and
- Goodwill.

Each count was given 0, 1/2, or 1 point depending on the level of its fulfillment. Each project could thus receive a maximum of four points, and the performance of all projects following a particular type of organizational structure was totaled. Average performance versus organizational structure is given in Table 4.

TABLE 4 Average Performance of Each Organizational Structure

Organizational Structure	Average Performance
Traditional A/E	2.26
D/C manager	2.69
Professional CM	2.79
Turnkey	1.33

CONSTRUCTION MANAGEMENT PROCEDURES

Methods of Project Control

Almost all of the projects visited used bar charts for schedule control. Thirty-two of 43 projects used computerized methods along with bar charts. In a few cases like King Khalid International Airport, a full-fledged computer center was in place and up-to-date programs were being used for project control and monitoring.

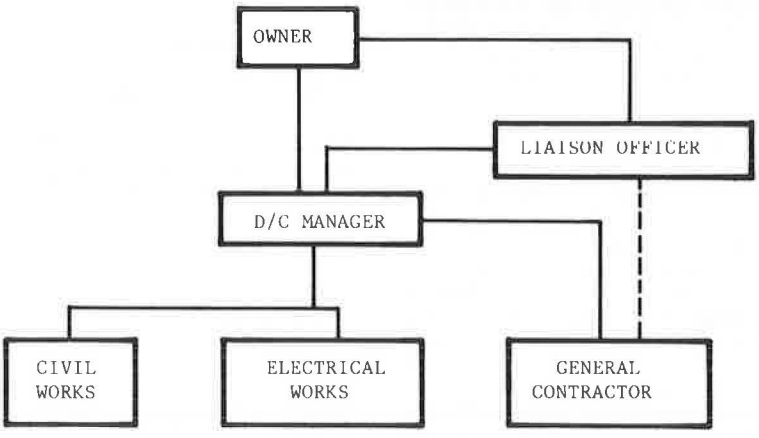

FIGURE 1 D/C manager type of organizational structure followed on the construction of TV center in Riyadh.

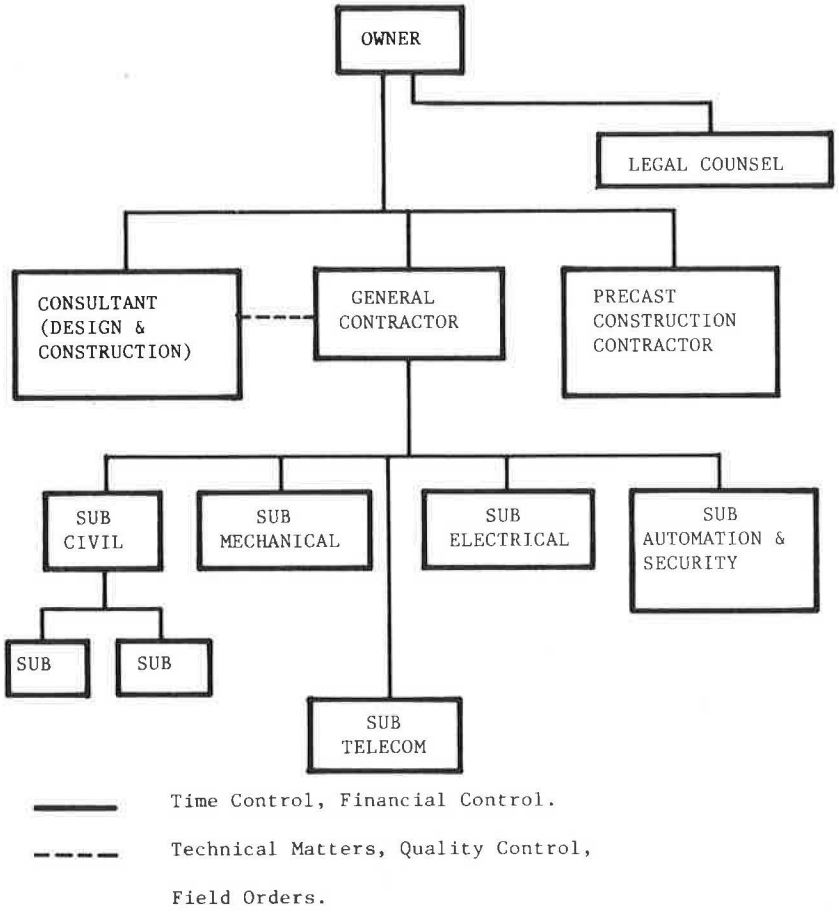

FIGURE 2 D/C manager type of organizational structure followed on the construction of the new campus for King Saud University, Riyadh.

Critical path method networks and time listings were in common use on all projects on which computers were used. Use of computer methods was more popular on projects following professional CM contracts than on those following traditional A/E contracts, as indicated by the data in Table 5.

TABLE 5 Computer Usage for Project Control

Organizational Structure	Computer Usage (%)
Traditional A/E	65
D/C manager	85
Professional CM	88
Turnkey	75

Value Engineering and Management

Value engineering (VE) and value management procedures have not been popular in Saudi Arabia. Although the projects represent huge amounts, there was no value engineer on any of the 43 projects. For two projects specifications and drawings were reviewed by the CM, and on one of them $150,000 was saved as a result. Three other projects had a VE incentive clause in the contract, one of them on a 50-50 sharing basis between the owner and the contractor. On another project $1 million in material changes was saved as a result of VE review. The project manager, however, reported that VE was not worthwhile because the procedure incurred delays.

Settlement of Claims and Disputes

Disputes range from specification problems to contractual problems and from a few thousand dollars to more than $100 million per claim. It goes without saying that the number and value of disputes in a contract are inversely proportional to the clarity of contract documents. These documents are usually prepared by the consultants who come from all parts of the world and are executed by contractors who are sometimes unfamiliar with the consultants' backgrounds. Changes and variations in the size and type of work, however, have been the source of most disputes, both claims for money and time extensions.

The method of settlement of contract disputes in Saudi Arabia depends on whether the project is public or private. In the project is public, disputes arising out of the contract must be settled at the "Grievance Board," which is an Islamic court fully authorized to settle such disputes. Its ruling is final and binding on both parties. If no governmental institution is directly involved, the contract provisions determine the way in which claims are settled. In most cases, each party is given the right to choose one member and the two members so chosen select a third member to form an arbitration committee that will settle the claim. Approximately two-

thirds of all disputes are settled out of court through direct negotiations in Saudi Arabia.

Resource Management

Of the four basic resources, men, machines, money, and materials, money has not been a problem in Saudi Arabia so far. Only one of the 43 projects experienced some financial problems.

Men

All construction workers, skilled, semiskilled, and unskilled, are imported from Far Eastern and Middle Eastern countries as well as from Europe and the United States. In addition to wages, these workers are provided with camp housing, food, insurance, bus transport, limited recreational facilities, medical care, and annual air transport to their home country. All of these fringe benefits add up to more than 100 percent of wages.

The importation of labor takes from 4 to 6 months, and after the men arrive they are paid whether or not they are put to work. Labor planning is therefore crucial. Most contractors prepare manpower loading schedules and keep updating them. Two examples of manpower loading patterns are shown in Figures 3 and 4. Peak manpower may exceed 12,000 men on one job. Manpower employed on a $59 million, 23-month road project is given in Table 6.

Machines

Because of the shortage of a permanent labor force in Saudi Arabia, construction equipment is used to the maximum possible extent. Usually the contractor imports equipment from his country or buys used equipment locally. The number of pieces of construction equipment of all types has ranged from 20 on a $157 million building project to 1,500 on a $1,142 million building project. A list of typical equipment used on a $59 million road project is given in Table 7.

An effort was made in this study to determine the cost of construction equipment as a fraction of project cost. Although the number of pieces of each type of equipment was available, in most cases their approximate cost could not be determined. According to the figures given by the project managers in a few cases, equipment cost ranged from 8 to 18 percent of project cost. About 10 to 12 percent was quoted as a common figure.

Quality Control

Quality control (QC) has been exercised rather well on most government projects in Saudi Arabia, and a considerable amount of resources is expended on this function. Thirty-one of 43 projects reportedly had a QC plan and 21 reportedly had a quality assurance (QA) plan as well. Staff to execute QC ranged from a single engineer to a group of 30. Qualified engineers have been employed by the owners. On one project, an engineer with a Ph.D was supervising the QC testing.

On most projects both in-house and outside laboratories were used for testing. Thirty-four projects had in-house testing laboratories under the supervision of the consultant. Twenty-five projects used the services of outside independent testing laboratories.

Construction Safety

Institutions like OSHA in the United States have not yet arisen in Saudi Arabia. Local rules require fencing the construction area, in most cases by a tin sheet wall; wearing hard hats and boots in the construction zone; and access to an ambulance and

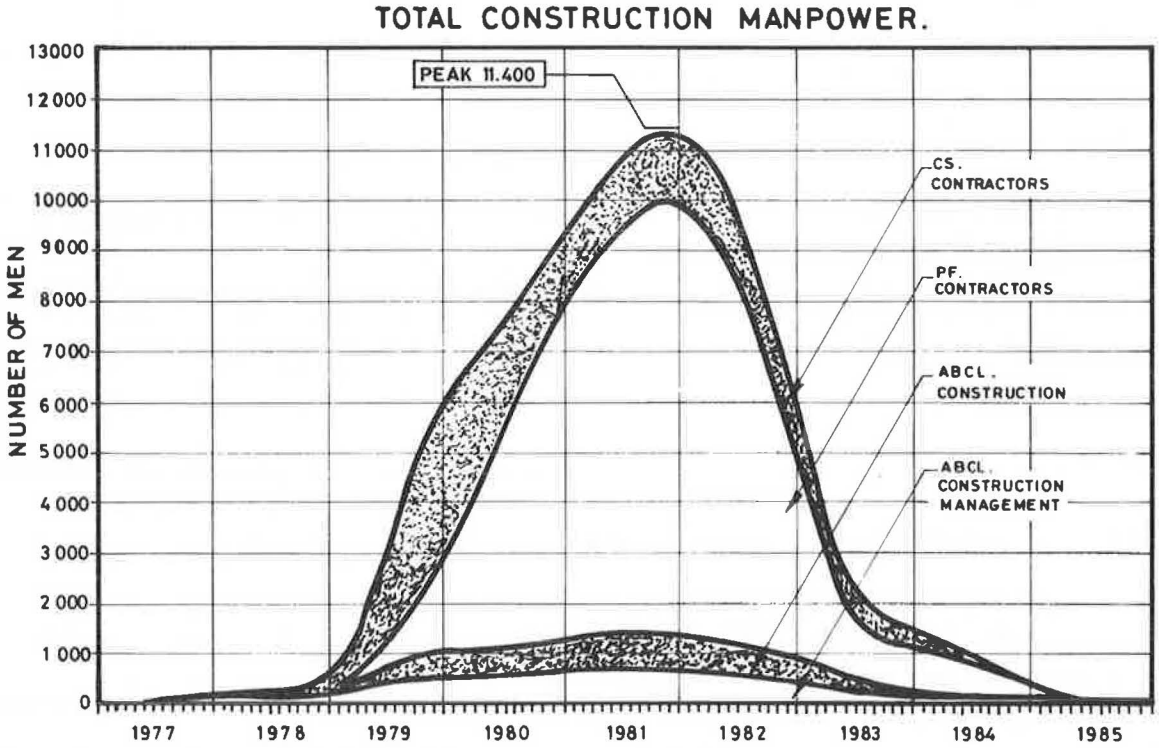

FIGURE 3 Manpower schedule for King Khalid International Airport, Riyadh.

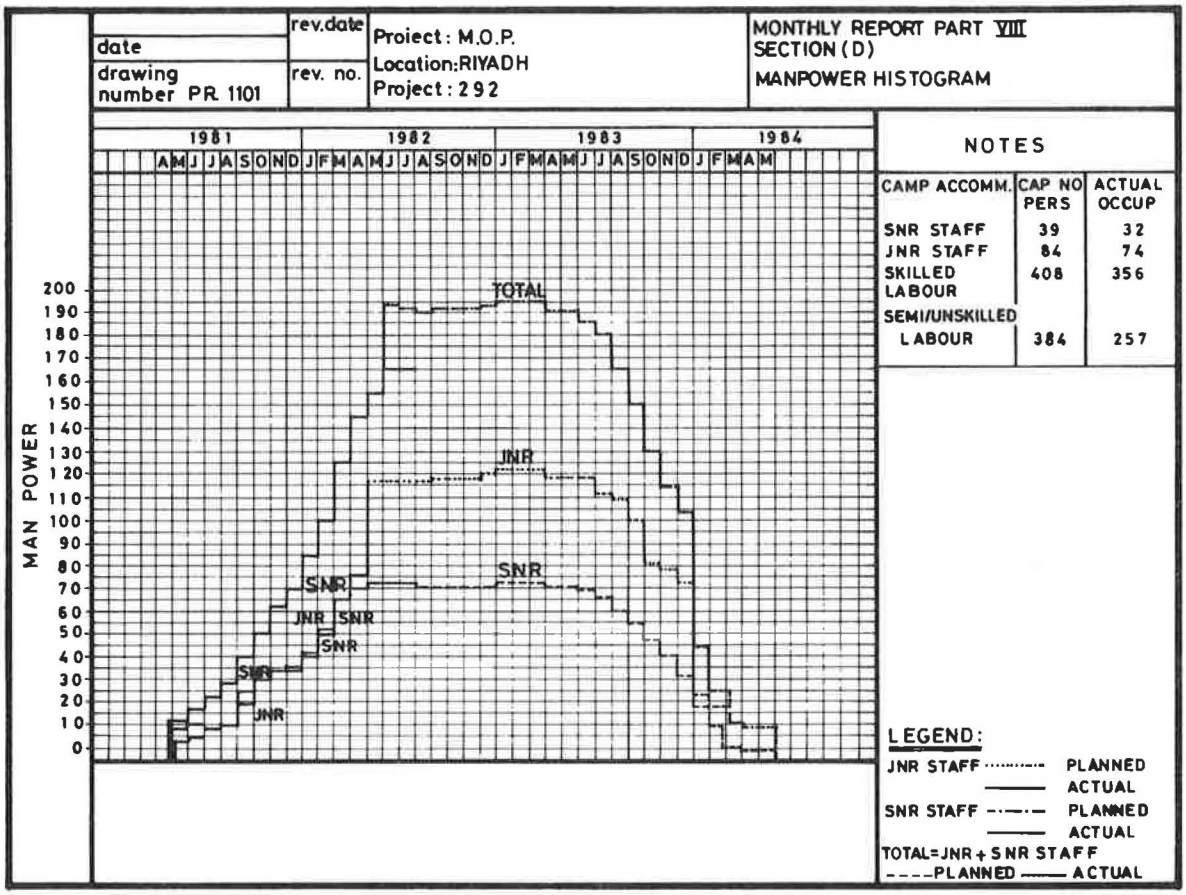

FIGURE 4 Manpower loading on a $112 million bridge project.

TABLE 6 Manpower for Riyadh Dammam Expressway Contract E

Description	No.
Project manager	1
Assistant project manager	2
Staff	8
Engineer (civil)	8
Engineer (mechanical)	2
Supervisor	29
Surveyor	4
Chainman	13
Draftsman	6
Laboratory technician	7
Foreman	24
Mechanic	27
Operator	129
Driver	101
Skilled labor	315
General labor	171
Total	847

TABLE 7 Equipment Used on a $59 Million Road Project

Description	No.
Bulldozer	11
Loader	23
Dump truck	56
Scraper	–
Motor grader	9
Water tank truck	8
Sprinkler	12
Sheepfoot roller	1
Vibratory roller	19
Pneumatic roller	10
Backhoe	1
Crane	3
Asphalt distributor	3
Asphalt finisher	5
Truck mixer	11
Concrete pump	2
Portable generator	6
Tractor	1
Concrete batching plant	2
Crushing plant	2
Asphalt mixing plant	2
Total	187

fire-fighting equipment. When the number of laborers exceeds 100, the construction company has to employ a qualified doctor and run a clinic on site.

Thirty-seven of the 43 projects studied had a safety plan. Twenty-four of these employed various kinds of personnel for the job. Three of the projects had clinics operating on site and two of them had fire-fighting vehicles. The size of safety staff ranged from 1 to 25 depending on the size and type of project.

CONTRACT ADMINISTRATION

The prime objectives of management are time, economy, and quality. The way these objectives are achieved, however, depends on many factors: the type of contractor's organization, terms and conditions of the

contract, and whether the project is private or government owned, to mention just a few.

The type of organization determines the hierarchial order of decision making. The degree of centralization or decentralization and the impact on the administrative process depend on the company's administrative chart.

The contract form of a project shapes the three-dimensional relationship among the contractor, the consultant, and the owner. The function of the consultant varies from a minimum, when the owner takes over the duties of the consultant by his own forces, to the other extreme at which the owner simply pays the monthly bills that are certified by the consultant. There is no standard national contract form in Saudi Arabia. Government departments and institutions draw up their own contract forms. These could be modified versions of the forms of the Fédération Internationale des Ingénieurs-Conseils or the American Institute of Architects or something different.

Finally, government contracts are different from private contracts. The former have to follow certain rules and must be in line with the Government Tender Law. The latter are usually written to protect the owner's interests regardless of any rules or regulations. Because of space limitations, only government contracts will be considered in the discussion of the major functions of contract administration.

Bid Evaluation

With the exception of the case in which a CM is hired, all government bids are evaluated by a technical committee. The number of committee members, their ranks, and their duties are outlined in the Government Tender Law as amended from time to time. The award of a contract depends heavily on the committee's recommendations. The Ministry of Finance and National Economy must approve the form of any government contract before signing to make sure it conforms to the Tender Law and regulations. Contracts that have a time of 1 year or less are exempted from this requirement. When a CM is hired, bid evaluation is usually carried out by him. CMs are used on defense-related contracts, civil aviation contracts, and other extremely large contracts like the Jubail and Yanbu industrial projects (1).

Change Orders

The Saudi Arabian Tender Law requires the inclusion of a clause in the contract that gives the owner the right to increase or decrease the volume of work by 20 percent of the total contracted scope of work. The flexibility to increase the scope of work has lately been reduced to 10 percent. The impact of change orders on both time and cost has to be evaluated. Disputes over the cost of such changes can be minimized by including a priced schedule of unit rates for some anticipated items of work in the bid documents.

Progress Payments

At the end of each month the contractor submits a payment application for work executed during that month. The way in which the payment certificate is checked before payment differs according to the procedure described in the contract. Under most government contracts, the consultant must check, inspect, and certify the payment. He forwards it to the owner who may check and randomly inspect the work to make sure he is not overpaying the contractor. Payment is then made after deductions are made to cover such items as retention money and advance payment.

Penalty for Delays

The owner, in any project, is as concerned about the timing of his project completion as he is about the cost. In Saudi Arabia timeliness is critical because a good number of construction projects are on a crash program. For this reason the Government Tender Law requires a clause in the contract that penalizes the contractor or the consultant for being late. The maximum penalty is limited to 10 percent of the total contract value, including change orders.

Management Cost

An effort was made in this study to determine the average cost of management as a percentage of project cost. Adequate data, however, were not available; partial information was obtained about only 8 of 43 projects. On the basis of this limited sample, owner's management cost including planning, design, and construction supervision ranged from 4.6 to 5.3 percent of the project cost on building works. The contractor's management cost on one $120 million building was 4.75 percent of the project cost. In one case in which the design and construction were managed by the owner himself, using his in-house staff, the total management cost was 10 percent of the project cost. It should be noted, however, that the sample represents primarily large-scale projects. For smaller projects, management costs will be higher than the figures cited here.

BOTTLENECKS AND PROBLEMS

During the interviews, project managers were asked if they faced any bottlenecks and problems during construction. Problems cited are summarized in Table 8 in the order of the number of citations. There had been no problems on 17 projects at the time of the interviews.

TABLE 8 Bottlenecks and Problems Ranked in Order of Number of Citations

Nature of Problem	No. of Citations
Material delays	6
Design errors	6
Geotechnical problems	6
Lack of initiative by consultant	5
Labor problems	4
Diversion of road traffic and utilities	4
Specifications and/or drawings not clear	3
Short contract time	3
Lack of coordination between contractors	2
Delay in progress payments	1
Many change orders	1
Difficult working area	1
Delay in urban land procurement	1

PROJECT CLOSEOUT

Construction contracts in Saudi Arabia are written to include a "maintenance year" as a general practice. Project closeout is a long and tiresome procedure. It starts the day the contractor officially informs the consultant and the owner that the work

is substantially complete and ready for inspection. Preparation for closeout, however, starts much earlier with the preparation of as-built documents and a punch list. For two reasons the concern here is with public works: first, the rules and regulations are mostly meant for government jobs and, second, a majority of construction works carried out during the last 10 years are publicly owned.

When the contractor informs the owner and the consultant that the project is ready for inspection, a preliminary takeover committee is formed. This committee is responsible for making sure that the contractor has executed the work according to the specifications and other contract documents. If the work is found to be substantially complete, the committee will recommend the issuance of a substantial completion certificate. The procedure could differ slightly from one project to another depending on the procedure described in the contract. A substantial completion certificate is issued with a punch list of defective or incomplete items. The contractor is required to complete these items within 365 days from the effective date of the certificate of substantial completion. If any parts or components of the permanent works become defective during the maintenance year, the contractor is required to fix or replace them. The owner, however, is usually responsible for operation and preventive maintenance from the delivery date.

When the contractor completes his maintenance year and fulfills his responsibility regarding the punch list items, he notifies the owner and the consultant again and a new and final takeover committee is formed. If the committee finds that the contractor has completed his contractual obligations, it will recommend the issuance of the final completion certificate and the settlement of accounts with the contractor. That involves securing certain documents from the contractor. These include proof that he has paid his taxes; settled his labor problems (including residence status); settled all accounts with his subcontractors, suppliers, and so forth, and a latent defect guarantee. The latent defect guarantee is simply a written statement from the contractor, if it is a Saudi firm or from the Saudi partner in the case of a consortium, certifying that he thereby undertakes the guarantee of smooth functioning of the permanent works free from any structural failures. If such failure occurs, he will fix it free of charge.

On 30 of the 43 projects studied, there were no closeout problems and the people interviewed about 11 others did not yet know because the projects were still under construction. The manager of one project reported that the handing-over inspection was delayed by the owner.

FUTURE OUTLOOK

Saudi Arabia has completed most of the infrastructure (housing, roads, agriculture, airports, seaports, defense establishments, educational and health institutions, and basic industries) for its population of 8 million who occupy some 2.25 million km^2. Oil revenues have dropped, and this will cause a slowdown of construction activity, at least in the near future.

The construction boom of the last decade has created a large number of local firms in the management as well as in the construction field. Some of them have entered into joint ventures with foreign firms. The government has issued regulations that give priority to national firms in the award of public contracts. In addition, foreign firms have to award at least 30 percent of the volume of their work to local firms. The entry of construction companies from the East and the Far East has almost ousted western companies because of their higher overhead and wage costs. There will be more competition in future bids, which should result in a downward trend in construction costs. Contractors will have to use local materials and local expertise to the extent they are available. There will perhaps be no fast-track projects, and the need for efficiency in construction management will be felt more and more. Operation and maintenance (O&M) problems will influence the thinking of the designers and planners of future projects. The market for O&M is expected to grow rapidly in both quality and quantity.

CONCLUSIONS AND RECOMMENDATIONS

The major conclusions of this work and the recommendations, based thereon, are summarized as follows:

1. An unmatched evolution in construction has taken place in Saudi Arabia. Government statistics show that more than $270 billion was spent on public construction projects between 1970 and 1984. A wide range of CM techniques has been used on these projects. Shortage of local contractors, local consultants, local labor, and local materials; harsh climate; local regulations; and a multinational influence have contributed to the creation of a unique construction industry in Saudi Arabia.
2. Lump sum contracts with a priced schedule of unit rates for change orders offered the best method for controlling cost overuns and time delay.
3. The best organizational structure was the professional CM type, followed by D/C manager, traditional A/E, and finally the turnkey type. This ranking was established on the basis of timely completion, cost optimality, quality of work, and goodwill.
4. The Grievance Board, with no appeal allowed, is in charge of settling claims resulting from public contracts in Saudi Arabia. The best and least expensive way of settling disputes is out of court through direct negotiations.
5. There is no standard form of contract in Saudi Arabia, but there are certain requirements dictated by the Government Tender Law. Among these requirements are a penalty clause with no incentive for acceleration, a maintenance year, submission of certain surety bonds, payment of taxes before settling the contract accounts, and the use of the Arabic language in all communications between the owner and contractor. There is a definite need for a standard form of contract.
6. Bid evaluation must be carried out by a qualified, honest, and unbiased team. The bid evaluation committee system followed for government contracts may result in the selection of less qualified contractors simply because they have offered the lowest price.
7. The construction industry in Saudi Arabia is changing direction. During the next 10 years concentration on industrial and commercial projects is expected.
8. To cut their running costs, foreign consulting firms have employed young, inexperienced engineers to do their field supervision. The design teams in most cases do their work abroad with little or no consideration of local conditions, culture, or heritage. This has resulted in design errors, geotechnical problems, and time delays. Consulting firms will have to avoid these practices in the future.

9. Project closeout is much more difficult than securing the contract itself. It requires a sincere joint effort by the owner and the contractor. The cases studied in this work indicate that Saudis are not claim oriented. They prefer settling differences through direct negotiations.
10. There has been a noticeable improvement in the quality of construction. It is expected that the industry will even be more efficient in the future.

REFERENCE

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Publication of this paper sponsored by Committee on Construction Management.

Use of Microwave Oven for Rapid Determination of Moisture Content of Highway Materials

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ABSTRACT

An overview of research findings on the use of a microwave oven for the rapid determination of the moisture content of soils, aggregates, waste materials, and stabilized materials is presented in this paper. Principles of microwave heating and factors that affect the test results are briefly reviewed. Conventional and microwave oven moisture content test results are compared to assess the accuracy of the microwave drying technique. Regression analyses are performed to establish the statistical relationship between the two parameters. It is shown that granular materials produce more accurate results than do cohesive soils. It is also shown that although discrepancies exist between conventional and microwave oven moisture contents, the two measurements are quite strongly correlated, and one can be consistently predicted from the other. Conclusions and recommendations, including research needs, are provided at the end of the paper.

The engineering properties and service behavior of highway materials such as soils, aggregates, and stabilized materials are greatly affected by the presence of moisture. Moisture content, defined as the ratio (as a percentage) of the weight of water contained in the material to that of the solid particles, is therefore considered a key parameter that must be accurately determined in the testing phases of all highway construction projects.

The standard and most widely accepted procedure for establishing moisture content is based on oven drying wet samples to constant weight at a controlled temperature of 110°C ±5°C (see, for example, ASTM D 2216). Although this method is fairly simple and accurate, it is rather time consuming because of the slow nature of the drying process in the conventional oven. Depending on the soil type and sample size, a drying period of from 4 to 24 hr may be required in the conventional oven. To meet the needs of expeditious construction control, various rapid moisture measurement techniques based on nuclear, hygrometric, electrical resistance, capacitance, electromagnetic, thermal, and gravimetric principles have been developed. However, success in obtaining the desired accuracy by these techniques has been varied (1).

Recently, because of their increased popularity and availability in the consumer market at a low cost, microwave ovens have attracted considerable attention as rapid moisture measuring devices. Research (2-8) performed to assess the feasibility of using a microwave oven in measuring the moisture contents of various highway materials has generally produced favorable results in terms of time savings and accuracy. However, some limitations have also surfaced. The purpose of this paper is to present an overview of the findings of this research.

In the following sections, principles of microwave heating and factors that affect the test results are briefly reviewed. Data obtained by the authors and data published by others form the basis for a comparison of moisture contents determined by microwave and conventional ovens. Predictive regression equations relating the two parameters are presented. Finally, conclusions and recommendations, including research needs, are provided at the end of the paper.

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